Anticipating EU transport sector governance

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Summary

This forward looking reflection paper aims to enrich the dialogue between stakeholders regarding shared decision-making and responsibilities in the automotive sector and the transport sector in general. Important additional challenges are identified which can complement the current roadmaps and research programs. The acceleration of innovation speed leads to faster market uptake of disruptive innovations than foreseen; not only in the transport sector but in many sectors at the same time. Consequently the predictive power of anticipation methods based on past experience should be reassessed. A new governance model is required which involves an enlarged and diversified group of stakeholders connecting developments in ICT, other modes and other sectors.

1 INTRODUCTION

This paper presents insights in future governance needs of the transport sector (including automotive) and how this could be shaped. Use is made of strategic future assessments done in different Horizon 2020 projects funded by the European Commission including Smart-Rail and USE-IT. The results are based on information from recent International comparative literature including foresighting, governance models, innovation and policy studies, industry strategic papers and road maps for different relevant sectors.

Using the current organisation of the automotive sector as basis is not sufficient due to all the rapidly upcoming and disruptive changes to be expected in the coming decade. For this reason this paper will start off with a general foresighting exercise which results in a general overview the impacts to be expected in the field of mobility and logistics.

The disruptive innovations will influence the automotive market but also the mobility and logistics demand (modal choice and patterns) and consequently the requirements for spatial planning and governance. At the same time, in other sectors disruptive innovations are likely to lead to major changes as well which will influence the demand of the mobility and logistics sectors either directly or indirectly through socio-economic trends.

New topics and challenges can be expected to emerge due to these developments and also reshape the stakeholder ecosystem with profound consequences for the organisation of the governance of automotive systems. In this paper we will discuss a selection of aspects that would benefit most from a multi-stakeholder governance model and the corresponding requirements and challenges.

The time horizon of when the different innovations and implications will occur is not specified in this paper. The future situation described is the aggregate result of the events and innovation that are in development and realistically could be on the market between today and about 15 years from now. Major disruptions can already be expected around 2020 and also many other disruptions can occur faster than expected. Although there is uncertainty about the innovations assumed and the order in which disruptions will occur, this exercise provides a valuable insight in upcoming challenges and opportunities to be anticipated.

2 GENERAL FORESIGHT

2.1 Major challenges

The challenges facing the world in the coming decades are providing the boundaries within which we can shape our future society. Amongst them, as the most important and well-known challenges are Global Population growth and growing global middle class, Climate change, Scarcity of some critical resources and Biodiversity which is at risk Some of these challenges are likely to bring about significant system changes within a short space of time and spur new innovative solutions which in turn could introduce new challenges yet to be defined.

Under the assumption as well as common goal [1], [2]) to overcome these major challenges and maintain global stability and the anticipated welfare levels, we will face a steady growth of the world population until at least 2050. Healthcare innovations are expected to contribute to the population growth beyond this time horizon making it a significant variable shaping our future.

An equally important variable is that of global welfare (traditionally measured in terms of GDP) and assumed to continue to grow over the same period. Especially in the less developed countries a growth of GDP could translate in less poverty and therewith increased life expectancy. Two further variables are defined in terms of the availability of resources required to generate the growth of welfare [3] (including biodiversity) and climate change which can be tackled for example by reducing CO^2 emissions [4]. Failing to face these challenges could result in global conflicts and instability with obvious negative impact on welfare and population growth.

The clear interdependency between all these important variables that are shaping our future, which is sometimes overlooked, is formalised in the following (decomposition) formula which shows that the total global demand for resources is a function of population size, the global average GDP per head (welfare) and the resources required to generate one unit of GDP (resource efficiency)[1].

$$resourceDemand = population \times \frac{GDP}{person} \times \frac{resources}{unitGDP}$$

Trying to cope with the major challenges and at the same time aiming for global GDP growth would require a complete system change, especially with regard to resource use. For the current carbon-based economies this would mean a virtually complete transition to sustainable energy sources. Failing to do so, would lead to a slowdown or decline in global GDP growth, increased inequality between and within countries and hightened risk of global political instability.

1 This is valid only for global demand since only then it can be considered to be a closed system.

ICT innovation could be harnessed to provide a partial solution and spur innovation in all sectors. This assumption is based on the exponential speed of development in ICT (Moore's law, see annex A), incomparable to what we have observed in the past with the introduction of many disruptive technologies [5]. It is not a bold statement to say that innovations to come will influence literally each aspect of our daily live and processes in each economic sector.

Although these innovations can provide solutions to the major challenges, they also are accompanied by large rebound effects [6]. More efficient use of resources lead to lower costs of production which implies that more products can be bought with the same available budgets. For production of these additional products also resources are used and therefor largely compensate for the benefits created by the resource efficiency improvement. In addition rapid innovation also leads to a longer life expectancy which also will result in an increase in the demand for resources. High hopes are therefore set on a significant increase of the share of the service sectors in the GDP growth for which less resources are required. It still has to be demonstrated though that it will be possible to build a stable economy on such a large share of services.

In view of the above, it is likely that the transition to sustainable energy sources and resource efficiency might at some point be accompanied by a more modest anticipating attitude towards economic development, which would redefine welfare beyond GDP and temper economic growth projections and expectations (see for instance the ‘Metamorphosis’ scenario of the FP 7 project Flagship [7]).

2.2 Competitiveness and labour

Innovations are also developed to improve economic competitiveness. Besides the development of new materials and products this also implies labour efficiency gains by automation of (production) processes. At moment of writing we are in the middle of an observable change where computers are already outperforming humans on specific and complex tasks. Artificial Intelligence has been developed so computers/robots can learn to perform complex tasks by themselves (machine learning), which is speeding up the innovation process considerably. Some of the more recent and notable successes include the Tesla autopilot, HoloLens, fully operational prosthesis, walking Robots, etc.. Technologies that have been in development for a long time, are now maturing. When combined with other matured technologies this will lead to a sudden acceleration of innovations. This implies that although innovation already seems to be at full speed, we should be prepared for a further acceleration (exponential growth of innovation [5]).

Technological progress could increase production efficiency in all sectors. Historically we have seen similar developments leading to a boost in the GDP [8]. Where traditionally the robots compete in particular with the low-skilled jobs, now the occupations at risk are more diverse, putting also the middle- and higher-skilled jobs at risk. A 2013 study by Frey and Osborne forecast that by 2030 about 47% of all jobs in the US could be automated [9]. The broadness of such a system change and especially the speed with which the disruptions are following each other up, is unprecedented and therefore the impact of it is not straightforwardly determined by use of historical indicators.

A more efficient production of physical products should amongst others be accompanied by an increase in consumption. The consumption in the developed countries is already at a high level providing many with all that is necessary to maintain a comfortable standard of living. This means that it is likely that the additional consumption of these products should come primarily from the developing countries. Automation of the production process means however that the demand for cheap labour will decrease and that therefor production can be brought back to the developed countries (for instance the Tesla factory in the US). Such a development would be consistent with the process of accumulation of capital as described by Piketty [10]. An important question to answer is therefore whether these lower-skilled workers in developing countries would find alternative employment in other sectors, which may also be automated, either in their own country or abroad.

Disruptive automation in itself is nothing new: windmills, steam engines, combustion engines, electrification are just a few past examples. However, the exponential speed of innovation and thus the short intervals between the many upcoming disruptions, is something we did not experience before. The likelihood of unpredictability of innovations over the coming decades is also increasing which is a further complication for strategic assessments. Anticipation of the future by use of methods using historical data therefor should be carefully assessed for their predictive power. The underlying drivers following the human needs to which these innovations are providing solutions can be useful tools to provide insight in the likely barriers and limitations of the changes of the system.

In conclusion, the exact impact of automation on the labour market remains largely unknown. Some efforts to bridge the knowledge gap in this field are ongoing [11]. However, significant changes to the global economic system can be expected, as well as a long period of disruption in the global labour market [12]. Some countries might choose to address it in order to avoid unrest and an increase of inequality, but , without concerted action and significant changes at global level more inequality can be expected. Results published by the Centre for Global Socio-economic Change show a strong correlation between GDP and equality based on the global Big Data exercise they conducted using time series data of many decades of economic performance of most countries in the world.; Countries that have shown deviations from this equality-curve at some moment in time have shown gradual movement back to the curve in the following years. Examples of too much equality given a certain level of GDP as well as too little equality are identified showing this tendency. According to this result an increase in inequality will eventually match with a lower GDP level[13].

3 THE FUTURE TRANSPORT SECTOR

3.1 Key developments and implications

A list of key future developments is listed in Annex B summarizing chapter 2. For each of the listed developments (potential) implications for the transport sector are indicated under the categories general, passenger transport, freight transport and infrastructure. Although this list is not exhaustive and in some cases intentionally abstract, it reveals some important points of attention. In the following paragraphs the main findings of interest for the transport sector are summarized.

3.2 Disruptive innovations for the transport sector

In general, the innovations in the transport sector are aimed at the following improvements:

- The innovations in passenger mobility should lead to better service levels where speed and/or costs (including external costs) are improved.
- The innovations related to freight transportation are targeted at (labour) cost reduction, (resource) efficiency and personalization of the products/services.

Major disrupting innovations to be expected are:

- Automation of all modes wherever acceptable and in particular for road vehicles
- Battery improvements making electric vehicles superior to traditional vehicles
- Mobility-as-a-service (including automation of public transport)
- (Full) Automation of production facilities (see box 3 and 4)
- (Full) Automation of logistical processes; Integrated systems bringing together demand and supply, taking care of the logistical organisation and administrative processes (physical internet) (see box 1).
- New modes (including Hyperloop - see box 2)

Box 1 - In Mobility and logistics the blockchain could be used as facilitator of smart logistics services or smart ticketing. The blockchain is a distributed database which was developed for the Bitcoin but could be used in other. transaction services. Transactions between peers are managed and controlled automatically by the system. Using the blockchain one can for instance create more sophisticated smart contracts and corresponding invoices that pay themselves when a shipment arrives. It can also be used to match transport demand and supply. Where the application possibilities in the financial world is obvious, blockchain can also be used for other services. As is the case with Bitcoin, the role of intermediaries could be reduced to a minimum with significant cost and time saving.

Important characteristics that complicate proper anticipation of the innovations/disruptions are:

- Many innovations cannot be foreseen and emerge suddenly.

- Foreseen innovations are often ready for market much faster than anticipated. by the roadmaps

3.3 Overview of implications for the transport sector

3.3.1 General implications (valid for passenger and freight)

Implications to be expected:

- Level 4 and 5 automation (SAE standard) will likely be on the market sooner than foreseen (due to exponetiality)
- Job loss for professional drivers in case of full automation. New jobs will be created related to the ICT/automation services and cyber security.
- Changing modal categorization (dedicated designs, ownership models, automation, etc.)
- Changing modal competition (due to different innovation (speed) potential)
- Frequent change in transport flow patterns and total demand due to market disruptions in different sectors
- Damage and criminal acts due to unforeseen privacy and cyber security issues.

Box 2 - The Hyperloop is now rapidly developing and on 11/5/2016 a first intermediate test was successful and reached 500 km/h (the final version will reach 1100 km/h)[2]. It should be noted that although the focus is on the speed of the Hyperloop, another selling point is that might use around 10% of the energy of alternatives (electricity) and therefor has lower variable and external costs. This means that also at lower speed and over shorter distances it might be able to compete with other modes of transport. Some international EU links are already mentioned in news articles for development of a Hyperloop connection as well as plans for connecting Moscow amongst others with its suburbs.

3.3.2 Implications for passenger transport:

Implications to be expected:

- Automated private cars lead to the possibility to perform parallel activities while driving. The otherwise historically fairly constant travel time budget could become larger if this time is perceived as leisure or working time. This can lead to an increase of the total mobility demand.
- A mix of shared and privately owned cars most likely will arise. A private car has the advantage that it can be personalized which has its value (for those who can afford it).

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2 https://www.theguardian.com/technology/2016/may/11/hyperloop-supersonic-train-test-propulsion-system

- Mobility-as-a-service (on demand options) could be interesting not only for urban, but also for interurban transport, especially in case the trip is shared with others in carpools or (smaller) busses that provide door-to-door services. Traditional public transport when automated will be chosen primarily for the lower costs. However mobility-on-demand might capture additional market which will have a negative impact on the frequency of the public transport services, leading to a negative impact on the average travel time. Consequently it is likely that the lines with high demand can survive and the low density connections will be replaced by on-demand services in the urban and interurban transport segments. Automated bus connections could have a cost and time advantage over rail in select cases.
- In case the Hyperloop (see box 2) will become a reality, it could lead to a modal-shift on dense interurban and international connections becoming a sustainable alternative. For longer distances, the number of passengers is most likely too low to establish direct connections and hubs should be used; which could lead to additional transfer/waiting times, limiting time savings compared to the air travel alternative. The cost/benefit ratio of the required infrastructure investment will determine the potential for this alternative for specific corridors.

Box 3 - Mega factories are fully automated and have a very large production capacity. Recently, a mega factory was opened in China by Foxconn (a supplier of Samsung and Apple) and consequently 60,000 employees were fired (of the 110,000 in total)[3]. Since mega factories do not require much human labour and therefor the main reason for producing in cheap labour countries is disappearing. A logical consequence would be to bring back production to the developed countries. An example is Gigafactory, the mega battery factory built in the Nevada desert in the USA by Tesla. By 2020, the factory will have a production capacity equal to the total world production of batteries in 2013[4]. The location in the desert is chosen so it can run on solar energy. If traditionally factories had a strong gravity towards the populated areas, that might soon no longer be the case as this example would indicate. Choice of location might become primarily a factor of convenient logistics, availability of required resources and, potentially, also minimisation of external costs.

3.3.3 Implications for freight transport (supply chain):

Implications to be expected:

3 http://www.scmp.com/news/china/economy/article/1949918/rise-robots-60000-workers-culled-just-one-factory-chinas

4 https://www.tesla.com/gigafactory

- Automated trucks will be cheap, flexible and efficient, and the speed of innovation of the road sector remains faster than for the other modes of transport. For bulk and long distance transportation the non-road modes are likely to remain the more efficient alternative, unless the flows on the specific corridor are small.
- Platooning and vehicle technology changes will bring down the energy costs and some external costs (emissions, accidents, noise). Congestion (which will gradually change into longer diversions or cueing at entry point of roads) could increase for certain corridors and compensate (partially) for the (external) cost savings achieved.
- Loading rates of the modes and their quality of service will improve. Improved logistical information systems will ensure a minimisation of (partially) empty rides.
- It is not unlikely that Mega factories will also arise in the EU to bring back production from Asia. More bulk commodities will be transported (to the factories, and waste from the factories) as well as more dense container flows using inland modes (from the factories). These facilities could best be located near ports, inland waterways or rail corridors in order to minimise the need for road transportation and congestion. Depending on the type of industry one could also choose a location where external costs to the population are minimised.
- Also developments in 3D printing will bring back production to the EU and will also create additional production. The 3-d printing facilities will be located near the clients minimising the distance for transportation of the final products but balancing this with the transportation of the required inputs (in bulk). The input to the process will be bulk commodities which could be largely transported by rail or inland waterways to distribution centres. From there it will be transported to the 3D factories. The output can be sent directly to the client by an automated logistical system or to pick-up places near the client or near the factory. City logistics is likely to grow due to 3D printing .
- Material efficiency can be achieved by applying circular economy concepts. This means also more reversed logistics of non-time sensitive low-value goods.
- Automation of the logistic system will lead to a loss of jobs (logistic service providers, terminal operation, distribution centres, etc.). A possible return of production to the EU on the other hand will create new jobs.

<u>Box 4</u> - The potential of <u>3D printing</u> is large and diverse. Typical for 3D printing is that products can be printed out according to the client's specifications, however it could also be used for mass production. Simple 3D printing could be done at home but more complex products will be printed in dedicated locations. These could be small or large but situated near the market and therefore close to or in cities. Much of the production will be automated but potentially it will create new jobs as well.

3.3.4 Implications for infrastructure

Implications to be expected:

- Robotics will lead to radical changes in mobility and logistics patterns and therefor infrastructure demand.
- The gravitation between population and locations which traditionally are labour intensive such as factories and ports, are likely to diminish. Especially polluting activities can in the future even be better situated in sparsely populated areas in order to minimise the negative impacts. Development of smart ports could become interesting for the smaller ports as well dedicated to for instance a Mega factory.
- A return of production to the EU has implications for the main ports. It is not unlikely that more bulk flows will arrive and less than foreseen containers. On the other hand transportation by short-sea of containers might increase.
- Also major inland flows to and from new factories could arise. New and dedicated infrastructure might be required (rail, inland ports or new mode).
- Energy efficiency innovations and a stronger drive away from carbon-based energy production and use (towards CO^2 neutral) will lead to a fast shift to sustainable energy also for road transport. This means that the sustainability advantage of rail gets smaller. For rail this in any case means that a shift to full electric is required including the last mile.
- Due to the more dedicated mobility as a service applications (including shared rides in pods/small busses) more people will make use of road vehicles and less of other public transport. Although automated driving and automated traffic systems are expected to lead to an increase in operational capacity on existing roads it is not unlikely that congestion remains an issue due to the resulting increase of demand for road transport. It is very well possible that an optimal use of the available rail capacity will remain an important and cost effective solution to the road congestion.
- Due to a possible shift from labour to leisure mobility resulting in a potentially lower peak demand, less capacity expansion might be needed.
- Less parking lots might be required in cities and alongside highways (especially for trucks). Automated on-demand vehicles will need parking lots for off-peak periods which are strategically positioned for expected demand in the next peak period.
- Changed fuelling infrastructure, local electricity production (Solaroad, solar panels at home, etc.) and local storage using large-capacity batteries near charging station will relieve the electricity network.
- Less damage on infrastructure due to lighter products. Improved technical life time of infrastructure. Replacement of old infrastructure to match new requirements. Shift from expansion to replacement and maintenance of the existing infrastructure.
- Increased risk for theft of valuable materials from infrastructure. Sensitive infrastructure requires additional security measures .

- Infrastructure needs should be strategically reassessed. Due to the high likelihood of many major disruptions in different sectors, methodologies to assess investments based on models calibrated on historical data should be critically reassessed for their predictive power.

3.3.5 Changes in the automotive stakeholder arena

In the following the main observations related to the changing environment of the automotive sector are listed:

- Besides the traditional stakeholders in the automotive industry, new stakeholders will claim a position in this market, most notably various branches of the ICT industry. Innovations introduced by the new players are likely to be disruptive to incumbents who have a vested interest in preserving the status quo.. Sudden changes could lead to sunk costs for incumbents, lead to market instability and at the same time provide a competitive advantage to the newcomers. Reducing the time to market of innovation is already part of the strategy of ICT incumbents and newcomers alike and that is likely to intensify.
- Differences in strategies between geographical and economic areas emerge which can lead to changes in weighing of priorities. For instance, the EU might aim for a gradual implementation strategy for automated vehicles, whilst competing economies such as those of the US and China might suddenly allow a faster than foreseen implementation. In such a situation EU policy makers will have to balance their preferred strategy with the potential competitive disadvantage of the EU. A possible scenario is that this leads to a sudden change of strategy where we have lost the opportunity to anticipate for the disruptions in the (labour) market. Anticipation also on the non-preferred situations is important to be able to make a fast and well-founded decision.
- Broadening the stakeholder arena in the roadmap discussions and aiming the preparations at the shortest possible moment (rather than the most likely moment) of implementation of the innovations will ensure a proper anticipation of the investments and changes involved.
- Automated vehicles are in fact a form of artificial intelligence. In addition, the communication between smart vehicles and infrastructure makes them a part of the internet of things and thus potentially vulnerable to cyber-attacks. Cyber security and privacy and data protection are likely to become major issues introducing new stakeholders to the market. Providing appropriate solutions to these issues will help contain broader risks, also outside the transport sector itself. For example, the hacking of vehicles can be used for robbery or hijacking of people, but also for terrorist acts with the purpose to cause as much damage as possible to specific sites or random people. This will bring new stakeholders in the discussions in the automotive sector from the ICT, security, legal and law enforcement fields.
- Harmonisation of systems, standardization and interoperability initiatives are difficult topics involving many stakeholder groups. For instance, communication between smart vehicles and infrastructure might require

harmonization of infrastructure investments of many stakeholders including national, regional and local governments as well as the private sector. Anticipation of these investments in future budgets is essential.
- Also electrification of automotive will bring new stakeholders from the energy and electricity storage sector.
- Requirements for urban planning might change (for instance due to changed demand for parking lots combined with smart mobility). The relevant stakeholders might then have to agree on joint decisions on individual available budgets so as to avoid sunk costs/double investments.
- One of the aims of the EU is to build a Single European Transport Area. This implies a highly interconnected system where all modes are interlinked. Therefor the road sector cannot be regarded as distinct from activities in other modes anymore and actors in other modes become stakeholders of the road sector as well.

3.4 Multi-stakeholder governance model

3.4.1 The need for a new governance model

Complex challenges with a global and macro reach looming ahead, heightened uncertainty about the outcomes of future developments, growing interdependencies with other sectors of the economy and a crowding of the traditional market place with the arrival of new players would indicate the need for new governance models for the sector. It can be expected that they will differ from current models, the difference constituting a coping mechanism with redefined needs. Amongst the new needs is that of providing legitimacy for radical new solutions likely to be adopted, managing complexities, incorporating specific needs of new groups of stakeholders. Issues of accountability and control would also have to be redefined for governance in the new context as sketched in the previous chapters. This would seem to point away from current insular models and more in the direction of decentralized but networked, multi-level and multi-stakeholders governance models as better suited for the future of the sector. In this case the changes would be far from trivial.

3.4.2 Governance model options

Many typologies for governance models exist but an convenient choice for this discussion is the typology of Provan and Kenis (2007) [15]. They distinguish between three forms of governance (the first form most network-oriented and the third most hierarchic):

- Shared Governance (or Participant-Governed network). In this governance model there is no unique or formal governance structure as all members have the same power to make decisions and manage network activities. There is no single member that represents the whole network.
- Network Administrative Organization (NAO). In the NAO governance model network members do not have power to make decisions and manage network activities, nor do they have one member of the network that acts as a leader. In this model there is a special administrative entity that is set up specifically to

manage the whole network. Often the separate members are represented in the board of the administrative body and thereby can influence the overall management of the network.
- Lead Organization. In the ‘lead organisation’ model there is one member that acts as leader and all decisions and network activities are coordinated and managed by the leader. The leader is usually a member of the network, has more power, resources and the formal legitimacy (or mandate) to lead the network.

The choice of the most effective governance model for an integrated transport system will depend on the size, form and dynamics of the regions where transport should be integrated as well as on legal cultural and other characteristics. The current types of governance of the transport sector in the EU vary from country to country and are based on institutional legacies, and (often country specific) public, private or public-private (PPP) ownership models (Christodoulou et al., 2012)[16].

Key for highly networked forms of governance is mutual trust between participants and goal consensus (Provan and Kenis, 2007)[15]. Trust, consensus in goals and domain similarity allows participants of the network to perform better than when there is distrust and/or conflicting interests.

When designing new governance structures for an EU-wide complex system it is important that it is substantial enough to offer stability and support for decisions without resulting in an over-controlled environment likely to stifle innovation (e.g. Schindler et al., 2012)[14].

Important in the European context is also the specific role the European Commission can play in achieving the required goals. That will have to take into account that Member States (mostly their local authorities) have the mandate to decide upon key mobility issues. While the EU for instance can act as a facilitator of good practice and a point of contact for sharing information and resources, it remain limited in its powers and capacity to advance the EU-wide integrated transport network without the strong co-operation and support of cities, regions and Member States.

3.4.3 The way towards a new governance model

Shaping the most optimal governance structure possible within the EU is not a straightforward task and should be done with care. However given the speed of the developments it is important to make progress in the shortest possible time. Steps towards an appropriate governance model for the automation of the transport sector can be initiated by the EU and could include:

- Study of transport governance models in various EU countries, focusing on essential dimensions such as ownership, control and accountability;
- Study of the cultural, legal, organizational backgrounds of transport systems in EU countries;
- Exploring alternative choices of governance models that can be applied and assessing their merits relative to traditional ones;

- Adopting good governance principles (e.g. accountability, responsiveness, sustainability)
- Integrating key EC values such as openness, cooperation, accountability, effectiveness and coherence
- Embedding key values such as privacy, equality, autonomy, self-determination
- Prioritizing the most appropriate governance model(s);
- Charting gaps between current (and fragmented) governance models and future models and the transformation steps that have to be taken.
- Defining the roadmap for transition and transformation.

4 DISCUSSION AND CONCLUSIONS

This reflection paper aims to enrich the dialogue between stakeholders regarding shared decision-making and responsibilities in the automotive sector and transport in general. It is a necessary step towards articulating specific requirements of each individual stakeholder group, harmonizing interests and formulating an action plan and concrete solutions to benefit innovation for smart mobility and society at large.

The foresighting exercise provides some important focal points resulting from the aggregate of likely future developments:

- Due to the exponential speed of innovation many disruptive innovations are on the market faster than foreseen in roadmaps. Anticipating for the fastest possible moment rather than the most likely moment of implementation will benefit the competitiveness of the EU.
- The acceleration of innovation and automation leads to socio-economic system changes which will introduce uncertainty around the predictive power of traditional investment/policy assessment methodologies which are using historical data as basis. These methodologies should be reassessed and adjusted where needed and possible.
- New stakeholders in the automotive arena originating from the ICT sector should be involved in the roadmap discussion.
- Harmonisation and anticipation of ITS infrastructure investments should be organised at an early stage. Due to uncertainty of the technical requirements this discussion should be done in a stepwise approach with a gradual shift of focus from general processes and organisation to detailed technical implementation.
- Cyber security and privacy are important potential bottlenecks/risks requiring much attention at an early stage. Clarity on allocation of responsibilities to the different stakeholders is essential to ensure progress.
- A long term strategy is required for a flexible and future proof design of the living environment.

The need for a new governance model for the automation of the automotive and the rest of the transport sector is identified. The requirements seem to point away from current insular models and more in the direction of decentralized but networked, multi-level and multi-stakeholders governance models as better suited for the future of the sector. The process for the identification of the most appropriate governance model and the further steps towards implementation could be initiated by the EU.

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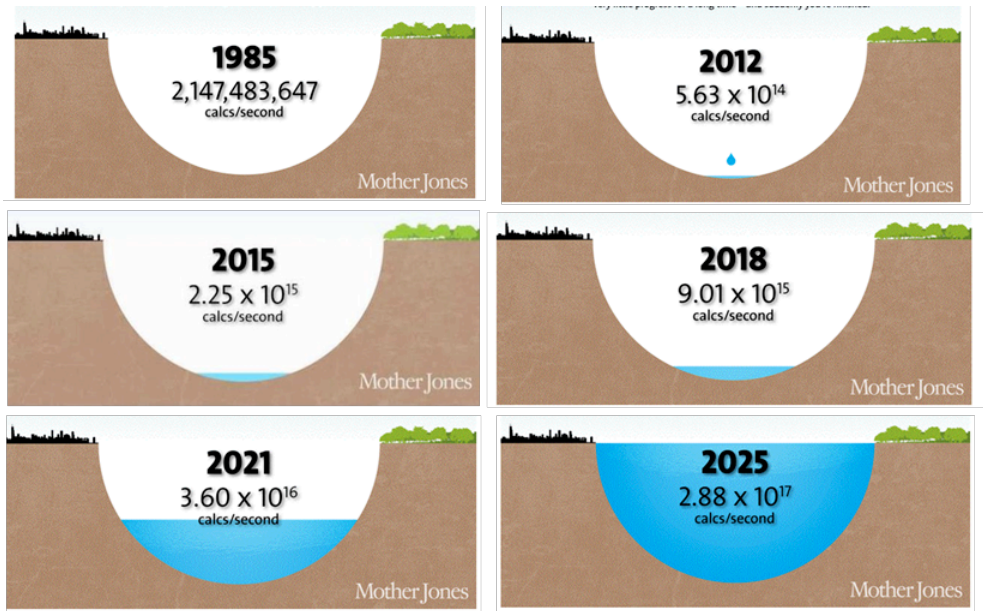
6 ANNEX A: EXPONENTIAL DEVELOPMENT OF TECHNOLOGY

Moore's Law is in the meantime a well-known phenomenon. Where at first it was an observation by Moore that the developments of ICT seemed be exponential, it now is already for some time used as an objective within the ICT sector. Consequently also other sectors benefiting from these developments and also shows an exponential growth of their innovation power.

Fig. 1: Exponential increase of computing power; calculations/second represented by water drops in a lake doubling every 18 months (volume lake equals human brain capacity)[5,6]



It is important to realise where we stand in the exponential development. A nice visualisation of the development over the years is shown in figure 1. Here a lake is schematically shown which has a volume (in fluid ounces) which, when translated into calculation/second, is about the same as the human brain capacity. The exponential growth of computing power is shown in drops filling the lake over time and doubling every 18 months like the computing power does following Moore's Law. Starting from 1940 we do not see much happening until about 2012. After this point suddenly we can observe that a small layer of water in the lake and slowly starts filling up, which goes on in a modest pace until about 2018. After 2018 the lake fills

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5 The exact timing of computer speed being at the level of human brain capacity is under debate, but most estimates range from 2025 to 2035. The more recent ones tend to move towards 2025.

6 Source: Kevin Drum, May 2013, MotherJones.com

up in more significant steps and in 2025 it suddenly is completely filled. This is also how we will observe the upcoming innovations. Suddenly they are there and years faster than anticipated in roadmaps.

7 ANNEX B: FUTURE DEVELOPMENTS AND IMPLICATIONS FOR THE TRANSPORT SECTOR

Tab. 1: Technology developments and implications for the transport sector

Future development	**implications transport sector**	
	category	**implication**
large number of disruptive innovations will follow each other up with short intervals	general	frequent change in transport flow patterns and total demand
	passenger	
	Freight	
	infra.	required supply hard to determine
misconception of exponentiality leads to reactive rather than anticipative policies of disruptive innovations	general	level 5 automation comes sooner, professional drivers sooner replaceable, larger than foreseen difference in innovation speed of competitive modes (f.i. rail vs road), new modes (Hyperloop) might become competitive sooner, electric vehicles competitive sooner, major sunk costs for incumbents and newcomers take a major market share....
	passenger	(automated) mobility as a service comes faster
	Freight	platooning comes faster, physical internet might come faster, service providers sooner replaceable
	infra.	infrastructure investments hard to assess
Human physical and mental capacities are challenged, augmented and optimised by ICT (Internet of things, Big Data, Machine learning, robotisation, augmented reality, …)	general	Job loss for professional drivers due to automated driving, changed requirements for human capital,
	passenger	decreasing work related mobility, increase of leisure movements
	Freight	job loss at terminals and service providers
	infra.	less parking lots required in cities and along highways (especially for trucks), terminals automated, connectivity to (remote) automated factories (possibility for dedicated (small) ports)
Nano-technology will lead to rapid discovery/targeted design of new breakthrough innovations (such as materials and	general	Battery improvements could make electric cars superior, vehicles will become lighter,
	passenger	more active mobility of elderly
	Freight	
	infra.	

Future development	implications transport sector	
	category	implication
medication)		

Tab. 2: Resource efficiency developments and implications for the transport sector

Future development	**implications transport sector**	
	category	**implication**
non-carbon energy > electric vehicles	general	potentially less CO2 emissions, less pollutants (near population), more batteries and demand for related materials
	passenger	more mobility due to lower costs and less environmental concerns
	Freight	
	infra.	changed fuelling infrastructure, local electricity production (Solaroad, solar panels at home, …) and local storage by large batteries near charging station
many (disruptive) innovative solutions	general	less material/energy scarcity, more material/energy demand due to lower production prices (rebound), more CO2 neutral solutions
	passenger	more mobility due to lower costs and less environmental concerns
	Freight	shifting balance EU/non-EU flows
	infra.	improved technical life time of infrastructure, replacement of old infrastructure to match new requirements, …
Less material per product	general	less energy use
	passenger	
	Freight	less bulk flows, volume restrictions more important than weight restrictions of vehicles
	infra.	less damage on infrastructure
Lighter materials	general	less energy use
	passenger	
	Freight	volume restrictions more important than weight restrictions of vehicles
	infra.	less damage on infrastructure
re-use of materials/circular economy	general	
	passenger	
	Freight	increased reversed logistics, shifting balance EU/non-EU flows
	infra.	

Tab. 3: Economic developments and implications for the transport sector

Future development	**implications transport sector**	
	category	**implication**
limits to global growth of production of physical products and GDP growth	general	More demand for shared products and services, strong drive for cost reduction
	passenger	from Über to mobility as a service, scheduled service partially replaced by services on demand
	Freight	reduction of costs by automation of processes, driving and physical handling of cargo
	infra.	from expansion to replacement and maintenance of the infrastructure
rapidly increasing automation/robo tisation (/disruptions) in many sectors at the same time	general	unstable total transport demand, demand possibly better spread over the day due to shift from labour to leisure movements
	passenger	decreasing work related mobility, increase of leisure movements, on line services replace shopping and administrative trips
	Freight	bulk flows to fully automated mega factories and 3D printing factories. Big final product flows from Mega factories to hubs and many dedicated deliveries from 3d printing factories and hubs to consumers. Continuation of on-line sales and dedicated deliveries.
	infra.	in case of lower peak demand less expansion needed
risk for growing inequality between countries	general	Following the accumulation of capital principle the EU will be on the positive side of the spectrum. Inequality within the EU could grow if not structurally dealt with in the coming years. Shifts in patterns are likely, changes in total demand uncertain
	passenger	Possibly disruptions in intercontinental flights. More security checks using advanced technologies.
	Freight	shifting trade patterns within the EU. Production moving back to the EU from cheap labour countries. Changing export patterns. Security checks for people smuggling using advanced technologies
	infra.	Port and border facility requirements changing
risk for growing inequality within countries	general	
	passenger	demand for both cost efficient solutions and high end solutions
	Freight	cost reduction in production and logistics could keep total demand stable. Demand for luxury products could grow
	infra.	

Tab. 4: Social developments and implications for the transport sector

Future development	**implications transport sector**	
	category	**implication**
increase of life expectancy and in good shape at old age (for those who can afford it)	general	increasing population means a positive impulse on transport demand
	passenger	more active mobility of elderly
	Freight	positive impact on freight transport demand
	infra.	
High pressure due to dependency of retired people on the workers (potentially leading to higher retirement age and larger labour market depending on social organisation).	general	The actual impact is depending on GDP development and the social organisation, however it is likely that this will have negative influence on transport demand.
	passenger	
	Freight	
	infra.	
More leisure time due to automation/ unemployment	general	demand possibly better spread over the day due to shift from labour to leisure movements
	passenger	
	Freight	
	infra.	in case of lower peak demand less expansion needed
increase of on-line time and geographically uninterrupted possibility to be on-line	general	
	passenger	travel time used for other on-line activities (leisure, work), consequently the average travel time per day could increase, shifting mobility patterns due to on-line services and facilities
	Freight	
	infra.	
Risk for growth of number of criminal acts	general	security issues will gain attention in general. Cyber security of automated vehicles and processes will be a booming topic. In case privacy is not guaranteed properly this could lead to additional security risks.
	passenger	Risk for hacking of vehicles, risk for burglary at home in case one could see that you are elsewhere with your care by tracking and tracing,....
	Freight	risk for hacking of automated trucks and robbery while driving,....
	infra.	increased risk for theft of valuable materials from infrastructure,...
risk for growing global instability (including virtual societies such as	general	EU Border issues remain relevant due to increased risk for instability and poverty in neighbouring countries.

Future development	**implications transport sector**	
	category	**implication**
ISIS)	passenger	Risk for hacking of vehicles
	Freight	Risk for people smuggling on automated vehicles. Risk for terrorist use of hacked trucks. Delays due to security checks
	infra.	sensitive infrastructure requires additional security measures