AN OUTLOOK ON FUTURE MOBILITY: KEY DRIVERS AND NEW CHALLENGES

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ABSTRACT

Mobility patterns and transport attitudes are the direct consequences of the mechanisms that operate in the society on the whole. Transport demand is a derivative one, and as such, it is mostly affected by pre-dominant factors and their interactions related to the social, economic, environmental and technology forces that interact in the present and that drive changes in the society. These key factors are obviously expected to put new pressures on the transport system in the incoming years. Population ageing, migration flows, global warming, scarcity of fossil fuels are among the phenomena expected to highly influence future mobility patterns.
The acknowledgment of these factors and trends is of a vital importance for those involved in planning mobility and in finding more sustainable solutions for transport, both for present but also for future needs. To be effective, transport policies should be designed and evaluated with a look towards existing trends and future challenges, providing as much as possible a global and long-term vision in the context of sustainable mobility. The aim of this paper is to provide a wide, even though still not exhaustive, review of key factors and drivers that will contribute to the development of the next European scenarios and its future mobility patterns. The results of the analysis are then used in the final section for providing some advices for future policies and planning activities which could be implemented to face these challenges.

Keywords: population aging, touristic flows, urbanisation and planning, GHG emissions and pollution abatement, Emission Trading Scheme, energy production and consumption, fossil fuels, fiscal incentives, GDP trends, public investments, Intelligent Transport Systems, new vehicles, alternative fuels, renewable energy, future transport demand in Europe.

INTRODUCTION

The research activity at the basis of this paper aims at identifying the key drivers in social, economic, environmental and technological domains that are likely to play a dominant role in the next decades in Europe and influence current and future mobility patterns.

So far, a huge amount of research projects and scientific publications have investigated the relationships between relevant socio-economic drivers and mobility patterns. Generally, the demand for the transport sector is examined by placing the sector itself at the centre of the analysis, and investigating variables that influence the changes to mobility and transport patterns. Nevertheless it cannot be neglected that transport demand is generated by factors that are exogenous to the transport sector and that mobility rises to satisfy specific individual needs as clearly expressed by the purpose for which passenger trips are made.
In order to identify the drivers of transport demand and its dynamics a detailed analysis of sectors of activities outside the transport domain is therefore needed.
The effort made by COMPASS (www.fp7-compass.eu) and ASSIST (www.assist-project.eu) EU funded research projects and presented in the next pages is trying to overcome the boundary of consolidated transport sector research and expanding the investigation of factors potentially affecting mobility also to the different domains of reality. The objective of this widening lies not only in the need to enrich the analysis of "well-known" key drivers, but mainly in the interest of complementing the investigation with additional side aspects potentially influencing mobility that could gain increasing importance in decades to come.
The research builds upon a wide review of existing literature, ranging from studies addressing the relationships between relevant socio-economic trends and mobility to other studies not directly addressing future mobility, but dealing with expected social, technological and economic transformations.
The analysis framework is based on the scanning of the Social, Technical, Environmental and Economic domains in order to provide an in-depth snapshot of the main drivers potentially impacting on mobility.

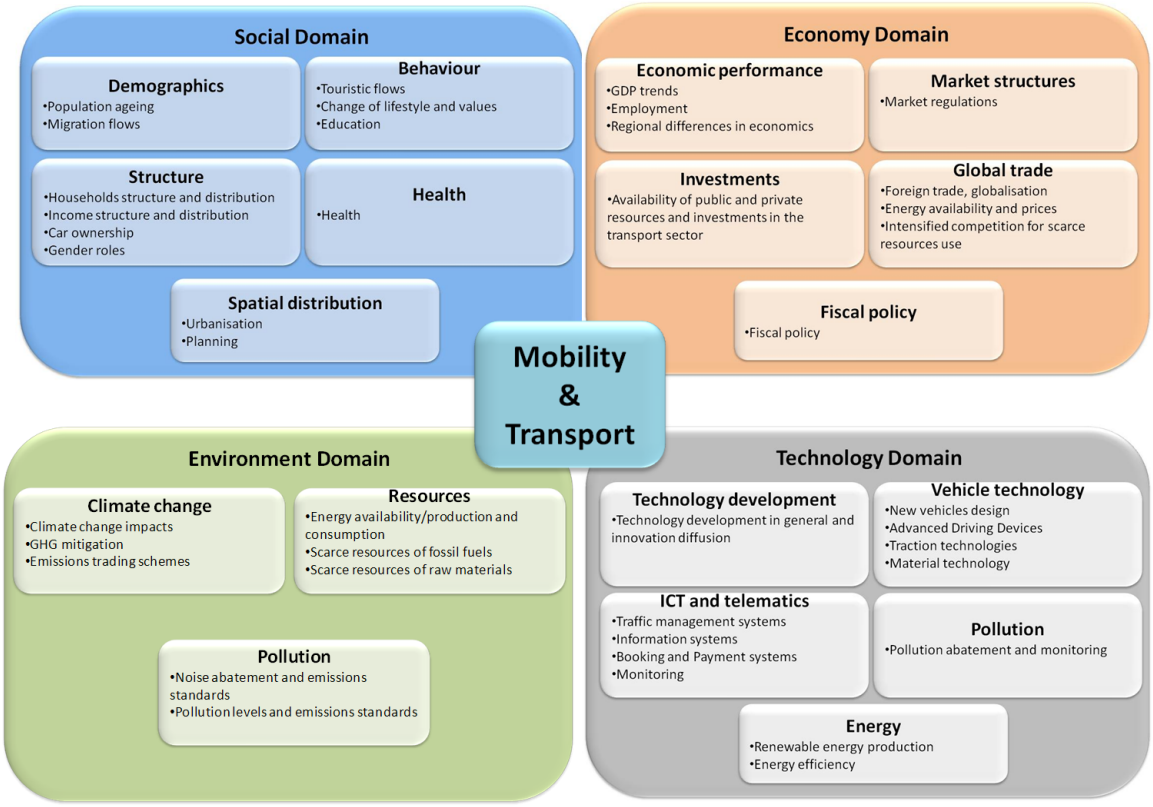

Figure 1 – The key drivers that will affect mobility and transport

For each domain the main factors have been selected and, for each factor, the key drivers have been identified and reviewed in terms of:

- **Driver description** intended at providing an overview of driver's nature, together with a summary of the existing and expected trends, when available;
- **Interactions within the domain** the driver belongs to, that explores the main intra-domain relationships with other drivers;
- **Interactions with the remaining domains**, which completes the coverage of possible relationships with the drivers of other domains.

Impacts on future mobility patterns and transport are highlighted and discussed in terms of the potential effects that the driver and its interactions has or could have on passenger demand (in terms of spatial and temporal distribution, population segments involved, behavioural aspects, etc.) and on the related transport modes.

The paper is intended to present the authors' understanding of current and future trends potentially impacting on mobility as emerged during the literature review. The authors are aware that diverse interpretations may arise from the reading of the reviewed documents as in several cases literature provides different, if not contradictory, interpretations of the same phenomenon. Additionally, several other hypothetical scenarios may arise when considering the combination of different factors, thus making it more difficult to reach an indisputable point of view.

Results presented in the paper can contribute to the discussion on the impacts of transport policies in a long-term and wide vision, in order to evaluate adjustment and/or mitigation actions which might be required for facing the future challenges for the transport system.

THE SOCIAL DOMAIN

The demographic factor

Projecting demographic developments in the next decades is one of the most daunting analytical tasks facing policy makers; a high uncertainty surrounds the projections and this uncertainty grows the longer the projection period.

Substantial uncertainty remains, for example, on migration flows, the health status of the elderly or on the incidence of disability; therefore the projection results are strongly influenced by the underlying assumptions.

As shown in EUROPOP2010, the overall size of the population is projected to be slightly larger in 50 years time, but much older than it is now: by 2060, the median age of the Europeans is projected to be more than 7 years higher than today and the number of people aged 65 or more is expected to represent 30% of the population as opposed to 17% today.

The **ageing of European population** is the result of different demographic factors: trends in fertility showing a reduction of birth rates, increased life expectancy due to the medical progress as well as migration dynamics and policies.

An ageing population could represent a huge problem for the economy. Most of the projected increase in public spending will be on pensions, health care, and long-term care. Recent demographic projections show that in 2060 there will be only two active workers for every pensioner.

The ageing of population will change the households' structure (smaller family units) so that social institutions will be required more and more to replace family care.
As far as mobility is concerned, transport supply will need to adapt to elderly people, especially in terms of accessibility, availability of public transport, user-friendliness of payment systems, safety and security. The effect of ageing on the total amount of transport demand is not straightforward to predict since it strictly depends on activity rates and income distribution. If the retirement age will be raised, everyday mobility patterns might not change dramatically even if a tendency towards shorter distances and public transport could be observed. However, if elderly people will be able to enjoy many years retired with a good income, commuting daily trips could be reduced whereas leisure and tourist trips could be increased.
Migration has become an increasingly important phenomenon for Europe: in 2009, about 3.0 million people immigrated into one of the EU Member States while at least 1.9 million emigrants were reported to have left an EU Member State.
Whereas migration used to be in the past predominantly a one-off movement leading to permanent resettlement, recent migration is more fluid, thanks to improved transport and communication networks. Migrants today may make consecutive stays in different countries, or alternate residence between countries.
A particular distinction must be made between intra-EU migration and migration from outside of the EU. Intra-European migration flows are very diverse. They comprise retirees from northern European regions moving south to the Mediterranean regions as well as East-European workers in search of jobs moving to West-European countries. Alongside traditional migration and mobility, new forms of mobility are taking place: well-educated young adults, towards the higher end of the occupational scale, are moving abroad for shorter periods to seek work, pursue their education or other life opportunities. Intra-European flows will probably intensify in a scenario shaped by weakened national borders and increased regional disparities.
When looking at inter-European migration, recent studies show that in 2010 4% of the total EU27 population (20.1 million) were citizens of a non-EU27 country. The distribution by continent of origin of third country nationals living in the EU shows that 7.2 million people were citizens of a European country outside the EU (mainly from Turkey, Albania or Ukraine). The second biggest group was from Africa (mainly from Morocco or Algeria), followed by Asia (in particular from India or China) and the Americas (Ecuador, Brazil and Colombia). Patterns of migration flows are influenced by several factors such as labour migration, historical links between origin and destination countries and established networks in destination countries.
Future trends in migration are hard to anticipate, as they depend on future events across the world ranging from economic and social factors to political developments. Even though the global economic crisis has slowed emigration in many parts of the world, with economic recovery and job growth, most consider this slowdown to be temporary. Recent projections for the EU as a whole show that annual net inflows are estimated to increase from about 1 million people in 2010 to 1.2 million by 2020 and thereafter declining to 878,000 people by 2060. The cumulative net migration to the EU over the entire projection period is 55 million, of which most is in the Eurozone (42 million).

Given the lower median age of migrants, migration flows could mitigate the speed of European population aging. However, studies reveal that in order to offset the population decline, immigration to Europe should double in the coming years. Unless future migration policy will not change dramatically, the ageing of European population and its impact on labour will only be slightly compensated by younger migrants.
Although the travel behaviour of immigrants and their attitudes toward different travel modes are generally scarcely researched by national travel survey in European countries, some studies reveal that, especially at the beginning of their experience, migrants are mainly concentrated in urban areas and, given the lower economic standards, have generally lower access to cars, travel less and mostly by public transport or by walking. Nevertheless, studies reveal also that many of the immigrants had access to a car and a driver license in the country of origin, and many would like to have a car and a driver license in the future again. This implies that their current mobility patterns are expected to change in case of improved economic conditions (following their integration in the society), and thus the differences in mobility between the immigrants who have stayed longer in their new country and the domestically born is expected to decline in the future.
When considering long-distance mobility, migration and tourism tend to become mutually interacting phenomena whose importance is rapidly growing. Given the expected trends in migration flows, increased movements of people within Europe and between Europe and the origin countries can be easily forecast, as well as an increase in the demand for international and intercontinental transport services.

The structure and spatial distribution factors

Mobility is strictly dependent on **income level**: lower incomes are usually accompanied by reduced trip rates while on the contrary higher incomes are associated with increased mobility.
The main source of income for individuals and households in the EU is earnings from employment. Recent analyses show that both earnings and income inequalities have increased in recent decades for most EU states, with the level of inequality varying between Member States as well as within them. In addition, new forms of social exclusion and poverty are emerging: “infrastructure-poor” (Eastern Europe); “feminisation of poverty”, mainly among single, immigrant mothers (Southern Europe); “immigrant poverty” (Central Europe and other countries); “young people at risk of poverty” (Eastern and Southern Europe); “the vulnerable elderly” (Eastern and Western Europe).
In the future private mobility might become unsustainable for an increased share of the population and reliable, safe, and affordable public transport options might have to be offered to an expanding number of poor people, thus putting more pressure on public transport policies and on the need for subsidies. The need for cheaper public transport options, both for short and long distances, might be also exacerbated by fiscal policies increasing fuel and car ownership taxes.
On the other side, people with higher income could increase their demand for faster transport modes. In a scenario of recovered economic growth and rising income levels, a rising demand for mobility might be expected, both in terms of number of trips and total length, with

travellers shifting from public modes (bus, railroads) to the private car and increasing the demand for faster modes (high-speed rail and air).

Car ownership is an important determinant of passenger travel behaviour and it is fundamentally interconnected with residential location and decision-making regarding motorised trips. Ownership rates increased significantly during the 70s and for lower-income households during the 80s, but flattened and declined in some cases during the 90s. Nowadays people living in urban areas are provided with several public transport and car sharing options to satisfy their mobility needs, and slow mobility (walking and cycling) is gaining increasing attention.

The ageing population will inevitably modify its long-term mobility patterns relying more and more on public transport as driving capability will expire; the observed trends of re-urbanisation and consumers' increased preference for walkable neighbourhoods will probably slow down the urban sprawl trends and reduce car dependency; in addition younger generations are showing more interest in technological gadgets and social networks rather than in owing a car.

Economic development has historically been strongly associated with an increase in the demand for transportation and particularly in the number of road vehicles. This relationship is also evident in the developing economies today with car ownership rapidly expanding with important implications for transport and environmental policies, as well as for the global oil market.

In the past decades the development of European cities was driven by **urban sprawl** with cities becoming much less compact even in the absence of demographic pressure. Urban expansion was mainly driven by economic growth and restructuring, new employment opportunities, growth of transport infrastructure, household change, as well as a decline of traditional rural economies.

Urban functions are being spread over larger and larger geographic areas so that the traditional distinction between urban and rural areas is becoming increasingly redundant for many purposes. From an economic perspective urban sprawl is a costly form of urban development and on the environmental side urban sprawl is the main factor behind the growth of urban transport and GHG emissions.

However, there is some evidence that sprawl has reached its peak in many cities and, in parallel with the sprawl reduction, a certain trend towards re-urbanisation is being observed with inner-city areas becoming more attractive to new target groups (e.g. high-income households, small families, older people etc.).

The reduction of urban sprawl may have major implications for mobility and transport especially on reduced travelled distance, lower dependency on the car, and thus on fuel, and reduced road congestion in accession to the city.

The behaviour factor

Like in the rest of the world, the European **tourism** industry was severely affected by the global economic recession in 2008-2009 with the region overall suffering a decline in arrivals and a fall in receipts. This trend confirms the great dependency between economic welfare and tourist flows and makes it extremely difficult to make forecasts for future trends.

In a suffering economy travellers may heavily change their behaviour by reducing tourism trips and shortening both distance and duration. Also business travel may be affected through companies curtailing business trips. As already registered, an economic recession may be associated with a decline in air travel. In contrast, in a scenario of growing economy, tourist trips would increase both in number and distance, as witnessed by the growing domestic and intra-regional tourism also in emerging economies.

Mobility patterns are also heavily affected by **changes in lifestyle and values**, but it is difficult to make future estimates about the intensity and timing with which these will impact on levels and distribution of demand. These changes could affect both short and long-distance mobility. Everyday mobility can be reduced given the home-working and home-entertainment options provided by new technologies. Different kind of activities can be currently executed via web (e.g. e-shopping, e-banking, e-booking of different services etc.) with these options becoming more and more available in the future with an increasing number of users due to the natural decline of digital illiteracy in the population. Additionally, the diffusion of immersive networking technology, especially among young people, may lead to the development of different sets of mobility preferences with future generations who are likely to spend more time in virtual spaces.

Nevertheless the potential impacts of telecommunications technology on life-style and travel demand tend still to be educated guesses. One critical difficulty is the lack of data that can support the effort to determine whether in-home activities may substitute for out-of-home activities, whether out-of-home activities will be suppressed, or whether new out-of-home activities will be induced as a result of new telecommunications technology.

On the other side, the intensification of information flows is increasing the interest of Europeans in international experiences. This factor, together with the reduction of air fares, has heavily changed mobility by increasing the demand for long-distance leisure trips and changing the way Europeans conduct business or, more in general, their lives.

Changing values can also impact on demand distribution “in space” as in the case of re-urbanisation driven by a new perception of urban living, “in time” as in the case of flexible working times taking place in several economic sectors, and “in modes” as in the case of increased environmental consciousness especially among young people. This last factor is further supported by the evidence, included in several studies, that obtaining a driving licence as part of the initiation into adult society is no more considered as a need among young people and that the popularity of the car as a status symbol is declining, especially as alternative status symbols (such as smart technology devices) emerge.

The impact of an emerging “sustainable consumption” culture on transport could be important. During the Twentieth Century, walking, cycling and travel by public transport were stigmatised, but in recent years alternative modes have become more socially acceptable. For example, bicycle commuting is increasingly accepted and even prestigious. Sustainable mobility concepts are more likely to emerge in the urban environment, with greater attention of people towards active travel (walking and cycling), combined with the use of high quality public transport (which can be more cost-effectively organised in compact urban environments) and information services.

THE ECONOMY DOMAIN

The economic performance factor

A wealthier economy (namely, higher per-capita **GDP**) encourages people to change habits, beliefs and values for example demanding for more expensive transport modes, inducing higher car ownership rates, high speed train services and diversion to air transport. Nevertheless, the understanding of the whole interaction remains knotty and still difficult to disentangle, because of the complex causal and feedback mechanism that are involved. Decoupling economy and transport is a cornerstone, as the historic link between GDP and traffic growth should be broken-up towards a more sustainable economic growth based on a lower transport intensity rate. In the current European scenario any long-term forecast about the GDP trend is extremely hard. As a consequence, it seems hard to envisage any noticeable variation of transport demand both for passengers and freight.

The gap between regions is expected to enlarge due to the persistence of the current economic situation. Forward looking, **regional differences** will become more evident in countries where underlying drivers, such as population growth, agglomeration economies, diffusion and development of technologies, globalisation and favourable economic policies (e.g. sustained public investment) will continue supporting a stable pace. Developing countries will become more urbanised, with higher motorisation rates and even more dependent from energy sources. This could determine an anticipated shortage of oil reserves, as well as an increase of the prices of the products related to oil with unavoidable consequences throughout all the transport sectors worldwide.

Emerging countries are still less inclined to address and issue measures to contain emissions, since these policies might slow down the gained progress rate. Due to the present crisis, differences across regions will be more likely to occur, and environmental pollution will increase amongst countries until governments will develop an even awareness in this respect. In emerging economies major transport investments can be expected to improve their accessibility domestically, from/to neighbouring countries and even further. Migration and tourist flows, as well as the trade sector, will highly benefit from improved accessibility. In particular, an increase of the air transport market is expected in emerging economies: by 2030 the combined domestic markets in China and India are projected to overtake the current US domestic market which, in 2010, was the largest in the world.

Currently, in the EU27 **employment** is projected to record an annual growth rate of only 0.3% over the period 2010 to 2020 and to reverse to a negative growth rate of a similar magnitude over the period 2020 to 2060. In particular, the share of workers within the range 55-64 years old is forecast to increase from 46.3% in 2010 to 56.1% in 2020 and to 62.7% in 2060, reflecting the expected impact of recent pension reforms in many European countries, aimed at postponing the retirement age.

Scenarios seem to be not encouraging also because full employment has not been in the policy agenda since the faith in market and supply-side economics has restricted labour policies to those targeted on improving (or trying to improve) labour participation.

Socially, employment as well as unemployment may both drive migration flows between regions. In the first case, skilled workers seek job opportunities in places where advanced capabilities are more likely to be required, on the other hand, unemployed people living in

distress and dwelling in depressed areas are more inclined to move to urban centres, where they could strive for becoming better off. If migration to specialised labour markets flows from rural and remote areas to the more urbanised ones, then occupation patterns will definitively also affect urban development and mobility.

The investment factor

The economy cycle impacts on public spending possibilities for **investments** in the transport sector. Under the current policy environment, budget constraints of Governments are manifold and hit transport mainly in terms of reduced funds granted to subsidise public transport and with respect to investments in new infrastructures.
From a macro-economic perspective, public investment in transport infrastructure may foster a suffering economy, although such a policy has not a clear and perfect causal-effect relationship. As a matter of fact, transport infrastructure may require a huge amount of financial resources and the returns on investments may not be perfectly overlapped with the real pattern of the economic cycle.
Europe invests on average 5% of GDP in transport infrastructure, with an increasing share of these resources being placed in upgrading and extending the trans-European rail network. The cost of EU infrastructure that would be required to match the demand for transport is estimated at over € 1.5 trillion in the time span 2010-2030. Additionally it can be supposed that further investments might be needed in the future in order to address the emerging mobility needs of the elderly working people: private and public vehicles will have to respond to new comfort and safety requirements and transport infrastructures will have to be adapted accordingly to reduced perceptions of aged people.
However, as introduced above, in the coming years and decades there might be an increasing difficulty in finding the means for investing in transport infrastructure, given that a larger amount of resources will be absorbed by social services provided to the ageing population. Additionally, the recent economic crisis has severely hit public budgets and private lending with direct impacts on the building of infrastructures and on the viability of companies providing transport services.

The market structure, the global trade and the fiscal policy factors

The **market structure** is going to influence future mobility trends to the extent that rules and regulations (e.g. more or less market liberalisation) will exert an impact on transport demand and supply via relevant drivers. The literature review has in fact established a correlation between market structure, ranging from lower levels of regulation (i.e. liberalised markets) to stricter rules (regulated markets), and important drivers of transport demand and supply, namely: a) GDP trends, correlated to higher market liberalisation, and leading to higher mobility rates; b) foreign trade and liberalisation, resulting from higher market opening and integration, leading to higher freight transport growth rates; c) technology development and innovation, assumed as a by-product of more competition and R&D investment, determining a positive impact on mobility of goods and people.

It is important to stress the implications of the market structure on the use of transport modes and the characteristics of travel, e.g. average distance. In market-oriented economies, mobility is more likely to be based on open-market structures that sustain economic integration through long-distance mobility (e.g. shipping and air transport), both for passengers and freight. On the other hand, a market structure with higher fragmentation and national-inward orientation may have the opposite effect, namely favouring short distance trips.

In the next decades, the **globalisation process**, driven by the trade liberalisation policies and accelerated by the falling of transport prices, is expected to continue and to influence economic growth, employment and transport. Currently, 1% GPD growth corresponds to a world trade growth of 2.5%-3.0% and a parallel rise of transport services.

According to the mainstream, globalisation's impacts on employment and regional wealth will depend upon the ability of European policies to respond to the increased competition that requires higher flexibility in the labour market and a deep restructuring of the industry sector. The policy challenge of the next years will be to decouple economic development from transport growth and it will require a rethinking of the transport services with the reorganisation of the rail network and flight connections as well as the reorganisation of urban and regional communities.

Energy availability and prices are underlying in the process of globalisation and economic growth. Severe price fluctuations and a high oil price are able to slow growth, raise the unemployment rate and reduce trade and mobility. Oil prices are expected to remain high and subjected to price volatility. The rise in fuels prices, especially of oil, will influence transport costs, though might not reduce traffic flows very strongly, since 80% of them are considered as non price sensitive. Vehicle-miles travelled tend to rebound as consumers become accustomed to the new level of price or income levels rise, and for freight transport, transport costs represent a relative low share of total production and goods prices.

A high oil price might increase the deployment of various oil derivates that could exacerbate the competition for the use of scarce resources as exemplified by the competition between the first generation of biofuels with food production. Some literature indicates that in 2030, powering 5% of global road transport by biofuel could consume between 20-100% of the total quantity of water now used for agriculture worldwide. With the global governance lies the responsibility for promoting policies and investments able to manage shared resources in a sustainable way, considering the interrelatedness of water, food and energy security.

Fiscal policy addresses the strategy of reaching a sustainable equilibrium between public revenues and expenditure. The implications of the fiscal policy scenarios on transport trends concern, on the one hand, the impacts on disposable net income and, on the other, the influence of the use of most pollutant transport modes (internalisation of externalities via environmental taxation). The former aspect may reduce the future transport demand (in particular long-distance leisure trips), to the extent that a tight fiscal policy reduces the actual demand. The latter aspect could influence the use of the most polluting transport modes: levying carbon taxes based on fossil fuel carbon content would lead, in the near future, to the reduction of the use of the most polluting and intensive carbon-use transport modes, e.g. cars and airplanes.

THE ENVIRONMENT DOMAIN

The climate change factor

Many impacts of **climate change** are already visible in Europe and worldwide and these impacts will become more pronounced in the future. In the short and medium term climate change will increase the occurrence of extreme weather events, while in the long run it will lead to an increase in average annual temperatures, alter rainfall, and raise the sea level and the risk of coastal erosion.
As a consequence, there might be strong distributional patterns: the UN predicts that there will be millions of "environmental" migrants in the next decades with climate change as one of the major drivers of this phenomenon. The different distribution of population might produce variations in demand for oil and coal in electricity production, having implications also for the transport sector. Furthermore, since much of the world's hydrocarbon reserves are in regions vulnerable to the impacts of climate change, instability is likely to increase generating greater energy insecurity and competition for resources.
Most writing about climate change and transport emphasises the role of greenhouse gas emissions from transport as a contributor. However, the inverse impact is also significant, since the transport system is liable to be adversely affected by climate change, particularly as a result of extreme weather conditions that might have immediate impacts on travel and damages that cause lasting service interruptions events.
Although attempts are being made on a worldwide scale to **reduce greenhouse gas emissions**, climate measures (even if successful) will be too late to avert climate change and its impacts over the next 50 years. Despite significant efforts to reduce emissions, transport has not achieved its decarbonising targets and in Europe it contributes 23% of all CO2 emissions.
A great array of GHG mitigation measures can be undertaken to reach the emission targets set by the EU: technology measures, new policies and a change in lifestyle for all citizens. Current vehicle technology can be improved in order to achieve greater fuel efficiency through the improved aerodynamic design (especially in the air transport sector), the reduction of vehicles' weight, the lowering of rolling resistance and the adoption of alternative propulsion technologies. Transport should become less dependent on fossil fuels, thus contributing to energy security, by relying more on low-carbon fuels to be provided at affordable prices and with an efficient distribution networks. Using a fuel mix of electricity, biofuels, and hydrogen could significantly reduce the number of gasoline-powered passenger vehicles on the road by 2050.
Supporting policies will need to pull existing technology in the marketplace and to promote technological development for the future, requiring a combination of performance standards, pricing mechanisms and R&D actions. Planning measures, especially at urban level, will become more urgent for developing compact communities more conducive to an efficient provision of public transport as well as to shorter vehicle trips and non-motorised travel.
Energy and CO2 emissions can also be reduced through interventions aimed at increasing drivers' acceptance of smaller vehicles and less powerful engines and changing driving behaviour, such as reductions in excessive vehicle acceleration and driving speeds. Eco-driving measures could be massively promoted both in the urban and inter-urban

environment through training and information guides, and actively supported by technologies providing real-time information by the vehicle to its driver. All these measures have a great potential to highly influence both the transport system and demand structure in the future. The European Union is leading global efforts to reduce greenhouse gas emissions and, as the cornerstone of its strategy has developed the **EU Emissions Trading Scheme** (ETS), which entered into force on 2005. Around 40% of EU greenhouse gas emissions are currently covered by the EU ETS, with the transport sector as one of the biggest sectors not covered so far. To tackle the fast-growing emissions from the aviation sector, from 2012 the EU ETS includes also CO2 emissions from civil aviation (all international flights – from or to anywhere in the world – that arrive at or depart from an EU airport). It might be expected that similar actions will be implemented in the mid to long term also to cover other transport modes.

The pollution factor

Measures to reduce **noise and environmental pollution** from the transport sector are already in place in the most of European countries. Generally, action to reduce noise has had a lower priority than actions taken to address other environmental problems. However, as more information has become available about the health impacts of noise, the need for a higher level of protection for European citizens has come to be recognised. Road traffic is the main source of noise in urban areas, however noise pollution from railways remains one of the main barriers for expanding their use in urban areas and along densely populated rail freight corridors; and aircraft noise is often the reason for the difficulty of expanding airport capacity at major European hubs.

The limiting of noise in urban areas could play an essential role in future city planning and the potential for closer co-ordination and integration of air quality and noise management has been suggested frequently. This might require the introduction of more diffused traffic management schemes potentially impacting on demand distribution by diverting demand towards less sensitive (and thus free from restrictions) areas, as well as on modal split by inducing a higher usage of public transport modes.

As far as air **pollution,** traffic emissions of particulate matter (PM10 and PM2.5) and nitrogen oxide (NOx) are of most concern. The road transport sector is a major source of the ozone[1] precursors NOx and CO by contributing respectively about 42% and 34% of total EU27 emissions in 2009. The application of technology has been the primary means of reducing the environmental impacts of transport in the last two decades; the Euro standards for vehicles have been, and continue to be, introduced in phases, with the introduction times and actual standards varying by pollutant, vehicle category and vehicle weight class or engine volume and fuel type.

To further reduce road transport's impact on air quality, diesel NOx emissions could for example be targeted through technologies for diesel-powered vehicles such as selective catalytic reduction (SCR) (especially for heavy-duty vehicles). Directive 2009/33/EC on the

[1] Ozone is a strong photochemical oxidant which, in elevated concentrations, causes serious health problems and damage to materials and vegetation.

"Promotion of Clean and Energy Efficient Road Transport Vehicles" aims at stimulating broad market introduction of environmentally friendly vehicles.
Besides these interventions targeted to vehicle fleets' innovation also traffic management measures and pricing policies are becoming more frequent at local level to reduce the exposure of population living in urban areas from high concentration of air pollutants. Such kind of solutions might become more common in the future, with cities more and more obliged to apply ever-stricter air quality legislation, and to reduce transport-related emissions in line with increasingly stringent European and global targets.

The resources factor

Energy is a basic need for the society and its pattern of **availability, production and consumption** are of greatest relevance in the context of the economic and environmental domains. Worldwide demand for energy is growing at an alarming rate and projections suggest that by 2030 world energy use will probably have increased by more than 50 per cent, thus exacerbating the competition for the primary energy sources.
Electricity production accounts for 32% of world global fossil fuel use and around 41% of total energy related CO2 emissions. Not only the burning of fossil fuels (coal, lignite, oil and natural gas) is the largest source of carbon dioxide emissions, but the extraction of coal, oil and gas as well as leaks from gas pipelines are among the main sources of energy-related methane emissions.
Current trends are economically, socially and environmentally unsustainable and, without decisive actions, global electricity generation will continue to be largely based on fossil fuels. In that case energy-related greenhouse emissions will more than double by 2050 and increased oil demand will heighten concerns over the security of supplies.
In this context of great European energy dependence and environmental concerns, it seems hard to predict what might be the fuel mix of EU energy production in the next decades. Some studies predict that in 2050 more domestic energy resources would be used, in particular renewables.
While there is agreement that electricity will have a role in transport, opinions diverged on how large its potential is. Alternative sources of energy in transport might be biofuels; nevertheless the literature review showed that the economics of conversion processes need to be further improved for biofuels to be really competitive with fossil fuels without subsidies in the longer term.
Despite the uncertainty surrounding the future sources of European energy production, it can be more certainly argued that energy "saving" and "efficiency" measures will become more and more prominent in the next decades especially in the transport sector. Energy efficiency in transport will rely on a broad range of technological solutions: traction technologies encompassing new engines and alternative sustainable fuels, improved vehicles aerodynamics and weight, regenerative breaking devices, modernising infrastructure and optimising operations.
Some literature suggests that the private economic cost of transport fuels will be by far higher than those of today, whatever mix of sources, carriers, and conversion systems there may be in the future. Therefore, the role of efficiency in the transport sector will become

critical, not only in terms of the environment, but also in terms of the overall affordability of mobility.

While it is clear that the roadmap for the transport system is to shift from carbon to low-carbon energy sources, it is unclear when this shift would be completed and whether this might occur in time to avoid major problems arising from the **scarcity of fossil fuels** and especially from oil. Even though it cannot be said with certainty that we will run out in the next thirty years, extracting and delivering the remaining oil to market is becoming increasingly difficult and costly: as reserves that are easy to access run out, the oil production has to rely on less accessible resources and on fossil fuels with lower energy content. Fossil fuels that are currently extracted from deposits would have been considered uneconomic two decades ago. This requires more transport and more energy with higher environmental impacts per unit of material or energy produced.

While improving vehicle efficiency is by far the most important low-cost way of reducing oil consumption and carbon emissions in the transport sector, biofuels are supposed to play a significant role in replacing liquid fossil fuels suitable for planes, marine vessels and other heavy transport modes that cannot be electrified. There is an urgent need to scale up investment in low-carbon energy technologies. Current investment levels are insufficient to make the necessary transition, and investment in traditional fossil-based technologies needs to be shifted towards low-carbon energy technologies.

Fiscal policy measures might be important in helping to redress investments. As a first step, fossil fuel subsidies, which are still applied in many countries, should be phased out. A taxation system based on the environmental and energy performance of individual fuel types, including a carbon tax (as is already the case in Sweden) might be one way of placing value on biofuels' environmental and societal contribution, and of reducing gaps in competitiveness with fossil fuels. Nevertheless, a key non-economic barrier to the development of biofuels is uncertainty regarding their sustainability.

Besides the scarcity of fossil fuels, other kinds of shortages are expected to occur in the next decades which might have impacts on the European transport sector. The accessibility and affordability of non-energy, non-agricultural **raw materials** is in fact crucial for the production of vehicles and transport infrastructure which require large amounts of materials and might be hampered by a limited or more costly supply of certain raw materials.

The EU has very few reserves of some, such as gallium (used in photovoltaics and microchips), tantalum (used in microelectronic capacitors), germanium (used in fibreglass cables) and neodymium (used in high performance magnets), which are essential for high-tech applications. Due to rising raw material input costs in the steel and non-ferrous metals industry, the automotive industry might face serious challenges, since cars are complex products consisting largely of steel, non-ferrous metals, as well as polymers, rubber and glass.

Furthermore, as a result of the future developments in car-design, the demand for critical raw materials is expected to increase. The demand for rare earths and lithium will rise, due to more use of advanced electronics, magnetic materials, new surface treatment systems and alternative propulsion technologies: this might increase the competition on such kind of resources. The recycling of scrap cars is of key importance nevertheless, ACEA estimates that the first significant volumes for recycling of electrical vehicles, which contain rare earths, cobalt and lithium, will come around 2025-2030 at the earliest, while demand for these

materials is expected to boom around 2015-2020. In this context it becomes crucial for the competitiveness of the industry to have a new generation of batteries based on other materials by 2025-2030.

THE TECHNOLOGY DOMAIN

The vehicle technology factor

On the technological side several factors are expected to contribute to the development of the future transport system and to influence mobility patterns.
The analysis of which impacts may derive from the spread diffusion of innovation in the transport sector starts from an insight on the new **vehicles design**.
The impact of technological innovations is not the same in relation to the different transport modes. In rail transport the slow pace of innovation is almost inherent in its nature: public spending and large amounts of investment in infrastructures and networking could not easily justify further investment aiming at the introduction of “disruptive technologies”. If adopted, however, these disruptive technologies would lead, for instance, to changing radically the mode itself: new technological improvements are envisaged in a general trend towards increasing adaptability of the railway to different spatial dimensions, trying to stimulate the spread of rail in urban areas (e.g. suspended light-rail).
On the contrary, major technical advancements have traditionally involved air transport. In this case, entrance barriers to the market and high-skill technological expertise has led to a logical and quite regular “step by step” technological development. At present, more attention has started to be reserved to airports and land-side facilities and infrastructure, trying to manage successfully the increasing air travel demand. However, improvements in aerodynamics and in engines are still at the core of the research given their potential in increasing the energy efficiency.
On the basis of these considerations, it can be easily argued (and literature confirms it) that the private mode is by far the more suitable one for testing and diffusing innovations. Firstly cars can offer a wide range of aspects to be improved both concerning their body (material, aerodynamics, etc.) and several on-board appliances and equipments (which are increasingly indispensible to the functionality of vehicles themselves); secondly, there are less constraints (physical but also financial) which have the power to hinder the development of new technologies. A great variety of car manufacturers compete worldwide in order to pioneer innovations resulting from their R&D activities.
The main targets of current technological development in cars are the reduction of occupied space (in order to decrease congestion) thus designing micro city-cars to be used in urban schemes and the mitigation of the environmental impacts (pollutant emissions and noise).
Strictly connected with the sphere of the design for new vehicles, improvements and diffusion of innovations in **advanced driving devices** are gradually emerging from a niche position market to a massive diffusion. More and more vehicles are being equipped with these devices, even the cheaper ones. Primarily these equipments are targeted at improving safety conditions for the vehicles. Most of them can be classified as active devices as they are able to avoid collisions. Other devices are instead developed in order to improve the quality of

health assistance in case of an accident (Automated Emergency Call). The other major branch of development is the provision of information to the drivers in order to prevent them from driving into possible bottlenecks caused by road works or accidents.
In addition to the cultural change needed to let these new technologies become the daily habits of our future life, also political and legislative aspects have to be tackled with (interoperability of the systems at European level, road prescriptions, etc).
In the field of vehicle innovation, **traction technologies** are the most explored and investigated. The internal combustion engine (ICE) will still play an important role in the future: obviously, many improvements are to be performed regarding GHG emissions, energy efficiency and costs, but, at the moment, though many alternatives are quite fully developed, no one of these has proved to be totally successful in replacing the "old" conventional ICE.
It is not feasible at the moment to state with any certainty which technology will be the real breakthrough in the traction of vehicles. Nevertheless, the most likely would be electricity. Until the massive diffusion of fully electric vehicles will take place, nowadays hybrid solutions are gradually gaining higher and higher market shares. Hybrid vehicles have many advantages in terms of energy efficiency, even though these advantages are still counterbalanced by the weight of the batteries, which make the vehicles heavier than traditional ones and also raise some safety issues. Thus, in parallel, research has started to look for new materials for lighter and high-performance batteries (super-capacitors). **New materials** will allow in general a reduction in the weight of vehicles and an increase in vehicles' performance, thus improving fuel efficiency and environmental impacts.
Besides the engine factor, the other main branch of research on new traction technologies regards fuels. Most alternative fuels come from bio-sources (biofuels): such a production still raises significant concerns about its sustainability in terms of biodiversity's preservation, land-use mitigation and total life-cycle assessment emissions.
Other potential for fuel is considered to be in hydrogen, but in this case new technological improvements are needed to significantly reduce total GHG emissions.
From an economic point of view, large amounts of funds and investments will be of vital importance to further develop innovations and making them widely affordable. This aspect is of crucial importance especially if the target is a real breakthrough in traction. The public fiscal revenue from oil fuels still represents one of the strongest hurdles in this sense. However, smart and effective policies could help to get over such barriers.

The ICT and telematics factor

Besides their application to vehicles, new technologies are affecting almost every aspect of our life and have started to change our daily habits significantly. With a major focus on travel habits in particular, the most prominent role is played by **information and communication technologies (ICT),** which have the great potential to lessen conventional constraints of time and space. New patterns of mobility are emerging since "tele-working" and "on-line shopping", just to name a few, have become feasible. Nonetheless, it would be misleading to conclude that the increasing diffusion of ICTs could reduce the need to travel in general. Innovation per se has not this powerful influence and the introduction and the diffusion of technology may produce some "rebound effects": in most cases the improvements in the

efficiency of the transport system (increasing speed, decreasing congestion, improving transport conditions) may lead to an increase in travel demand. The awareness of this one-to-one connection between transport and technologies has to be widely achieved yet.

Technologies can not only be considered simply as one among all the external factors impacting on the transport sector: they have, indeed, a key role in shaping its development and their diffusion within the sector has become a more and more impelling need.

Nowadays Intelligent Transport Systems (ITS) applications are common both in urban (parking information, variable message signs (VMS), public transport prioritisation, etc.) and in interurban areas, managing problems connected with rerouting (accidents or weather conditions), tolling or for automated enforcement for safety reasons.

Monitoring systems have been increasing in number and application in recent years. Sensors are being installed along roads for different purposes: speed cameras to detect vehicles' speed (for safety reasons), inductive loops to count traffic flows and measure speeds and send this data to traffic management (for information) and Closed Circuit Television for plate recognition (for road charging).

Traffic management systems are very important tools for planning. With relatively small investments, they can lead to significant improvements in public transport, in reducing congestion, waste of time and avoiding further large investments, for example in constructing new roads. Especially under a global downturn in the economy, a deeper insight should be reserved to "soft" innovations driven by technology improvements which proved to be the most effective in tackling transportation issues without major infrastructure investments.

Information systems are playing a key role in the transport sector: thanks to the wide spread of information, people are becoming increasingly more conscious of their mobility choices, discovering benefits of using public transport and taking advantage of well-planned intermodal journeys.

The first effect of an increasing availability of information on different modal options is the need for interlinked connections also from the point of view of tickets and fares. Information technology is fostering more and more the diffusion of electronic **booking and payment systems**. Ticketing systems present great advantages in terms of general efficiency for the transport sector. Users can save time (or even avoid trips to purchase tickets in advance) and can sometimes also save money (as electronic ticketing systems calculate the lowest fare for their trips); on the other side public transport operators may rely on precious data on users' travel habits and behaviour thus having a better chance to efficiently plan different targeted solutions.

Amongst the main barriers related to the spread of these technologies and systems there are regulatory issues and digital divide. Regulatory actions should be implemented in order to diminish market fragmentation between different operators and to increase the interoperability of the different transport systems.

A second aspect to be considered is the different level of digital skills across countries and within each country between people from different economic and social conditions; though the spread of "smart-phones" is increasing very fast, purchasing them is not affordable for everyone, and today not everyone has adequate skills to exploit the transport applications offered by these devices.

The energy factor

Also in terms of energy, technology has been playing an increasing role in the last decades: new sources for energy production are always under development. The desirable and environment-friendly shift to electric traction or hybrid engines will imply a boost in energy demand for the transport sector, and therefore the investigation of new sources for **renewable energy** will likely be the main stream of research in the field of energy in order to achieve a less fossil-fuel based system. Without any relevant change in policies and actions, the future production of energy will be still dominated by fossil fuels. This scenario looks totally unsustainable.

So far the number of vehicles running by electricity produced from renewables is low, but it is expected to grow rapidly; this objective is in line with the Renewable Energy Directive which sets a 10% minimum target to be achieved by all EU Member States for the share of renewable energy in EU transport petrol and diesel consumption by 2020. Several companies and governments started to finance investments in the sector of renewables.

In addition to research efforts in terms of technological improvements, there is still much to do in order to overtake policy barriers: incentives have to be urgently foreseen in order to sustain the development of these sustainable alternative energy sources.

The other main target that technology development and innovation may help to achieve is the reduction in energy consumption (fixed in a 20% cut by 2020 in the Energy Efficiency Plan 2011). Energy is vital for social and economic aspects of our life: without energy our society cannot survive or thrive, and, as already pointed out above, the demand for energy is expected to grow further while (as already explained above) Europe's energy security still largely depends on extra-EU imports.

Against these unsustainable trends, **energy efficiency** can be a cost-effective solution. Policies started to pave the way in this direction introducing the concept of energy labels for most household appliances and recently extending its use to other sectors (buildings, and tyres will be soon labelled as well). More consciousness in consumers has risen in recent years thanks to these policies, making people more aware of the environmental effects of their choices when purchasing home-appliances or cars. But there is still much to do from the political side for addressing the challenge of energy efficiency. Incentives and investments should be introduced systematically in every sector and in transport in particular as it accounts for 32% of final energy consumption. Investing in energy efficiency might also have substantial positive impacts on the economic domain (in particular on employment - creating new jobs) and on the environmental domain as each gain in term of energy efficiency directly results in a reduction in emissions and pollutants.

KEY CHALLENGES FOR FUTURE POLICY AND PLANNING

The scanning of the social, economic, environmental and technological domains has revealed that all of them could play an important role in reshaping future mobility: every domain has relevant driving forces that, by their own, or in combination with others, could substantially impact on transport demand.

In most cases it is hard, if not impossible, to predict the intensity of such impacts as well as their rapidity in the course of the years: in fact, the speed by which environmental and

technological mutations could take place is really hard to predict, and thus their implications on the planning and development of the future transport system remain uncertain.
As witnessed by the current European situation, it is also very hard to predict the development and the implications of economic, political and financial decisions on the global market, affecting in second order overall mobility of people and goods.
Less challenging could be the prediction of the impacts deriving from demographic factors whose dynamics, unless there will be disruptive events, can be more easily understood and forecasted.
Future planning and policy interventions are crucial in addressing the new challenges deriving from the key drivers. Transport policy measures are supposed to increasingly address the characteristics of an ageing population in order to support both private and collective mobility of elderly as long as possible and the transport system should be adapted to cope with the reduced physical and cognitive capabilities of elderly.
As urbanisation continues to be a relevant phenomenon, urban and suburban transport networks must be properly planned to face an increasing number of people that will travel in and across urban centres. Measures to tackle congestion, air pollution and noise are expected to be applied more and more in metropolitan and urban areas. Public transport has to be properly planned and subsidised in order to satisfy the potential increase in demand.
The emerging “sustainable consumption” culture on transport which is contributing to and increasing the shift towards alternative mobility by walking and cycling in urban areas should be properly incentivised by adequate planning and policy measures. Awareness campaigns and training on environmental issues, already proved to be cost-effective, should become a major priority for policy makers.
In parallel with increasing efforts in enhancing environmental consciousness, appropriate fiscal policy measures and market regulation should be more and more implemented, in order to make environmental aspects enter the market (ETS, polluter-pays and user-pays policies to be extensively applied). In addition market regulation should be properly developed in order to prevent inefficiencies and/or inequalities while applying these mechanisms.
Increasing scarcity of fossil fuels and environmental concerns are accelerating the pace for technological development. Policy measures have to increasingly support the investments sustaining the spread of innovations in the “green transport” sector.
Future transport planning should take account of the possibility for the transport systems to be severely affected by extreme weather conditions and disruptive events in order to develop some resilience to these aspects and to prevent major damage from services and network interruptions.
It is up to all policy levels (European, national and local) to consider all the challenges deriving from expected trends and exploiting all the potential in order to drive the changes on a sustainable track and to satisfy future traveller needs.
However, the analysis disclosed that the relative importance of all future challenges and needs is still not fully established, due to lack of studies which have attempted to address this question. More research is needed to clearly understand the magnitude of the impacts that the key drivers, by their own or in combination with other, might have on future mobility and transport.

The analysis of future European transport scenarios should require a more holistic approach than the one traditionally used and should be widened to properly consider the complexity of the system and its interactions with all the domains of human activities.
Appropriate strategic modelling tools should be more and more deployed in order to investigate on this complexity, to analyse wide-vision scenarios and to quantify the expected impacts on future mobility and transport.
Also data gaps are to be addressed by researching more on travel behaviour and needs of specific user groups (older, mobility impaired, migrant groups etc.) which are expected to be the majority of future European travellers.
To overcome all these gaps in knowledge major efforts and investments should be therefore devoted to R&D activities for properly supporting the definition of adequate planning and policy measures.

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