The Socio-Economic Impact of Urban Road Automation Scenarios: CityMobil2 Participatory Appraisal Exercise

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Abstract This document aims at assessing and fine tuning alternative scenarios concerning road automated transport, based on the contribution of research, industry and public stakeholders convened at the CityMobil2 Workshops organised in La Rochelle on 30–31st March 2015. Two different paradigms—with and without a shift to shared mobility—were debated and a number of potential socio-economic impacts were identified. Road automation scenarios are devised for different urban typologies—large metropolitan areas, polycentric city networks, small-medium towns, rural/tourist areas. Impacts are assessed in a qualitative fashion—with the support of an online DELPHI survey followed by the workshop debates—in relation to a number of variables. These include: job disruption and creation; personal trips costs; public budget effects; insurance costs; accessibility to remote areas; road capacity and its use; journey comfort and convenience; energy and emissions; land saving for new public space uses; social impacts in terms of

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safety, personal security, health and active travel (trade-offs in automated rides vs. walking or cycling) and different perception/value of time spent travelling in automated vehicles.

Keywords Automated transport · Collective · Private · Scenario · Modal share · Car ownership · Survey · Urban sprawl · Compact city · City network · Private car use · Shared transport · Public transport · Walking and cycling · Future · Challenges

1 Introduction

On 30–31st March 2015, more than 100 experts from Europe, the US, Japan and Singapore met in La Rochelle (France) in a workshop organized by the European project CityMobil2. The workshop focused on the expected impacts of road vehicle automation take up in different typologies of urban environments—compact cities, sprawled cities, connected cities and rural areas—and for two different scenarios: automation of private cars and diffusion of shared self-driving vehicles. The experts had to assess the potential impacts of automation on the economy, transport, the environment and society.

The pros and cons of two "caricature" scenarios—automation with and without a paradigm shift to shared mobility—were debated and a number of potential impacts were identified in terms of: job disruption and creation; personal trips costs; public budget effects; insurance costs; accessibility to remote areas; road capacity and its use; journey comfort and convenience; energy and emissions; land saving for new public space uses; social impacts in terms of safety, personal security, health and active travel (trade-offs in automated rides vs. walking or cycling) and different perception/value of time spent travelling in automated vehicles.

Preliminary analyses undertaken to prepare for the workshop included a review of recent urban self-driving transport scenario studies, an online DELPHI survey, and a qualitative evaluation of the socio-economic impacts of different urban road automated transport scenarios.

In this paper we summarize the key results of:

- The online survey focusing on road transport automation in different urban contexts.
- The qualitative appraisal of the expected impacts of driverless urban transport scenarios and the results of the 1st Day session discussing the impacts.
- The 2nd Day session on the stakeholders' perspectives concerning the preferred scenario, and which business model changes and policies would be needed to enable the transition to the preferred scenario of urban transport automation.

2 Results of the Online Survey

The aim of the on-line survey was to evaluate 8 options of urban transport automation, contrasting 2 extreme scenarios (automated private car ownership vs. automated car-fleet sharing) in four different urban typologies:

- *Urban Sprawl* Large cities with a city core surrounded by low density suburbs, with the prevalence of fast trips mostly done alone to/from the city centre and—to a limited extent—of tangential trips. Car ownership is high, the daily trips per capita in a working day are high, the average distance is high and the occupancy rate is low.
- *City Network* Polycentric regions/city networks with the prevalence of fast trips mostly done together. Car ownership is low, while all other benchmark values—daily trips per capita, average distance occupancy rate—are high.
- *Small Compact City* The prevalence of short distance/slow trips, done together or by foot and bicycle, characterize small compact cities. The occupancy rate is high, while all the other benchmark values—car ownership, daily trips per capita, average distance—are low.
- *Rural/Tourist Areas* Low density areas with the prevalence of slow trips mostly done alone. Car ownership is low, the daily trips per capita are low, the average distance is high and the occupancy rate is low.

A key assumption underpinning this approach is that—besides some general technological and social drivers—urban transport automation challenges, opportunities and impacts will be different in low and high density city contexts, and depending on the available transport infrastructure (in particular the existence of high capacity links). The survey was concentrated only on the direct impact on transport patterns in each urban form, not on second order land use impacts of automation on the urban forms themselves—for instance the extent to which automation may provide a further impulse to urban sprawl facilitating longer journeys is beyond the scope of our study.

For each urban form, respondents to the online survey had to consider two contrasted and somehow “extreme” scenarios:

- *Scenario 1: Automated car ownership-centred mobility.* A private automated mobility scenario is the result of a technology revolution without a significant change in the conventional private transport behaviour. Most of the people will continue to own and drive their cars. Self-driving vehicle sharing will develop to a limited extent, within the same household—reducing in some contexts the need to purchase a second car—or more broadly by means of peer-to-peer car sharing schemes. In any event, the autonomous vehicles will continue to be mostly in private ownership.
- *Scenario 2: Automated car fleets-centred mobility.* This scenario envisages a shift from privately owned individual vehicles to collective purchase and operation of fleets of self-driving vehicles—that may be owned by private or

public service operators—and are available for simultaneous (ride-sharing) or sequential use (car sharing) on demand, complementing and integrating existing mass transits.

89 participants answered to the survey. The majority of respondents was interested to evaluate automation scenarios only in the urban sprawl context, considering the other contexts less relevant or because they were less confident in assessing likely self-driving scenarios for other urban forms. The car ownership centered scenarios was also slightly more popular than the shared self-driving vehicles, collecting more answers. Figure 1 summarizes the main results concerning the expected changes of four key variables characterizing urban mobility—daily trips per capita, average journey distance, occupancy rate and car ownership—for the 8 options considered (2 scenarios × 4 urban forms):

The arrows (red for scenario 1 and yellow for scenario 2) represent for each key variable both the direction (increase, decrease or stability) and the intensity (bigger arrows for >30 % change in the base variable, smaller arrows for a change between 10 and 30 %) of the likely change, according to the most frequent responses to the survey (modal values).

The most frequent answers have been more conservative than our impact assumptions presented in the online questionnaire. According to the majority of respondents urban transport automation will cause the key variables to change within the range 10–30 % at most—or to stay the same—not changing radically (more than 30 %) in one direction or the other. This is because—in the opinion of many—autonomous vehicles, are only one of many factors that will affect transport demands and costs in the next few decades, and not necessarily the most important. More in detail, the key insights and conclusions for the single variables characterizing urban mobility are as follows:

- *Daily trips per capita* will increase in the urban sprawl and rural areas settings, as the self-driving car availability will augment the flexibility and opportunity to combine daily travel schedules for different members of the household. In the more compact forms—city network and small compact city—daily trips are expected to increase only in the automated car-fleet scenario, thanks to the availability of more capillary services. The impact pathway presented in the survey assumes that the cars are more often available because of their capability of self-driving, and this alone will induce more daily trips per capita (increasing more than 30 %). Most of the respondents to the survey were more prudent, guessing for a more moderate increase, as car availability is not the only factor affecting car use, especially in potentially congested urban contexts or where a good high capacity public transport is available. The number of impaired mobility people trips should increase, but it also depends on the availability of the facilities at the end of the journey and on the easiness in getting in and out of a car. By the same token, the impact on aged people propensity to travel may be important, but insofar as the aging population do not easily understand and adopt new technologies may be scared by these developments.

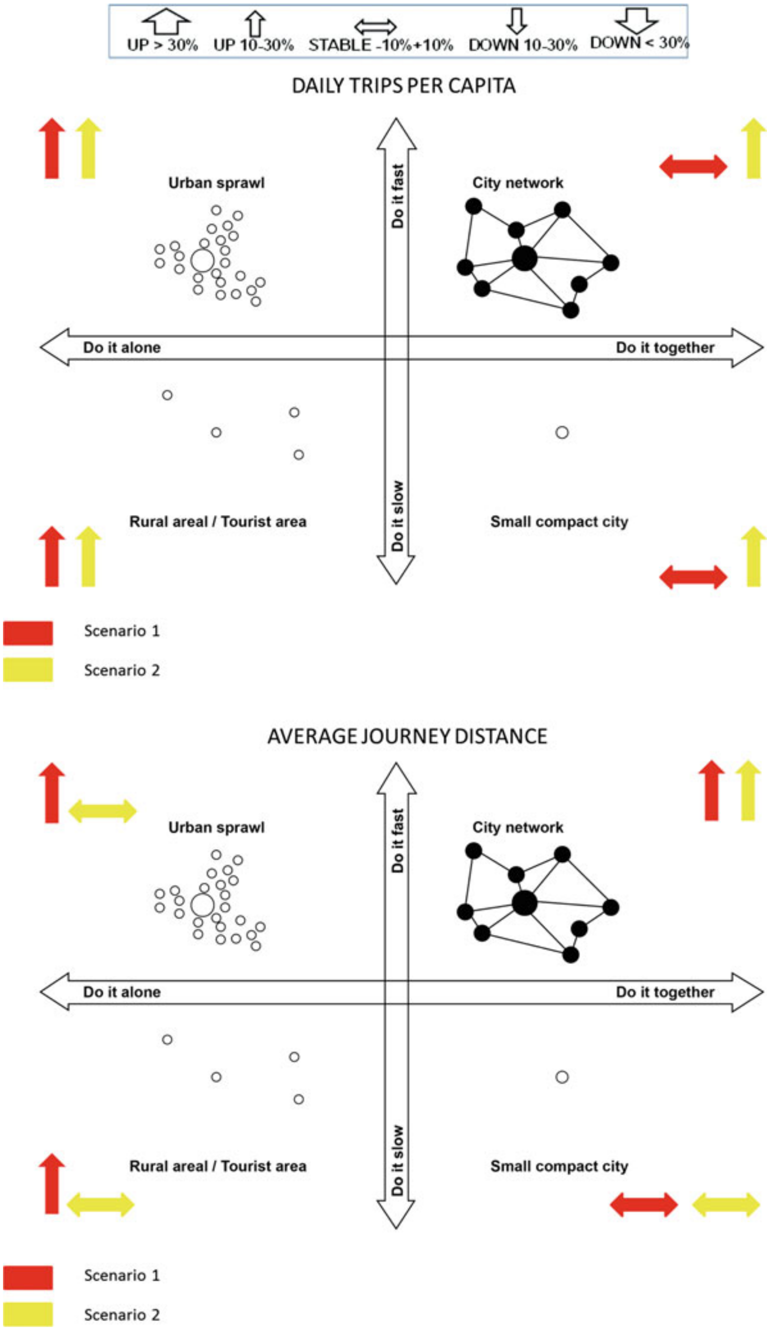

Fig. 1 Survey results

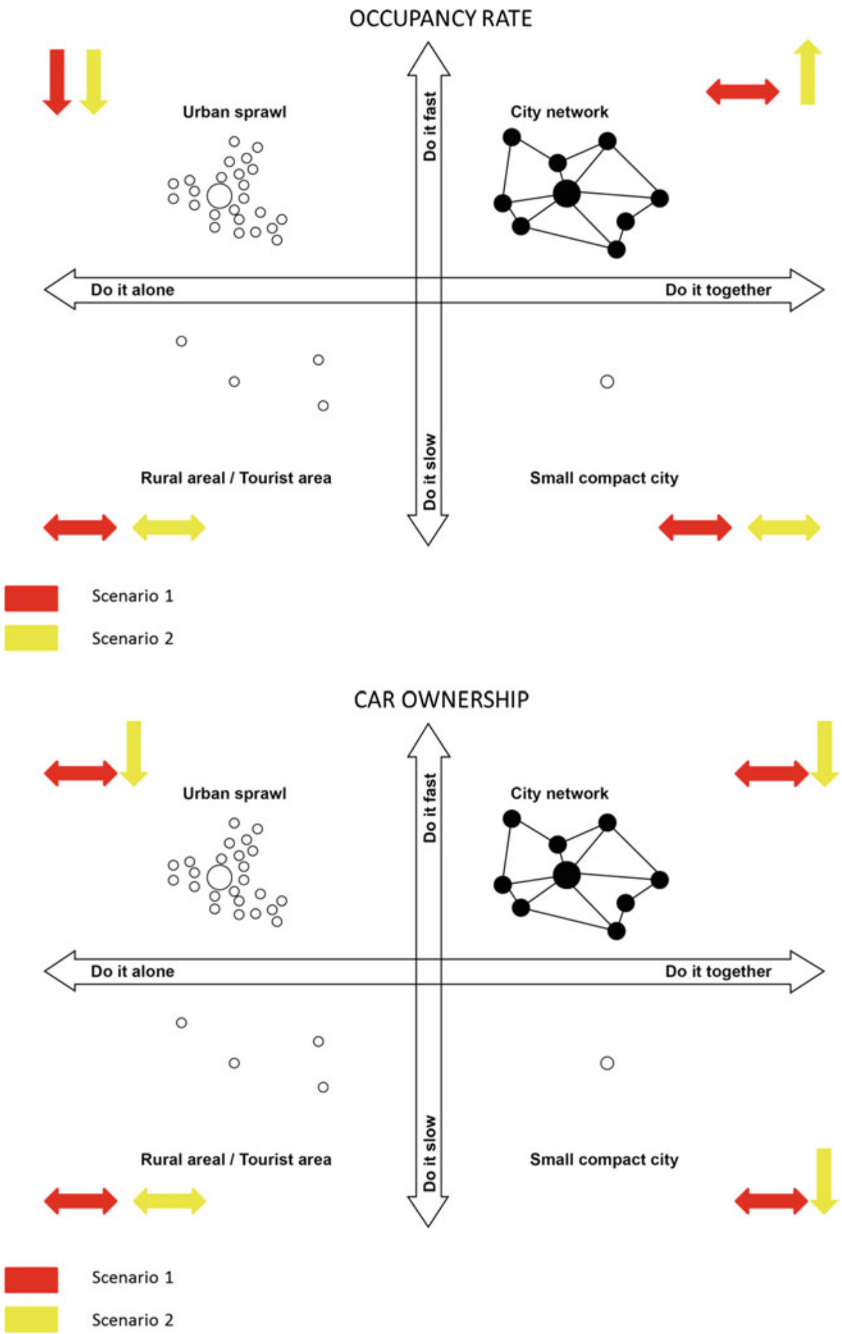

Fig. 1 (continued)

- The *average journey distance* will increase in the private automated scenarios for all urban forms, except in the small compact city, where short distance trips are prevailing and self-driving will not change substantially the range of accessibility choices. On the contrary, the average journey distance will not increase in all car-fleet automated scenarios, except in the city network, where the offer of coordinated car sharing and ride sharing options is likely to increase the longer trips between the different cities of the network. The impact pathway presented in the survey assumes that the car use for longer trips is encouraged because the trips become more comfortable and the passengers are free to choose what to do while the car is driving itself. Average distance may increase between 10 and 30 % as a result. Most of the respondents to the survey agreed on this assumption. However, a consistent minority were more skeptical due to the higher autonomous vehicle costs, which may reduce both the penetration of these vehicles in the market and their extensive operation and use by households members. In addition, the length of the trip is primarily affected by the current city size and form, a factor that influences travel needs and cannot be changed in short times. Both factors—low driverless cars penetration and rigid land use patterns—may cause average distance not to increase, at least in the short term. The average commuting time may also remain constant, as automated modes will not automatically be faster—indeed speed limitations for the autonomous driving are in the cards. The picture can obviously change in the long term, as the greater travel comfort can induce further urban sprawl and longer commuting trips.
- The *occupancy rate* will decrease in the urban sprawl context, as an effect of the empty trips to relocate the self-driving cars to the next users—i.e. another member of the household in the private automated scenario or another user in the car-fleet scenario. This effect is not considered significant instead in other urban contexts (small compact cities, rural/tourist areas), with the exception of the car-fleet scenario in the city network, where fleet based car sharing and ride sharing services are assumed to optimize the journeys and bring an increased occupancy rate (between 10 and 30 % more). The impact pathway presented in the survey assumes that empty trips will increase substantially (causing an average occupancy rate increase of 30 % or more) in the private automated mobility scenario, to allow different members of the household to use the same car during different hours of the day. Automation will not deliver the same effect in the car fleet scenarios, because fleet owners will be motivated to minimize empty running, e.g. through dynamic pricing. Most of the respondents to the survey consider the assumption for the private automated mobility scenario too pessimistic. Occupancy rates—some respondents claimed—are already low especially in the urban sprawl context (around 1.3), it is difficult to reduce them further. In addition, the operating costs of "dead-heading" empty private vehicles will become something households examine, pushing for a more efficient use of the car. Empty trips could be reduced as well by the sharing of self-driving cars between members of the same household or trough ride sharing with neighbors or work colleagues. In a nutshell, a decrease of occupancy rate is

expected, but more moderate—below 30 %—in the private automated mobility scenarios, and not expected at all in the automated car fleet scenarios. In the city network automated car fleet scenario—as mentioned—the occupancy rate will increase, as most of the respondents to the survey agree.

- Finally, according to the majority of respondents, *car ownership* is poorly affected in the private automation scenario—whatever the urban form. On the contrary, it is obviously likely to decrease in the car-fleet sharing scenarios, but the latter not in the rural area context, where the car will remain a key asset to hold (with more opportunities however for ride sharing or peer-to-peer sharing). However, some respondents to the survey highlight that car ownership could decrease substantially also in the private automated mobility scenarios, because self-driving cars may serve the mobility need of more than one family member in the same day, and the ownership of second or third cars could drop for this reason. If the autonomous vehicles are more expensive than the conventional ones, new vehicles purchase will be also limited, with a detrimental effect on car ownership. On the other hand, in the automated car fleet based scenario—according to some respondents car ownership will decline if car and/or ride sharing will effectively happen—in particular in the city network context where a radical decrease of car ownership is assumed (more than 30 % of decrease). However, for this to happen it will require new business to start up, which will need payback to cover for car purchase, depreciation, maintenance, insurance and fuel, and based in the right places. Thus, the cost could be high to the consumer, which may mean that the adoption takes longer and thus car ownership would not change so rapidly.

As it concerns the changes of modal share, between *private car use*, *shared transport, public transport and walking and cycling*, the results of the survey are shown for the two scenarios in the Figs. 2, 3, 4 and 5:

Not surprisingly, in the private automated scenario the private car use is expected to increase for all urban contexts, as a consequence of the greater comfort of using and travelling with a self-driving car. The only exception is observed in the rural area context, where the majority of respondents think private car use will remain the same. A reduction of the public transport share is expected, almost mirroring the increase of the private car use, while most of the respondents think that walking and cycling shares will remain stable, as automated transport should not attract those that enjoy walking or cycling.

The impact pathway presented in the survey assumes for modal shares in the private automated scenario an increase of private car use. This primarily because thanks to new self-driving capabilities cars can be used by people that cannot drive (children and elderly people with reduced driving capabilities). In addition, the pathway assumes stable share of car/ride sharing especially in the urban sprawl context, a reduction of public transport ridership, and a slight negative trend from walking and cycling, mainly due to the trips made with new automated vehicles when the conditions for walking or cycling are not comfortable (e.g. bad weather). Further comments from the respondents to the survey pointed towards a possible

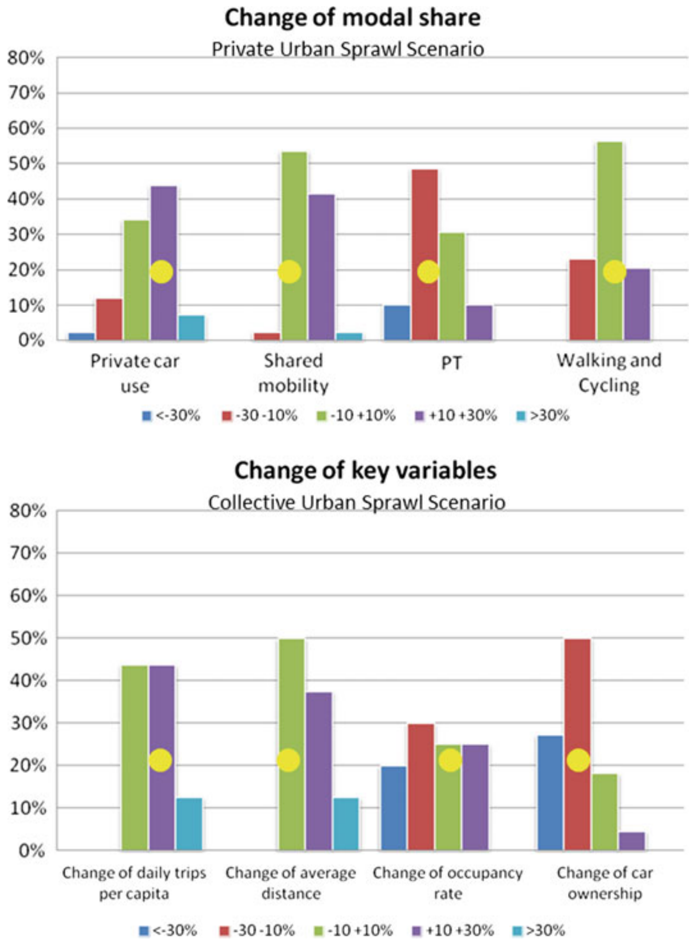

Fig. 2 Survey results for the model share scenario—Urban Sprawl

increase of shared transport also in this scenario. Shared mobility will be higher if cars become available to younger people who currently travel by public transport, and the acquisition of private—and expensive—automated vehicles will probably encourage their owners to propose more ride sharing to others to amortize the purchase costs. Some peer-to-peer car sharing will be also encouraged—although less than ride sharing—as connected and automated features of the new cars will reassure owners and let them share their cars more easily, reducing the risks of accidents, thefts, etc., and ensuring that the cars come back to the owners when needed. Finally, some respondents questioned the expected reduction of the public transport share. This depends by what will happen with the costs of the different options for the user: self-driving, shared transport, public transport. Insofar as the prices of automated vehicles will be higher, this will reduce private car usage by

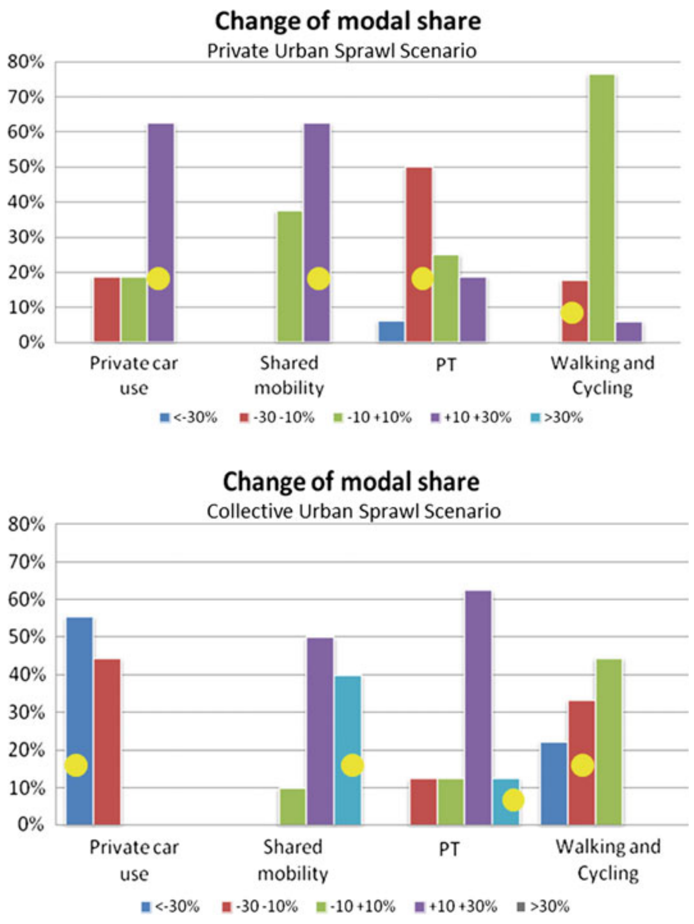

Fig. 3 Survey results for the model share scenario—City Network

raising public transport and shared mobility. In addition, if the circulation of self-driving private vehicles in the urban areas will be more easily controlled and managed, this may have a positive effect also on the reliability of public transport in the same areas, increasing its use. In the car-fleet centered scenario, there is a potential complementarity between public transport and self-driving shared transport modes in the city network context, as both shares are expected to increase while private car use is likely to decrease radically. The same effect is not expected in the small compact city and in the rural area contexts, where shared transport will increase but the public transport share is likely to remain the same. On the contrary, in the urban sprawl context the new self-driving shared transport mode can be a potential substitute for public transport, with shared mobility eroding not only the private car use but also the public transport share. The impact pathway presented in the survey assumes for modal shares in the automated car fleet based scenario that

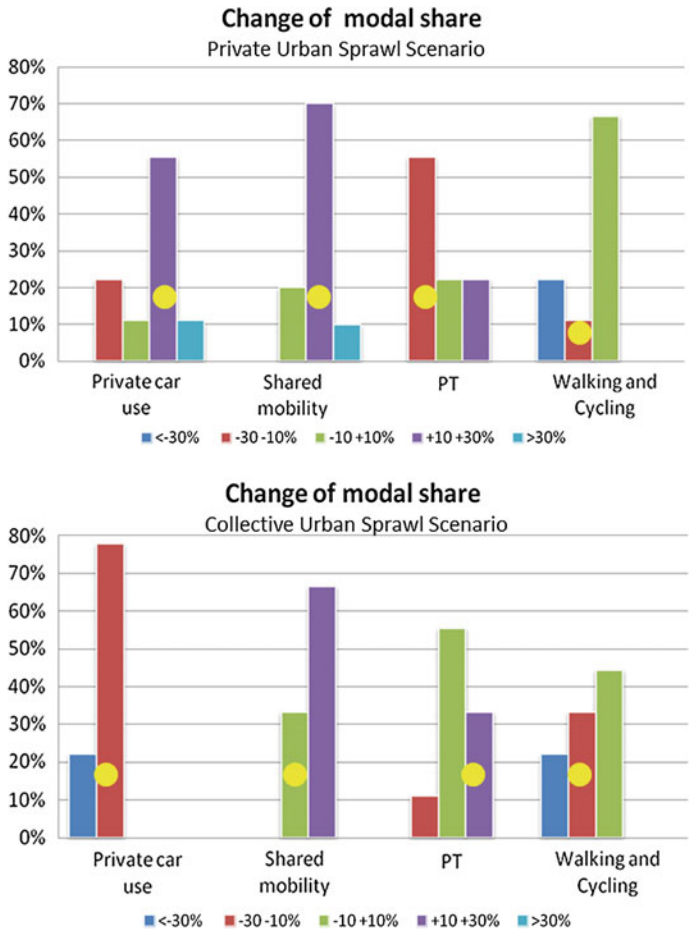

Fig. 4 Survey results for the model share scenario—Small Compact City

the car use decreases because efficient public transport becomes available where it was not before the automation (last-mile public transport), increasing the share of seamless public transport intermodal trips. Shared mobility is also increased a lot as the availability of fleets of shareable self-driving cars is the main feature of this scenario, while soft modes are not affected. Most of the respondents agreed with these assumptions. Although not mentioned in the scenario, driverless taxis will be a form of shared mobility, and they will increase substantially. Public transport might see even a rise of high capacity arterials (e.g. metro rides) since publicly run and maintained automated vehicles might serve as feeders thus offering for the first time—especially in sprawled areas—a competitive public transport option. However, one comment “out of the chore” highlighted that shared mobility services would not hold the same characteristics (e.g. response time) in central/high demand

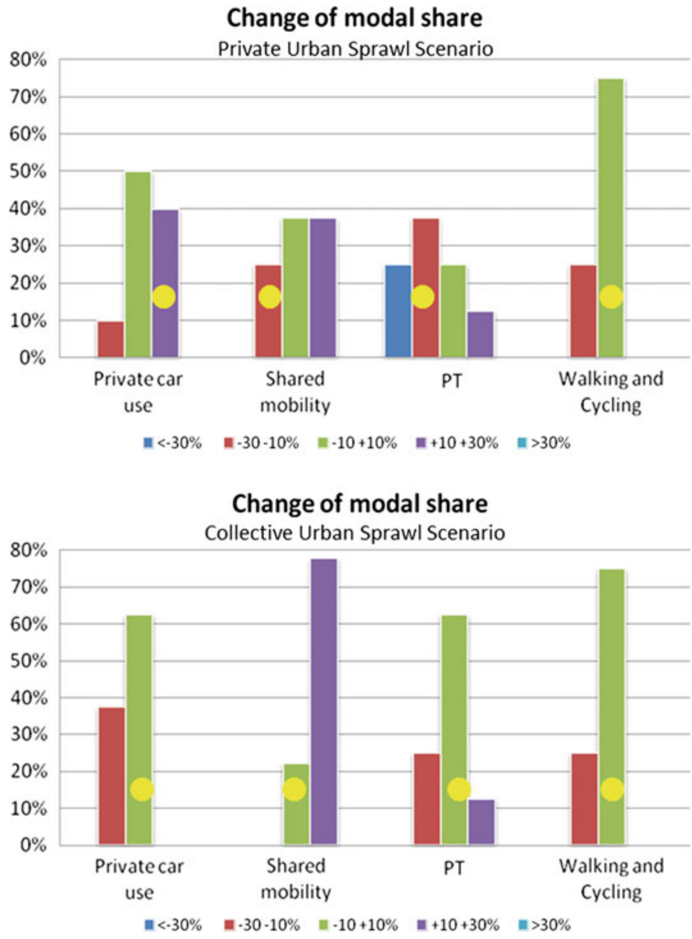

Fig. 5 Survey results for the model share scenario—Rural/Touristic Area

and in peripheral/low demand areas, and the same applies to conventional public transport services. Although it is true indeed that shared vehicles could offer a solution for the last mile problem, this would not dramatically change the level of service between central and peripheral zones, and the households living in peripheral locations might choose to still own and use a private vehicle. Finally, a potential positive side-effect on walking and cycling has been also mentioned, as the new free space due to less need of parking space for the self-driving cars (which are expected to circulate more continuously during their lifetime) may lead to reconversion of parking lot space to more attractive pedestrian zones. This means that more people might prefer to walk due to enhanced safety, walking space and less pollution.

3 Qualitative Appraisal of Expected Impacts and Highlights from the 1s Day Session

The number of trips per capita, the average travelled distance and the occupancy rate of each transport mode are the key variables to determine the number of vehicle-kilometers travelled each day. This, together with the modal share of the different modes, allows to know whether in each scenario the number of vehicle-kilometer travelled overall increases or decreases with respect to the "do nothing" scenario and how much. Most of society and environment impacts of transport depends on the vehicle-kilometer travelled. Even if an automated vehicle can be less polluting or less prone to accidents than a manually driven one, the overall impact might still be negative if the increase in the number of vehicle-kilometer (exposure) is more than the reduction of accident risk or emission per vehicle-kilometer, producing a rebound effect. Similarly, the economic impacts are dependent on the car ownership rate and the vehicle-kilometers travelled because these variables influence the number of vehicles sold and the economy related to fleet maintenance and management. The key variables considered in the online survey have then be used to give a qualitative evaluation of 13 long-term socio-economic impacts belonging to 4 evaluation categories on the basis of the survey indicator results, as illustrated in the scheme below (Fig. 6).

A first qualitative appraisal of impacts has been presented at the La Rochelle workshop. The results of the discussions are summarized below for the four categories of impacts.

3.1 Economy

The *economic impacts* computed with the qualitative methodology included *new jobs, employment, personal trip costs, fines, and the impacts on insurance costs and*

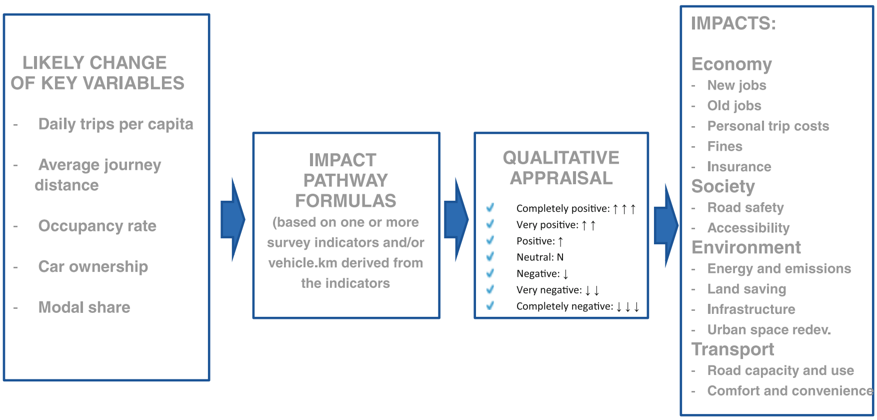

Fig. 6 Evaluation of survey results

services. According to the computations, all economic impacts will be positive in the private automated scenario, in particular in the urban sprawl context but also, with slight differences of intensity, in the other urban contexts (city network, small compact city, rural area). This is caused primarily by the significant increase of total mileage expected when autonomous vehicles will be diffused, making travel more comfortable and accessible to categories of users—elderly, disabled—that today are excluded. Impacts will be positive also in the shared transport scenario, with the only exception of employment in old jobs, where the effect is considered neutral, because traditional jobs in the car manufacturing, repair, maintenance etc. will not increase due to the reduction of cars sold on the market. However, according to most of the survey respondents the impact on employment may be less favorable for the private automated scenario, in all urban contexts, because of job losses in maintenance and control services needed per km travelled, not compensated by the increase of total mileage. Moreover, other economic impacts include:

- The impact of travel comfort on personal productivity, during and after the trip
- The impact of safety on human capital health and productive value
- The impact of accessibility enabling economic development, in particular of more remote suburban areas where self-driving cars contribute to improve accessibility
- The impact of fines not only on household budgets, but also on public budgets that will suffer a loss.
- The same for parking fees: their reduction is a benefit in terms of personnel trip costs, but would have an heavy negative impact on the local authorities budget, as parking charges are an important source of revenue

3.2 Society

The *social impacts* computed with the qualitative methodology include *safety and accessibility for disabled and elderly people*. According to the computations, these social impacts will be positive in the collective automated scenario, for all urban contexts, while in the private automated scenario the impact on safety is assumed moderately negative, as the reduction of self-driving vehicle accident risk would be more than offset by a significant increase in the total mileage. The positive impact on accessibility will be higher in the private automated scenario compared to the shared self-driving transport scenario, as in the former privately owned cars will be available at the door-step. However, most of the survey respondents do not agree with the pessimistic forecast of road safety decrease in the private automated scenario, because they think improving safety is a must for introducing automated transport—a new technology cannot succeed if it eventually reduces safety on the roads. Moreover, the substantial increase of exposure to risk in the private automated scenario is considered plausible only for the urban sprawl and rural areas contexts, while the increase of mileage is expected to be less significant in the compact city and city networks contexts. Other social impacts include:

- Health: what impact will automated demand responsive vehicles have on our health? Will we cease to walk or ride a bike? Cities are promoting active travel today, especially for the first/last mile.
- Well-being/quality of life.
- Urban space redesign: with fewer private cars in the city, there would be the opportunity to use parking facilities for other purposes (offices, homes) leading to new high quality urban fabric, which is denser without giving the impression of higher density.
- Residential relocation: on the one hand, automation may offer the option of moving away from the city to areas where housing is cheaper. On the other, it may induce forced relocation because accessible areas in the city could push up property prices, thereby pushing poorer people out of the city.
- Improved access to employment—the absence of transport is no longer a barrier, unless it is unaffordable.
- The perception of travel time will change—as it will be possible to work or sleep while travelling.

3.3 Environment

The *environmental impacts* computed with the qualitative methodology include *energy and emissions, land saving, urban space requalification and infrastructure modification*. According to the computations, energy and emissions impacts will worsen in the private automated scenario, due to the increased mileage not compensated by better vehicle and driving performances. In this scenario, the other environmental impacts are expected instead to remain more or less the same (with the exception of the impact on land saving and urban requalification in the rural/touristic area context, which is expected to worsen). In the shared self-driving transport scenario, the environmental impacts are always expected to improve—with the exception of infrastructure modification—for all four urban contexts, and particularly favorable for land saving and urban requalification in the city network context. However, most of the survey respondents do not agree with the pessimistic forecast of increasing energy and emissions in the private automated scenario whatever the urban context, as they think the total mileage will increase significantly only in the urban sprawl and rural area contexts, not in the other more compact urban contexts (small compact city and city network). The most relevant insights from the workshop discussion of environmental impacts include the following:

- Private automation may increase accessibility of remote areas and facilitate urban sprawl. This will cause an increase in distances and in number of trips and may naturally lead to shift away from environmentally friendly modes such as soft and PT.
- On the contrary, collective scenarios may increase *urbanisation* by attracting citizens to live where flexible mobility options are available. The city in this

scenario may be manageable *through integrated PT management* in which all available mobility solutions are considered and can be compared in relation with many different criteria such as cost, time, comfort, need to drive/wish to "do something else than driving" or environmental impacts. In any case, it is important to avoid mode shifts from soft and collective modes (and understand how to do this).

- Concerning *energy and emissions* in the private scenario the main concern in the urban sprawl pattern is the increased mileage that cannot be compensated by better vehicle performances, use of platoons and lower cruising speeds. Only increased use of carpooling solutions may compensate the increased VMT. For vehicles able to search parking on their own, the vehicle owner may be more inclined to enter city centres without the burden to search for a parking place or pay for one as the vehicle may even drive a couple of km to reach an empty parking place. This is highly unattractive for city authorities.
- In the collective scenario the *investment in fleets* offers eventually much more potential to further improve the system gradually as demand increases. Most waste comes from relocation of the empty vehicles but this may be balanced by the increased carpooling which becomes a kind of flexible public transport system.
- In the private scenario most of the *land saving* is connected with parking in urban areas. In the urban sprawl case there will be a high demand on land use outside city areas and higher infrastructure and city running costs. In the collective scenario there will be positive impacts in land use due to a very low need for car parks and no need for car parks in city centres. It will be easier to manage the interface with the public transport and car sharing fleets.
- A private scenario will have less *impact on infrastructure modifications* in comparison with the collective one. On a macroscopic point of view, the *impacts on urban requalification* will be negligible in terms of road network length because there will be the need to maintain an urban road network which can accommodate for both automated and manual vehicles. However, in a collective scenario, part of the urban environment is converted to full automation mixed with pedestrian and cyclist traffic. This may lead to a radical requalification of the centre urban environment, offering to cities the option to become *more liveable* keeping vehicles outside the city centres. It will give the opportunity to rethink the urban environment for pedestrians, autonomous vehicles and deliveries. The need of dedicated lanes will require investments in *infrastructure modifications*.

3.4 Transport

The *transport impacts* computed with the qualitative methodology include *road capacity and use, and travel comfort/convenience*. According to the computations, for the private automated scenario these impacts are expected to be respectively neutral (road capacity) and highly positive (comfort) in all the urban contexts. The road capacity constraints are lessened in the shared self-driving transport scenario, as the total expected mileage is lower than in the private scenario, while the comfort of sharing is considered still positive, but more moderately. However, also in the private scenario the road capacity constraints are somehow lessened in the compact and especially in the city network contexts, because the increase of total mileage is lower than in the urban sprawl and rural contexts. Finally, the impact on road capacity will be particularly favorable for rural/touristic areas in the shared self-driving transport scenario. Besides road capacity and travel comfort, the participants wanted to re-discuss some of the key variables in the survey, to suggest few other elements for the qualitative impact evaluation procedure:

- Modal share is expected not to change in the urban sprawl context for the private automated mobility scenario, while to significantly favour public transport in the collective scenario (with shared automated vehicles mostly serving last mile legs of high capacity public transport routes).
- Earlier adopters of automation would benefit the greatest. Too many automated vehicles would be detrimental to mobility due to limited space. Automated small vehicles (whether private or collective/shared) cannot replace the high capacity public transport systems (bus, tram, etc.). This capacity issue may be resolved with pods operating in ‘train mode’.
- The overall travelled vehicle-kilometre are expected to increase significantly (very negative impact ↓↓) in the urban sprawl context for the private automated mobility scenario and even worse (↓↓↓) for the collective scenario (due to self-driving empty trips)
- Few more impacts were asked to be considered, including *travel time*, its *reliability* and the *connectivity* (maybe overlapping with the accessibility in the social category). Travel time is expected to be negatively affected by congestion in the private automated mobility scenario and be very positive in the collective scenario, while its reliability would require further investigation. Connectivity is expected to be positive in both scenarios for the urban sprawl context.

4 Assessment of Survey Results by Stakeholders

4.1 Public Authorities

The *urban transport automation scenarios*—private cars automation versus shared self-driving—are two extreme pictures of the future, real future developments will depend on the environment and what the public authority and the users want. However, it is likely that the automated car ownership-centered mobility scenario will drive this domain forward because the private sector has the means to drive technology development. The public sector is not in a position to make such large investments. The real scenario likely to emerge will also depend on the value of space and peoples’ attitude towards car ownership. The value of space is far higher in city centers and compact cities than in the rural environment. To achieve successful automation, there is in any event the need to engage with other stakeholder groups, such as the freight sector and vehicle manufacturers. Diverging views between the public sector and Original Equipment Manufacturers (OEMs) is an obstacle to engagement, i.e., the OEMs business is to sell cars whereas city authorities are striving to reduce car movements. There is therefore a higher potential for collaboration between service providers (private bus operators, car service providers) and public authorities. Freight should not be overlooked too. Car-borne shopping can be replaced by internet shopping and home deliveries. Ideally, vehicles should be adaptable so that they can carry both people and goods.

About the needed *business model changes*, some key issues and insights are apparent:

- *Public or private business?* The key issue for shared services is to figure out the dominant business model, and if this should be publicly or privately run. There is a widely held view that private sector actors will have to take the risk. However, cities need to support them. Cities need to follow and anticipate what the private sector is doing, e.g. car-sharing, Uber. Should the city allow that to happen and simply adapt to it? In any event, in the private business model, if there is no profit for the bus/transport operator company, then it will not operate the shared service. One use case offering an interesting business case is a Park and Ride shuttle service to the city centre.
- *Urban automation as a city policy focus?* The majority of city authorities are not talking about automation—currently, the key issues are active modes and eBikes.
- *Scenarios for coping with uncertain future developments?* It is difficult for cities to make decisions when there are so many unknowns. Hence, the importance of building scenarios and understanding the potential and the risk of these types of services.
- *Avoid generalizations?* Each city is very different and may need to think of a business model for each of the applications of automated systems (CM1). For instance, a first/last mile solution may be not relevant in the inner parts of cities like London/Brussels where everybody is close to a public transport stop.

Finally, about the needed policy changes, the following key issues and insights emerged in the discussion:

- There is a lack of joined up thinking within the EC; for instance, automation is not mentioned in the SUMPs discussion.
- Automation can make underused urban space/land (i.e. car parks) available for other productive uses. It also allows the provision of services of different size/speeds and the possibility of public or private operations. What is paramount is the integration of transport services, where cities do have a role to play.
- Cities need to think about street design to allow the penetration of these cars whilst retaining liveable cities. A crucial point for cities is car ownership. New developments are low car intensity. Are the new developments today fit for

purpose for the next 20+ years? Car ownership is not addressed in the European urban mobility package.

- In relation to the issue of active modes (walking and cycling) for the first mile/last mile, a CityMobil analysis found that less than one-quarter of modal shift came from cars, more came from public transport and cycling/walking. It is important to limit such substitution effect, in order to gain previous car users that will find convenient to shift to alternative modes
- The public transport sector views other innovations as competition (e.g. car sharing/clubs). If automation is detrimental to public sector patronage, then it becomes unviable.
- There are diverging views regarding C-ITS as an enabler of automation.

4.2 Automotive Industry

About the proposed urban transport automation scenarios, the possibly most plausible solution is a *complementarity of automation scenarios*. Mixed solutions of transport will be necessary in most of the urban contexts considered (urban sprawl, compact cities and city networks, rural areas). Furthermore, reaching ultimately the level 5 of automation is not really a necessity for the industry, and for practical reasons it may not be needed to automate everywhere all the time. Where it makes sense, in city centers, around suburban PT nodes and in industry parks, last mile solutions to PT are demanded and the collective scenario may be the best solution.

If there is a demand in this direction, the industry will invest and provide solutions to the city authorities. Indeed, it will be up to the city authorities to establish clear policies and urban requalification programs to facilitate the introduction and the operation of these vehicles. Unless there is no clear demand and critical mass of political willingness, it is unlikely that the automotive industry will invest. If this status quo will continue, the private scenario may be the most likely. Most investments will go to the improvement of current vehicles and the preservation of the vehicle manufacturer's business model which is the sales of vehicles rather than an integrated mobility service. In this case, vehicle automation will increase gradually starting from high-end vehicles and operate in less and less complicated traffic environment starting from congested highways, then autopilot on highways and gradually on arteries and in intersections. Also the automation of the parking task may be realized first in parking houses then on street. This scenario is the most likely if there is little unified policy to encourage alternate integrated mobility solutions in urban environment.

A key aspect and future driver is how to develop and implement the needed standards and regulations for different typologies of roads and users in the different scenarios. and. A *framework* to authorize or not the automation in given parts of the road network will be highly appreciated by the industry. It would mean that the road operator commits to a given level of maintenance and enforcement on the authorized sections of the road network. Maintenance is meant in terms of road markings, posting, digital maps, traffic and incident information, etc. Enforcement is meant in terms of not authorized parking, speeding, loading/unloading, etc. There is also a need for proper *standards* to ensure good level of reliability in automation of vehicles (something like the "functional safety standards"). Finally, in order to best address the industrial challenges, it is important to create *clusters of competences* and expertise bringing together automotive, robotics, IT, telecom and consumer electronics.

About the needed *business model changes*, the industry, in general, is already used to answer to the highest potential demand of the market. In this respect, it is clear that currently the priority is for the private automation scenario. There are a couple of market-driven needs that are clearly addressed by the industry:

- The avoidance of higher-risk situations related to monotonous and stressful driving tasks. This is driven by customer demands but also under the pressure of public awareness and societal needs.
- The accessibility for ageing population. The baby boomers are the most inclined to keep opt for private vehicles rather than other modes in the next decades. This represents a very high potential market but increased pressure on safety of elderly drivers may deplete this user base. New vehicles put on the market need to consider the needs of elderly drivers and user-centric automation may be part of the answer.

The automotive industry traditional business model may be challenged by threats that are at the same time opportunities for new entrants:

- Shifts to more mobility services with a higher importance of fleets e.g. car sharing
- Gradual downturn of dealerships: Less sales through dealerships; less maintenance; less fender benders and accidents
- Shift of current players along the value chain: OEM start operating fleet where emerging OEMs may even leapfrog others and drive innovation through partnership with IT industry.

So, if automation is gradually increasing, the traditional business model of the automotive industry is put under high pressure. Automation and electrification combined may decrease dramatically the after sales and maintenance incomes. The latter are strategic, as the parts business accounts for only 10–15 % of sales, but it typically averages 25–50 % of profits. Additionally, profit margins on service contracts are around 50 %, with strong impact on customer loyalty. In addition, sales price may be greatly impacted if the increased product liability of the vehicle manufacturers is passed on to the end-users. In case, the lost income of after-sales and maintenance and the increased liability risks directly to affect the vehicle prices, and it is unclear today if the individual end-users would like to go for a private scenario and would be ready to pay for it. Some premium vehicle owners, sales persons and long distance travelers will certainly keep this scenario option, but other options will be considered for the majority of commuters.

At the end of the day, the most likely option may be the “status quo”, meaning the use of manually driven vehicles. But with some incentives and good political will the scenario may shift to the collective one. So there is a great need to try to understand what the users really want now and in the future, and how they will be able to afford it given the impacts that automation implies on the industry revenues. Eventually, Citymobil type vehicles may be considered as yet another mode of public transport completing the PT offering.

About the needed *policy changes*, currently the public authorities face the urbanization and urban sprawl challenges translated in unacceptable levels of traffic congestion and increased need for liveable cities. As automation is brought to the market, authorities see many opportunities but also real threats if the technology is misused or used for individual purposes. It looks like the best solutions are not necessarily compatible with the individual needs. In this context, as politicians are under pressure to find solutions to make their cities more liveable, they try to understand how automation can contribute positively to the new needs to promote mobility as a whole i.e. in an integrated way. So, their key focus is to turn the automation progress at the service of the cities, i.e. of the community, rather than at the benefit of the individuals. This trend is in-line with the current city developments and urban design in many regions of Europe, which claim for:

- Keeping out the private cars from larger and larger portions of the city centre
- Favouring the soft modes and public transports
- Creating liveable areas surrounded by parking areas and crossed by public transport routes
- Reserving limited access to facility services (waste collection, delivery services, etc.).

The main issue in this top-down approach is the political willingness to create a livable environment at the cost of reducing the access to the users living outside the city. So one needs to work on the awareness of the benefits of livable cities and make sure that the demand comes from the citizens themselves rather than only through regulations. Then to make sure the outsiders can still access the city but in a controlled and livable way with more public transport and less cars. Fully automated transport has a clear role to play to convince the populations that manually driven vehicles do not belong to city centers.

4.3 Freight Operators

Freight discussion is difficult to fit in the scenarios discussed which are centered on passengers. In general, freight transport in cities is expected to be automated later than passenger transport because there is the need of a man to unload the parcels (the problem of last-meter transport). In Europe—this is no longer true in the US—there is also the need of a human to get the delivery document signed. Furthermore, the great difference in economic terms between passenger and freight transport is the little margins to which freight operators are working, which discourage to follow innovation for innovation sake; only when innovation will prove to be productive freight operator will invest in it.

The business model for the urban freight distribution is key. It is necessary to think to the adapted distribution chain already using Urban Distribution Centers. A push can come from sharing distribution vehicles to monetize assets (UBER_Freight Warehouse_B&B). It is necessary to make a distinction between delivering large quantities to large warehouses *versus* to small parcels to shops or private receivers. For the latter, it is possible to consider re-using the same (CityMobil2 like) vehicles for small parcels distribution (courier like). This would maximize the use of the vehicle and increase the investment return. A good example is provided by the city of La Rochelle, where there is already a mixed use of busses to deliver goods. This is a good way to develop a new integrated business model for transport. Besides the city logistic focus within the cities, urban distribution automation is seen as very positive also for long distance journeys. A new business model should therefore integrate long distance with urban distribution. The key enablers for long distance transport are:

- Removing the driver will extend operating hours and reducing operating costs (economy)
- Platooning will give advantages on fuel consumption (environment)
- Improved security.

About the needed *policy changes and key enablers*, there is a need to develop (or revise) the legislation on the driving/resting depending on the "auto-pilot" to monetize the positive effects of not having the driver engaged in driving tasks. The road code defines the following distance based on the human driving but platooning should enable shorter gaps, which would need to become legal. There would be the need to adapt the motorway maintenance program to the more precise driving, which will consume asphalt in precise location leaving it almost untouched elsewhere. A good enabler could be priority for freight delivery at traffic lights, which would save the pollution and road wear due to decelerating and accelerating a heavy vehicle. Finally, the tagging of the parcels is one of the key enablers as it would allow identification and automated retrieval of the package in the loading unit.

4.4 Private Operators

The session was attended by the few representatives of stakeholders' categories other than public authorities, automotive industry and freight transport operators. The discussion focused on the preferred scenario and, thanks to the presence of one stakeholder from the insurance industry, on issues of laws and liability.

As for the preferred scenario, both caricatural scenarios discussed in the workshop were considered as extreme cases, valuable to stimulate the discussion, not as realistic options. It is much more realistic a *hybrid scenario*, with a combination of privately owned and shared autonomous vehicles and still a portion of human driven cars even in the distant future. The main driver for the realization of the hybrid scenario will remain the private sector (companies and households), not the public, as only the former is considered to have in the future the assets to make the necessary investments. However, in the hybrid scenario there will be an important deployment and diffusion of *peer-to-peer sharing of autonomous vehicles*, also to help reducing the costs of the vehicles themselves, which are expected to be higher than the current prices of traditional cars (because the self-driving cars include more sophisticated equipment). The carmakers themselves will offer new multi-ownership options, to allow for example customers to buy self-driving vehicles only in the season they need to use them (it could be for summer holidays, for example, while in the working period the same customers could find convenient to commute with other modes). Peer-to-peer sharing will allow to abate directly the cost of car use, for example in case of ride sharing on commuting or long distance trips sharing the gasoline and toll costs with passengers, or by renting the car for a revenue in periods in which the owner does not need it.

As for the laws and liability issue, a major barrier to the full implementation of autonomous vehicles is legislation and governance. While Google has been testing its driverless technology in a fleet of cars for the past 3 years in the US and lobbying for new legislation, current European laws state that a person must be in control of a vehicle at all times. Autonomous vehicles also raise the question of liability. If these vehicles are safer and leave little room for error, other than potential mechanical or software glitches, who is responsible in the event of an accident? Is the technology company, the carmaker, or the occupant? By the same token, how alert will occupants need to be? This question is one many carmakers and technology providers are currently exploring. Many are looking for ways to keep the driver engaged since there will be some instances where the driver will need to be alert, or take control, particularly in the transition stages of autonomous technologies. There is also the risk that drivers' skills will reduce significantly with the use of more and more autonomous functions.

Finally, as it concerns the insurance issue, it is clear that with cars currently driven by humans there is a high risk of an accident due to the probability of human error. In the absence of human error, new forms of insurance will need to be devised. This necessity could be perceived as a barrier for insurance companies.

5 Conclusion

According to the majority of respondents urban transport automation will not cause in the key variables a radical change (within the range 10–30 %) in one direction or the other. This is because—in the opinion of many—autonomous vehicles, are only one of many factors that will affect transport demands and costs in the next few decades, and not necessarily the most important.

All *economic impacts* are expected to be positive in the private automated scenario, in particular in the urban sprawl context but also, with slight differences of intensity, in the other urban contexts (city network, small compact city, rural area).

The *social impacts* are expected to be positive in the collective automated scenario, for all urban contexts, while in the private automated scenario the impact on safety is assumed moderately negative, as the reduction of self-driving vehicle accident risk would be mitigated by a significant increase in the total mileage.

The *environmental impacts* are expected to worsen in the private automated scenario, due to the increased mileage not compensated by better vehicle and driving performances. In the shared self-driving transport scenario, the environmental impacts are always expected to improve—with the exception of infrastructure modification.

The *transport impacts* for the private automated scenario are expected to be respectively neutral (road capacity) and highly positive (comfort) in all the urban contexts.

The caricature scenarios discussed in the workshop were considered as extreme cases, valuable to stimulate the discussion, not as realistic options. It is much more realistic a hybrid scenario, with a combination of privately owned and shared autonomous vehicles and still a portion of human driven cars even in the distant future. The main driver for the realization of the hybrid scenario will remain the private sector, considered the strongest actor to make the necessary investments.

There is a need of *policy changes*.

It is clear indeed that autonomous vehicles are poised to be the next disruptive technology to travel. The challenge now for the world's city planners and managers is to understand how quickly autonomous vehicles will disrupt current patterns of passenger mobility, and if and how they may help public authorities to face the urbanization and urban sprawl challenges currently causing unacceptable levels of traffic congestion and an increased quest for more livable cities.

References

1. The study is our own original elaboration and it is part of the CityMobil2 project co-funded by the European Commission under the Framework Program 7
2. The complete report is available on the project website: http://www.citymobil2.eu/en/Downloads/Public-deliverables/