CROWD4ROADS

CROWD sensing and ride sharing FOR ROAD Sustainability
Project Number: 687959

D2.1 — Socio-economic Analysis and Sustainability Threat

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Abstract: This report documents the work taken to analyse the socio-economic framework and the sustainability threats of passenger road transportation that can be addressed by means of crowd-sensing and ride sharing.

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Executive summary

This document corresponds to deliverable 2.1 of the CROWD4ROADS project, namely the need to complete a Socio Economic analysis of the prevailing market conditions and undertake an analysis of the Sustainability Threats that potentially impacting on the project.

The goal of this work-package is primarily focused on analysing the socio-economic framework and the sustainability threats of passenger road transportation that can be addressed by means of crowd-sensing and ride sharing.

Based on the analysis, representative scenarios and use cases will be defined to drive the definition of deployment of pilots and test beds. System requirements, design metrics and indicators will be also defined in order to drive the design and implementation of the platform, (WP3) and its deployment and validation (WP4).

The purpose of this task is the analysis of the socio-economic impact of the sustainability threats of road passenger transport and of the potential impacts of grassroots ride sharing and crowd sensing initiatives. In particular, the direct and indirect effects of car occupancy rate and road maintenance will be carefully analysed, together with the community scale dynamics that can be exploited to motivate end-users to act as prosumers and engage in road sustainability. The critical mass and the adoption rate required to trigger positive externalities and network effects will be also estimated, together with the effectiveness of the cooperation incentives that might contribute to reach it.

In producing the first draft of this report, we have collaborated particularly with COVUNI, who have led on the development of the Representative Scenarios and Use Cases, and now commit it to the partnership for further comment/consideration.

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1. Preface

Road networks are the largest publicly owned assets and they play a fundamental role in socio-economic development and competitiveness. At the same time, roads have huge environmental impacts and maintenance costs. Passenger cars account for 73.7% of total intra-EU passenger transport, with an average car occupancy rate well below 2 passengers per car. The resulting traffic accounts for about 12% of CO2 emissions. Delayed maintenance impairs road safety and increases cost of intervention, vehicle operating costs, and emissions.

The CROWD4ROADS project combines trip sharing and crowd sensing initiatives to harness collective intelligence to contribute to the solution of the sustainability issues of road passenger transport, by increasing the car occupancy rate and by engaging drivers and passengers in road monitoring. BlaBlaCar (http://blablacar.com/) is the largest trusted ride sharing community worldwide, with more than 10.000.000 members in 14 countries, while SmartRoadSense (http://smartroadsense.it/) is a crowd sensing system which makes use of the accelerometers of car-mounted smartphones to estimate the roughness of the road surface. The CROWD4ROADS platform establishes a synergistic relationship between BlaBlaCar and SmartRoadSense, exploiting the network effect which is inherent in both the initiatives, to provide a sizeable impact in terms of car occupancy rate, road monitoring, and end-user engagement in road maintenance and transport sustainability.

The focus of this report is on analysing the prevailing socio-economic conditions and the sustainability threats impacting on passenger road transportation that can be addressed by means of crowd-sensing and ride sharing.

In order to undertake this task, we have sought to break the analysis down into four discrete components, in order to examine;

- The general socio economic context within which this project has been developed,
- A socio-economic analysis of ridesharing,
- A socio economic analysis of road maintenance,
- A more detailed analysis of the sustainability issues.

2. General socio-economic context

Transport plays a major role throughout the economy, generating substantial employment and contributing to trade, as well as providing access to education, leisure, healthcare, rural towns and urban areas.

However, population increases; consumers natural preference for personal modes of transport; and decreasing public sector budgets are causing significant environmental and economic pressures across Europe. Network congestion and overcrowding are obvious indicators that the networks are becoming saturated.

Congestion currently costs Europe about EUR 100 billion, or 1% of Gross Domestic Product (GDP) every year . EU drivers currently own one third of the world's 750 million cars, with vehicle numbers forecast to increase to more than 2.2 billion worldwide by 2050 .

Increasing levels of congestion are impacting on journey time and journey time reliability, which, in turn, is impacting on productivity. This in turn is impacting negatively on air quality levels and CO_2 emissions.

To maintain its capability and capacity for growth, Europe needs to develop its transport systems. However, there are a number of political, economic, social, technological, legal and environmental pressures that are constraining the development, adoption and diffusion of new transport systems.

2.1. Political Issues

Transport policy is becoming ever more important in Europe, with an efficient, sustainable and safe transport system being considered integral to achieving the aims of the Lisbon Strategy.

European transport policy has been formulated by, amongst others, the European Commission White Papers on transport (2011, 2001 and 1992); the Future of Transport and Maritime Transport (2009); the Greening transport report (2008); the Keeping freight moving (2007); and Keep Europe moving report (2006).

The 2001 White Paper emphasised the need to improve the sustainability of transport whereas the mid-term review (2006) focused on optimising use of the different modes of transport.

Whilst many cities across Europe are looking to develop as Liveable Cities, with integrated sustainable public transport systems, the current fiscal pressures on many municipalities and regional authorities within Europe is making it difficult for them to implement viable sustainable public transport solutions.

The European level of funding for urban transport is limited and the political pressure on member state governments to find more money is increasing. However, in addition to needing to address national structural debt and deficit issues, economic and demographic changes are also placing further pressure on the political system to concentrate scarce resources on economic, health and social care, further impacting on the availability of resources to invest in transport. Some cities have brought in additional funding by regulating mobility through taxation or/and C02 free zones.

International liberalisation of trade is likely to continue to remain an important driver of change in the future across the globe. Whilst this market liberalisation process has eased, some of the financial pressures in some public transport segments, population growth, the rise of the middle classes and the general tendency for consumers to aspire to car ownership has brought with it significant infrastructure investment pressures. Furthermore, the increasing tendency for citizens being required to pay more to use the transport system may give rise to additional barriers to implementation.

In response to these issues, Infrastructure is increasingly being planned and discussed at EU level. The EU promotes major transport infrastructure projects across Member State borders, the so-called trans-European networks (TENs). The emphasis on major cross-European transport corridors can be expected to be a continuing driver of change in the future, highlighting the need for cross-border planning and internationalisation of the transport labour market.

As of January 2014, the EU has a new transport infrastructure policy that aims to close the gaps between national transport networks, remove bottlenecks that hamper the smooth functioning of the single market and overcome technical barriers such as incompatible standards for rail traffic. Funded through the Connecting Europe Facility, with a budget of €26bn up to 2020, the policy will also benefit from the Commission's 3-year investment plan, designed to unlock public and private investment of at least €315bn by 2017.

EU enlargement could create an even larger transport sector, driving economic growth in the new member states, enhancing mobility of passengers and goods within these countries further fuelling growth in car ownership and increased demand for freight transport.

Bottlenecks, congestion and pollution have put transport sustainability on the European political transport agenda. As part of this agenda, the EU aims to boost more sustainable transport modes, including, trains, bicycles and walking. The use of freight by road constitutes a particular challenge in this respect because it is one of the few areas in which transport growth has not been decoupled from economic growth.

The transport sector is presently also strongly dependent on oil supplies, and concerns about climate change combined with longstanding problems regarding congestion, noise and urban pollution have put environmental issues high on the political agenda.

Different political mind-sets and policy priorities in various parts of Europe also means there are no 'one-size-fits-all' solution. For example, attitudes towards public procurement and collaborative working with the private sector in particular differ massively across Europe. In some member states, this is making it difficult for the private sector to find profitable business models and investment strategies for new transport paradigms.

Whilst the number of deaths on Europe's roads halved between 1992 and 2010 (falling from 70,000 to 31,000) and fell by a further 17% between 2010 and 2013 , road safety continues to be an important policy driver.

The EU also supports research & innovation, and the effective deployment of new green transport technologies. For example, new rules require EU countries to promote clean technologies (including low carbon vehicles) by building a minimum number of recharging and refuelling stations.

In summation, the objectives now for much of the political system is to enhance mobility while at the same time reducing congestion, accidents and pollution in European cities.

Political efforts to change the balance between transport modes can be expected to continue in the future, as long as environmental issues and problems such as congestion remain unresolved. While the modal shift is sought, it is also important to increase vehicle efficiency by improving vehicle routings, increasing utilisation/loads and reducing empty running.

2.2. Economic Issues

Economic growth and transport growth are closely associated and interdependent. Good quality infrastructure is vital for economic growth.

The current global financial and economic crisis is affecting transport infrastructure projects worldwide in several ways. It has had a major negative impact on the availability of both private and public finance for transport infrastructure investment. At the same time, many countries are pursuing policies to ease the current economic downturn with an emphasis on transport infrastructure spending, thus relieving the shortage of financial resources to some extent.

Economic growth also affects the demand for transport. Energy prices, labour costs and economic integration also affect demand for transport and the relative demand for different modes of transport.

According to research by the International Association of Public Transport) , 2014 was the first year of distinct growth in demand for public transport after years of stable demand following the start of the economic crisis in 2008. The highest total demand in 2014 for bus, tram, metro and suburban rail was recorded in Germany (10.9 billion journeys), UK (7.7 billion) and France (7.6 billion). Between 2013 and 2014, 'growth leaders' France, Italy, Poland and the UK recorded a combined increase of 600 million journeys, driving up the total EU figure.

Of the 57.9 billion public transport journeys made in 2014, 55.8 per cent were by bus, 16.1 per cent by metro, 14.5 per cent by tram and 13.6 per cent by suburban rail.

However, these figures mask significant national variations, which are quite closely linked to national employment figures. 17 EU countries saw higher ridership in 2014 compared to 2010 but only seven had sustained growth: Austria, France, Germany, Lithuania, Malta, Sweden and the UK. Bulgaria was the only country where ridership dropped every year since 2000. Encouragingly, countries such as Spain, Ireland and Italy that have been impacted by the crisis saw a return to growth in 2014.

Increasing integration of national and regional economies into the world economy will further fuel the growth in transport. Globalisation of the world economy means that production costs are now more important than transport costs, particularly in industries with a high labour input.

The increasing movement towards a service economy could potentially diminish freight transport's share of GDP. However, this tendency is mitigated by the substantial growth in international and interregional trade, which increases demand for freight transport. Furthermore, a service economy requires more intensive passenger transport.

In some industries, rising energy prices – and higher oil prices in particular – will make it less attractive to outsource the production of goods. Oil prices are projected to increase between now and 2030. And thus, the global division of work and transportation that thrives on low energy prices are at the same time one of the causes of rising oil prices.

2.3. Social Issues

Changes in the demographic structure of the European population and changes in lifestyle and preferences will influence demand for transport – and the ability of the transport sector to meet that demand.

The European population – and thus the age of the average transport worker - is ageing.

Current forecasts suggest that the share of people aged 65 years or over in the total population (EU-27) is projected to increase from 17.5% in 2010 to 29.5% in 2060. Similarly, the number of people aged 80 years or over is expected to increase from 4.8% in 2011 to 12% in 2060.

In order to keep older people actively involved in their daily activities, it is vital that they are able to travel and have access to acceptable levels of mobility. These demographic changes produce considerable challenges for future transportation systems and place new and growing demands on transport systems.

According to the OECD report 'Ageing and Transport, Mobility Needs and Safety Issues' (2001) , on the whole, older people who drive will prefer to continue doing so for as long as possible and will also expect to have access to alternative transport modes that meet their individual needs, especially as they approach 80 years of age.

Clearly, future transport systems and services will play an essential role in supporting independent, healthy ageing.

Demographic and Labour Market trends are also exacerbating existing shortages of transport labour, particularly engineers. Presently, only 22 % of transport workers are women. A third of all transport workers are over 50 years of age . Future labour market policies will have to work actively in the areas of: recruitment of new groups of people, particularly women; and strategies to retain older workers.

Labour shortages in the Transportation sector will very likely constrain old delivery models. In order to accommodate labour shortages, employers will probably increasingly need to innovate.

Geographic mobility is a major policy challenge for the EU. Poor mobility may impact on adaptability and competitiveness. By contrast, too much mobility – particularly between the poorer regions of Europe and richer northern and western parts of Europe – are already creating tensions. For both the receiving and sending regions, a high level of mobility is a continuous challenge to social cohesion and economic performance within the regions and also between regions.

Many European countries are experiencing difficulties in recruiting sufficient numbers of students for transport-related education and staff for existing positions. The challenge for governments and the industry will be to change the image of the sector and innovate to be sufficiently attractive .

2.4. Technological Issues

Road congestion, noise, energy prices and air pollution will make alternative transport systems more attractive in the future and technological development carries the potential to make this feasible.

Rapid technological development requires a workforce with adaptable and flexible skills. On the other hand, modern technologies also require specialised and highly skilled personnel. These two counteracting trends pose serious challenges for future education and training in the transport sector.

The transport sector represents 70% of European oil consumption, and alternative power technologies are essential for environmental, resource and security reasons . Only fundamental changes in behaviour and transport structure can deliver sustainable solutions.

Cleaner technologies, such as alternative power technologies, more efficient engines or improvement in the standards for gaseous emissions and noise, can contribute to a more sustainable transport sector. Several of these new power technologies are taking increasing hold in the market, including electricity; hydrogen; hybrid; bio fuels; LPG; and compressed natural gases.

Tax systems and the necessary infrastructure have to be in place for the technology to spread to a wider market.

It is difficult to assess the future development and uptake of technology in society. However, technologies are evolving rapidly and governments must be aware of future changes in skills needs as a result of these developments.

Technologies for intelligent and efficient use of existing roads, rail and motorways, and of seaport and airport infrastructure are also emerging. Standardisation of new technologies like Satellite and mobile technologies can ease cross-border traffic, make logistics and handling of goods more efficient, and improve just-in-time deliveries. Moreover, these technologies can also help to ease congestion in cities.

Information and wireless communications technology are increasingly being applied to transport infrastructure and vehicles, whether to improve the management of vehicles, loads and routes; improve safety; and/or reduce vehicle wear, transportation times and fuel consumption.

Proposals for autonomous vehicles have been around for decades. Telematics technologies offer many possibilities for improving vehicle control, comfort and safety. New materials and nanotechnologies will reduce weight and energy use.

However, developing new and unconventional transport systems can take a long time. New transport modes are emerging in a more distant future and cannot be expected to influence the markets in a 5 to 10-year perspective.

2.5. Legal and Regulatory Issues

The legislative push towards the single European market that began in the 1980s also heralded a turning point in transport policy. Since then, the trend has focused on facilitating cross-border movements of goods and services.

This has resulted in softening cross-border barriers and greater integration in national markets. Transport legislation also aims to open access to markets and infrastructure, achieve technical compatibility and remove other technical and administrative barriers to competition. In turn this has led to rising GDP figures across the EU, linked to increases in passenger and freight transport.

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Market access is balanced with EU-wide rules in areas such as driving and rest times for road freight, guaranteed rights for passengers across all forms of transport and social equality in conditions that ensure a fair and open environment for competition.

In December 1992, the European Commission published its Communication on the Future Development of the Common Transport Policy, which made the transition from a very sector focused approach to transport policy to one focussed on promoting an integrated approach and sustainable mobility. Until 1st of January 1993, European transport policy was based on two principles: the users' free choice of the transport modes and the principle of subsidiary.

In 1992, Pilot Actions Combined Transport (PACT) was implemented, in order to focus all transport operators on supporting and promoting international transport. The Maastricht Treaty stipulated as main objectives: socio-economic cohesion through the Trans-European Networks and other transport infrastructures development; traffic safety improvement; and creating conditions to ensure the enterprises' competitiveness, including those of transport.

The Communication COM 95/0302, published in July 1995, had as a primary objective the quality improvement of transport activities, in order to optimize the functioning of transport markets and to develop the external dimension of transport policy.

In December 1995, the Communication COM 95/691 approached, for the first time, the tax issues related to transport activities. Moreover, the Communication COM 98/466 raised the question of setting up a harmonized system of transport taxation.

In 1996, the European Commission adopted the Eurovignette Directive to regulate the non-discriminatory access to the transport infrastructure of heavy transport vehicles on the average infrastructure costs basis. In ports and airports, access to transport infrastructure was made on the fair competition conditions provision, in accordance with the guidelines established by the European Commission in 1997.

The Transport White Paper in 2011 established ten goals for a competitive and resource efficient transport system:

- Halving the use of 'conventionally fuelled' cars in urban transport by 2030; phasing them out in cities by 2050; achieving essentially CO2-free city logistics in major urban centre's by 2030;
- Low-carbon sustainable fuels in aviation to reach 40% by 2050;
- Reducing EU CO2 emissions from maritime bunker fuels by 40% by 2050 (if feasible 50%);

- 30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50 % by 2050, facilitated by efficient and green freight corridors;
- Complete a European high-speed rail network by 2050. Triple the length of the existing high-speed rail network by 2030 and maintain a dense railway network in all Member States. By 2050 the majority of medium-distance passenger transport should go by rail;
- A fully functional and EU-wide multimodal TEN-T 'core network' should be in place by 2030, with a high-quality and capacity network by 2050 and a corresponding set of information services;
- By 2050, connect all core network airports to the rail network, preferably high-speed; ensure that all core seaports are sufficiently connected to the rail freight and, where possible, inland waterway system;
- Deployment of the modernized air traffic management infrastructure (SESAR) in Europe by 2020 and completion of the European common aviation area. Deployment of equivalent land and waterborne transport management systems. Deployment of the European global navigation satellite system (Galileo);
- By 2020, establish the framework for a European multimodal transport information, management and payment system;
- By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road casualties by 2020. Make sure that the EU is a world leader in safety and security of transport in all modes of transport;
- Move towards full application of 'user pays' and 'polluter pays' principles and private sector engagement to eliminate distortions, including harmful subsidies, generate revenues and ensure financing for future transport investments.

2.6. Environmental Issues

A strong link exists between economic growth and transport volume, but also between transport volume and pollution.

The economic recession led to reduced pollutant emissions by lowering transport demand. Transport is still responsible for 25% of EU greenhouse gas emissions , and contributes significantly to air pollution, noise and habitat fragmentation.

While progress has been made in meeting certain policy objectives, including efficiency and short-term greenhouse gas reduction targets, major challenges remain toward meeting longer term objectives. The European Commission's target of a 60% reduction in greenhouse gas emissions by 2050 will require significant additional measures.

Transport is highly dependent on oil. 95% of all kilometres travelled (both passenger and freight) in the EU are powered by oil derived fuels. The combustion of this oil releases pollution in the form of emissions, which place significant burdens on human health and the environment. In 2012, the transport sector (including bunker fuels) accounted for 24.3% of total EU GHG (greenhouse gas) emissions.

Emissions of air pollutants from transport have generally declined over the past two decades. However, around 90% of city dwellers in the European Union (EU) are still exposed to air pollutants at levels deemed harmful to health by the World Health Organization (WHO), and transport is a large contributor to this.

Transport also causes noise impacts. Road traffic exposes more people to harmful levels of noise than any other source, followed by rail and aircraft. Data also shows that fragmentation due to transport infrastructure and urban sprawl constitutes a growing threat to many wildlife populations via reduced connectivity among habitats, becoming increasingly isolated.

Transport demand, fuel consumption, and transport-related GHG emissions have all increased since 1990. They peaked around the beginning of the economic crisis and have shown unstable trends since.

EU measures to reduce transport emissions have included the introduction of fuel-quality standards and exhaust-emission limits for air pollutants and CO2. They have also included the incorporation of the transport sector into national emission-limit calculations for both air pollutants and GHGs (under the EU Effort Sharing Decision).

The European Commission's White Paper on Transport is a further political response to these issues. It was designed to guide future policy developments in the transport sector over the next decade and in accordance with the long-term EU objective to reduce GHG emissions by 80–95% by 2050. The White Paper calls for a reduction of CO2 from transport of at least 60% by 2050 from 1990 levels. It envisages the target being met by a combination of new technology and more efficient use of existing technology.

On a more positive note, the transport sector shows progress towards the goal of achieving a 10% share of renewable energy by 2020 in each Member State. The average EU-28 share of renewable energy in transport increased from 3.4% in 2011 to 5.1% in 2012.

The efficiency of new cars has also improved, encouraged by EU regulations. The average CO_2 emissions level of a new car sold in 2013 was 127 g of carbon dioxide per kilometre, significantly below the 2015 target of 130 g. However, manufacturers will have to keep reducing emissions levels to meet the target of 95g CO_2/km by 2021.

Unlike the trend for GHGs, emissions of the main air pollutants from transport have generally declined over the past two decades. However, the decreases for certain pollutants (SOx, NOx and PM), are much less when emissions from international shipping are taken into account. The introduction of catalytic converters, progressively stricter Euro emission standards, and increasingly strict fuel quality standards are the main factors behind past reductions.

A less positive development is the increase in the fraction of NOx emitted by diesel vehicles, leading to increases in NO_2 values in many European cities. Increasing traffic volumes, coupled with the promotion of diesel vehicles in many EU Member States, have thus become one of the main reasons why countries do not meet EU air quality regulations.

To make matters worse, NOx emissions from diesel vehicles under real-world driving conditions often exceed the test-cycle limits specified in the Euro emission standards, a problem that also affects official fuel consumption and CO_2-emission values. In general, an average diesel car emits more PM and NOX than petrol, but less CO_2. Recent data show that the CO_2 difference is decreasing.

Before the economic crisis, Europeans were travelling more than ever before. Based on past trends, the European Commission's 60% transport GHG reduction target by 2050 will not be met. Meeting these targets will therefore require fundamental transitions in the European transport sector.

One of these transitions is the shift to alternative fuel vehicles. However, too few alternative fuel vehicles are currently being sold. Consumers are reluctant to purchase these vehicles, and manufacturers are deterred from investing further in them. The European Commission has recently submitted a proposal to significantly develop the infrastructure for alternative fuels as a way of addressing the problem of low uptake of vehicles and lack of infrastructure. As well as delivering clear environmental benefits (reducing average CO_2 emissions and reducing air pollutant emissions etc.), the uptake of new technologies will also reduce Europe's dependency on oil.

However, changes in the transport sector — such as renewing an entire country's fleet of vehicles — require time to take effect. Delivery of benefits from an uptake of new vehicle technologies also depends on developments in other sectors, such as clean electricity production to cope with increasing demand.

Moreover, alternative fuel vehicles will not on their own solve other existing problems such as congestion levels, accidents and road safety, or noise levels. For this reason, additional fundamental changes in the way Europe transports passengers and goods are needed.

These additional changes include avoiding the use of transportation where possible; shifting necessary transport from environmentally harmful modes to more environmentally friendly modes; and improving the efficiency of all modes of transport. It is essential for the public to accept the need for these changes. Public acceptance is critical to overcoming the two main barriers for implementation of these changes: lack of political will and lack of funding .

Fortunately, signs of a potential cultural change have already been identified in recent research. In countries such as Germany, the United Kingdom, Australia, Japan and the USA, car travel demand appears to be decreasing, remaining at the same level, or growing only slowly. A number of reasons have been suggested for this change, including improved public transport, fuel prices, and changes in the symbolic value attached to vehicles.

In the longer-term, Europe will need a coordinated approach, which integrates all of the above policy measures: alternative-fuel vehicles, transport avoidance, shifting to less environmentally damaging modes of transport, new infrastructure, and financial measures. In order to gain public support, this coordinated approach must aim to address not just the environmental impacts of the transport system but create better health and improved quality of life for Europe's citizens.

2.7. The need for a new transport model

The scale of the global transport industry is truly astounding. Transport is essential in every aspect of our daily lives, playing a key role in supporting the European economy through the movement of people and goods, getting people to work and food to the supermarkets. However, the impact of growing demand for transport is clearly reaching saturation.

In simple terms, the 'old' personal transport model is broken, with the road network simply not being unable to cope with more and more cars going on the road, with lots of unutilised spare capacity. In many countries, the 'old' public transport system is similarly challenged with many member states/municipalities finding it difficult to allocate the level of public investment and subsidy needed to sustain an efficient and effective public transport system.

This situation now demands a step change in system performance to deliver a new, sustainable transport model.

In response to these issues, many member states/municipalities are turning to big data and technology platforms to try and provide consumers with better information about the availability of different public transport solutions.

Some examples of new transport applications that have been built on sharing economy business models include;

- **Turo:** a car rental service (https://turo.com/)
- **JustPark:** aims to solve the problem of finding a parking space, circling the block, feeding the meter, worrying about moving your car, or paying too much for a parking space by leveraging vacant privately-owned parking spaces in your city (https://www.justpark.com/)
- **Uber:** a car sharing platform which provides a cheap alternative to standard taxi services (https://www.uber.com/)
- **Getaround:** allows you to rent a car from someone in the Getaround network. You can set your desired rates and the company handles all the payment processing and insurance (https://www.getaround.com/)
- **Postmates:** aims to "revolutionize urban logistics" by changing how local goods are acquired, delivered, and consumed. Employing an army of on-demand couriers (primarily on bikes, but sometimes in cars), the company promises quick, low cost delivery of any local item (https://postmates.com/)
- **Sidecar:** offers three services: Sidecar, a ride app that connects riders with everyday drivers in their personal vehicle; Shared Rides, a discounted instant carpooling app; and Sidecar Deliveries, which combines people and packages on the same route (https://www.side.cr/)

These systems take a variety of forms but all leverage information technology to empower individuals, corporations, non-profits and government with information that enables distribution, sharing and reuse of excess capacity in goods and services.

The real power of these kind of tools really come into their own when harnessed as part of a 'sharing economy' solution, which encourages firms and communities to develop innovative transport platforms and applications which utilise new business models to break down the barriers between the traditional paradigms of personal, public and freight transport; deliver modal shift; and encourage road users to 'trade' their unutilized vehicle capacity.

Today there are numerous open data sources that might be leveraged in any number of ways to combat the congestion challenge and open a world of optimized real time transport alternatives. However, many in the application developer community struggle to access the real time data sources they need to develop proprietary solutions. This is particularly the case in local authorities who quite often use different proprietary approaches even within their own ecosystem.

Today's transport networks are fragmented, and work in silos rather than being overall effective and usable systems. This fragmentation and isolation has confused the customer, increased CO2 emissions thus losing the original aim and benefit of these technologies. A potential solution is to integrate them through systems engineering, thus increasing overall performance of the network and the vehicles and infrastructure that operate within it.

In response to these issues – largely in recognition of the fact that public bodies already possess significant amounts of transport/personal data and are generally viewed as a 'trusted data brokers' many municipalities/regional authorities are;

- Investing in establishing comprehensive data warehouses that enable them create the kind of base infrastructure that is needed to support the delivery of localised 'Big Data' projects;
- Exploring the potential of linking previously disparate datasets to provide additional 'value added' services;
- Exploring the potential of working with private sector partners – particularly App. Developers and the IT Community – to develop new transport solutions.

These kind of aggregated, 'Big Data' projects enable public sector partners to develop innovative new services which aggregate freely available data-sets together (in many cases thereby enabling them to charge for these new services, because of the level of value added they achieve) and address significant demand management challenges (by churning residents to self-service and online channels, rather than them needing to pull on more premium public services.

3. Car & Ride Sharing: Socio-economic and sustainability issues

Car sharing and trip sharing strategies, attempt to change consumer behaviors in consumption practices, by offering less environmentally damaging travel options through the promotion of less traffic. Car/trip sharing has been linked to developing positive behavior change concerning reduced travel activities of an individual, leading to environmental benefits such as lower carbon emissions.

3.1. The difference between car and ride sharing

Car Sharing and Ride Sharing are two alternative methods of sustainable transport that have increased in popularity of late. They both operate on the principle of the Sharing Economy, whereby the owner of a resource promotes the use of that resource by and for wider society, on a 'as needs' basis, rather than the individual in question having to own that resource permanently.

Ride sharing is when the ride is going to happen anyway and multiple people are allowed to join it. Car sharing is when the car is available for use more than is necessary for one user, so another user gets to use the car as well in a defined way that is independent of the other user.

According to the 'Assessing the Size and Presence of the Collaborative Economy in Europe' report from PwC and the European Commission. The collaborative economy generated revenues of nearly €4 billion in Europe – and facilitated €28 billion of transactions – in 2015, with these platforms doubling their revenues over the course of the year.

3.1.1. How car sharing works

Car sharing offers and promotes adopting the use of rental cars in daily life instead of owning a private vehicle for travel-based needs. This paradigm promotes a personal lifestyle shift for the car owner, from private vehicle ownership to a more environmentally friendly, service use option .

A car sharing system is often supported by a car-sharing organisation, which is usually a non-profit organisations that owns a fleet of cars, a car station/park and normally operates within dense, urban areas, where environmental concerns are particularly strong. Subscription to a car sharing organisation normally requires a joining deposit and a monthly subscription fee. Drivers can book short-term access to a vehicle that matches the driver's travel requirements (depending on the availability of the vehicle), 24 hours a day, 7 days a week.

Drivers are responsible for collecting and dropping off a vehicle themselves and are charged based on two components; hours used and kilometres/miles driven each month. Car sharing organisations operate at both a local and national level, providing coverage for drivers across a widespread area and thus allowing travel further afield.

3.1.2. How ride sharing works

Ride sharing (also known as carpooling or lift-sharing) is an eco-efficient service that promotes a similar philosophy to car sharing systems, that strive to develop positive behavior change in order to obtain sustainable travel. The function of ride sharing and ride-share systems, is to primarily connect and match together travelers with similar travel needs such as destination and schedule, in order to reduce the number of single driver vehicles on the road.

Ride sharing operates by employing effective use of a driver's empty car seats, offering opportunities to split the costs, effort and efficiency of travel to and from pre-specified designations. Based on the occupation records of private vehicle usage; 1.2 to 1.4 persons on average per car, compared to occupancy records for carpooling vehicles at 2.5 persons on average per car, indicate that ride sharing could be an effective measure to reduce the number of vehicles for personal travel.

3.2. Socio-Economic issues with ride and car sharing

Generally speaking, recent increases in the volumes of people utilising ride and car sharing have come about because of a direct consequence of prevailing socio-economic tensions in the transport sector and within the wider environment.

In recent years, the sharing economy has generated heated controversy, with supporters claiming it brings efficiency, opportunity and sociability and critics arguing it's undermining the existing labour arrangements, exacerbating inequality and weakening the psychological contract between employee and employer.

Much of the recent socio-economic analysis of the implications of the sharing economy has tended to look at the experiences of disruptive platforms like Airbnb and Uber. Understanding what socio-economic issues these kind of pervasive platforms give rise to, together with more traditional car and ride sharing applications, is useful in considering the implication for any new/future transport applications.

3.2.1. Economic Issues

The sharing economy challenges traditional notions of private ownership and seeks to establish new business models based on the shared production or consumption of goods and services.

The origins of the sharing economy can be traced back to a myriad of community, not-for-profit initiatives such as Wikipedia (2001), Couchsurfing (2003) and Freecycle (2003). However, over the years a number of these platforms have become increasingly commercial. Mobile technologies have fuelled the expansion of the sharing economy and turned it into a big business.

In 2013 it was estimated that revenues passing through the sharing economy into people's wallets exceeded $3.5 billion, up 25% from the previous year . By 2016, according to PwC, the global sharing economy had grown to be worth $15bn per year, and is projected to soar to $335bn in 10 years.

Airbnb has exceeded 10 million guest stay's since its launch and now has more than half a million properties listed. Meanwhile Uber has said that it is doubling its revenue every six months.

The potential of companies operating peer-to-peer service platforms is illustrated by the funding that successful US based ventures have attracted. TaskRabbit, for example, launched in 2008, has already acquired $37.7 million in funding. Its domestic competitor Zaarly boasts $15.2 million in acquired funding.

Advances in information technology have enabled cities like Lyon to create large-scale bike-share systems, which have subsequently expanded around the world.

From an economic perspective, digital peer-peer platforms are forecast to be a significant contributor to growth. A report by Europe Economics estimated that the sharing economy could boost the EU's GDP by £125bn due to better utilisation of assets.

3.2.2. Political, Legal & Regulatory Issues

Peer-Peer ride-sharing platforms like Uber and Lyft have opted for a seemingly infinitely scalable, pure, for-profit business model. As these - and other ride-share platforms like them - have no need to hire drivers or acquire vehicles, they rely on the power of social networking to scale their service. As evidenced by their rapid growth and high valuations, it is clear these ride-share companies have achieved some early success in maximizing value to their customers.

Similarly, Airbnb's business model is built around allowing people to rent out rooms or entire apartments on a short-term basis.

However, in October 2014 the New York State Attorney General released a report into Airbnb's operations that concluded that 72% of the site's rentals violated state zoning regulations or other laws. This report is the latest in a series of ongoing battles Airbnb is engaged in with regulators across the world.

Berlin has banned regular short-term rentals in the most popular parts of the city without the prior approval of the authorities. Paris passed a law in February 2014 to allow city inspectors to check the Airbnb rental properties of owners that are suspected of renting them out to visitors illegally. Airbnb has published its own reports on the benefits of its short-term accommodation model on local housing markets and local economies.

Other cities are implementing more pro-sharing-economy legislation. In February 2014, Amsterdam became the first city to pass so-called "Airbnb friendly" legislation. In October 2014, San Francisco passed legislation allowing short-term rentals by permanent residents, but required them to collect city hotel taxes.

Earlier this year in the US, Austin City Council, passed a regulation requiring Uber and Lyft to obtain fingerprint-based background checks for all drivers. In response to this regulation, Uber and Lyft pulled their business out of Austin. Residents and tourists lost a transportation option sorely needed in a congested city with few efficient transportation alternatives.

In London, 1970s regulations limiting short-term stays were scrapped, making it easier for Airbnb and others to operate in the city. The British government has even launched an initiative to make the U.K. the "global centre for the sharing economy. In 2013 Avis paid half a billion dollars for the car-sharing service Zipcar, and Hertz has started a similar service.

Given the above evidence, private ride-share operators are well advised to engage with local governments if they want to avoid legal action and other threats posed by local governments and taxi operators. While the go-it-alone approach and avoiding local government and regulation has been a historical modus operandi in other sectors, shared mobility service providers would be better served by finding ways to collaborate with local governments if they want to achieve long-term viability.

Not only would this entail adhering to regulations in areas such as vehicle and driver safety requirements but also seeking to optimize the citizen and environmental goals to achieve active city support. Any direct financial support, or incentives that promote the use of these P2P networks, such as embedding the ride-sharing data into transit applications, could result in a reduction in costs for riders.

3.2.3. Social Issues

It is also true that the rise of the sharing economy, with its greater reliance on independent 'workers' has potentially led to weaker ties between 'employer' and 'employee' and created greater job insecurity and potentially greater risk of social exclusion.

Despite the benefits offered by sharing economy, a number of researchers have identified several challenges preventing disadvantaged groups (i.e. those with low socioeconomic status, unemployed and/or users from emerging regions) from receiving the same level of benefits as those from advantaged populations.

Research into public attitudes and opinions concerning ride sharing schemes indicate that there can be several barriers including; beliefs, negative pre-dispositions towards an object and intention (Horowitz and Sheth). Additionally, there have been a number of empirical studies that show there are physical barriers such as; travel time, cost, convenience, auto-availability and socio-economic/household characteristics, that influence these beliefs and intentions (Hwang and Giuliano 1990).

Attitudinal studies conducted by Margolin and Misch (1978) revealed that subjective factors such as; interpersonal and social connection to unfamiliar persons, expectations of social protocols, perceptions of lost independence and overall status as a passenger, are more of a factor in the consideration of using ride sharing than cost or convenience (Horowitz and Sheth). A study into commuter attitudes and behaviour by Glazer and Curry (1987) indicated that commuters were unlikely to adopt ride sharing as they valued their freedom of being alone whilst driving. These findings can be linked to the psychological barriers that make up general distrust and perceived energy required to develop connections to unfamiliar people. Another study into travel inclinations of commuters, found that only a minority of people would feel comfortable and willing to carpool with strangers. Given the option they were more likely to carpool with family or friends (Flannelly et al. 1990). The trust/unfamiliarity barrier therefore appears to be one of the biggest psychological factors that discourage individuals from using ride sharing as their main source of travel.

In order to encourage new users into adopting ride sharing, these psychological barriers must be addressed on a very fundamental level and be visually accessible and communicated to potential new users. As previously discussed, travel management systems that have adopted a social networking element of their structure, go some way to help build levels of trust and the feeling of a community surrounding ride sharing schemes. However, more effort needs to be applied to change existing beliefs up front for gathering initial interest and engagement from a wide range of demographic groups.

According to Rayle et al. (2014) typical users of ride share services have been shown to fall mainly into the 25-34 age category (57%), with male users making up 60% of the rideshare passenger population. Users have generally received further education past college with 80% of passengers holding a Bachelor's Degree or higher. Another notable characteristic of typical users, is that 56% reported a household income of $71,000 or higher and a further 40% of all user's household income rose to $100,000 or more.

The top 10 destinations for using these ride sharing services were recorded as follows:

1. Home (residential addresses)
2. Workplaces
3. Tourist Destinations
4. Restaurant & Food
5. Bars
6. Airports
7. Retail Stores
8. Fitness Clubs
9. Doctors/Hospital
10. Bus & Transit Stations

A study to identify ride share demographics across Europe conducted by Delhomme & Gheorghiu (Delhomme and Gheorghiu 2016), attempted to define some characteristics of ride share users travelling across EU countries. Within their study, they identified six hundred and thirty-four participants who regularly carpooled as drivers and/or as passengers. Among these, 72.2% said they carpooled for work/school trips, 50.9% for children's trips, 86.1% for personal leisure, and 86.5% for shopping. Other significant data from this study found that carpoolers were more likely to younger and have more children than non-carpoolers. Middle aged participants (age 35-49) were more likely to be female and were three times more likely to use carpooling than any other user group. This could be a factor of shared household carpooling, in which other family members/children add to travel needs.

Other considerations of demographic data concern gender tendencies of travel behaviours. Across Europe, travel based demographic data indicates that in low-car households, men are much more likely to be the primary driver. In Germany, a similar study found that men were also more likely to use cars than women (Delbosc and Currie 2012). This disparity however, is smaller amongst households with children, younger households and where women work for longer periods of time. As documented by Jones and Lucas (Jones and Lucas 2012), 19% of women in the UK who are part of car-owning households, are nearly twice as likely to be non-drivers compared to 10% of men. This paradigm however is slowly changing, with the gender disparity closing throughout Europe.

3.2.4. Technological Issues

Effective and efficient technologies that match drivers and riders using real-time access has been identified as a necessary component for creating successful user engagement with ride-share systems (Agatz et al. 2010).

In order to compete with private car usage, Agatz et al., propose that ride sharing must offer an immediate access to door-to-door transportation to be seen as a viable option.

Whilst ride sharing is not a new concept, a new configuration of the old system has emerged. Labelled as 'dynamic ride sharing', the new system utilizes technological advancements for providing instant and attainable access to users, providing an automatic ride-matching system for members at very short notice (Amey 2010). With dynamic ride sharing, commercial systems available via mobile apps or web-based access are used for managing ride sharing information, allowing users instant access to post and search for relevant trips of interest (Gidófalvi, Herenyi and Bach Pedersen 2008).

Within these systems there is often provided a series of options that allow members to provide user ratings and feedback based on the experiences of the trip (Assael 2006). This level of social networking, provides both a motivator for ride sharing drivers to create pleasant experiences for their passengers, whilst also creating a community of trusting members due to easily viewable driver/passenger recommendations and ratings. Most systems even support user profiling for both drivers and passengers, that can act as indicators for matching up preferences such as personality types, interests, music likes, smoking habits and preferred conversation levels (talkative, quiet etc.).

Creating greater public access to user data and personal information via social networking accounts, has attempted to address the barriers of safety and social awkwardness of sharing space with strangers, a main factor of user resistance to ride sharing (Van Lange et al. 1998). It is therefore reasoned, that to increase adoption rates of ride sharing schemes, technologies and management systems must invest heavily in creating social networks and varied incentives to encourage sharing of personal information, and leaving feedback/ratings to inform other members of their experiences.

3.2.5. Environmental Issues

Car/trip sharing has been linked to developing positive behaviour change concerning reduced travel activities of an individual, leading to environmental benefits such as lower carbon emissions (Millard-Ball 2005). Similarly, road maintenance and management provides benefits to improving access, comfort, speed and safety and in turn means lower vehicle-operating costs, providing relief to not only the occupants of the car but less emissions are produced overall in to the environment (Burningham and Stankevich 2005). For these benefits to be sustained however, a well-planned program of maintenance strategies must be implemented and supported in order to avoid potential loss of economic and social development opportunities (Burningham and Stankevich 2005).

3.3. Quantifying the benefits of car & ride sharing

There is clear evidence to support the impact possibility that ride and car sharing could have on reducing travel emissions, congestion, fuel consumption, costs and vehicle kilometers traveled, to establish a more sustainable travel system for the future.

Several technical studies have developed frameworks for evaluating and quantifying the benefits of car and ride sharing.

These studies tend to focus on commute trip reduction programs (Concas and Winters 2007; Modarres 1993), land use policy reforms, such as smart growth and transit oriented development (Seggerman, et al, 2005), reducing traffic congestion (ITE 1997) or air pollution (USEPA 2004).

There is extensive literature on some transportation costs, such as congestion, accidents and pollution (VTPI 2006). A few studies provide a framework for evaluating the cost savings and benefits of vehicle travel reductions (Delucchi 1998; Litman 2009; ExternE; and UNITE)

A growing body of literature concerns how various factors affect travel behavior (Pratt 2007).

Despite this wide array of benefits that ride sharing and car sharing can deliver, the reality is that many of the current platforms generally tend to focus on more direct benefits to end-users, like securing a financial contribution towards their travel costs (for the car owner) and reduced travel costs (for the sharer). A few also promote reduced congestion (through less traffic on the road) and or improvements to the environment (through Co2 reduction).

Very few platforms tend to offer differentiated benefits for different 'communities of interest' or provide consumers with a holistic analysis of the total benefits achieved from sharing a ride/car.

Going forward, both these developments provide opportunities for future developments in car and ride sharing platforms, enabling them to develop new audiences, new customer groups and/or event attempt to radically reform the underpinning financial models by which their core business operates.

4. Road Maintenance: Socio-economic & sustainability issues

Turning our attention to the Socio-Economic and Sustainability impacts of Road Maintenance, highway maintenance is of immense importance to motorists and other road users.

Despite this, the large backlog of work and decreasing expenditure by highway authorities since the advent of the crisis is having a number of negative impacts.

A number of important studies have been conducted in the last few years at both a European and Member State level which provide us with some useful insights about the dangers of not maintaining roads.

Historically, transport engineers have been slow to assess the economic cost of not maintaining our roads properly, and the value of investing in doing so. Many governments simply do not have a systematic way of measuring the extent to which poor road maintenance wastes economic value and/or impacts on social mobility or the environment. If something is not accurately assessed then it cannot be adequately managed.

In 2014, the European Parliament's Committee on Transport and Tourism commissioned a report on EU Road Surfaces, which looked at the Economic and Safety impact of the lack of regular road maintenance , with a view to informing the parliamentary debate looking at the condition and the quality of road surfaces in the EU. This study also sought to analyse the trends registered in the budget assigned by EU Member States to road maintenance activities in recent years, with the aim of reviewing the economic and safety consequences of the lack of regular road maintenance.

This study found that road maintenance expenditures also yield substantial wider socio-economic impacts.

Whilst the reduction in journey times associated with timely maintenance is one of the most widely recognised economic benefits of road maintenance, a survey carried out by the Asphalt Industry Association (2010) also found that the average cost of poor maintenance per business was €16,300 per annum.

Similarly, research by the Scottish government and the RAC Foundation confirms that under-maintaining roads is a false economy. The RAC Foundation found that it will cost more today to put right the consequential damage created from not addressing it now.

There is also some evidence of the social cost of road accidents which has been quantified in studies in France, Lithuania and the Netherlands.

Other studies that have sought to quantify the wider economic impacts of road maintenance activities indicate that the reduction in road maintenance expenditure can have an impact to the wider economy in the range of 100%-250%.

4.1. Road investment and maintenance expenditure trends

To assess the historical expenditure patterns of maintenance activities on road works in the EU in recent years, the European Parliament's Committee on Transport and Tourism brought together the road expenditure dataset produced by the OECD/ITF, the asphalt production data reported by EAPA and specific country information.

Their research indicates that, between 2006 and 2011, road investment levels remained relatively static across the EU, with investment levels reaching a peak in 2009, but falling away by 7.1% by 2011. Member state data suggests there is a great deal of variation across the EU in road investment expenditure, with Bulgaria and Poland both having increased their investment expenditure over these years; Slovenia, Austria and Ireland having drastically reduced theirs; and Germany, France and the UK broadly having maintained their investment patterns.

As far as road maintenance expenditure is concerned, the same study suggests Italy, Ireland, Slovenia and Spain have significantly reduced their maintenance budgets; Slovakia, Finland, Czech Republic, the UK, Portugal and Hungary have shown a slight downward trend; whilst Austria, Germany, France, Croatia, Lithuania, Luxemburg, and Poland have all increased their overall spend.

Collectively, this data suggests that road investment and maintenance budgets are more sensitive to fluctuations in those countries where the funding of road infrastructure is highly dependent on government spending (rather than from other sources of financing, like toll roads).

4.2. Consumer attitudes towards roads and road maintenance

A Euro-barometer survey also shows that a large majority of European citizens (73%) considers road safety to be a serious problem in cities. In the European Commission study "Attitudes of Europeans Towards Urban Mobility";

- Half of Europeans use a car everyday (50%) which is more than the proportion who cycle (12%) or use public transport (16%) combined, although these figures vary drastically by member state;
- Around four in ten Europeans encounter problems when travelling within cities (38%);
- A substantial majority of Europeans believe that air pollution (81%), road congestion (76%), travelling costs (74%), accidents (73%) and noise pollution (72%) are important problems within cities;
- Reduced travel costs are frequently mentioned as a way to improve travelling within cities. More than half of Europeans believe that better public transport (56%) and lower prices for public transport (59%), would be the best ways to improve urban travel; and
- Less than a quarter of Europeans believe that the urban traffic situation will improve in the future (24%) and most believe it will stay the same (35%) or get worse (37%).

The Directorate-General for Mobility and Transport (DG MOVE) has also conducted research into the "Attitudes of Europeans towards the use of roads located outside of cities ", which suggests respondents are almost evenly divided in their opinion of the quality of European roads.

In this survey, 50% of them rated them as "good" whereas 48% of them rate them as "poor".

Across the EU, countries where respondents think the overall quality of the roads as low are more likely to support increased spending on roads. Eight in ten Europeans (80%) agree that their government or local authorities should increase spending on maintaining and repairing roads outside of cities.

Respondents are most likely to agree that government spending on road maintenance should be increased in Malta (97%), Latvia (96%) and Slovakia (95%), where support for increases in government spending on road maintenance outside of cities is nearly unanimous.

There is a strong relationship at the Member State level between levels of support for government spending more on roads and the perceptions of road quality. Three in ten respondents who use roads outside of cities experienced congestion regularly (30%).

The worst experiences of congestion are in Malta (45% every day), followed by Italy (26%) and Luxembourg (22%). Respondents who use roads to go to work (53%) or for work related reasons (48%) are more likely to have experienced congestion on roads outside of cities compared with respondents who used roads mainly for leisure (19%).

Across the EU, slightly more than four in ten citizens do not pay road tolls (42%). Of the respondents who do pay these tolls, two thirds (66%) felt they are not informed about the use of the tolls. A quarter of EU citizens (25%) would be willing to pay higher road tolls either for better road maintenance and repair, to improve road safety, to benefit the environment, to improve public transportation, or to ensure less congestion.

Respondents are most likely to report that they would not be willing to pay more for tolls in Portugal (92%), Spain (89%) and France (82%), whereas respondents in Sweden (52%), Denmark (46%) and Cyprus (45%) would be most willing to pay higher road tolls. It is important to underline that that Portugal, Spain and France have already tolling on a high proportion of inter-urban motorways.

Respondents who finished education at age 15 or younger are more likely to report they would not be willing to pay higher road tolls (79%) than those who finished education aged 16-19 (76%) and at age 20+ (66%).

As for how highly voters prioritise road investment, a UK Audit Commission report on road maintenance quotes a 2008 survey asking what services local residents think "need improving". Astonishingly, number two from a long list was "road and pavement repairs", ahead of crime at number four and health services at number fourteen .

The RAC Foundation found the same thing during the UK 2010 General Election campaign, when they asked people their highest transport priorities of an incoming government. Top at 58% was "condition of roads and pavements"; next at 46% was "curbing the cost of driving"; public transport fares came farther down the list; and bottom at 3% was "developing a new high speed railway."

In 2012, the National Highways & Transport Survey (NHT Survey) found that 61% of residents in England were dissatisfied with the condition of local roads. Only 27% were satisfied with the condition of this asset, giving a net satisfaction rating of minus 34%, much worse than for the years that preceded the recent hard winters . Similarly, in the 2013 RAC Report on Motoring, respondents were asked about the "issues that most concern motorists." Condition/maintenance of UK roads was equal second in importance, after the cost of fuel for running a car .

Collectively, all this evidence indicates investment in road infrastructure, road maintenance and keeping the cost of driving down are important priorities for European voters.

4.3. Quantifying the impact of reduced road maintenance

A review of a number of studies into the negative impacts of reduced maintenance budgets identifies three major quantifiable issues which can be attributed to reduced road maintenance budgets, namely vehicle maintenance costs; health and safety issues and lost productivity.

The efficiency of the commercial transport sector depends on a range of factors, including labour costs and road infrastructure quality. Because of the variability of these factors across Europe, the competitiveness of individual member states transport sectors varies considerably. Private car users also face significant personal costs from the maintenance and repair of their vehicles, brought about because of deteriorating road surfaces.

Deterioration in road conditions will cause an increase in vehicle operating costs (e.g. fuel consumption, vehicle damage due to defects). Deterioration in road conditions will cause increases in travel time as vehicle travel slower on roads in poorer condition. Infrastructure failures are likely to increase journey times for all types of road users due to travel diversions.

The annual socio-economic cost of road traffic deaths and injuries was estimated to be equivalent to around 2% of GDP or EUR 250 billion in 2012 . Whilst driver behaviour has been identified as the principal cause of accidents, the impact of poor road condition and maintenance cannot be ignored. There are five different ways in which the condition of the road surface contributes to, or compromises road safety, namely: localised anomalies (such as ruts or potholes); poor wheel-road contact (thereby failing to guarantee adhesion); poor geometry and alignment design; poor level of service; and poor signage/lighting.

Lack of regular road maintenance can exacerbate some of these factors, especially those linked to the road surface condition.

Studies to assess skid resistance clearly indicate that accident rates increase as the International Roughness Index (IRI, measure in millimetres/metre) of a road increases. Research conducted by the National Cooperative Highway Research Program (NCHRP) has shown that there is a direct correlation between the number of accidents and the skid resistance value. In this study, poor road condition caused by insufficient regular (and extraordinary) maintenance was seen as being particularly dangerous when anomalies are localised.

As the 2014, Committee on Transport and Tourism report on EU Road Surfaces states, "In dry surface conditions these anomalies, if evenly distributed, cause continuous vibrations and bumps which usually increase drivers' attention and, as a result, the risk of accident seems to decrease. If the same anomalies are spread more thinly the risk increases as it is difficult for drivers to assess the pavement's skid resistance and adapt their driving style accordingly. In wet conditions, surfaces anomalies (especially rutting) lead to an increased risk of aquaplaning (a phenomenon whereby the vehicle floats on a layer of water, there is no longer contact between the road and the wheels) and the driver can lose control of the vehicle. The risk of aquaplaning accidents is greatest for large rut depths and during conditions of poor water drainage (small cross fall)".

Road markings, signs and lighting also contribute to make the road safe and easy to understand. A study developed by the EU Road Federation shows that good maintenance of road markings and signs reduces accident risk. Good and continuous street lighting also contributes to improved road safety especially in specific locations such as at intersections, pedestrian crossings, and generally in urban areas.

That said, a number of different projects have taken different approaches to quantifying the impact of reduced road maintenance;

4.2.1. The World Bank HDM-4 Model

This issue is of such significance that The World Bank has developed a series of tools to assess the economic benefits of a marginal change in maintenance expenditure through the use of the Highway Development and Management Model, currently in its fourth version (HDM-4).

The model can be used to assess the implications of maintenance expenditure in terms of traffic delays and vehicle operating costs. It also offers a good analytical framework within which to analyse the effects of road conditions on vehicle operations. The

World Bank suggests that the main elements that contribute to vehicle operational efficiency are:

- Fuel consumption;
- Tyre repairs costs;
- Costs of other vehicle maintenance and repairs (e.g. shock absorbers); and
- Depreciation.

In addition, the HDM-4 model can analyse the relationship between road characteristics, vehicle performance and economic or environmental impacts. For example, lower speeds (which can be due to bad road conditions) lead to increased fuel consumption.

4.2.2. The Transport Scotland/TRL Approach

Analysis undertaken by TRL commissioned as part of a review of the impacts of reducing road maintenance spending across the Scottish road network provides compelling evidence of the negative effects that reducing road maintenance would have on roads users, communities and the environment.

Transport Scotland has also recently carried out a comprehensive study on the socio-economic impacts of maintenance spend in Scotland, using HDM-4 as part of the cost-benefit analysis to assess different spending scenarios. As part of this study, TRL gathered evidence, not only from a comprehensive literature review, but also undertook a quantitative appraisal of three separate spending scenarios:

1. Maintaining Scotland's road maintenance spending at 2010/11 levels (the base case);
2. Reducing this 2010/11 baseline by 20% over the next 10 years; and
3. Reducing this 2010/11 baseline by 40% over the next 10 years.

The base case scenario still resulted in an increase in the maintenance backlog, as current levels of expenditure were not sufficient to address the needs of the road network.

The report assesses road maintenance in terms of the standard Transport Appraisal Guidelines used in Scotland. In doing so, it highlights the potential effects of these budget scenarios on the five key areas of; the environment; safety; the economy; integration and social inclusion and accessibility.

The quantitative analysis is based on a net present value appraisal of the additional costs and benefits arising from each scenario. As part of this work, the impact of poor quality roads on the following were assessed:

- Vehicle operating costs - if roads deteriorate in condition, vehicles incur more costs for example through increased fuel consumption and wear and tear;
- Travel time costs - if roads deteriorate in condition, vehicles will also travel more slowly and so journey times will increase;
- Skid related accident costs- if roads deteriorate in condition, skidding accidents increase, particularly on lower quality road surfaces in wet conditions.
- Delay costs at roadworks - roadworks cause disruption to travel and so reductions in roadworks due to funding constraints will generate less disruption; and
- Lighting related accident costs- the economic justification for provision of streetlights is a reduction in night-time accidents on well-lit roads.

In simple terms, this research indicated that savings on road maintenance are significantly outweighed by the wider additional costs. Under scenarios 2 and 3 (ie, either a 20% or a 40% reduction in roads maintenance spending) TRL found there was a negative net present value (NPV). This conclusion applied to trunk roads and, to an even greater extent, the local road network.

Under Scenario 3, whilst there savings of £2.027 billion were capable of being generated by reducing all road maintenance investment by 40% over ten years, the impact of this policy decision resulted in additional costs to Scotland's road users and communities of over £3 billion. The overall dis-benefit to society of a 40% cut in road maintenance budgets was therefore estimated at £1.053 billion. This research suggested that a £1 reduction in road maintenance resulted in a £1.50 cost to the wider Scottish economy and society.

The assessment by TRL supports many Transport Engineers assertions that reducing budgets results in not only a deterioration of the infrastructure, but also an acceleration of that decline. This argument also supports the case for preventative spending.

4.2.3. The JASPERS54 Project

Results from analysis carried out in Poland as part of the JASPERS54 project suggest similar conclusions. By comparing vehicle operating costs at different speeds, the

JASPERS54 project found that at a speed of 60 km/h the difference in operating costs is PLN 0.017/km (€0.004/km) for cars and PLN 0.1/km (€0.02km) for goods vehicles.

From this data, the project concluded vehicle operating costs appear to be in region of 2-3% higher when travelling on roads with deteriorated conditions.

4.2.4. The Infraplanas Project

The Infraplanas Project estimated the savings in transport costs for road users (excluding travel time savings) of road repair and rehabilitation in Lithuania. For each Euro invested in road maintenance, they calculated transport cost savings in the region of €0.7 for urban road users and €1.4 for rural road users.

4.2.5. The EU Road Surfaces Project

The Committee on Transport and Tourism report on EU Road Surfaces, utilised a methodology that identified the number and value of requests for damages made by road users to local authorities, to shed some light on the extent to which extra costs are borne by road users due to poor road maintenance.

A consultation carried out by Insurance Europe for the EU Road Surfaces Study found that;

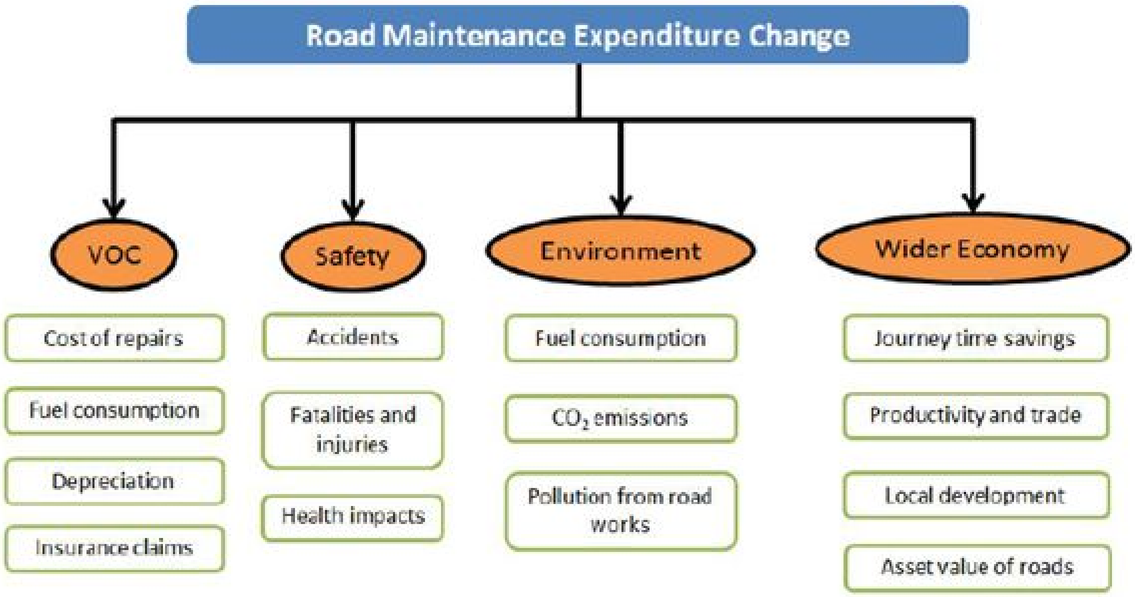
- Some insurance schemes have been set up by highway operators in France, Italy, Austria and Poland. The limits for liability are usually around €50m. In these Member States, claims are made frequently by road users;
- In Poland, on average motorists make about 2,000 per year for a network of around 17,000km managed by the national authority GDDKiA;
- A survey carried out among local authorities in England and Wales indicates that the overall cost of motor insurance claims amounted to just under £32m (€38.5m) in the financial year 2011/12 and that councils have paid out a total of £2.5m (€3m) in compensation to motorists in the financial year 2012/13 for pothole related damage to cars (an increase of 80% over the previous year);

This study also identifies that, in addition to the direct cost of claims, poor road maintenance also adds an indirect cost in terms of working hours spent by public sector employees dealing with these claims.

The diagram below summarises the conceptual framework that this project recommended for any comprehensive assessment of the socio-economic impacts of a change in road maintenance expenditure, based on the author's review of the literature mentioned above.

In their concluding remarks, the authors state *"No relevant evidence relating to road maintenance environmental impacts has been identified during the course of this study. A well maintained road surface reduces the deterioration rate of tyres and also fuel consumption but these have to be balanced against the additional environmental negative externalities from the maintenance activity"*.

Potential impacts of a change in road maintenance expenditure



Note: VOC=vehicle operating costs
Source: Steer Davies Gleave elaboration.

This framework provides us with a useful model on which to build a more detailed framework for the analysis of road maintenance and ridesharing

4.3. Non-Quantifiable impacts of reduced road maintenance budgets

In addition to considering the quantifiable impacts of road maintenance, we also think there is some value in considering what evidence exists about the non-quantifiable benefits (in case we identify any particular linkages with ridesharing, or any interesting ways of quantifying/incentivising these issues).

The TRL/Transport Scotland project identified quite a comprehensive list of non-quantifiable effects of reduced road maintenance budgets, which may be equally significant (because, whilst they might not be quantifiable, they could be incentivisable).

For the purposes of this research, we have listed this analysis, precisely as it appears in the TRL/Transport Scotland study;

4.3.1. Economy

- Journey reliability and quality will both deteriorate as road maintenance deteriorates. It is difficult to quantify the effects of decreased journey time reliability due to the potential reliability increase in risk of disruptions on the network (e.g. due to failure of signs, signals, structures or other assets). No matter how small, the effect still serves to increase costs to society. The journey quality for all users will deteriorate if funding is decreased. Rougher roads are less comfortable to drive on, reduced lighting (if applied on parts of the network) will affect the ease of driving and the visual appearance of the roadway will deteriorate for both road users and local residents. Customer satisfaction surveys ((Ramdas, Thomas, Lehman, & Young, 2007) for the trunk road network show that road users regard roads in poor condition as one of the most significant detractors on their journeys, and Local Authorities will face similar concerns. Local Authority customer satisfaction surveys show the reduction in satisfaction with road maintenance and road condition to be the source of two of the biggest reductions in satisfaction with Local Authority services in recent years.

- Increasing road condition deterioration caused by delays in maintenance will mean a rise in temporary repairs and the overall costs of road works. Reductions in the maintenance budget are aimed primarily at planned maintenance activities. Studies have shown that the costs of recovering from deterioration in infrastructure quality are much higher than the costs of retaining existing quality levels.

- Local economies may be disproportionately affected should there be an increase in emergency incidents and there is also an increased risk of emergency incidents on strategic infrastructure. Responding to emergency incidents on strategic infrastructure would likely divert further resources from maintenance budgets. Infrastructure failures are likely to decrease economic activity and reduce local trade.

4.3.2. Health and Safety

- Lower levels of spending on key structures are likely to increase the frequency of emergency incidents leading to, at a minimum, local economy disruptions and increased journey times. Poor condition of the road surface can increase the risk of accidents due to skidding and also due to road users taking evasive action to avoid hazards (e.g. potholes). This view is likely to be exacerbated with the funding cuts considered in this study. A review of condition and accident trends suggests accidents due to skidding could increase from 400 to around 450 per year, with a 40% funding reduction. International evidence suggests the risk of skidding will reduce with the introduction of skid resistance policies. Introduction of a skid policy might only reprioritise existing road surfacing funds and it will inevitably require start-up and monitoring investment which may be considered unaffordable if road maintenance funding is reduced. Funding reductions potentially represent a lost opportunity to reduce road accidents due to poor skid resistance on local roads. There will almost inevitably be an increase in the risk of failures as budgets reduce. Infrastructure failures (e.g. failures of structures) potentially result in accidents for all types of road users.

- The balance of evidence suggests lower levels of street lighting increases accidents, increases the public's fear of crime and reduces the public's use of footpaths and cycle-tracks. Historically, one of the justifications for the introduction of street lighting has been to reduce road accidents. With recent constrained funding and an aim to reduce the carbon footprint of road network operations, some Authorities have reduced the level of street lighting and reported no disbenefit, but the balance of evidence still suggests lighting reduces the risk of accidents. Low levels of street lighting and poorly maintained street lighting furniture increase the public fear of crime (Institution of Lighting Engineers, 2010). Funding reductions that lead to lower levels of lighting will therefore reduce the use of streets for walking and cycling. Studies have found that improved levels of street lighting lead to reductions of more than 40% in recorded crime and that crime is not displaced.

- Deterioration in footways and cycle-tracks will cause increased safety risk to pedestrians and cyclists. All evidence suggests increased deterioration of footways and cycle-tracks will cause an increased safety risk to pedestrians and cyclists.

4.3.3. Accessibility and Social Inclusion

- Remote communities likely to suffer as priorities for spending reduced budgets focus on where risks and traffic are most significant. New investment may be focused on improving links with rural communities which often do not show a quantifiable economic benefit. Lifeline roads, where there is usually only one route for access to a community, will be strongly affected if the condition of the route significantly deteriorates. Road maintenance management approaches inevitably focus funding where risks and traffic are most significant, therefore it is expected that remote communities will suffer a bigger disadvantage if maintenance funding is reduced and less used routes are not prioritised. Potential increases in risk of structural failure could have a significant effect on community accessibility (e.g. a bridge spanning a river with a community on both sides of the river) ((James, Harper, Reid, McColl-Grubb, & Tomlinson, 2004). However, due to safety concerns it is likely that such assets will be shielded the most from the effect of budget reductions. If facilities such as pedestrian underpasses or footpaths are poorly maintained and suffer reduced use due to fears of crime and accidents, as noted elsewhere, a similar effect of severance will be realised in the long term. Studies in the Netherlands have shown that well maintained public areas had fewer incidents of dishonesty, suggesting they reduce the propensity to criminal activity.

- Community accessibility will face greatest challenges in the event of emergency closures where alternative access routes are limited or non-existent. Older people are more likely to be adversely affected if there are more and worse defects on footways and if street lighting and other amenity assets and activities are reduced. The elderly have a greater fear of crime and potential accidents and will therefore experience a comparatively bigger effect from these impacts than other road users.

- Vulnerable groups particularly those with a visual or mobility impairment are most likely to be affected from increased defects on footpaths and increased perceptions of crime caused by poorer levels of street lighting. Local Authorities must ensure that road maintenance policies do not disadvantage disabled people. Uneven footways have a bigger impact on people with disabilities (e.g. visual impairment, or mobility) so that deterioration in the quality of such assets will have a comparatively bigger effect on disabled people. If carriageways and footways fall below accepted standards of accessibility then this will have a direct impact on the use of the road network by disabled people by affecting access to local businesses and facilities, thus increasing the severance for those affected.

- Pedestrians and residents will experience poorer amenity from increased roadside noise and reduced local air quality. An increase in roadside noise or deterioration in local air quality, visual amenity and appearance (e.g. graffiti) and street lighting will have a comparatively bigger effect on pedestrians than other road users. Deterioration in road and footway condition can deter movement by pedestrians, particularly the elderly, adults with young children and the disabled. Reductions in planned maintenance will put more pressure on the need for unplanned maintenance and delays to unplanned maintenance will further deter pedestrians.

- Cyclists are likely to face poorer cycling conditions. Reduction in traffic calming measures will lead to less favourable conditions for cyclists (where the measures adequately address the needs of cyclists). Poorly maintained road surfacing with loose material, uneven edges and potholes increase the risk of accidents and are a major deterrent for cyclists. Such budget areas are often one of the first carriageway items to be reduced when funding is constrained. It is therefore likely that, for a given level of reduction in funding, cyclists will experience comparatively bigger impacts than other road users. Reductions in planned maintenance will put more pressure on the need for unplanned maintenance and delays to the unplanned maintenance will further deter cyclists.

4.3.4. Integration

- Lower quality footways and cycleways will act as disincentives to physical fitness aimed at increasing improved health outcomes. Improved health outcomes are in many cases strongly linked to the levels of physical fitness of a community. The potential for increased severance noted under the accessibility and social inclusion criterion will be a disincentive for affected communities to maintain physical fitness levels. There are strong connections between road condition and policies on health and obesity as poor carriageway and footway condition deter walking and cycling. Road condition also affects equalities since women will often view the public realm differently from men, primarily because of fear of crime and being alone in an unsafe environment. Government policies often include statements on the value placed on delivering healthy lifestyles and growing local economies which are closely linked to well designed and well maintained environments. Attractive and well-connected street networks encourage more people to walk and cycle to local destinations, improving their health while reducing motor traffic, energy use and pollution.

4.3.5. Environment

- Noise and vibration effects will worsen. New road projects adopt the latest standards and often provide noise mitigation measures (e.g. noise barriers in urban areas). If maintenance budgets are reduced, the funding for the repair of existing barriers will likely be reduced. New surfaces, to current standards, lead to low levels of vibration in adjacent buildings but in the early life of some new surfaces there may still be high levels of noise from the interaction between vehicle tyres and the road surface. The amount of maintenance reduces with the funding reductions, so this effect is likely to be reduced. The desire to minimise resurfacing costs will lead to increased lives of surfacings and a pressure to adopt cheaper surfacings. After an initial settling-in period, surfacings generally generate more noise with trafficking as they age (Abbott, Morgan, & McKell, 2010). Limited experience on Scottish local roads of potentially lower noise surfacings has been that they are of a similar final outturn cost but higher whole life cost as they do not last as long as other more traditional surfacings. The potential effect of changes in noise due to reduced maintenance expenditure is therefore considered neutral. The impact is more one of the lost opportunity to potentially invest in higher cost surfacings to reduce noise. There will only be a marginal effect due to ageing of existing road surfacings on the network. As surfaces deteriorate and funding for routine maintenance (e.g. patching) reduces, the likelihood for potholes and other sudden surface discontinuities increases. It is these sudden changes in ride quality that lead to increased vibrations and noise in near-by buildings which are likely to be a concern to local communities but these have not been quantified in this study. Increases in vibrations might also adversely affect vehicle users, particularly those who drive for long periods (e.g. truck drivers).

- Global and local air quality may benefit from less planned maintenance activity, but this may then be countered by increased emissions arising from a greater number of unplanned interventions. Local air quality due to vehicle use will be proportional to the effects of global air quality noted above. Overall there will be a marginal reduction in amounts of NOx (nitric oxide and nitrogen dioxide) and Particulate Matter (PM10 and PM2.5) for both Scenarios (i.e. the 20% maintenance funding reduction and the 40% maintenance funding reduction). However these changes cannot be treated as indicative of changes in local air quality at specific sites. Reduced road maintenance will mean less planned maintenance work on the network. Particularly at major carriageway maintenance sites and for bridge or structures repairs, significant dust can be generated. With lower funding, the number of planned events may reduce and this may lead to better air quality, but this will be part offset by any increase in unplanned maintenance (e.g. more potholes and carriageway surface disintegration) and, potentially, other more significant and intrusive work (e.g. a weakened or collapsed structure requiring urgent repair). Anecdotal evidence suggests that local air quality will deteriorate due to increased dust if streets are cleaned less but there is no quantified or reported evidence of this.

- Biodiversity will be negatively affected if vegetation control is reduced and weeds spread. There is evidence that bats will not fly in directly illuminated areas so any reductions in street lighting due to lower funding may be beneficial to the bat population (Emery, 2008). Roadside vegetation provides important grassland habitats and migration routes for many species. It has been found that a reduction in appropriate vegetation control leads to increases in noxious plants and a decline in species rich habitats. Reduced funding may therefore have a negative impact on biodiversity.

- Landscape, visual amenity and cultural effects will be significantly affected - poorly maintained streets and public spaces have a negative effect on quality of life. Customer satisfaction studies have shown the public has a clear impression of their local area and numerous studies support the 'broken windows' theory (i.e. poor amenity and appearance lead to an increased deterioration in the locality and the need for higher subsequent costs). Studies have also shown the public judge the need for maintenance on appearance. Studies by the Commission for Architecture and the Built Environment (CABE) since 2001 have promoted the higher quality of life provided by improved streets (CABE, 2007). A survey has shown 85% of the people felt the standard of public space and environment provided by improved maintenance (e.g. road condition, clear signing, street furniture) and non-maintenance related expenditure (e.g. pedestrianisation, CCTV and alcohol free zones) impacted directly on the quality of life. Studies have however also shown that priorities of local residents do not always match the priorities of planners and designers and may lead to lower cost options for maintenance and improvements.

- Poor walking environments and transport links leave areas isolated and damage community cohesion. CABE (CABE, 2007) showed people value improvements to their streets. Studies by Transport for London have valued the increase in residential prices and retail rents achieved by roadspace improvements or close proximity to open space (e.g. parks). Transport for London has demonstrated benefit-cost ratios of between 2.5 and 5.5, without indirect benefits, from improvements in the public realm. Other studies have shown improvements to footfall for retailers after carriageway and footway improvements. As well as showing the benefits of maintenance and improvements these valuations provide measures to use in attracting private sector funding for maintenance and improvements in local areas. Poor walking environments and transport links can leave areas isolated and damage community cohesion (Social Exclusion Unit, 2003). Increases in cat and dog mess, litter, broken glass, vandalism and uneven footways all represent disincentives to the use of pedestrian footways and reduction in visual amenity. These negative impacts will be increased with reductions in maintenance funding for footways.

- Lower levels of street cleaning lead to increased environmental pollution (dust levels), local flooding along with reduced amenity. If street cleaning is reduced, the amenity and cultural heritage of an area will decrease and levels of crime may increase. Evidence suggests that the public places importance on a clean environment such that, for example, only partial graffiti removal would still impact negatively. However, studies in New York have shown the public believed the cost of maintaining cleaner streets to improve the public realm was too high. Experience from Scotland shows the severe impact on street cleaning costs from clearing the grit on footways used to reduce accidents during bad winter weather.

- Lower levels of street lighting make commercial areas less attractive to businesses. There is evidence that bats will not fly in directly illuminated areas so any reductions in street lighting due to lower funding may be beneficial to the bat population (Emery, 2008).

We shall return to these in the conclusion section of this report.

4.4. Methodologies for collecting data on road surface quality

Up to 2008, the EU lacked a standardised framework for undertaking road safety audits and impact assessments on the European road network (although Directive 2004/54/EC set out arrangements for monitoring tunnels on the trans-European road network).

On 19 November 2008 the European Commission approved Directive 2008/96/EC, a framework for road infrastructure safety management in the EU, although this was limited to roads on the TEN-T network.

The Directive indicates the necessary procedures relating to road safety impact assessments, road safety audits, the management of road network safety and safety inspections by the Member States. Five operational provisions are included in the text:

I. Road impact assessment for infrastructure projects at initial planning stage (impact assessment shall indicate the road safety considerations which contribute to the choice of the proposed solution);
II. Road Safety Audits (RSAs) for all infrastructure projects during all the phases (draft design, pre-opening and early operation);
III. The identification of "black spots" for road safety, ranking Accident Concentration sections (black spots) to be reviewed every three years ;
IV. The undertaking of periodic Road Safety Inspections (RSIs) to be carried out by the competent authorities ;
V. The data management of fatal accidents consisting of compulsory reporting of each fatal accident and of setting up a methodology to calculate the cost of a fatal accident.

Member States were given until 19 December 2010 to bring into force the laws, regulations and administrative provisions necessary to comply with this Directive.

On 19 December 2011, the EC published "Guidelines for competent authorities on application of the Directive". Member States were given until March 2012 to fulfil these requirements.

4.4.1. Road Monitoring procedures in different member states

Despite the publication of this operational guidance, empirical evidence suggests;

- Road Safety Audits (RSA) and Road Safety Inspections (RSI) are conducted differently across the EU, and the experience and the background of road safety inspectors can vary significantly.
- Most Member States have well established procedures for monitoring the road safety performance on their network.

According to the Committee on Transport and Tourism report on EU Road Surfaces, "to assess a road's condition, authorities in each MS evaluate a number of common parameters, including the following:

- Skid resistance - to provide a good relationship between road and tire;
- Texture (macro and micro) - to evaluate the roughness of the surface;
- Longitudinal and transverse profile - to ensure ride comfort;

- Rutting, cracks and defects;
- Bearing capacity - the ability to sustain a given level of road traffic".

4.4.2. Road sensing methodologies

Many municipalities utilise dedicated monitoring equipment to identify and measure these parameters.

In most cases this involves a monitoring vehicle, designed to be used in moving traffic, that records the operational parameters listed above in real time. Vehicles typically use laser technology and a GPS device to record this data.

In order to establish a visual record of road surface characteristics, a high resolution camera in combination with special lighting is also used. These systems however, can be expensive, both to install and to maintain.

By employing mobile phone sensors to help measure some of these issues, this expense could be reduced dramatically, adopting a more shared public responsibility of road monitoring and management.

Mobile phones provide access to a number of key functions that can be used to aid road monitoring. Each of these functions are usually available to most smartphones meaning members of the public that have access to a smartphone are able to switch on an application and contribute to building a body of knowledge and data on their local road systems. Using a shared responsibility paradigm for maintaining the road systems, supports the development of healthy travel behaviors and assigns a more personal feeling of responsibility to individual members of the public.

4.4.3. SmartRoadSense

SmartRoadSense (SRS) is a crowd sensing system for the continued monitoring of road state. SRS uses smartphones' accelerometers and GPS systems to detect and classify irregularities of the road surface and transmit them to a server which links them to the nearest road, collects data from all different users and shows the results on an interactive, public online map. Aggregate data are open and available online, so as to promote their use from the public (Alessandroni et al. 2014).

SmartRoadSense is aimed at estimating the quality of the road surface exploiting the sensors of a mobile device anchored to the car cabin. Using the data of the triaxial accelerometer and the vehicle speed provided by GPS system, it has been shown that an estimate of the quality of road surface can be obtained. In order to improve this estimate, the dependence of the mobile device vertical acceleration on the vehicle speed has been tested. Using a theoretical model and experimental results, it is shown how the average power of the vertical acceleration and the road roughness index estimated by SmartRoadSense are related to speed.

5. Conclusions

The goal of this work-package is primarily focused on analysing the socio-economic framework and the sustainability threats of passenger road transportation that can be addressed by means of crowd based road-sensing and ride sharing.

Our research suggests there are a number of possible use cases that could be developed in the next stage of this project, to innovate and extend the current crowd based road-sensing and ride-sharing platforms, that could be taken forward in the next stage of the project, in deploying pilots and test beds.

The strategic framework for developing new use cases for collaborative working between a crowd based roads sensing platform and a ridesharing platform have sought to take account of the current business models of BlaBlaCar and Smart Road Sense and develop a hierarchy of different levels of collaboration between the two platforms. In simple terms, the available use cases are shown in Table 1.

TABLE 1. List of use cases and applications for collaboration between SmartRoadSense and BlaBlaCar.

Use Case	Business Model	Key Customers	3rd-party Stakeholders
A joint data sharing model	Data/customer information sharing agreements to allow the transfer of data between both parties, and the potential presentation of additional benefits to end users from the other platform. A partnership marketing model with cross promotion of each other's platforms to present customers with additional benefits and open up new market segments.	Blablacar users and non-users	Smart Road Sense users
An open, consumer oriented application to incentivise customers to reduce their road use by providing them with data on their travel behaviour	A new application or an integration of an existing application to incentivise residents to mitigate their road use by simply providing them with data about the impact of their travel behaviours. This would make use of the current Smart Road Sense data collection, with Blablacar providing expertise on monitoring and ridesharing.	Any local resident that has a personal concern about the quality of the roads and is a Blablacar user	Blablacar
A next generation ridesharing application	An extension to the current Blablacar application, which utilises inbuilt Smart Road Sense technology to provide users with additional (road maintenance based) incentives to car share or information about their impact on road maintenance.	Any customer that is not currently a Blablacar customer but has significant concerns about their cost of travel, congestion, and road maintenance	Ridesharing Application

		concerns	
A place based road sensing application for municipalities (for maintenance measurement only)	An openly accessible road surface monitoring tool to help municipalities improve their road surface monitoring. A data sharing agreement with Blablacar users might enable more widespread adoption and improve the quality of data monitoring. In turn, this approach might enable Blablacar to develop closer relationships with municipalities.	Any local resident that has a personal concern about the quality of the roads and is willing to help the municipality reduce costs	Municipality
A place based road sensing application for municipalities (to reduce insurance premiums and counter claims)	A road surface quality monitoring tool to help municipalities to keep track of road quality, direct road maintenance efforts, and reduce the costs of their insurance premiums and counterclaims for vehicle damage. A data sharing agreement with Blablacar users might enable more widespread adoption and improve the quality of data monitoring. In turn, this approach might enable Blablacar to develop closer relationships with municipalities.	Staff employed by the Municipality and local residents	Municipality
A Road Sensing and Ride Sharing 'Serious Game'	A standalone road maintenance game, where users try and make decisions in the game to maximise use of the total road maintenance budget to deliver the best outcomes for taxpayers.	30-50 year old male 'game' players	Data Providers and Municipality

In reality, many of the above proposed applications and use cases are actually built on the principle of data sharing and partnership working to explore the potential of:

- Better incentivizing existing ridesharing customers; or attracting new customers groups into ridesharing;
- Utilizing the ridesharing community to adopt Smart Road Sense, in such a way that delivers a benefit to the ridesharing community organization; and/or
- Identifying a way of working with municipalities to provide more accurate/detailed information on road surface quality, such that they can make financial savings to improve the quality, effectiveness and efficiency of public services, and incentivize customers to improve/maintain positive transport behaviours.

The idea that a ridesharing and/or road sensing application could potentially generate cash to subsidise road maintenance budgets is probably a bit unrealistic at this early stage of the project. It is unlikely that this project will have sufficient funds to directly influence road maintenance budgets or to fully develop stand-alone tools with this purpose.

The development of new applications, as mentioned in Table 1, must be carefully considered also in light of the economics and issues concerning mobile application development and publication. Especially because of the temporal and resource constraints the CROWD4ROADS project operates, the development effort of new applications and modifications of existing ones must be carefully taken into exam. Also, publishing software on application stores, such as the Apple "App Store" and Google Play for Android, not always entails the wished-for visibility and exposure. Even if application store downloads are growing, and time spent on apps is likewise, a large share of user interest is focused on "top apps" in certain, narrow categories [28]. Moreover, it has been shown that applications have a very high abandonment rate: as little as 20% of the overall users of an application keep using it on medium periods [27], except for a limited number of "top apps", which are used daily by the majority of users.

More online searches are indeed conducted on mobile phones, however they usually drive traffic to web sites and mobile web applications, not to applications [29]. The development of applications must be carefully weighed against the development of an engaging web presence or a multi-platform mobile web application, that can be accessed directly through search on any platform—mobile or desktop—and thus avoid the access barriers of app stores.

Our experience suggests that one of the main tasks of the project is to test the aforementioned use cases, including any other use cases that partners may consider relevant and exploring potential consumer, financial, and benefit metrics to better understand which of the considered use cases have the strongest viability as business endeavors and the strongest impact on road maintenance sustainability.

Because many mobility management programs involve innovative and multiple strategies, conventional models for monitoring potential benefits do not always predict travel impacts accurately, although this is improving with newer models. In response to this issue, it's vital that use cases are evaluated using a framework which is sufficiently strategic and analyses the range of potential cashable and non-cashable benefits that could flow to the developer and conduct a detailed viability assessment on each use case.

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