Assessing the Carbon Impact of ICT measures

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1 Abstract

Fostering co-modality and consequently reducing carbon emissions is a leading objective of the Scottish and UK governments and the wider EU community. The achievement of such goals can be facilitated by the adoption of ICT measures within the transport systems. Over recent years, many online and mobile applications have emerged which improve the usability and attractiveness of more sustainable transport modes (such as public transport, taxis, and cycling) and can help to utilise private cars more effectively by promoting and enabling car-sharing and car-pooling.

The recently completed FP7 funded EU project COMPASS has investigated the impact of a range of ICT tools which have the potential to improve co-modality. Modelling at both the EU level and at Scotland level has been undertaken, and the impacts in terms of carbon emissions and congestion reduction of ICT measures have been evaluated. The project has involved also an in-depth case study analysis reviewing various tools across the EU.

The paper discusses the results of the EU wide modelling in relation to the Scotland specific modelling. The latter utilised the LATIS model and is able to demonstrate and quantify the relative carbon/congestion reductions feasible from ICT measures to improve bus journey times and ICT measures to improve car-sharing.

The COMPASS case studies are presented as well, including Regional (Marche, Italy) and EU wide travel planners, Bus Network ITS applications (Barcelona), Bike Sharing (Vienna), Car Sharing (Karlsruhe and Austria), Intelligent motorway tolling (Sant Cugat), accessibility apps for disabled travellers (UK) and mobile apps for taxi services (global). The case study on mobile apps for taxi services and the potential impact for co-modal transport in Scotland in promoting such apps are examined in detail.

2 COMPASS motivation and overview

The motivation and the general objectives of the COMPASS project are deeply rooted in the European Transport Policy (ETP) in the first decade of the 21st Century, with a look towards the new challenges of the incoming second decade of the century. In particular, three topics must be stressed:

- Challenges from the key socio-economic trends. The Communication from the Commission – A sustainable future for transport: Towards an integrated, technology-led and user friendly system (COM/2009/0279) has described the main socio-economic trends shaping the future of transport. Population ageing, that will place more emphasis on the provision of transport services involving a high level of perceived security and reliability, and which features appropriate solutions for users with reduced mobility. Migration and internal mobility, with migrants, generally young and mainly living in urban areas, which will entail more movement of people and goods. Urbanisation trends, according to which the proportion of European population residing in urban areas is projected to increase from 72% in 2007 to 84% in 2050. This trend, in association with the related growth of urban sprawl can be considered among the main challenges for urban transport, as it brings about greater need for individual transport modes, thereby affecting the environmental quality and generating large costs in terms of delays and higher fuel consumption.
- Challenges from environmental concerns. There is growing concern that the transport sector must tackle dramatic challenges in trying to mitigate its negative impact on the environment.

The EU has in fact recently adopted a Climate and Energy package that sets a target of reducing GHG emissions in the EU by 20% with respect to 1990 and transport is going to play a key role in achieving this goal (COM (2011)112). But an inversion of some of the current trends will be necessary. Transport itself will suffer from the effects of climate change and this will necessitate adaptation measures.

- Challenges from technological changes. The EC Directive on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport (Directive 2010/40/EU) has stressed the potential benefits arising from the application of information and communication technologies to the road transport sector and its interfaces with other modes of transport, in terms of significant contributions to improving environmental performance, efficiency and safety. In particular, the potential for ensuring higher levels of integration between road transport and other modes of transport has been stressed. It is in fact widely acknowledged from EU research projects (e.g. MIRACLES, 2006) the potential ICT development and ITS applications in developing a new model of transport, which links and integrates conventional and innovative transport systems, offering a public transport service which better matches the needs and expectations in terms of reducing mode changes, providing better accessibility, and improving journey times. ITS applications bring significant improvements in transportation system performance, but it requires the optimisation and operation of the network as a single entity, whereas currently modal networks are largely separated and even within modes there is a lack of integration between countries.

Taking all this into account, the general objectives of the COMPASS project were:

- To provide an overall picture of the future travellers needs in the light of the key socio-economic trends;
- To analyse how ICT and ITS applications can meet the new demands, favouring the integration of multimodal transport solutions;
- To assess how these solutions can contribute to the de-carbonisation of transport activities.

In such a framework, the following collateral and important objectives were also addressed:

- The potentials of the ICT and ITS applications to provide behavioural data and information to improve travel surveys and fostering harmonisation;
- The validation of the ICT solutions with stakeholders rooted in the national contexts.

To fulfil these objectives the COMPASS project built on a substantial body of knowledge on co-modal and intermodal passenger transport already available from past and current projects, in particular KITE, LINK, INTERCONNECT, HERMES, CLOSER, ORIGAMI and USEmobility The main contributions of COMPASS are an assessment of existing travel demand data sources, an appraisal of the role of ICT in these data sources, development of business models for the ICT solutions, development of a body of fact-sheets forming a comprehensive database and finally an <u>in-depth set of case studies concerned with assessing the carbon impact of a selection of important ICT measures with a trans-EU modelling assessment quantifying carbon reductions achievable from packages of ICT solutions</u>. This paper presents the COMPASS case studies, summarises their carbon impacts and finally comments on the EU-wide modelling assessment.

3 Case Studies: Methodology

COMPASS compiled a comprehensive data-base of possible ICT measures (Table 1).

Table 1: COMPASS ICT categorisation

ICT category	Technological solutions (applications)
Transportation Management Systems	Urban Traffic Control (UTC); European Railway Traffic Management System (ERTMS) River Information Services (RIS) Traffic Management Systems for Air Transport (SESAR) Strategic Transport Management for Corridors and Networks Public Transport Management Demand Management Systems Probe Vehicles or Devices

Traveller Information Systems	Travel Planners Real-time Co-Modal Traveller Information Services Real-Time Travel Time and Vehicle Positioning Information Services Weather Information Services Parking Management Systems (PGI)
Smart Ticketing and Tolling	Electronic Toll Collection (ETC) Access Management Automated Fare Collection Systems (AFC) - Ticketing Systems
Vehicle-to-Infrastructure (V2I) Applications	Cooperative Urban Applications Cooperative Interurban Applications Intelligent Speed Adaptation (ISA) Yellow Signal Warning System (YSWS) Probe Vehicles or Devices
Vehicle-to-Vehicle (V2V) Applications	Advanced Driver Assistance Systems (ADAS) Adaptive Cruise Control (ACC) Incident Management and ITC Safety Services
Demand Responsive Transport Services (DRTs)	Public Transport Services in Low Demand Areas Car Sharing Collective Taxi

The following 11 case studies were developed. They were selected to have geographical coverage at EU level (ensuring metropolitan, city, and rural areas were all covered) and coverage across ICT categories.

1. An EU wide multi-modal travel planner: ROUTERANK;
2. A regional multi-modal travel-planner: Marche
3. Accessibility Applications for Disabled People
4. ITS solutions for Barcelona’s local bus network
5. Future interurban public transport in Warminsko-Mazurskie voivodship
6. Online and mobile applications for taxi fare quotes
7. Bike sharing in Vienna and the Surrounding Region
8. A car sharing in Karlsruhe
9. Grass-root cooperative smartphone-based car-sharing
10. Sant-Cugat intelligent motorway toll system
11. LATIS: Scotland Region 2007 to 2027

The case studies were all described and then assessed against common headings. We present one case study *6 - Online and mobile applications for taxi fare quotes* in detail here to illustrate the assessment approach. All case studies are then compared in section-5.
All case studies were introduced with an executive summary, followed by details on motivation and methodology. These elements were case study dependent.
The case studies were then assessed with qualitative discussion under the following headings:

Assessment of Applicability

Operation and maintenance costs, Financial viability, Technical feasibility, Organisational feasibility, Administrative burden, User acceptance, Public acceptance

Assessment of Interest for Travellers

Door to door travel time, Door to door travel costs, Comfort and convenience, Safety, Security, Accessibility for mobility impaired passengers

Assessment of Modal Change

Car usage, Bus and coach usage, Rail usage, Ferry usage, Aeroplane usage

Assessment of Other Impacts

Increased mobility, Congestion, CO2 emissions, Contribution to user pays principle, European economic progress, Territorial cohesion

These areas and subheadings then formed the basis of a common classification, where each element was assigned a "points score" related to the subheadings. The total score was then assigned to give a comparative metric. The resulting comparisons are discussed in section 5.

3.1 CASE STUDY 6 - mobile applications for taxi SERVICES

4.1.1 Executive Summary of the Case Study

The last generation of what are commonly identified as "taxi apps" is a disruptive technology with the potential to promote co-modality because of its capacity to gather the supply of different forms of non-private car transport in the same virtual place. Such apps have evolved from simple taxi company directories to complex platforms able to provide access to a set of services ranging from taxis, to for-hire vehicles, to limousines, to car sharing.

This case study analyses the scope for taxi apps in four cities: two large US metropolitan cities, one east coast and one west coast, and two UK capital cities (London and Edinburgh). Operational data can be sensitive and has been anonymised. The development of taxi apps seems to be correlated with taxi market expansion. The penetration of taxi apps is greater in cities with long waiting times associated to traditional booking systems.

The taxi segment alone (not considering other services promoted by taxi apps) serves more than 5 million trips per year in the west coast US city and more than 14 million in the east coast city, with turnovers of $ 100 million and $ 250 million respectively. The west coast city has three main origins of taxi trips: residential locations (28%), evening entertainment venues (20%) and the airport (18%). Trips starting from residential locations are traditionally dominated by dispatched trips and so constitute the most promising market for taxi apps. Most of trips are engaged by phone booking (50%) and hailing (20%); apps are still a minority booking method used in only 10% of cases.

The diffusion of taxi apps is giving rise to different reactions among the stakeholders of the taxi industry. Dispatching companies and taxi drivers worry about the diversion of potential customers to different kinds of non-private cars. For dispatching companies apps are also competitors within the same market, while the opposition of the taxi drivers is mitigated by the opportunities generated by the apps both in terms of market expansion and of "attraction of business to my car". Additional matters of concerns for drivers are "top slicing", reliability of payment methods, and privacy issues with the "rate my driver" function. The strongest opposition comes from the market regulators, who still do not know how to deal with this almost unknown and quickly changing player. Responses include denial, ignoring and rejection of apps.

The main costs to develop and run a taxi app are generated by driver recruitment and retention, marketing within regulator communities, and challenges to its legality. Revenues are collected on both a per use basis (the common method when bookings are dispatched to drivers directly) or through subscriptions (frequent for apps forwarding bookings to dispatching companies). From the technical point of view the apps must be able supply at least three services: vehicle location, booking, and payment. No real barrier exists to the implementation of such functions. The most burdensome features to develop are the API links between the apps and existing software and information services. The apps are increasingly permeating the market. The strong competition that exists exposes badly planned, marketed or poorly operated apps to quick failures. The next generation of "taxi apps" will probably implement price comparison.

Apps cannot reduce door-to-door travel time but they can reduce the delay between booking and service delivery. Theoretically, passenger costs should be unaffected because taxis fares are generally regulated, though this is not always the case and differs in the short term, where fares remain consistent, and the longer term where the (perverse) effect of competition from higher priced app services pushes the regulated fare up as a result of income-
based models used to determine taxi fare rates.

3.1.2 Motivation for this Case Study

The case study reviews the development of mobile applications (apps) applied to the taxi industry, using the experience of two specific differing apps in peer cities. Apps have a demonstrable impact on the use of taxis and similar services also served through 'taxi' apps, and have been suggested to increase the accessibility, ease of use and convenience of the taxi mode. The potential benefits of the 'taxi app' extend to the (various) passenger(s) both current and intending but should also be considered in terms of positive and negative impacts on the industry and on the regulating authorities.
Taxi apps have developed rapidly, with next 'generations' and new functionality emerging approximately every 6 – 12 months. As a result rapid changes in their use and utility are commonplace. The technology will alter the methods by which consumers consider approach and use taxis, often positively. Some literature relates to the 'taxi app' as being disruptive.

'Disruptive' technologies, those that radically alter our relationship with a service, fundamentally change the nature of the product and affect the user, provider and controlling authority in equal, if opposing measures. This is true in the case of the taxi app, which has developed to date to include four notable generations of apps at the time of writing, discussed below. Each presents a new method of achieving a basic service relating to location, booking, reporting and payment. Much of the current development reflects the availability and capability of the hardware, with the ultimate function (the booking of a taxi to a specified location) actually achieving little more than the traditional phone call. It is the hardware, the ubiquitous nature of the smartphones, and the willingness of the user and intermediate app manufacturer that creates a new paradigm in accessing taxi services.

3.1.3 Main Features of the Taxi App

To explore in more detail, the "taxi app" should be more precisely split by function and location. Functions may differ by location given differences in legislation across cities and countries but more fundamentally reflecting differences in the market of each. App functionality may also be grouped into generations, broadly chronological distinctions of app and function, applied in this case study to allow for a consistency in discussion. It should be noted that not all apps will fall into single generations or categorisations.
Taxi App Generations are broadly defined as:

Generation 1: Taxi company directories, providing broad listings and telephone numbers.

Generation 2: Taxi company booking, using existing infrastructure, typically existing taxi dispatch company systems. Examples include TaxiMagic. The term 'white label' is also used in subsequent text to describe third party apps branded to a named taxi company.

Generation 3: Taxi / for-hire vehicle (FHV) direct booking, using bespoke infrastructure to bypass existing taxi dispatch systems, typically engaging drivers directly and using a single vehicle type on a single platform. Examples include Hailo, Get Taxi.

Generation 4: Taxi / FHV and car sharing, offering a wider range of vehicle type on a common platform. Examples include Uber (UberX / UberSUV / UberTaxi / UberBlack)

As each location may impact differently on a 'global' product, apps may differ slightly between locations, even where provided by the same manufacturer offering (ostensibly) the same services. This is well illustrated in the instance of Uber, a San Francisco-based provider, offering differing combinations of 'products' depending on the acceptance and prevailing legislation in each country.

Taxi app manufacturers can be local, but are dominated by large international (multinational) providers. Hailo originated in the London market and has built up a large global presence; Uber originates in San Francisco with a similar international reach. The market for small independent apps has been significantly reduced (removed) by the presence of international, well-funded, suppliers. Geographical limitations are more likely to follow the spatial boundaries defined in licensing regulation, then any specific geographical distinction. This said, the economic viability of an app will reflect on the extent to which market demand and available supply can support the operation of an app.

3.1.4 Assessment of the Solution – Mobile Applications for Taxi Services: Taxi Apps and Taxi Like Apps

The development of the taxi app has had a significant impact on the markets into which it has been introduced. The case study does not seek to identify one brand of app as being preferable to any other, but does identify both the circumstances in which apps have been successful. As the technologies develop, so do the opportunities beyond the known traditional use of the taxi. A distinction can be made between opportunities that enhance current use, the opportunity to verify route and meter rate for the passenger, and those which allow for innovation or new uses, new markets and new income streams to the taxi operator. These are addressed below in terms of market application, traveller and operator impacts, as well as impacts on the regulator.

Assessment of Applicability

The development (application) of apps within the taxi industry should be recognised as a significant development with the potential to provide a step change in service delivery. This disruptive technology should not, however, be achieved at the cost of passenger protection – the most common justification for regulation. The relationship between apps and the taxi regulating community has a mixed record, with many instances of clear hostility on both sides. Market uncertainty has resulted, with a significant split between small (and very small) app manufacturers, of which there are many hundreds, who may be unaware of the legal implications of the regulations applied to the taxi market, and much larger players, of which there are around a dozen. Large players, those with traction, best typified by multi-national companies are both aware of and willing to invest significant time and costs in defending a legal position as well as aggressively marketing their product.

Assessment of Interest for Travellers

Door to door travel time

Door-to-door travel times are not impacted by the expansion of taxi apps. However, a critical time reduction may be achieved in the delay between initial booking and service delivery. Where this is included in a calculation of global journey time, i.e. time need from booking to drop off, journey time may actually reduce, and this is a better indicator of service level than purely basing the analysis on door to door travel time. Locations with extended traditional taxi waiting times are likely to be more impacted by the introduction taxi apps, than locations with good levels of taxi service. The city of Edinburgh, with the lowest market penetration by apps, offers the highest level of traditional taxi booking service, measured on booking time delay, while the city with the longest delays (West Coast) displays the greatest market penetration taxi and taxi like apps.

Door to door travel costs

The taxi app should, in theory, not impact on the door to door travel costs experienced by passengers. Taxi fares are regulated and defined in each of the locations included in the case study. That said, however, perverse incentives appear to apply, suggesting value associated with apps and beyond those seen in the traditional taxi industry. Both Hailo and Uber allow booking fees to be assessed and charged in many instances. Moreover the Uber app can charge significantly greater amounts then would be experienced in using a taxi, even a taxi booked through an alternative taxi app. The result can be a large increase in the trip cost experienced by users of some apps, while many users will (at the same time) express a preference for this (higher-priced) service, the economic explanation for which relates purely to service level benefits (quality) rather than cost.

Comfort and convenience

Additional value arises from certainty of booking, a major issue in two of the case study locations. Both Hailo and Uber include visual mapping of vehicle location, reducing uncertainty. Further ‘vehicle quality’ benefits may also be attributed to vehicle types where limousines, rather than taxis, are used, but this is not the case in all apps.

Assessment of Modal Change

The development of taxi apps has, in all of the case study locations, resulted in additional taxi use. This use has expanded the market for taxis, and is visible in operation data from the US cities.

Table 1: West Coast taxi use statistics 2009 – 2012

YEAR	2009 - 2010	2010 - 2011	2011 – 2012
Total (Odometer) Miles	53,124,959	57,248,383	68,096,348

Source: Licensing Authority

Modal diversion is less defined, whether trips represent totally new travel, or diversion from other modes, though public demand in city centre locations has increased above the rate of economic development, suggesting that trips would have been made by an alternative mode in preceding years.

Assessment of Other Impacts

To the member of the public seeking reliability, speed and service, the taxi app is already a reality. While the consumer may play between alternatives, taking a look at the latest or the most visible app, the need to make taxi bookings and the need to have a reliable service will be understood far more than the legal framework under which such services are provided. This reflects the nature of the internet-type mentality underlying both the apps and their users. Here then the critical and most important point is that the taxi user will continue to seek better, more reliable services, and better value. The taxi appears, and is likely, to contribute to better services and possibly to a small extent also increasing mobility.

Congestion : Where the taxi app increases mobility or leads to the replacement of a public transport trip in a major city, it will also contribute to congestion. In comparison to the use of a private car, a taxi trips avoids a car driving around in search of a parking space, but on the other side they increase mileage through the trips to the next taxi station in the best place and driving around waiting for a hail, as in many cities, in the worst case.

CO2 emissions: To the same extent as taxis add to congestion, they also add to CO2 emissions. A further aggravating factor is that they are usually large cars with much higher fuel consumption and emissions than the average private car – in Europe even more so than in the US.

The qualitative discussion under the 4 sections and their subheadings then resulted in the quantitative assessment chart as given below:

Table 3: Case-study Taxi-apps assessment

	Score	
Investment costs	€€€	-2
Operation and maintenance costs	€	+2
Financial viability	✓	+2
Technical feasibility	*0*	0
Organisational feasibility	(X)	-0.5
Administrative burden	X	-1
Legal feasibility	*0*	0
User acceptance	✓	+2
Public acceptance	✓	+1
D2D travel time	✓	+2
D2D travel costs	(X)	-0.5
Comfort and convenience	✓	+1
Safety	*0*	0
Security	*0*	0
Accessibility for mobility impaired passengers	*0*	0
Car usage	*0*	0
Bus and coach usage	*0*	0
Rail usage	*0*	0
Ferry usage	*0*	0
Aeroplane usage	*0*	0
Mobility	*0*	0
Congestion in overcrowded corridors	X	-2
CO2 emissions	X	-4
Contribution to user pays principle	*0*	0
European economic progress	*0*	0
Territorial cohesion	*0*	0
Total score		**+/- 0**

4 Evaluating Carbon Impact Case Studies

The evaluation of the COMPASS case studies can be divided into two main streams:

1. Evaluating the case study against qualitative criteria and the categorised COMPASS assessment criteria which allocates a "point" value to each case study.
2. Carbon emissions modelling for a regional case (Scotland) and EU-wide.

Firstly we introduce the case studies and then discuss the evaluation above.

4.1 COMPASS case studies

CASE STUDY 1 - An EU wide multi-modal travel planner: ROUTERANK;
routeRANK provides a software solution for travel planning. Unlike other solutions that consider only one means of transport at a time, routeRANK addresses the entire city to city travel route by integrating rail, road and air connections and their many multimodal combinations. In a single search, routeRANK's patent-pending technology finds and ranks the best possible travel routes, allowing users to sort them according to their priorities such as price, travel time and CO2 emissions. This is done by checking websites of unimodal transport providers, combining the findings to multimodal transport chains and then display these travel suggestions with their attributes (route, schedules, prices …) together with a link leading the user to the website(s) where a distinct travel solution then can be booked.

CASE STUDY 2 - A regional multi-modal travel-planner: Marche
This case study addressed the potential for serving sustainable transport policies as a result of the use

of regional traveller information systems, i.e. applications situated at an intermediate level between the urban scale and the national/international one. At the urban scale, the multimodal passenger travel information system essentially aims to favour short-distance trips through the utilisation of public transportation modes, e.g. primarily buses and metro, including options to reduce walking distance to the destination point. At the national/international level, the multimodal passenger travel information systems cover in general all transport modes, focusing on long-distance trips (e.g. including air and maritime transport means), for which the existence of effective interconnections (infrastructure, interchanges, etc.) between the trip legs can be considered as a necessary requirement.

CASE STUDY 3 - Accessibility Applications for Disabled People
This case study looked at a range of smart-phone travel applications (apps) with a range of different attributes with the potential to improve accessibility to the transport system for disabled people. It is estimated that disabled people comprise approximately 15% of the population. Furthermore, it is widely observed that there is a strong link between ageing and impairment and that the proportion of older people in society is increasing over time.
By opening up information sources and support services, smart-phone travel apps offer huge potential to help and liberate disabled and older people who face challenges with other methods of communication and information-gathering. Whilst the COMPASS survey indicates that people do place value on particular aspects of these apps, their potential is, as yet, under-utilised, and so actions to improve take-up should be explored further.
Case study 3 was assessed qualitatively, and does not appear in the comparative assessment scheme.

CASE STUDY 4 - ITS solutions for Barcelona's local bus network
The technical solutions introduced and presented in this case study are in short the following:
4.1: Smartphone Applications: the general functioning and the innovative features of the "TMB on your mobile phone" smart app, and its level of awareness and use by citizens are analysed. The case study also surveyed the interest of citizens in other potential smart-phone applications.
4.2 Smart Bus Stops: the ITS equipment of new pilot bus stops is analysed: interactive multimodal travel planners for public transport services in Barcelona and its metropolitan region; real time information screens on expected times of arrival of buses (updated every 30 seconds); information on eventual service disruptions; audio systems assisting blind people; ticket sales booths.
4.3 Smart applications allowing for DRT services in Barcelona mountain neighbourhoods: the case study surveyed the potential interest of implementing DRT systems between the city of Barcelona and Collserola, a mountainous neighbourhood, and between other relevant metropolitan rail stations and the Collserola hinterland.
This case study was based on desk work and a user survey was carried out at different access points of "Passeig de les Aigües" in the Collserola hills. A survey was held on the February 3rd 2013 (Sunday) from 8 am till 5 pm (9 hours in total) with a total number of 533 surveys obtained from 329 to pedestrians and 240 bikers. The survey was specifically focused on gaining knowledge of:

- Citizens' awareness of the services that TMB offers today to improve the general bus services in Barcelona (orthogonal reorganisation of bus services, upgraded bus stops, TMB smart-phone app)
- Citizens' awareness of the services that TMB (Barcelona's bus operator) offers to access the mountain neighbourhoods of Barcelona (proximity buses).
- Willingness of citizens to pay for additional services provided with smart-phone applications.

CASE STUDY 5: - Future interurban public transport in Warminsko-Mazurskie voivodship
This case study used a test bed approach for identification of possibilities and barriers for the introduction of some ITC solutions in rural areas. It is based on transport users' response to the proposed ICTs as recorded through qualitative and quantitative surveys. Surveys were carried out in the Szczytno region in the Warminsko-Mazurskie voivodship in the north-eastern part of Poland. This is a low GDP rural area. Szczytno has about 28,000 inhabitants, while in the close vicinity of the Szczytno area (poviat) about 70,000 people live for whom Szczytno is the centre of gravity. ICT solutions tested in this setting were:
5.1: Internet based travel planners;
5.2: Electronic real time information at bus stops;
5.3: Ticket purchasing via mobile phones / internet;
5.4: Real time information on services via mobile phones / internet;
5.5: Real time information on estimated arrival times, stops, route on board of vehicles;
5.6: Demand responsive services - possibility for direct pick-up/delivery of passengers in response

to prior request.

CASE STUDY 6: - Online and mobile applications for taxi fare quotes
This case study considers the use of mobile applications (apps) applied to the taxi industry using the experience of (different) apps in peer cities. The case study is motivated by the impacts that the taxi app may have on the industry. Four peer cities have been analysed: one on the east and one on the west coast of the USA, London and Edinburgh.
Apps have a demonstrable impact on the use of taxis and similar services served by taxi apps. They have been suggested to increase accessibility, ease of use and convenience of the taxi mode. The potential benefits of the taxi app extend to the (various) passenger(s) both current and intending; but should also be considered in terms of positive and negative impacts on the industry and on the regulating authorities.

CASE STUDY 7: - Bike sharing in Vienna and the Surrounding Region
This case study focused on the bike sharing schemes in Vienna and the surrounding region Lower Austria (Niederösterreich). A computer assisted telephone interview (CATI) was carried out to capture user responses to two different bike-sharing schemes in and around Vienna. The survey was carried out in Vienna, where Citybike is in operation, and in Lower Austria, where nextbike, also sometimes called as LEIHRADL-nextbike, is in operation. The survey conducted in Lower Austria was designed to be comparable to a survey in 2009 and thus the survey result is presented together with 2009 data where comparable, while the survey in Vienna was the first of its kind. The CATI survey in Lower Austria was carried out in small villages up to 2,500 inhabitants, (7 municipalities), towns up to 5,000 inhabitants (5 municipalities), regional centre up to 10,000 inhabitants (5 municipalities), large regional centres with more than 10,000 inhabitants (2 municipalities) as well as in a town in a suburb of Vienna (1 municipality), and in total 248 valid responses were collected. Distribution among the municipalities corresponds to the actual population based on the 2001 census, which was the latest available one at the time of the survey. The survey in Vienna was carried out in all districts in Vienna and 252 valid respondents are collected. The proportion of the respondents between Lower Austria and Vienna is also in line with the 2001 census. The assessment framework separates the impact for cities and for rural areas.

CASE STUDY 8: - A car sharing in Karlsruhe
Car sharing in Karlsruhe, when measured by cars per inhabitant, probably is the most successful system of this kind of mobility concept in the world. It is a system of classical car sharing (car club), where all cars have fixed locations i.e. when renting a car, the user has to pick it up at a distinct location and drop it off at the same point.
The case describes demand and supply structure, pointing out that strong demand occurs mainly in quarters of the town with a high population density, situated directly in or close to the city centre, while usage intensity of the system in remote districts of the area is more moderate.

CASE STUDY 9:- Grass-root cooperative smart-phone-based car-sharing in Austria. It has several interesting features different from conventional car-sharing:

- It is used not only in urban areas but also in rural areas.
- The scale is small with one or a few cars to be shared among up to 30 users.
- The users have to form a car-sharing group spontaneously based on their needs. Ø The shared cars are provided by a group member (e.g. an individual, public organisation such as municipality, private companies, etc.) or procured cooperatively by the group and there is no car-sharing company owning and offering vehicles.
- A special insurance policy package dedicated for CARUSO offered by a regional insurance company covers the mandatory insurance needed for this form of car-sharing.
- The reservation and usage-logging platforms on board are provided as an internet application by CARUSO.
- The user fee can be set in a flexible way and each group adopts different pricing models such as a linear per-km tariff with or without annual fee or just 6-month user fee divided based on the approximate usages by users.
- Some groups share EV(s).

CASE STUDY 10:- Sant-Cugat intelligent motorway toll system
The motorway between Sant-Cugat and Barcelona is a 13 km toll highway operating since 1991. This motorway, which includes a 2.5 km tunnel under the Collserola hills, had large impact on the

attractiveness of Sant-Cugat and the Vallès Occidental county as levels of accessibility increased dramatically, inducing an important migration flow of middle and upper class residents from Barcelona. The Sant-Cugat population has increased dramatically, by 60% only since the year 2000 reaching a population of 84.000 people in 2012. Prior to the existence of the motorway, a regular trip from Barcelona to Sant-Cugat took approximately 40 minutes, whereas today a regular trip takes no more than 20 minutes during rush hours.
The technical solutions introduced analysed in the Sant-Cugat case study are aimed at improving safety, reducing congestion and increasingly becoming environmentally friendly. They are the following:

10.1: Automatic detection of high-occupancy vehicles and applications of discounts

Sant-Cugat Motorway applies discounts for vehicles with three or more occupants. In order to be able to get the discount, drivers need to belong to the ViaT program, the OBU based system for semiautomated free-flow toll payment linked to a bank account.

10.2: Environmental discounts for ecological vehicles

Sant-Cugat Motorway has implemented discounts for low emissions cars since the 2000s. The vehicles that can register on the ecoviat program are those with emission ratios under 120 g/km for gasoline and 108 g/km for diesel, and also vehicles run by hydrogen, GPL or electricity. ECO vehicles get a 30% discount.

10.3: ViaT electronic toll system

ViaT enables users making toll payments on Sant-Cugat Motorway on the move, without having to stop. A wide-spread system in Europe today, the motorway was one of the first ones in Spain to implement such system already in the 90s.

10.4: Automatic incident detection system

The Sant-Cugat motorway is equipped with technology in order to automatically manage incidents inside the tunnel, increasing the overall levels of safety. The tunnel is equipped with cameras linked to incident recognition algorithms, which, in case of emergency or of heavy congestion, activate a red traffic light located at the entrance of the tunnel not allowing more vehicles in.

4.2 Assessment of (Business Case), User Benefits, (Mode Split), Societal Benefits

Each case study classified each included application in the assessment scheme (the full assessment scheme is included in Appendix A). In this paper we will concentrate on the user benefits and wider benefits.
USER BENEFITS:

D2D travel time: A significant change is travel time is a √ (+2) or an X(-2). If the changes are about a few minutes then this should remain 0. There may be borderline cases of 10 minutes in so many occasions that may be (X) or (√) (-1 or +1).

D2D travel costs: Travel cost can increase or decrease due to a change in fuel and vehicle operating costs and/or to fees and charges.

Comfort and convenience: A typical example for an increase in comfort is the situation where a better weather forecasting system allows pilots to avoid areas of turbulence. Another is the seat choice via facebook, where the passenger has a better chance to sit next to somebody who either wants to talk or be silent.

Safety, Security, Accessibility for impaired passengers: These are straightforward: an increase in safety is a √ (+1) and a reduction is a X (-1).

Table 4: Case-study comparison: User benefits

User Benefits	D2D-time	D2D-cost	comfort	safety	security	accessibility	Sub-total	TOTAL-ALL
	XX-✓ -4, +2	XX-✓ -2, +1	X-✓✓ -1, +2	X-✓ -1, +1	X-✓ -1, +1	X-✓ -1, +1	-10 +8	
CS1: ROUTERANK	**+2**	**+1**	**+1**	**0**	**0**	**0**	**4**	**17**
CS2: Marche	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**12**
CS3: Apps for the disabled	**+1**	**0**	**0**	**+1**	**+1**	**+1**	**4**	**12**
CS4: ITS Barcelona Bus								
CS4.1: Smart-phone apps	**+2**	**0**	**+1**	**0**	**0**	**0**	**3**	**13**
CS4.2: Smart Bus-stops	**+1**	**0**	**+1**	**0**	**0**	**+1**	**3**	**5**
CS4.3: DRT smart-apps	**+2**	**0**	**+1**	**0**	**0**	**+1**	**4**	**11**
CS5: Interurban PT- Warminsko-Mazurskie voivodship								
CS5.1: Net-based travel planner	**+2**	**0**	**+1**	**0**	**0**	**+0.5**	**3.5**	**15**
CS5.2: RTPI -bus stops	**+1**	**0**	**+1**	**0**	**0**	**0**	**2**	**6**
CS5.3: Ticket purchasing (mob/net)	**+1**	**0**	**+0.5**	**0**	**0**	**0**	**1.5**	**13**
CS5.4: RTPI (mobile/internet)	**+2**	**0**	**+1**	**0**	**+1**	**0**	**4**	**12**
CS5.5: RTPI (onboard vehicles)	**+1**	**0**	**+1**	**0**	**0**	**0**	**2**	**10**
CS5.6: DRT	**+2**	**-1**	**+1**	**0**	**+1**	**+1**	**4**	**9**
CS6: Taxi apps	**+2**	**-0.5**	**+1**	**0**	**0**	**0**	**2.5**	**0.5**
CS7: Bike-sharing Vienna and Region								
CS7.1: Cities	**+2**	**+1**	**+1**	**0**	**0**	**0**	**4**	**15**
CS7.2: Rural areas	**0**	**+1**	**+1**	**0**	**0**	**0**	**2**	**10**
CS8: Car-sharing in Karlsruhe								
CS8.1: car-sharing scheme (dynamic)	**+1**	**+0.5**	**+1**	**0**	**0**	**0**	**2.5**	**10 (7)**
CS8.2: booking system (mobile/internet)	**+1**	**0**	**+1**	**0**	**0**	**0**	**2**	**10**
CS8.3: data transfer of booking system	**0**	**0**	**+1**	**0**	**0**	**0**	**1**	**7**
CS9: Grass-root cooperative smart-phone based car-sharing	**+1**	**+1**	**+1**	**0**	**0**	**0**	**4**	**16**
CS10: Sant-Cugat intelligent motorway toll system								
CS10.1: Automatic detection HOV	**-1**	**+1**	**0**	**0**	**0**	**0**	**0**	**6**
CS10.2: Environmental discounts (eco-V)	**0**	**+1**	**0**	**0**	**0**	**0**	**1**	**17**
CS10.3: Electronic toll system	**+2**	**+1**	**+1**	**0**	**0**	**0**	**4**	**8**
CS10.4: Auto Incident detection	**+2**	**0**	**+1**	**+1**	**0**	**0**	**4**	**8**

WIDER BENEFITS

Mobility: The constant rise in mobility is a European policy target, even if environmentalists dispute that this is a sustainable policy. So increases get √s and decreases Xs.

Congestion in overcrowded corridors: A reduction in congestion gets double points, and a full √ should only be given when the reduction congestion is not only very localised.

CO2 emissions: A reduction in CO_2 emissions can come from two main sources: one is the reduction in congestion and concurrent reduction in fuel consumption and the other one is a shift towards more sustainable modes. CO_2 emissions score 4 points for a single √ or X.

Contribution to user pays principle: This is a simple case of √ if there is a contribution, 0 if there is none, and X if the system is counterproductive to this target.

Table 5: Case-study comparison: Wider Benefits

Wider Benefits	**Mobility**	**Congestion**	**CO2 emissions**	**User pays principle**	**EU economic progress**	**Territorial cohesion**	**Sub-total**	**TOTAL-ALL**
	xx-✓✓ -2, +2	**X-✓ -2, +2**	**xx-✓✓ -8, +8**	**X-✓ -1, +1**	**X-✓ -1, +1**	**X-✓ -1, +1**	**-15 +15**	
CS1: ROUTERANK	**0**	**0**	**+4**	**0**	**0**	**0**	**4**	**17**
CS2: Marche	**+2**	**0**	**+8**	**-1**	**0**	**+1**	**10**	**12**
CS3: Apps for the disabled	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**12**
CS4: ITS Barcelona Bus								
CS4.1: Smart-phone apps	**0**	**+2**	**+4**	**0**	**0**	**0**	**6**	**13**
CS4.2: Smart Bus-stops	**+1**	**0**	**-2**	**0**	**0**	**0**	**-1**	**5**
CS4.3: DRT smart-apps	**0**	**0**	**0**	**0**	**0**	**+1**	**1**	**11**
CS5: Interurban PT- Warminsko-Mazurskie voivodship								
CS5.1: Net-based travel planner	**+1**	**0**	**+4**	**0**	**0**	**0**	**5**	**15**
CS5.2: RTPI -bus stops	**0**	**0**	**+4**	**0**	**0**	**0**	**4**	**6**
CS5.3: Ticket purchasing (mob/net)	**0**	**0**	**+4**	**0**	**0**	**0**	**4**	**13**
CS5.4: RTPI (mobile/internet)	**0**	**0**	**+4**	**0**	**0**	**0**	**4**	**12**
CS5.5: RTPI (onboard vehicles)	**0**	**0**	**+4**	**0**	**0**	**0**	**4**	**10**
CS5.6: DRT	**0**	**0**	**+2**	**0**	**0**	**+1**	**3**	**9**
CS6: Taxi apps	**+0.5**	**-2**	**-4**	**0**	**0**	**0**	**-5.5**	**0.5**
CS7: Bike-sharing Vienna and Region								
CS7.1: Cities	**+1**	**+2**	**+4**	**0**	**0**	**0**	**7**	**15**
CS7.2: Rural areas	**+1**	**0**	**+4**	**0**	**0**	**0**	**5**	**10**
CS8: Car-sharing in Karlsruhe								
CS8.1: car-sharing scheme (dynamic)	**+0.5**	**+2**	**+4**	**0**	**0**	**0**	**6.5**	**10 (7)**
CS8.2: booking system (mobile/internet)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**10**
CS8.3: data transfer of booking system	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7**
CS9: Grass-root cooperative smart-phone based car-sharing	**+1**	**0**	**+4**	**0**	**0**	**0**	**5**	**16**
CS10: Sant-Cugat intelligent motorway toll system								
CS10.1: Automatic detection HOV	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6**
CS10.2: Environmental discounts (eco-V)	**+1**	**+2**	**+8**	**0**	**0**	**0**	**11**	**17**
CS10.3: Electronic toll system	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**8**
CS10.4: Auto Incident detection	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**8**

European economic progress: Improvements through a system must be very wide ranging and of large scale to allow the judgement that it is making any significant progress towards European economic progress.

Territorial cohesion: The main aspect that would allow a √ for this would be an improvement in cross-border connections.

It may be seen that the solutions with highest scores for overall benefits appear as solutions with highest scores for either user or wider benefits. The case study applications mainly showed user benefits for D2D-time, D2D-cost and comfort with little impact on safety or security. All the case studies showed positive user benefits with personalisation of information or payment having good impact. In the consideration of wider benefits, the results were more varied, with the high weighting attached to CO2 highlighting the case studies where this reduction was greatest. The applications with highest impact for CO2 are not those with highest user benefit, so the overall weighting of these benefits is clearly of importance to decision makers. For high CO2 impact, mode shift to sustainable modes, including to eco-vehicles is necessary, small improvements in user experience, whilst important to individuals are unlikely to provide desired CO2 reductions unless part of a wider package of measures,

4.3 Carbon Assessment from Models (Scotland Region and EU-wide)

The individual case studies provided evidence of likely mode shift and other effects of certain ICT applications. These results were then used to undertake the final case study of modelling ICT within the Scotland region, and finally an EU-wide modelling exercise based on defined ICT scenarios.
The results of the modelling exercises are presented below.

4.3.1 Scotland region-LATIS: ICT modelling in Scotland Region 2007 to 2027

This case study used the existing Transport Model for Scotland which is owned by Transport Scotland (The Scottish Government) to produce quantitative estimates for traffic and emissions reductions resulting from the potential implementation of two general ICT solutions.

The ICT measures assessed in the case studies generally have a broad range of impacts, the relative impacts of which have been assessed against the COMPASS assessment matrix. This case study aims to quantify some of the potential impacts relative to reduction in CO2 emissions and traffic congestion levels. This quantification is made feasible by the existence of the LATIS model (Land Use and Transport Integration in Scotland) which is an integrated Land-use and Transport model for strategic assessment across the full Scotland Region. The nature of the model is such that the relative impact of possible ICT scenario effects could be assessed across different sub-regions; specifically Urban regions, inter-urban and rural.

The first solution assesses the impact of a reduction in In-Vehicle travel time on road-based Public Transport which may be the result of smart ticketing measures. (Other ICT measures such as improved traveller information and bus signal priority may also contribute to the reduction in overall/in-vehicle Public Transport journey time).

The second solution assesses the impact of increased car occupancy levels which may be achieved by lift-sharing initiatives.

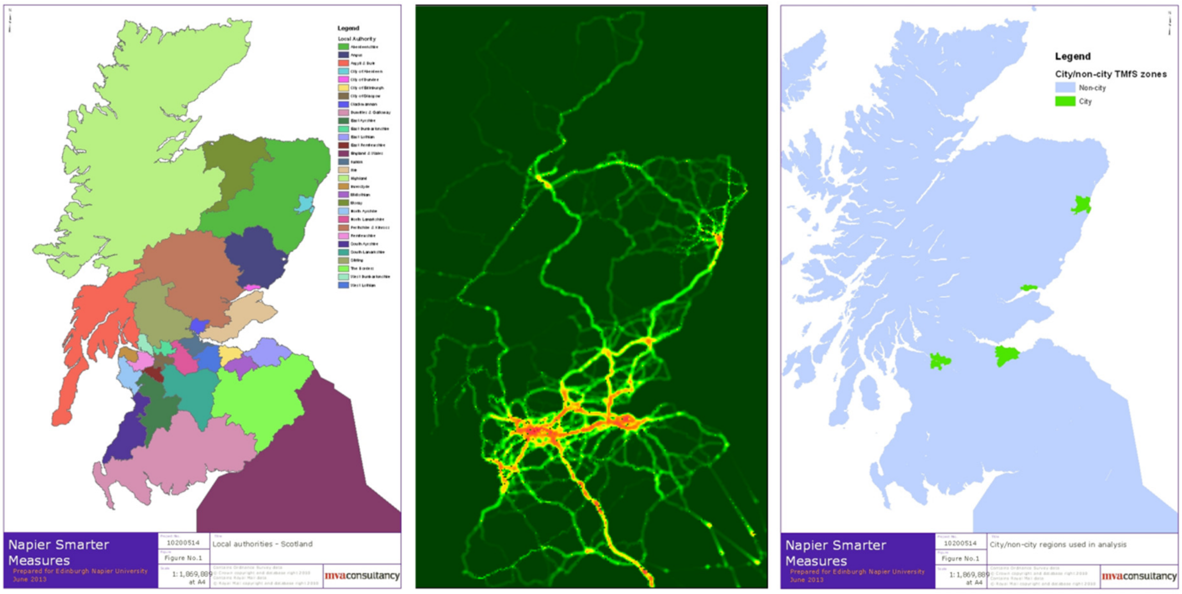

Figure 1: Scotland Local Authority Regions: Vehicle Emissions 2007: Scotland City Regions

Model data outputs were extracted from the TMfS07 2007 Base Year, 2027 Do Minimum Forecast year scenario and each 2027 Option Test scenario. The following scenarios were appraised and analysed:

- Test 1 PT: 5% reduction in urban bus journey times (Glasgow, Edinburgh, Aberdeen & Dundee) – all journey purposes and time periods. The in-vehicle time (IVT) factor for urban buses was reduced from 1.2 to 1.15;
- Test 2 PT: 10% reduction in urban bus journey times (Glasgow, Edinburgh, Aberdeen & Dundee) - all journey purposes and time periods. The in-vehicle time (IVT) factor for urban buses was reduced from 1.2 to 1.1;
- Test 3 Car: 5% increase in car occupancy - subsequent reduction in AM & PM Peak commuter matrices (Car occupancy increased from 1.03 to 1.08);
- Test 4 Car: 5% increase in car occupancy for 'city' origins – subsequent reduction in AM & PM Peak commuter matrices (Car occupancy increased from 1.03 to 1.08);
- Test 5 Car: 5% increase in car occupancy for 'non-city' origins – subsequent reduction in AM & PM Peak commuter matrices (Car occupancy increased from 1.03 to 1.08)

Generally, the impacts of each of the tests is relatively marginal (when compared to major schemes such as infrastructure schemes), but some of the measures do start to take an impact with the higher-end assumptions in place. The relatively marginal impacts are likely to stem from some of the test assumptions, whereby the aspects that are changed/appraised here only make up one specific component of travel time. This illustrates some of the challenges of encouraging greater use of public transport or car sharing, but whilst reductions are not large relative to major strategic assessment, the carbon reductions are apparent and in some cases could be quite significant.

First Solution: Reduction in Urban Bus Journey Times as a Result of ICT

The change to in-vehicle time (IVT) for urban buses to represent smart ticketing has little effect at a 5% level but the trend associated with decreasing IVT becomes more apparent in the 10% test, where small but consistent percentage decreases may be observed across Carbon and CO2 emissions (tonnes) and total v-km. As might be expected the effects of reduction in PT journey times in the urban regions shows some spill over into the adjacent interurban regions and negligible impact into the rural regions. The city of Glasgow would benefit most from a 10% decrease in PT-IVT with a reduction of 108 tonnes of CO2 (equivalent per annum) and a reduction in 1.06 million veh-kms (per annum). Emission/Congestion maps (from the model-base year 2007) show that the rural areas are generally uncongested and that reductions are most beneficial within the central belt.

For a 10% decrease in PT-IVT in city regions, v-km driven reduce across all regions ranging from 0% to 0.06% reduction and the annualised CO2 (equivalent) emissions reduce across all regions ranging from 0% to 0.06% reduction. This gives average reductions by region of:

- Urban(City) 0.48 mill-v-km/annum 38 tonnes;
- Interurban 0.15 mill-v-km/annum 18 tonnes;
- Rural 0.05 mill-v-km/annum 4 tonnes.

Second Solution: Mobile technology to encourage car sharing

The change to car occupancy levels to represent increased lift-sharing presents much more promising results in terms of quantifiable carbon reduction. If average car occupancy levels were increased from 1.03 to 1.08 across the entire Scotland region, an annualised equivalent CO2 saving of 17,897 tonnes could be made. The modelling suggests that regional effects would produce regional benefits and that the percentage benefits are slightly more favourable in Interurban/rural regions than in urban regions, which supports the introduction of lift-sharing schemes in rural areas. The change in both congestion and emissions for a 5% increase in vehicle occupancy caused by lift-sharing is much more significant than for reducing public transport in-vehicle journey time.

Table 6: Congestion/CO2 reductions

	v-km (10^6)			CO2 (tonnes)		
	All	**Urban-origins**	**Non-urban origins**	**All**	**Urban-origins**	**Non-urban origins**
Urban	-5.00	-3.82	-1.27	-552	-444	-97
Interurban	-5.20	-1.21	-3.94	-660	-179	-470
Rural	-5.13	-0.45	-4.65	-606	-57	-550

Significant reductions in overall CO2 emissions could be achieved if national car occupancy increases could be made. Any scheme to promote this objective would be expected to perform well on emission reduction measures. Local schemes however would be expected to benefit the local area and whilst detailed local schemes have not been specifically tested it is clear that the location of the origin where the increase in occupancy occurs will produce a strong local effect.

- The effects of this measure were significant for all tests and approximately an order of magnitude greater than for the PT journey reduction of 10%
- The regional effects were strongly apparent suggesting that local-lift sharing schemes with high take up could produce significant carbon reductions at a local level
- City based lift sharing schemes would have little impact in rural areas.

  - Increased publicity of the issue can lead to an increase in the number of complaints/reports of conflict which in turn pushes the issue of coexistence higher up the political agenda.
  - Conducting well thought out baseline measurement of the situation following an established model helped prevent approaching the problem with political statements and prejudices.
  - Involving different stakeholders with differing viewpoints and agendas (e.g. cyclist groups and department dealing with complaints) helps develop a balanced campaign and can help prevent it being perceived by citizens as a ‘top down’ measure.
  - A campaign tackling coexistence should raise awareness about bad behaviour in all groups

4.3.2 A European Assessment of ICT solutions

Based on the findings at local scale from case studies and on knowledge gained from the analysis of ICT transport solutions in the COMPASS Handbook, quantitative modelling has then been used to assess the potential impact of ICT solutions at European scale. The assessment of long-distance ICT solutions is based on quantitative modelling using MOSAIC, the European-wide model developed in the INTERCONNECT FP7 research project, a modal choice and assignment module originally programmed to investigate how upgrading the interconnections between transport networks in Europe impacted on the European transport system.

Modelling hypotheses were made on both supply and demand side, and ICT scenarios were developed on two made areas; 1. Modelling "more efficient infrastructure, service and traffic management" and 2. "ICTs can increase vehicle occupancies".

From the demand side,
ICT impacts both on trip substitution (e.g. teleworking, teleconferencing...) and on trip induction (e.g. enlarged personal and business relations supported by ICT inducing to trip demand increases).

- The net impact of ICT in travel induction and substitution is difficult to assess isolated from other social, economic and technologic drivers.
- ICT allows for better real time transport management of user needs, transport conditions and externalities, creating incentives for more informed user choices leading to more efficient transport system.

From a supply point of view,
The ICT implementation on transport systems results on efficiency improvements, in:

- More reliable transport services and vehicles leading to a change in the value of the time spent when travelling.
- More efficient traffic management leading to travel time reductions
- More efficient infrastructure management, leading to operating costs savings and, to the extent infrastructure managers transfer these savings to users, also to travel fees and user costs reduction.

1. Modelling "more efficient infrastructure, service and traffic management"

This ICT scenario includes

- Optimised infrastructure and service management:

  road cost decrease due

  A) to better vehicle performance and more efficient driving regimes via semi or fully-autonomous vehicles

  B) less congestion thanks to more intelligent GPS routing avoiding congestion, traffic jam assistants

  air mode and long distance rail cost decreases due to more efficient management
- Optimised intermodality:

  Easier interconnections. Less time for formalities in airports. Road mode speed at connectors increases due to better management of metropolitan motorways (e.g. Ramp metering, HOV/HOT lanes, variable speeds)

- Optimised traffic management:

  air speed increases obtained: from more direct routing and better management of take-off and landing operations

  Rail speed slightly lower due to more difficult implantation of ERTMS all over Europe.

  Road speed increase: more autonomous vehicle driving (e.g. SARTRE platooning, Advanced Cruise Control).

Four ICT levels were defined for this scenario, baseline, mid-ICT, high-ICT and very high-ICT. The modelling shows that the road modal share increases in each consecutive scenario. Decreasing travel costs and fees in all modes simultaneously, but higher decrease in the cost of interconnections involving the road mode making it easier to access the road mode. Speed increases are lower than for air, but greater than for train.

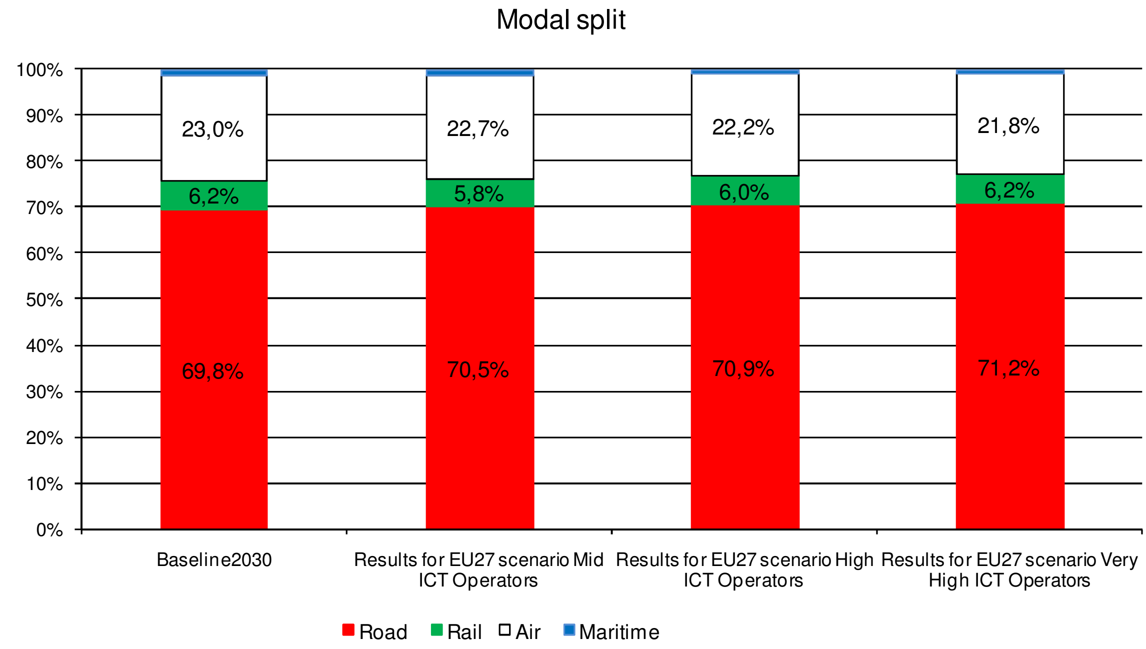

Figure 2: Modal split from EU-wide modelling

Rail modal share decreases initially but then recovers between Mid and High/Very High ICT scenarios. Decreasing travel costs and fees in all modes simultaneously, but higher decrease in the cost of interconnections involving the road mode making it easier to access the road mode. Speed increases are lower than for air, but greater than for train.

The impact on traffic is that modal shift from air, rail and maritime to the road implies more vehicles on the network, up to 1.8% increase. Large numbers of cars are needed to substitute air, rail and maritime services. The impact on CO2 is that modal shift implies an overall increase on fuel consumption and resulting CO2 emissions (up to 4.2%), provided that emission factors are kept stable.

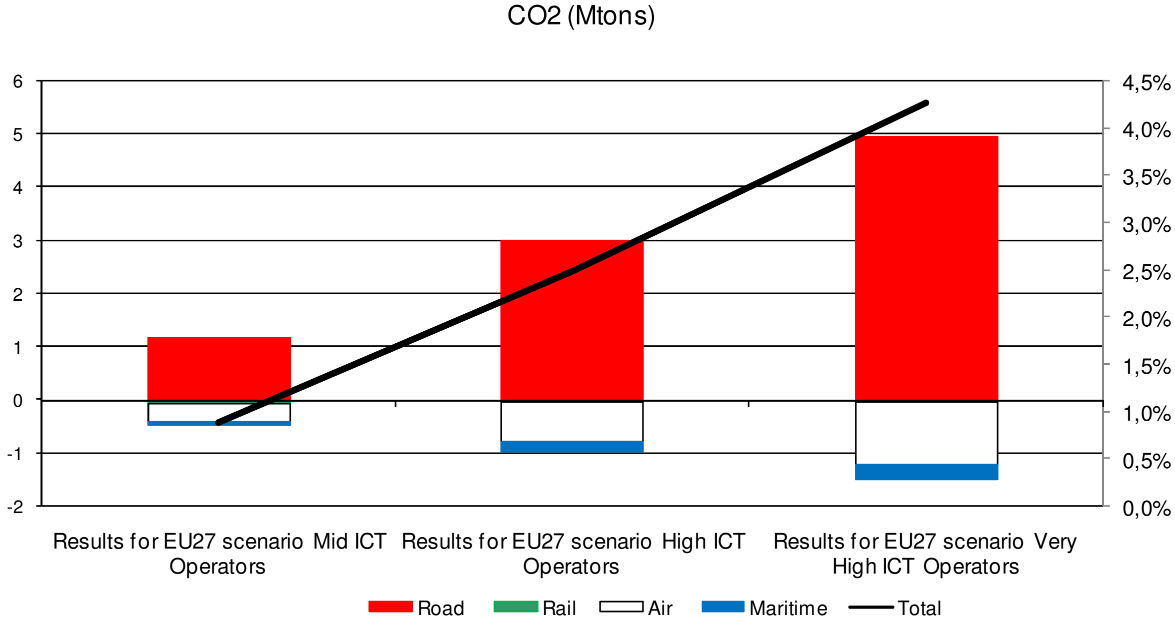

Figure 3: CO2 impact from EU-wide modelling

Travel Time in the network decreases, due to management measures that increase the average speed in all modes (exogenous) and in the interconnections between them. Especially important decrease for the road mode given that road has the biggest modal share.

2. Modelling "ICTs can increase vehicle occupancies"
Derived from car-pooling and ride sharing options, set to increase in the future, and from smart pricing, HOT/HOV policies inducing better use of vehicle space give rise to the four ICT levels defined below.

Table 7: Quantitative definition of scenarios Mid, High and Very High ICT

		units	Baseline	Mid ICT	High ICT	Very High ICT
Enhanced traveller comfort and convenience	Car occupation	users	1,5	1,75	2,0	2,25

Increasing vehicle occupancy a 50% results on a 33% vehicle kilometres reduction, 20% generalised cost decrease and fuel consumption.

Travel cost of the global transport system decreases up to 20% due to increase in car occupation, making the average car trip per person much cheaper.

4.4 Summary

The modelling scenarios, whilst utilising different models and assumptions, show broadly similar results. In both cases, the CO2 benefits were significant for increased car occupancy levels and negligible or decreased for service improvements due to ICT. The measures included in the EU-wide modelling included road infrastructure and traffic management improvements which made car-travel relatively more attractive and hence increased mode share of car. The public transport improvements modelled in LATIS showed some shift to public transport, but this resulted in negligible reduction in CO2. Whilst improved user benefits may not greatly impact on CO2 emissions, targeting these benefits to public transport rather than road based ICT measures will help improve public satisfaction and should not be ignored. For targeted CO2 benefits however, improved efficiency through greater utilisation of space within private cars is clearly beneficial, and efforts to increase occupancy levels through ICT improvements should be made.

5 Conclusions

The conclusions of the case studies are case dependent and cannot be treated as one EU-wide response to the ICTs. Certain trends are however visible regardless of regional differences. Firstly, there is relatively high acceptability among users. Users generally welcome introduction of ICTs. This is however very dependent on user age with older users more often rejecting ICTs than younger. Secondly it is visible that user acceptance is combination of many sub factors of which the most important are the potential of the ICT solution in reducing D2D travel time and costs, and increasing comfort and convenience of travelling. Most ICTs - as case studies confirm - contribute to travel time reduction and comfort increase. While travel cost can increase or decrease in response to ICTs an increase in punctuality and reliability and a reduction in delays are often first visible effects of ICTs. The major barrier for ICTs application revealed by case studies is of financial nature. Users are generally unwilling to pay extra for ICTs. Only limited profits for operators could result from increased demand or optimised use of resources gained through ICTs. From the society point of view ICTs could contribute to achievement of CO2 emissions reduction or increased territorial cohesion or they may facilitate economic progress. Accordingly to case studies reduction in CO2 emissions can come from two main sources: one is the reduction in congestion and concurrent reduction in fuel consumption, and the other one is a shift towards more sustainable modes.

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Appendix A

Point score for the criteria

	Score									
Investment Costs			€€€	-2	€€	0	€	+2		
Operation and maintenance costs			€€€	-2	€€	0	€	+2		
Financial viability	XX	-2	X	-1	0	0	✓	+1		
Technical feasibility	XX	-2	X	-1	0	0				
Organisational feasibility	XX	-2	X	-1	0	0	✓	+1		
Administrative burden			X	-1	0	0	✓	+1		
Legal feasibility	XX	-2	X	-1	0	0				
User acceptance	XX	-4	X	-2	0	0	✓	+2		
Public acceptance	XX	-2	X	-1	0	0	✓	+1		
D2D travel time	XX	-4	X	-2	0	0	✓	+2		
D2D travel costs	XX	-2	X	-1	0	0	✓	+1		
Comfort and convenience			X	-1	0	0	✓	+1	✓✓	+2
Safety			X	-1	0	0	✓	+1		
Security			X	-1	0	0	✓	+1		
Accessibility for mob. imp. passengers			X	-1	0	0	✓	+1		
Car usage	- -	0	-	0	0	0	+	0	++	0
Bus and coach usage	- -	0	-	0	0	0	+	0	++	0
Rail usage	- -	0	-	0	0	0	+	0	++	0
Ferry usage	- -	0	-	0	0	0	+	0	++	0
Aeroplane usage	- -	0	-	0	0	0	+	0	++	0
Mobility	XX	-2	X	-1	0	0	✓	+1	✓✓	+2
Congestion in overcrowded corridors			X	-2	0	0	✓	+2		
CO2 emissions	XX	-8	X	-4	0	0	✓	+4	✓✓	+8
European economic progress			X	-1	0	0	✓	+1		
Contribution to User Pays principle			X	-1	0	0	✓	+1		
Territorial cohesion			X	-1	0	0	✓	+1		

Final Case Study Scores	**Feasibility**									**Interest for Travellers**						**Modal Change**					**Other Impacts**						
	Investment costs	Operation and maintenance costs	Financial viability	Technical feasibility	Organisation feasibility	Administrative burden	Legal feasibility	User acceptance	Public acceptance	D2D travel time	D2D travel costs	Comfort and convenience	Safety	Security	Accessibility for mob. imp. Passengers	Car usage	Bus and coach usage	Rail usage	Ferry usage	Aeroplane usage	Mobility	Congestion	CO2 emissions	Contribution to user pays principle	European economic progress	Territorial cohesion	**OVERALL SCORE**
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	
Routerank	€	€	V	0	0	V	0	V	0	V	V	V	0	0	0	-	0	+	0	-	0	0	V	0	0	0	**17**
Tuscany travel planner	€	€	X	0	0	X	0	0	0	0	0	0	0	0	0	++	++	++	++	++	VV	0	VV	X	0	V	**12**
Apps for the disabled	€	€	V	0	0	0	0	V	0	(V)	0	0	V	V	V	0	0	+	0	0	0	0	0	0	0	0	**12**
Barcelona bus network - Apps	€€	€	0	0	0	0	0	V	0	V	0	V	0	0	0	-	+	0	0	0	0	V	V	0	0	0	**13**
Barcelona bus network - smart bus stops	€€	€€	0	0	0	0	0	V	V	(V)	0	V	0	0	V	-	+	0	0	0	V	0	(X)	0	0	0	**5**
Barcelona bus network - DRT	€€	€	V	0	0	0	0	V	V	V	0	V	0	0	V	-	+	-	0	0	0	0	0	0	0	V	**11**
Interurban public transport in Poland - Internet-based travel planners	€€	€	V	0	0	0	0	V	V	V	0	V	0	0	(V)	-	+	0	0	0	V	0	V	0	0	0	**15**
Interurban public transport in Poland - Real-time information at bus stops	€€	€€	XX	0	0	X	0	V	V	(V)	0	V	0	0	0	-	+	0	0	0	0	0	V	0	0	0	**6**
Interurban public transport in Poland - Real-time information on-board the vehicle	€€	€	X	0	0	0	0	V	V	(V)	0	V	0	0	0	-	+	0	0	0	0	0	V	0	0	0	**10**
Interurban public transport in Poland - Ticket purchasing via mobile phones/internet	€€	€	V	0	0	0	0	V	V	V	0	(V)	0	0	0	-	+	0	0	0	0	0	V	0	0	0	**13**
Interurban public transport in Poland - Real-time information on bus position via mobile phone/internet	€€	€	X	0	0	0	0	V	V	V	0	V	0	V	0	-	+	0	0	0	0	0	V	0	0	0	**12**
Interurban public transport in Poland - Demand responsive services	€€	€	XX	0	0	0	0	V	0	V	X	V	0	V	V	-	+	0	0	0	0	0	(V)	0	0	V	**9**
Mobile apps for taxi fare quotes	€€€	€	V	0	(V)	X	0	V	V	V	(X)	V	0	0	0	+	-	0	0	0	(V)	X	X	0	0	0	**0.5**
Bike sharing in cities	€€	€€	V	0	0	0	0	V	V	V	V	V	0	0	0	-	-	0	0	0	V	V	V	0	0	0	**15**
Bike sharing in rural areas	€€	€€	0	0	0	0	0	V	V	0	V	V	0	0	0	-	+	0	0	0	V	0	V	0	0	0	**10**
Classic car sharing in Karlsruhe	€€€	€€€	VV	0	0	0	0	V	V	(V)	(V)	V	0	0	0	-	+	+	0	0	(V)	V	V	0	0	0	**10**
Dynamic car sharing	€€€	€€€	X	0	0	0	0	V	V	(V)	(V)	V	0	0	0	-	+	+	0	0	(V)	V	V	0	0	0	**7**
Car share booking system	€	€	V	0	0	V	0	V	0	(V)	0	V	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**10**
Booking data transfer system	€€	€	V	0	0	V	0	V	0	0	0	V	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**7**
Cooperative car sharing in Austria	€	€	V	0	0	0	0	V	V	(V)	V	V	0	0	0	-	+	+	0	0	V	0	V	0	0	0	**16**
Sant Cugat HOV discounts	€	€	(V)	(X)	0	X	0	V	V	(X)	V	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	**6**
San Cugat environmental discounts	€	€	0	0	0	0	0	V	V	0	V	0	0	0	0	(+)	0	(-)	0	0	0	0	V	0	0	0	**17**
San Cugat electronic toll	€	€	V	0	0	V	0	V	V	V	V	V	0	0	0	0	0	0	0	0	0	V	V	0	0	0	**8**
San Cugat AID	€€€	€€	V	(X)	0	V	0	V	V	V	0	V	V	0	0	0	0	0	0	0	0	V	V	0	0	0	**8**
Latis bus journey times	0	0	0	0	0	0	0	0	0	V	V	V	0	0	0	-	+	0	0	0	0	V	V	0	0	0	**8**
Latis car sharing	0	0	0	0	0	0	0	0	0	X	V	X	X	0	V	0	0	0	0	0	V	V	VV	0	0	0	**17**