Connected Living

Intelligent Transportation Systems Report for Mobile

GSMA Connected Living Programme

Contents

Figures

0. Executive Summary

0.1 Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) is the use of Information Technology, sensors and communications in surface transport applications - especially roads. ITS is a major sector of the US economy: 3,000 companies with 445,000 jobs; bigger than computers, movies and internet advertising. The global ITS market will be USD30 billion by 2020. ITS can reduce congestion, accident rates, energy consumption and greenhouse gas emissions.

0.2 Standards, communications and cloud-based computing in ITS

Cellular radio and smart-phone development are expanding many areas of ITS. The GSMA has set up the Automotive Special Interest Group (ASIG) to enable dialogue between mobile operators and vehicle manufacturers. The global cloud computing market is growing at 30% CAGR.

0.3 Intelligent Mobility and Cooperative ITS

There are Intelligent Mobility and Cooperative ITS (C-ITS) programmes world-wide, with wireless data exchange from vehicle to infrastructure (V2I) or vehicle to vehicle (V2V). "Connected cars" and "autonomous vehicles" are "hot topics" world-wide, due to converging interests of MNOs, automotive companies and ITS organisations, influenced by developments in consumer electronics. Priorities of the US Department of Transportation's "ITS Strategic Plan 2015-2019" are: "Realising connected vehicle implementation and advancing automation". Autonomous vehicles have now entered public and political consciousness – largely due to the Google self-driving car.

0.4 Enforcement and security

Autonomous and connected vehicles are susceptible to hacking; researchers have demonstrated attacks, though none have occurred as yet in the "real world". Viruses or malware in smart-phones, music-players or USB sticks can infect automotive electronics. Vehicles contain 100 electronic control units and 10 million lines of software; they are vulnerable because of their real-time operation, components from different suppliers and difficulty of updating security software. Concerns have reached the highest levels, including the World Economic Forum and the US Senate. GPS location signals used by smart-phones and in-vehicle systems can be spoofed or jammed. *Defence mechanisms against cyber attacks of automobiles must be designed. MNOs can contribute because of their expertise in authentication and security.*

0.5 Fleet Management, Pay As You Drive Insurance & Parking

Fleet management includes optimal routing, and monitoring of vehicle health and driving style. At least 80% of freight traffic by weight – more by value - travels by road; it is vital to national economies. The fleet management markets in Europe, Russia/CIS and China have annual growth rates of 14%, 16% and 23% respectively. Penetration will reach 20% by 2019. GPRS meets the key parameters of area coverage, network latency and data bandwidth; *3G/4G technologies will bring increased uplink speeds and reduced latency, improving the end-user experience and creating opportunities for MNOs.*

Pay As You Drive Insurance (PAYDI – aka Usage-Based Insurance - UBI) is an expanding field, doubling annually in some cases, as insurance companies reduce costs and acquire more sophisticated tools to categorise drivers, using “dongles” with GPS receiver and SIM card in the vehicle OBD, or smartphone apps. *PAYD/UBI are new sources of growth for MNOs as the mobile phone voice market saturates.*

Helping drivers find parking spaces minimises congestion and pollution. Charges can be sent wirelessly to meters. Motorists can pay from their mobile. *MNOs and cities use SMS for parking charges in the US, Europe, Australia and United Arab Emirates.*

0.6 Road Pricing

‘The potential for benefits from a well-designed, large-scale road pricing scheme is unrivalled by any other intervention’ - though commercially progress has been slow, because of fears of public and political unacceptability. But road pricing is acceptable if it is equitable, revenue-neutral and efficient. Dramatic traffic reduction is achieved with minimal charges, without diversion onto other routes. Satellite technology with mobile communications allows charging by Time, Distance and Place. Germany and Slovakia use GPS/GSM-based truck-tolling schemes, as will Belgium (T-Systems & Belgacom) and Bulgaria. Singapore will migrate to GSM/GPS for all vehicles by 2020. In the US Oregon is trialling road pricing as a ”gas tax” replacement, with one option using a smartphone. Verizon is involved in the trial through insurance company State Farm. California and other western states are closely following the trials. Other countries also have declining revenue from motor (especially fuel) taxes. *Mobile operators are used to keeping large volumes of sensitive data secure, so are ideally placed to play a role in road pricing; whether city-based or over wider areas.*

0.7 Public Transport/Transit

Public transport works well in high-density urban environments, but less so in rural or suburban environments. It is important with the world-wide trend to urbanisation. Mobile technology allows travel time to be used productively – a trend that MNOs should encourage. Public bodies are making transport data available for app developers, increasing transport efficiency. Benefits of smart-phone Near Field Communication (NFC) include passenger convenience, lower sales and distribution costs, more flexibility, personalised communication with passengers and promotion of public transport. Mobile ticketing will triple between 2013 and 2018. Benefits for mobile operators include greater use of mobile services, upgrading of handsets and UICCs, and a platform for mobile commerce.

Car-pooling and dynamic ride-sharing, encouraged by mobile technology, reduce congestion and pollution, and commuter costs. Zipcar (Avis) claims to be the world's leading car sharing club, based in North America and Europe. DriveNow (BMW/Sixt) operates in Europe and San Francisco. Some companies, including Uber (Google) and Lyft, have turned dynamic ride-sharing into a successful business. Car-pooling, car clubs and dynamic ridesharing rely on mobile technology, and their use will increase.

Cycling is increasingly used for short journeys in cities. Customers of cycle-hire schemes use smart-phones to check availability. The Dutch VANMOOF company has GPS connectivity and Vodafone M2M SIMs in its e-bike to combat theft and to map commuter routes. Vodafone sponsors the Barcelona bicycle sharing scheme. *Other MNOs could sponsor cycle hire and monitor cycle fleets.*

0.8 Travel information and Traffic management

Traffic and traveler information play an increasingly part in traffic management, and empower passengers. Car drivers will switch to transit if they can manage their commutes through smartphone apps with real-time information on schedules and delays. Apps are cheaper than electronic displays at bus-stops. So mobile technology and social media can improve the passenger experience and benefit the transport operator and the MNO. The annual "App Quest" competition of New York State's Metropolitan Transportation Authority (MTA) uses real-time data sets and APIs, with $50,000 prize money from AT&T. *MNOs could set up similar competitions, generating good publicity, branding opportunities, and network traffic.*

Road traffic information is supplied by mobile technology. The Singapore Land Transport Authority use drivers' smart-phones as traffic sensors and to deliver personalised real-time traffic information. The Waze (Google) app generates traffic, mapping and other road data in back-ground mode, and reports on traffic disruptions or fuel prices. Social media, especially Twitter and crowd-sourcing, are important sources of transport information and control. 90% of US States use Twitter and Facebook to publicise traffic incidents, construction projects and safety initiatives; 50% offer mobile apps and 73% have mobile-friendly web sites. But keeping up with public expectations on information supply is challenging – *an opportunity for MNOs.*

0.9 Smart cities and the Internet of Things (IOT)

A smart city uses intelligent technology to sustainably enhance the quality of life. The GSMA has identified 99 smart-city mobile transport products and services worldwide, such as ticketing, intelligent transport systems and traffic information. Deutsche Telekom is rolling out services to German cities. The Amsterdam Smart City project, with KPN Telecom, aims to make it the smartest in the world. Singapore has created 23 mobile apps since 2010. India will build 12 pollution-free smart cities by 2020. *Mobile operators can play a role in smart city services by connecting infrastructure and individuals' handsets to central servers and databases, with data aggregation and analysis to produce new insights, real-time information sent to people and machines, and customer support operations, such as call centers and web portals.*

The "Internet of Things" (IoT), enabled by Machine to Machine (M2M) communication, is the most promising market in the technology industry according to Samsung; by 2020 all its hardware will be IoT devices. Ford will become a transport data analytics organisation, collecting data from cars and people and turning it into a business, related to vehicle quality, insurance costs, car sharing, driving patterns, parking apps, transportation analysis and societal problems. Daimler-Mercedes-Benz bought RideScout, a US developer of transport apps. The existing mobile spectrum is adequate for IoT applications, but network resilience and data security are increasingly important. IoT will be a heterogeneous collection of technologies operating on both licensed and unlicensed spectrum. *The IoT is a major opportunity for MNOs, not only in providing mobile network connectivity, but also in adapting the cellular radio standards to facilitate these new services.*

A new type of mobile network user will emerge, with billions of embedded devices in vehicles, consumer and industrial electronic equipment, using the "embedded Universal Integrated Circuit Card" (eUICC). The GSMA eUICC specification will accelerate M2M growth by providing a standard mechanism for remote management and "over the air" provisioning, while maintaining the same security as in removable SIMs. Use of the eUICC can minimise some of the connected car security problems. *The eUICC provides new business opportunities for MNOs, safely and with minimal impact to the network infrastructure.*

0.10 Conclusions and recommendations

ITS has many communications needs that MNOs can address. MNOs should keep abreast of the field by attending and exhibiting at the annual ITS World Congress, the ITS Asia Pacific Forum and the IEEE and ITS America events. MNOs should participate in ITS standards development, and in collaborative R&D programmes to get experience of new ITS areas and new partnerships.

Connected and driverless cars are “hot topics” and mobile communications are crucial. But security is an issue, including in fleet management and Pay As You Drive Insurance; MNOs have relevant expertise, including advocating wider use of eUICCs.

Promising long-term areas are road pricing and congestion charging, using satellite positioning and mobile communications. MNOs are used to securing large volumes of sensitive data, so are well-placed to collaborate with administrations, since privacy and mistrust of Governments are issues.

Public and private transport systems are improved by using mobile communications and smartphones, including car sharing , car clubs, bicycle security schemes and cycle hire – and also can attract new mobile subscribers. Mobile technology and social media improve the public transport experience and benefit transport operators and MNOs. Sponsoring competitions to develop transport apps will generate good publicity, branding opportunities, and network traffic. Mobile technology and crowd-sourcing can augment infrastructure-based traffic data sensors. By making transport more efficient, mobile technology improves the environment.

MNOs have important roles to play in Smart Cities and the Internet of Things. They should partner with or acquire technology companies, consultancies or systems integrators to facilitate solutions, including connecting city infrastructure and individuals’ handsets to central servers and databases, combining data from multiple sources to produce new insights; delivering real-time information to people and machines, and providing customer support operations, such as call centers and web portals – though a prerequisite is the adaptation of the cellular network standards to facilitate these new services.


KB

1. Introduction to Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) is an expanding and diverse subject, though some of its areas are becoming linked or are converging and overlapping. For example, transport and travel information might have been covered under Smart Cities rather than being a separate section; similarly "connected cars" are a manifestation of Machine-to-Machine (M2M) communications and the Internet of Things (IoT).

Note that items likely to be of commercial interest to MNOs are highlighted in italics throughout the text.

1.1 Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) is the use of Information Technology (IT), sensors and communications technologies for surface transport applications - though road transport applications vastly predominate. Road and other infrastructure building is expensive and environmentally unfriendly; we can make better use of the civil infrastructure by using a broad range of electronic technologies, making transportation systems safe, efficient, reliable and environmentally friendly, without implementing new physical infrastructure. ITS cuts across disciplines such as transportation, engineering, telecommunications, computer science, finance, electronic commerce and automotive manufacturing. Use of wireless/radio mobile communications and satellite positioning systems are particularly important.

The ITS field probably has more than its fair share of acronyms. Where possible, each one will be explained when it is first introduced but a complete list will be found in section 12.1. ITS also a big subject, and what were previously distinct and separate areas are now starting to overlap, partly though the influence of mobile communications - as we will see in this Report.

1.1.1 Intelligent Mobility

The term "Intelligent Mobility" has gained currency, particularly amongst automobile manufacturers. It is not clear how it differs from ITS. The UK Automotive Council uses it to describe the convergence between electronic communications technologies and transport systems, which up to now have been developed in isolation, to create a safer, intelligent, highly interlinked transport network. The key to Intelligent Mobility lies in connecting a range of independent industries and technologies such as vehicle manufacturing, transport information systems, communications technologies, logistics and distribution and infrastructure management. The EU has an iMobility Support operation to foster the deployment of intelligent mobility in Europe. **http://www.imobilitysupport.eu/**

1.1.2 Telematics

Wikipedia defines telematics as an interdisciplinary field encompassing telecommunications, vehicular technologies, road transportation, road safety, electrical engineering and computer science. However the term is most commonly used in the transport field and this is how we will use it here. (Indeed ITS was once known as "Transport Telematics" - first coined by the French as "télématique", combining "telecommunications" and "informatics"). It usually refers to fleet management, where haulage companies, car hire organisations and other companies manage their vehicle fleets, including optimal routing, monitoring of vehicle health and driving style. For a time "telematics" was particularly applied to technology used in the automotive insurance industry, but the more specific terms Pay As You Drive Insurance (PAYDI) and Usage-Based Insurance (UBI) (section 5) are now favoured .

1.2 A brief history of ITS

Research on the application of control and information technologies to surface transportation began in the 1950s and 1960s in the United States, including automatic control of the automobile and electronic route guidance. In the late 1980s a coalition of private, public and academic organisations convinced Congress to legislate support for a comprehensive program in Intelligent Vehicle-Highway Systems (renamed Intelligent Transportation Systems or ITS in 1994) to reflect a broader mission, including all parts of public transportation and intermodal connections.

The potential benefits of ITS had not gone unnoticed Europe. In 1987 the European Commission (EC) announced its DRIVE (Dedicated Road Infrastructure for Vehicle safety in Europe) research program, aimed at employing information technology to improve the efficiency of road transport and road safety, and to reduce its environmental effect. The subsequent DRIVE 2 and following "Framework" programs have continued this initiative. In the same timeframe, in mobile communications, Europe was adopting the first generation cellular radio systems, and developing its second generation system GSM (Global System for Mobiles).

1.3 ITS markets and prospects

In 2011 ITS was identified by ITS America as a major sector of the US economy, comprising 3,000 companies with total revenues of $48 billion in 2009, with 180,000 private sector jobs in the end-use market, and 445,000 jobs in the total industry value chain; end-use revenue was predicted to increase by 41% by 2015, and total industry employment to exceed 500,000. ITS market revenues exceeded those for electronic computers, motion picture and video products, and internet advertising. The 2015 total U.S. private sector ITS market was projected to be $67 billion[1].

A June 2014 report by Juniper Research on the telematics sector says that the number of in-vehicle apps in use is expected to reach 269 million by 2018, representing a more than fivefold increase on 2013. According to the report “Connected Cars: Consumer & Commercial Telematics and Infotainment 2014-2018”, growth will be fuelled by solutions such as Apple’s CarPlay, which will promote in-vehicle apps to the mainstream, and app integration will be facilitated as standardised approaches like MirrorLink are adopted by OEMs, content providers and automotive entertainment specialists.

The Electronic Toll Collection System Market is forecast to reach $9.5 Billion in 2020. Tolls are collected using electronic equipment installed on the roadside and without reducing vehicle speed, particularly on highways and in congested cities.

According to MarketsandMarkets (“Intelligent Transport Systems Market by System (ATMS, ATIS, ITS- Enabled Transportation, Pricing System, APTS and CVO), by Component, Application and Geography (Americas, Europe, Asia-Pacific, ROW) Analysis and Forecast to 2014 - 2020”[2] the ITS market will grow at a CAGR of 11.3% from 2014 to 2020 and reach $33.75 Billion. The major market share is in the US, followed by Europe.

A growing focus on efficient traffic management drives the global ITS market, according to a new report by Global Industry Analysts, Inc. (April 2014). It will reach US$26.3 billion by 2020, driven by continued rise in vehicular traffic and the need to regulate traffic flow, enhance road safety, and escalate awareness of the socio-environmental implications of traffic congestion.

Grand View Research, Inc forecasts the global ITS Market will reach USD38.68 Billion by 2020. Growing demand for optimising fuel consumption and reducing emissions will be the key driving forces. ITS can reduce incidents and improve safety. North America accounted for 43.8% of the global market in 2013 and will remain the dominant ITS market over the next six years because of favorable regulatory initiatives from transportation authorities for increasing driver safety and reducing traffic congestion. Asia Pacific will register the fastest growth of 14% from 2014 to 2020, as a result of a need to improve transportation networks and high ITS growth expected in India and China to tackle congestion and energy consumption.

1. http://www.itsa.org/knowledgecenter/market-data-analysis
2. ATMS: Advanced Traffic Management Information Systems; ATIS: Advanced Traveler Information Systems; APTS: Advanced Public Transportation Systems; CVO: Commercial Vehicle Operations; ROW: Rest Of the World; CAGR: Compound Annual Growth Rate.

A new "hot topic" is "self-driving cars" (aka autonomous vehicles), still in the research stage but sales are forecast to explode over the next decade. Automotive and other companies are racing to develop them, including Audi, Daimler, Google.

- **Sales will increase from 230,000 in 2025 to 11.8 million by 2035, says IHS Automotive, with a cumulative total of 54 million self-driving cars in use worldwide. By 2050, nearly all vehicles — private and commercial — will be self-driving cars, and the roads will be safer. Traffic congestion and air pollution per car will also decline, because cars can be programmed to be more efficient in their driving patterns. A third of all global sales in 2035 will be in North America. Many cars already have the technologies needed for self-driving, such as lane-keeping assist and automated braking. But self-driving cars will add $7,000 to $10,000 to a car's price in 2025, dropping to $5,000 in 2030 and $3,000 in 2035. The two big barriers to development are software reliability and cyber security. Governments will play a key role, setting the rules for deployment.**
- **According to an October 2013 market report from Transparency Market Research "Connected Car Market -Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013- 2019," the global connected car market will reach USD 131.9 billion by 2019, growing 34.7% per year from 2013 to 2019. 4G/long-term evolution (LTE) technology is in a commanding position to supply this connectivity due to its lower operating costs and high data transmission volumes compared to other technologies. The market is primarily driven by changing consumer preferences and growing awareness of safety and security, as well as the need for connectivity, and government mandates; inhibiting factors include high hardware cost and risk of driver distraction. Rapid advancements in network technology serve as an opportunity, fuelling the growth of this market. The connected car market has been segmented into 4G (LTE), 3G (UMTS, HSPA, HSPA+)[3], and 2G (GSM, GPRS, EDGE)[4]. Mobile network operators (MNOs) will play a vital role in the future of the connected car and will have to work with car OEMs, says the GSM Association.**

1.4 The European Commission's ITS Action Plan and Directive

The European Commission's 'Action plan for the deployment of intelligent transport systems in Europe' — the 'ITS action plan' — aims to make road transport, and its interfaces with other transport modes, more environmentally friendly, more efficient, safer and more secure. Deployment of ITS in Europe needs to be accelerated in a coordinated way and European standards, for example for the exchange of data, should be set. This plan and the accompanying proposal for a directive laying down the framework for the deployment of ITS, were both adopted in 2008 (EC 2008, 2009).

The EU wants to encourage 'co-modality' (the efficient use of different transport modes together and separately), to cut congestion, reduce the number of road traffic accidents, reduce energy consumption, cut greenhouse gas emissions and reduce dependence on fossil fuel. The plan is a response to the slow and fragmented deployment of ITS in road transport in Europe. Possible ITS applications include electronic tolling, dynamic traffic management with variable speed limits, parking guidance and reservation, navigation devices and driver assistance systems.

3. LTE: Long Term Evolution; UMTS: Universal Mobile Telecommunications Service - the ETSI third generation mobile radio standard; HSPA: High Speed Packet Access
4. GSM: Global System for Mobiles; GPRS: General Packet Radio Service; EDGE: Enhanced Data rates for GSM Evolution

A new legal framework (Directive 2010/40/EU) was adopted on 7 July 2010 to accelerate the deployment of ITS across Europe, aiming to establish interoperable and "seamless" ITS services while leaving Member States the flexibility to decide which systems to implement. By 2017 the European Commission has to adopt functional, technical, organisational or service provision specifications to address compatibility, interoperability and continuity of ITS solutions across the EU.

The Directive identifies four Priority areas and actions:

- **Optimal use of road, traffic and travel data;**
- **Continuity of traffic and freight management ITS services;**
- **Road safety and security applications;**
- **Linking the vehicle with the transport infrastructure.**

The Action Plan is supported by five Directorates-General: Mobility and Transport (lead); Communications Networks, Content & Technology; Research & Innovation; Enterprise and Industry; Climate Action.

1.4.1 eCall

eCall is an EC initiative aiming to bring help to motorists involved in a collision anywhere in the European Union. An eCall-equipped vehicle monitors its in-vehicle sensors for events such as airbag deployment and automatically sends a "Minimum Set of Data" including the location of the crash, to the nearest emergency centre via the cellular network, permitting a rapid and potentially life-saving response by the emergency services. SMS and GPRS are not suitable for eCall due to delays; an "in-band modem" is used to send data over the voice channel, compliant with the 3GPP specification TS 26.267: "eCall Data Transfer; In-band modem solution; General Description." eCall was planned to be operational throughout Europe by the end of 2015, but progress has been slow and the current deadline is likely be 2018.
http://ec.europa.eu/digital-agenda/en/ecall-time-saved-lives-saved


Hurontario Street
PARAMEDIC
AMBULANCE
3073
SUPERINTENDENT
PARAMEDIC

2. Standards, communications and cloud-based computing in ITS

There are many standards relating to ITS in general and to communications in ITS in particular – see for example "D3.5b – Standardisation Handbook" (Evensen & Schmitting, 2014).

2.1 Short-range communications

Dedicated Short-Range Communications (DSRC) is much used in ITS. There has been standardisation activity in this area going back 20 years. But the term DSRC is ambiguous; DSRC in the US context is different from the European usage, particularly in tolling systems.

2.1.1 CEN DSRC 5.8 GHz

CEN/TC 278 was established in 1992 and coordinates with ISO/TC 204 Intelligent Transport Systems, which is responsible for developing international standards, and with the European Telecommunications Standards Institute (ETSI) which produces globally-applicable standards for telecommunications and ITS.

CEN DSRC is the 5.8 GHz system developed by the European Committee for Standardisation's Technical Committee TC278 Working Group 9 (ISO WG15) and used for tolling systems world-wide, though both these working Groups are currently dormant. Its full list of Working Groups is:

WG 1 Electronic Fee Collection

WG 2 Freight, Logistics and Commercial Vehicle Operations

WG 3 Public Transport

WG 4 Traffic and Travel Information

WG 5 Traffic Control Systems

WG 6 Parking management (disbanded)

WG 7 Geographic Data Files

WG 8 Road Traffic Data

WG 9 Dedicated Short Range Communications (dormant)

WG 10 Human-Machine Interfacing

WG 12 Automatic Vehicle and Equipment ID.

WG 13 Architecture and Terminology

WG 14 Recovery of stolen vehicles

WG 15 eSafety / eCall

WG 16 Cooperative systems

WG 9 produced 4 basic standards between 1993 and 2001, which provide the basics of tolling systems around the world, and applying to what was called at the time "Road Transport and Traffic Telematics" (RTTT). They are:

- **EN 12253:2004 RTTT - Dedicated short-range communication - Physical layer using microwave at 5.8 GHz;**
- **EN 12795:2003 RTTT - DSRC data link layer: medium access and logical link control;**
- **EN 12834:2003 RTT - DSRC application layer;**
- **EN 13372:2004 RTTT -DSRC - Profiles for RTTT applications.**

As indicated earlier (section 1.4) the European Commission Directives aim to accelerate the deployment of ITS in Europe, and the Commission has asked the European Standards Organisations to develop and adapt the supporting European standards. The following documents are relevant to CEN/TC 278:

- **EFC Directive 2004/52/EC on the interoperability of electronic toll systems;**
- **ITS Directive 2010/40/EU for the deployment of ITS in road transport and for interfaces with other transport modes;**
- **Commission Decision 2009/750/EC on the definition of the European Electronic Toll Service (EETS);**
- **Mandate M/338 on Electronic Fee Collection in support of Interoperability of electronic road toll systems; 19 standards have been published and 22 are under development;**
- **Mandate M/453 on Co-operative ITS (C-ITS);**
- **2010-2013 EC ICT standardisation work programme to promote use of standards to increase interoperability between services and applications; several standards are being developed, including eCall (section 1.4.1);**
- **The ITS action plan identifies priority areas for a wider and more coordinated deployment and use of ITS.**

For more information see **http://www.itsstandards.eu/**

2.1.2 US DSRC 5.9 GHz - WAVE

DSRC is also used in the United States as a synonym for WAVE (Wireless Access in the Vehicular Environment - the 5.9 GHz IEEE standard, document number 1609).

Provision of external services to vehicles has previously been limited because of the lack of high-speed communications between vehicles and service providers, and homogeneous communications interfaces between automotive manufacturers. The IEEE 1609 Family of Standards for Wireless Access in Vehicular Environments (WAVE) addresses the latter issue, and provide a foundation for the former. They define an architecture and a set of services and interfaces that enable secure vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) wireless communications, permitting a range of applications in transportation, including vehicle safety, road tolling, navigation, and traffic management.

Existing active standards include:

- **1609.0-2013 IEEE Guide for Wireless Access in Vehicular Environments (WAVE) - Architecture ;**
- **1609.2-2013 IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages Active Standard;**
- **1609.3-2010 IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services;**
- **1609.3-2010/Cor 1-2012 IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Networking Services Corrigendum 1: Miscellaneous Corrections;**
- **1609.4-2010 IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Multi-channel Operation.**

For more details see **http://standards.ieee.org/develop/wg/1609_WG.html** and **http://www.standards.its.dot.gov/Factsheets/Factsheet/80#sthash.iRyF2xgA.dpuf**

2.2 Wide area communications

2.2.1 Broadcast communications

Traffic and Travel Information (TTI) services may be delivered by "1-to-1" (point-to-point) or "1-to-a few" channels (point-to-multipoint) such as provided by mobile phone networks, or they may be delivered by "1-to-many" channels using broadcast technology. The former has significant cost. Currently, FM-broadcast TTI data services are delivered using a narrow band channel which is part of the RDS (Radio Data System) . RDS-TMC (Radio Data System – Traffic Message Channel) services are delivered in a sub-carrier channel of fixed bandwidth that is added to existing FM transmissions with virtually no impact on the audio channel and with no specific need for regulatory intervention. Consequently TMC based services have spread worldwide where FM radio is available.

ERTICO and TISA (the Traveller Information Services Association) expect RDS-TMC services to continue for many years, but gradual transition to Transport Protocol Experts Group (TPEG) based services delivered via Digital Radio is likely, to deliver significantly more TTI content including safety information, multi-modal information (e.g. Public Transport) and on-trip enhancements such as traffic flow and prediction, fuel prices and Points-Of-Interest (POI) information.

TPEG based services are operational in the US, Western Europe and Australia, and are planned in China. Digital Radio is normally the TTI data delivery channel for TPEG based services. Its technical structure is significantly different from FM Radio; due to multiplexing of the audio and data services a more complex scheme is required to accommodate all services within a particular transmission area. In Europe, TPEG-based TTI services must be delivered via Digital Radio to meet the objectives of the European Commission's ITS Action Plan and Directive (section 1.4).

2.2.2 Cellular radio in ITS

Cellular radio in all its incarnations (2G (GSM, GPRS, EDGE), 3G (UMTS, HSPA, HSPA+), 4G (LTE) and in the not too distant future 5G) is an enabler of many new developments in ITS. Mobile Network Operators will play an important role in ITS in the future and are looking to ITS as an expanding market for their data services.

Almost half the world's population now uses mobile communications - 3.4 billion by the end of 2013, and expected to pass 4 billion in 2018, with strongest growth in Asia-Pacific. Developed markets' connection and subscriber growth is slowing – subscriber numbers will grow at just 1% p.a. between now and 2017 in Europe and North America due to market maturity. However, total connections will grow at 9% -10% p.a. due to strong Machine-to-Machine (M2M) connections growth - 1.2 billion connected devices by 2017 (GSMA 2013b). Much of this will be in the automotive and ITS sectors. The 2020 Addressable opportunity for MNOs in the automotive sector is forecast to be US$196Bn (GSMA 2014b).

Mobile data continues to drive rapid traffic growth for mobile operators with all regions showing impressive data volume growth rates as more people connect to the internet via mobile. In emerging markets, growth will be driven by the increased penetration of smartphones, while in developed markets it will be driven by both greater smartphone adoption and by increased download speeds made possible by new technology - two thirds of subscribers will be on 3G and 4G networks by 2020. Total traffic volumes in 2012 alone exceeded all the previous years combined and globally data is projected to grow by 66% p.a. through 2017 to 11.2 exabytes per month (GSMA 2013b, 2014b).

“Connected car” (section 3.2.1) penetration will increase globally from 11% in 2012 to 60% in 2017 (and to more than 80% in the United States and Western Europe). Mobile technology can revolutionise the way we use cars, saving lives, improving the driving experience through access to real-time information, allowing remote monitoring of performance and location for more effective preventative maintenance measures, delivery networks and public transport travel information (GSMA 2013b). Payment systems will be facilitated and part or even all of the driving task will be automated, as will be shown below (section 3.2.3).

The GSMA has set up the Automotive Special Interest Group (ASIG)to enable dialogue between mobile operators and vehicle manufacturers. By working together, manufacturers and mobile operators can share information, resolve barriers to connected car deployment and accelerate the adoption of telematics and infotainment services. The ASIG has set targets for connectivity solutions to be embedded in over 20% of global vehicle sales, and over 50% of cars to be connected, by 2015 – as outlined in the Mission Statement; it hopes to have every car multiply connected by 2025 (GSMA 2013b).

2.3 Smart phones

Although smartphones have a history going back to the mid-1990s with the Nokia 9000, they really took off in the mid-2000s with the Blackberry, the Apple iPhone and the Google Android operating system. They have continued to gain in computing power, connectivity (Wi-Fi and Near Field Communications (NFC) as well as cellular), screen size and resolution, and sensor facilities (cameras, GNSS positioning, motion-sensing) – and this trend seems set to continue for the foreseeable future.

By the end of 2013, there were 1.5 billion smartphones in use world-wide, of which half were in Asia Pacific. By 2017 there will be 3 billion, with 1.6 billion in Asia-Pacific, 500 million in the Americas, 400 million in Europe, and 300 million in Africa-Middle-East. Global smartphone penetration will rise from 19% in 2012 to 32% in 2017; in Sub-Saharan Africa it will grow from 4% to 20%, in Latin America, from 20% to 44%. Six in 10 global 4G-LTE connections will come from developing regions by 2020 (GSMA 2013b, 2014b, 2014c).

This ubiquity, power and versatility of smart-phones, as sensor platforms and as generators of useful data, is driving applications in commerce, financial services, infotainment and many other areas, including transport – as covered in later sections of this report.

2.4 Cloud-based computing

In Cloud-based computing, data, applications, services and infrastructure are provided in "the Cloud", hosted on remote infrastructure, available from anywhere. The advantages are:

- **Highly scalable implementation; the cloud operator can support sudden changes in computational requirements.**
- **The Cloud operator handles back-up and software upgrades, with resulting economies of scale.**
- **All users can access the latest data.**
- **Terminals & user devices can be of lower computing power.**
- **There is less need for specialist IT skills in the organisation, and no need to understand how the service is provided**
- **There is no need for large capital outlay; resources can be provided on a "pay as you go" basis.**

On the downside:

- **High capacity connectivity is essential - potentially an issue for mobile services.**
- **Performance may be inadequate; the server may be heavily loaded when the user's application needs to run, and may be slow.**
- **Failure of the Cloud operator's system could leave users with no back-up.**
- **Confidential information is held in the Cloud.**
- **Lack of open standards makes it difficult to transfer business between service providers.**

In the UK, cloud computing is being increasingly used by Local Authorities, including in transport applications. For example the "National traffic disruptions hub" in the UK has been cloud-based since 2003, evolving from a road-works database. The objective is to unite 175 Local Authorities on a common platform for road-works, incidents and other disruptions. Dynamic traffic management information is provided by 40 UK Local Authorities, and is linked to the UTMC (Urban Traffic Management and Control) systems to give a single integrated view of traffic management information. The data is widely disseminated, including to Google, Here (Nokia Navteq), and TomTom.

As pointed out by the GSMA (2013a), making use of cloud-based or managed smart city services, billed on a pay-as-you-go basis, is likely to be more cost-effective than deploying the city's own dedicated infrastructure.

A slightly different model is envisaged by the US Federal Highway Administration (FWHA), which in February 2015 issued a request for information for proposals to develop a cloud-based repository for its transportation datasets for use by commercial and other organisations. Companies will partner with FHWA, fund the transfer of data to the cloud and charge customers for access to the data - on roads, bridges, travel and transport generally – since it potentially has economic value. Currently only a small percentage of FHWA data is publicly available.

According to Market Research Media, the global cloud computing market will grow at 30% CAGR reaching $270 billion in 2020; one fast growing segment is the "mobile cloud".

3. Intelligent Mobility and C-ITS

The term "Intelligent Mobility" has gained currency, particularly amongst automobile manufacturers. It is not clear how it differs from ITS; perhaps ITS is perceived as technology-centric whereas IM is perceived as user-centred. The UK Automotive Council has used the term to describe the convergence between electronic communications technologies and transport systems, which previously have been developed in isolation, to create a safer, intelligent, highly interlinked transport network. The key to Intelligent Mobility is to connect a range of independent industries and technologies such as vehicle manufacturing, transport information systems, communications technologies, logistics and distribution and infrastructure management.

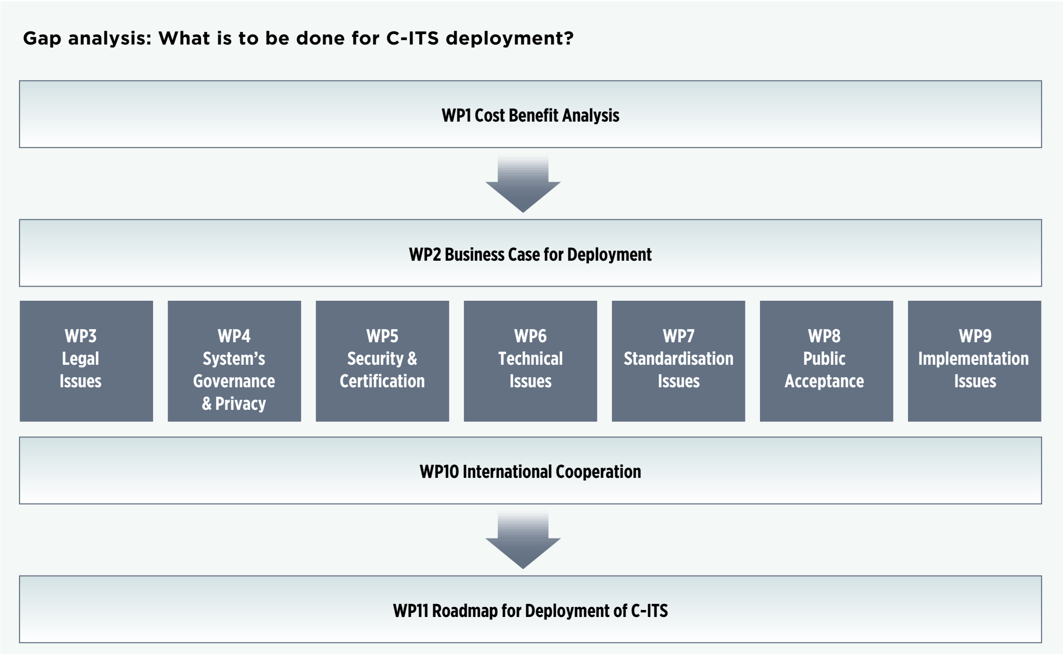
3.1 Cooperative ITS

The EC ITS Action Plan was addressed in section 1.4. Cooperative ITS (C-ITS) is another term which has gained currency; there are C-ITS programmes in Europe, the US, Japan and Australia. C-ITS includes technologies and applications that allow wireless data exchange within the transport system, between vehicles (V2V), and between vehicles and infrastructure (V2I), but also covers vulnerable road users such as pedestrians, cyclists and motorcyclists.

The European Commission has decided to take a more prominent role in the deployment of cooperative systems. To that end, DG MOVE (the Directorate General for Transport and Mobility) is setting up a C-ITS Deployment Platform, a cooperative framework including national authorities and other stakeholders, aiming to develop a roadmap and a deployment strategy for C-ITS in the EU and identify potential solutions to cross-cutting issues, by the end of 2015. In addition to DG MOVE, the Directorates General for Communication Networks Content and Technology (DG CNECT), for Research and Innovation (DG RTD), for Enterprise and Industry (DG ENTR) will also participate. A draft work programme "Gap Analysis: What is to be done for C-ITS Deployment" was developed during 2014, outlining barriers and enablers (EU 2014).

There are 200 million vehicles on European roads and some 13 million jobs in the automotive industry, so Europe would like to be in the lead in introducing new technologies. But connected cars need common technical specifications, including radio frequencies and message formats. Hence the Commission's formal request (Mandate 453, 2009) asking CEN and ETSI to prepare a coherent set of standards, specifications and guidelines to support implementation and deployment of C-ITS across Europe. It was confirmed at the 6th ETSI workshop on ITS in Berlin in February 2014 that these standards were in place. These 'Release 1 specifications' will enable vehicles made by different manufacturers to communicate with each other and with the road infrastructure. **http://release1.its-standards.eu/**

FIGURE 1: C-ITS GAP ANALYSIS



Source: European Commission document "Gap Analysis: What is to be done for C-ITS Deployment" (EU 2014).

3.2 The connected car and autonomous vehicles

These topics are driven from two sides. As conventional cellular data and especially voice traffic become saturated in developed countries, MNOs are increasingly turning to data including transport applications for new markets. Conversely, automotive companies and ITS industry are appreciating the benefits and the necessity of using mobile communications technology to improve both traffic control and the driving experience. They are also strongly influenced by consumer electronics; in January 2015 the keynote addresses at the Las Vegas Consumer Electronics Show were given by the Chairmen of Mercedes and Ford, and the show featured self-driving cars from Mercedes-Benz, Audi and BMW.

And it is noteworthy that in the US Department of Transportation (USDOT)'s "ITS Strategic Plan 2015-2019" the two primary strategic priorities are: "Realising Connected Vehicle (CV) Implementation and Advancing Automation" (USDoT 2014).

3.2.1 The connected car

Connected vehicles can communicate with each other and their surroundings. They are equipped with internet access, cellular radio, radar and other communication links including DSRC and an internal wireless local area network, allowing internet access to other devices both inside and outside the vehicle. Benefits to the driver include prevention or automatic notification of crashes, speeding and congestion. Increasingly, connected cars use smartphone apps to interact with the car from any distance. Users can unlock their cars, check the status of batteries on electric cars, find the location of the car, or remotely activate the climate control system.

As indicated earlier, the market size for the connected car is expected to increase dramatically. According to the GSMA (2013c) the global connected car market will be worth €39 billion in 2018, up from €13 billion in 2012. There will be a sevenfold increase in the number of new cars equipped with factory-fitted mobile connectivity to meet demand among regulators and consumers for safety and security features, as well as infotainment and navigation. This rapid growth will be driven in part by positive regulatory action in Europe, Russia and Brazil.

Connected vehicle technology includes the following:

- **Fleet telematics allows emergency services and commercial fleet operators to increase utilisation factors for their vehicles, improve driving standards and fuel efficiency, reducing emissions and vehicle wear.**
- **Links to infrastructure systems which manage traffic flows on roads, including Urban Traffic Management & Control, roadside Variable Message Signs to inform drivers of reduced speed limits, traffic jams and other safety messages.**
- **Communication with public transport measures including selective vehicle detection, traffic light control and real time passenger information.**
- **Vehicle to Vehicle systems (V2V), where vehicles interact with each other using wireless networks, sending information about weather, speed, location, direction of travel, braking, and loss of stability, typically using Dedicated Short-Range Communications (DSRC) at 5.8 or 5.9 GHz, and/or a mesh radio network.**
- **Vehicle to Infrastructure systems (V2I) allow wider area dissemination of traffic and safety information, as well as vehicle tracking and recovery, emergency call (e-Call), the set-up of WiFi and 3G hot-spots, reservation of and guidance to parking spaces.**

Telefónica has an agreement with Tesla to supply connectivity for its in-car infotainment system and remote vehicle diagnostics, in Germany, the UK and Spain.
http://www.gsma.com/connectedliving/telefonica-tesla-agreement/

3.2.2 Driver support and Intelligent Speed Adaptation (ISA)

This includes:

- **ADAS (Advanced Driver Assistance Systems), including collision avoidance which support the driving task by reducing work-load and raising awareness of risk. It can be autonomous (contained within the vehicle) or cooperative by interfacing to other vehicles and to infrastructure.**
- **Autonomous Cruise Control (ACC)**
- **Crash avoidance and Black Box recorders**
- **Intelligent Speed Adaptation (ISA) – advice on or control of vehicle speed and driver advisories. There has been much research on ISA, especially in Sweden, Australia and the UK, including a large-scale trial in London, but the transition to wide commercial use still hasn't happened. It may come about through the widespread availability of smartphones, coupled with the increasing interest in Usage-based Insurance (UBI). Also it is being subsumed into and replaced by the connected car and "autonomous vehicles".**

3.2.3 Autonomous vehicles and self-driving cars

Self-driving cars are one of the hottest of current hot topics. Research has been carried out in the US, Western Europe and Asia-Pacific for decades, but the topic has now entered the public and political consciousness – largely due to the Google self-driving car.

Autonomous vehicles sense their surroundings using radar, LIDAR (Light Detection And Ranging – like radar but using light instead of microwaves), GPS, and computer vision, and can navigate without human input. Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage. Autonomous vehicles can update their maps based on sensory input, allowing the vehicles to keep track of their position even when conditions change.

3.2.3.1Brief history of autonomous vehicles

Although self-driving cars have been the subject of research since the 1960s, for example at the UK Transport Research Laboratory (TRL), the first prototype autonomous cars appeared in the 1980s, including Carnegie Mellon University's Navlab and ALV (Autonomous Land Vehicle) projects and the European Prometheus Project. Since then, numerous organisations have developed vehicles, including Mercedes-Benz, General Motors, Continental Automotive Systems, Autoliv Inc., Bosch, BMW, Nissan, Toyota, Audi, Volvo, Vislab from University of Parma, Oxford University and Google. In July 2013, Vislab demonstrated BRAiVE (BRAin-drIVE), a vehicle that moved autonomously on a mixed traffic route open to public traffic. Four U.S. states have passed laws permitting autonomous cars: Nevada, Florida, California, and Michigan. In Europe, cities in Belgium, France, Italy and the UK are planning to operate transport systems for driverless cars, and Germany, the Netherlands, and Spain have allowed testing of robotic cars in traffic.

3.2.3.2 Autonomous vehicles in 2015

Autonomous vehicles exist mainly as prototypes and demonstration systems. However, as of early 2015, the only self-driving vehicles that are commercially available are open-air slow-speed shuttles for pedestrian zones, though many countries are gearing up to run trials and to amend legislation to permit driverless cars on their roads, and several developments were publicised in late 2014 and January 2015:

- **China held its sixth driverless car competition, "Future Challenge 2014" in Changsu, in the eastern province of Jiangsu. In a two-day competition teams from 14 universities entered 20 self-driving vehicles, which drove on highways and suburban roads plus an urban stage. The cars were assessed on safety, intelligence, smoothness and speed.**
- **The Dutch Government announced that the Netherlands would become a testing ground for self-driving vehicles. It approved a legislative amendment to enable large-scale tests of self-driving cars and trucks on public roads. The expectation is that communicating vehicles can improve the flow of traffic, increase traffic safety and be more economical and environmentally friendly.**
- **The Government of the State of South Australia plans to update its road laws to permit driverless cars. Its Motor Vehicles Act dates from 1959 and its Road Traffic Act from 1961 The Government plans to reform both Acts and also legislate for driverless vehicles.**
- **The Japanese Nissan Motor Co. and the US's Nasa's Ames Research Center in California announced a five-year R&D partnership for autonomous vehicle systems, to be applied ultimately to private cars.**
- **Innovate UK, on behalf of the UK Government's Departments of Transport and Business, announced the funding of three "Driverless car" consortia, testing such vehicles in the Bristol area, Greenwich in London and Coventry/Milton Keynes in the English Midlands.**
- **Apple is said to have set up a secret lab in 2014 to develop an autonomous electric car; Apple has apparently recruited the former head of the Mercedes-Benz Californian R&D facility. But others say that Apple's interest is really in bringing iPhone functionality into all cars – see section 5.1.**

The promised benefits of autonomous road vehicles (reductions in road accidents, congestion, fuel consumption and journey times) will require not only the development of new technologies, but also changes in social attitudes, regulation, ownership and business models. And there is currently little evidence to support the claims that autonomous vehicles will reduce congestion and increase safety. Even if driver error is the main cause of accidents, it doesn't follow that autonomous vehicles will eliminate accidents – they may have their own, different, failure modes. See for example Siviak & Schoettle (2015).

3.2.4 NHTSA five levels of vehicle automation

The US National Highway Traffic Safety Administration (NHTSA) defines vehicle automation as having five levels:

- **No-Automation (Level 0): The driver is in complete and sole control of brake, steering, throttle, and motive power at all times.**
- **Function-specific Automation (Level 1): Automation of one or more specific control functions, such as electronic stability control or pre-charged brakes; the vehicle automatically assists with braking, enabling the driver to regain control of the vehicle or stop faster.**
- **Combined Function Automation (Level 2): Automation of at least two primary control functions designed to work in unison to relieve the driver of control of them; for example, adaptive cruise control combined with lane centering.**
- **Limited Self-Driving Automation (Level 3): At this level the driver can give up control of all safety-critical functions under certain traffic or environmental conditions and rely on the vehicle to monitor changes in those conditions requiring return to driver control. The driver needs to be available for occasional control, but with a comfortable transition time. The Google car is an example of limited self-driving automation.**
- **Full Self-Driving Automation (Level 4): The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. The driver will provide destination or navigation input, but need not be available for control during the trip. The vehicle may be occupied or unoccupied.**

4. Enforcement and security

4.1 Enforcement

"Enforcement" covers topics such as detection of toll evaders, bus lane and red light running, speed cameras, crime detection and security. A related topic is "vehicle classification systems" (because tolls may be dependent on vehicle size and other characteristics). One hot topic is "average speed zones", where speed limits are enforced by cameras in a road corridor or area, rather than at a single point, with proven safety benefits. By definition, such zones need communications between cameras, or to a control centre, in contrast to the "Gatso" spot-speed cameras.

4.1.1 European Cross-border enforcement

In January 2015, The European Parliament approved a new directive for tracking traffic offences committed by drivers from other EU member states – something that has been a problem for many years. A new directive was needed because the European Court of Justice annulled the previous directive because of an incorrect legal basis. The old directive will remain in place until 6 May 2015, when the new one will come into operation. Member states will be allowed access to each other's national vehicle registration data in order to identify persons liable for safety related offences such as speeding, not using a seatbelt, failing to stop at red lights, driving under the influence of drink or drugs, not wearing a safety helmet, using a forbidden lane, and illegally using a mobile phone, or any other communications device, while driving. The new directive applies to all 28 member states.
http://www.erticonetwork.com/index.php?option=com_easyblog&view=entry&id=3296

4.1.2 Enforcement technology

Technologies involved include Automatic Number-Plate/License Plate Recognition (ANPR/ALPR), which is used to recognise and identify vehicles. There are many suppliers of this technology, which is a very computing and electronics-intensive topic – and is being increasingly used in the US in "video tolling" – see section 6.

4.2 Networking & security in vehicles

An important topic in many areas, not just in transport. Homeland Security continues to be of importance in ITS, especially in the US but also more widely. The UK and the US have just entered into a joint agreement to collaborate on this topic. There are concerns about protecting infrastructure, and about the susceptibility of autonomous and connected vehicles to hacking and cyber terrorism. Chinese students recently hacked a Tesla electric car and opened its doors while it was on the road; US researchers have demonstrated a cyber attack on Toyota Prius and Ford Escape vehicles which could affect steering and braking; but these incidents were in research and test environments; no such attacks have been reported in the "real world" – as yet.

Nonetheless, viruses or malware carried in smart-phones or music-players or USB sticks can infect automotive electronics; defence and mitigation mechanisms need to be designed and there is considerable activity in this area worldwide – to which MNOs can contribute because of their expertise in authentication and security.

A modern vehicle may contain over 100 electronic control units (ECUs) and 10 million lines of software. Vehicles are relatively vulnerable to cyber attacks (Onishi 2014) because of their:

- **Limited vehicle external connectivity, making it difficult to update security software and to monitor the status of automotive electronics;**
- **Limited computational capability, due to long vehicle life-cycle;**
- **Real-time operation;**
- **Components from different suppliers;**
- **Unpredictable attack scenario and threats;**
- **Potential hazard to life and limb of drivers and passengers.**

There are many potentially hackable features on new cars, including self-parking, active lane and cruise control, collision avoidance, antitheft systems and remote keyless entry; but Bluetooth and telematics systems with cellular or Wi-Fi capabilities, significantly increase vulnerability.

Concerns about these issues have reached the highest levels, including the World Economic Forum. Its Global Risks 2015 report identified the increasing potential for digital attacks on cars. In the United States a report written by the staff of Senator Edward J. Markey, a member of the Commerce, Science and Transportation Committee , was released in early 2015 (Markey2015). Entitled "Tracking & Hacking: Security & Privacy Gaps Put American Drivers at Risk", it claims that wireless technologies make vehicles vulnerable to hackers, that driver privacy can be compromised, and that new security and privacy standards are needed. The study is based on questionnaire replies from sixteen major automobile manufacturers. The main findings are:

1. **Almost all cars on the market use wireless technologies that potentially allow hacking or privacy intrusions.**
2. **Most automobile manufacturers were apparently unaware of or unable to report on past hacking incidents.**
3. **Security measures to prevent remote access to vehicle electronics are inconsistent and haphazard across automobile manufacturers; many manufacturers did not seem to understand the questions posed.**
4. **Only two automobile manufacturers seemed to have any capabilities to diagnose or defend against an attack in real-time; most relied on inadequate technologies.**
5. **Automobile manufacturers collect large amounts of data on driving history and vehicle performance.**
6. **Most automobile manufacturers use technologies that collect and wirelessly transmit driving history data to data centers, the data does not seem to be well secured.**
7. **Manufacturers use personal vehicle data in various ways; their retention policies –vary considerably.**
8. **Customers may not be aware of this data collection and may not be able to opt out without disabling valuable features, such as navigation.**

In November 2014 the automobile manufacturers agreed to a voluntary set of privacy principles to address some of these concerns - an important first step, according to Senator Markey, but they fall short by not offering explicit assurances of choice and transparency.

However, these concerns are not being ignored. The US NHTSA has set up a new division to focus on automotive cybersecurity, especially in relation to automated vehicles. Elsewhere guidelines have been issued or are under development, including:

- **Europe: EVITA (E-safety vehicle intrusion protected applications) guidelines http://www.evita-project.org/ ;**
- **Japan: IPA(Information Promotion Agency) guidelines "Information Security for Networked Vehicles", http://www.ipa.go.jp/files/000033402.pdf ;**
- **United States: SAE guidelines J3061 "Cyber security Guidebook for Cyber-Physical Automotive Systems" under development. http://www.sae.org/servlets/works/documentHome.do?comtID=TEVEES18&docID=J3061&inputPage=dOcDeTallS**

There have also been initiatives in the private sector.

- **Hyundai has created its own "cloud" to provide enhanced security for its Blue Link infotainment system. The details of this cloud are kept secret, and all information from other clouds must get through Hyundai before being transmitted to the vehicle.**
- **In the UK, cyber security group NCC (www.nccgroup.com/) have set up a strategic partnership with automotive technology expert SBD, to address automotive cyber security. Similar alliances are likely elsewhere.**
- **The first annual Embedded Security in Cars (ESCAR) Conference was held in 2003 in Cologne. It has since been held annually in Germany, and since 2013 in the US and since 2014 in Asia.**

Security approaches that could be adopted, as advocated by a group of ethical hackers, include mandatory design processes and testing of automotive digital systems, third-party collaboration and a disclosure program so researchers can safely divulge vulnerabilities in vehicle software, a black box recorder in every vehicle to log data, prompt and secure software updates, and segmentation and separation of the different functions inside a vehicle's internal networks. **https://www.iamthecavalry.org/domains/automotive/5star/**

In addition, there are potential safety and security issues due to interference with the GNSS signals, such as spoofing or jamming – instances of this certainly are known in the real world.

4.2.1 BMW ConnectedDrive

In January 2015 BMW announced that it had fixed a security flaw potentially affecting 2.2 million Rolls-Royce, Mini and BMW vehicles. The problem was identified by the German motoring organisation ADAC (Allgemeine Deutsche Automobil Club). It affected cars equipped with the ConnectedDrive software using on-board SIM cards, which enables remote door locking, real-time traffic information, online entertainment and air conditioning. Researchers simulated a fake phone network, allowing them to manipulate functions activated by the SIM card. BMW fixed the problem by encrypting communications using the HTTPS (Hypertext Transfer Protocol Secure) Internet standard, and by updating the ConnectedDrive software automatically over the air.

The security flaw didn't seem to have been exploited in the real world, and it didn't affect driving, steering or braking.

4.2.2 Telematics dongles

Dongles connected to a vehicle's OBD2 port are used to monitor driving behavior for insurance and fleet management purposes (section 5.1). It was claimed by a security researcher that a dongle provided by a large US insurance company, Progressive, was insecure, potentially allowing a hacker to take control of the vehicle. The researcher extracted the dongle firmware, reverse engineered it, and found that it was insecure in various ways, including no validation or signing of firmware updates, no cellular authentication, and no secure communications or encryption – though it was noted that for a remote attack to succeed, the modem connecting Progressive's servers to the dongle would also have to be compromised.
http://www.forbes.com/sites/thomasbrewster/2015/01/15/researcher-says-progressive-insurance-dongle-totally-insecure/

A similar case is Zubie, a dongle which tracks cars' performance and location to encourage more efficient and responsible driving. The Zubie dongle also plugs into the OBD2 port, to communicate with the vehicle's internal network, using a GPRS modem to connect and send information to the Zubie cloud, which passes it to iOS or Android apps. Again the device did not use encrypted communications or signed updates. But with help from the security firm which uncovered the flaws, the Zubie device is now secure.
http://www.forbes.com/sites/thomasbrewster/2014/11/07/car-safety-tool-could-have-given-hackers-control-of-your-vehicle/

As alluded to above, MNOs and the GSMA are well-placed to contribute to automotive cyber security, and need to get involved in order to safeguard their role in the expanding market in connected and autonomous vehicles. The eUICC (section 9.3) is a step in the right direction.

5. Fleet Management, PayAsYouDrive Insurance & Parking

As indicated in section 1.1.2, the term "telematics" can refer to fleet management, and to Pay As You Drive Insurance (PAYDI).

5.1 Fleet management

Fleet management refers to haulage companies, car hire organisations, emergency services, breakdown/rescue services and others managing their vehicle fleets, including optimal routing, monitoring of vehicle health and driving style. It has been used for 40 years, though in the past it may have necessitated an organisation having its own mobile radio network. But the availability of ubiquitous and affordable mobile communications, satellite location systems, the significantly reduced cost of in-vehicle equipment, and the wish to maximise productivity and customer service while minimising environmental pollution, means that it is an expanding marketplace, with increasing opportunities for MNOs.

Most freight traffic travels by road rather than by rail – typically 85% according to official statistics, which are usually based on tonne-kilometres – but in terms of value the road freight proportion tends to be higher since much rail freight is low value bulk material. Hence road freight is vital to national economies – it has been estimated that 15% of the cost of everything we buy is a transport cost.

Berg Insight has recently published a number of studies into fleet management in Europe (Berg Insight 2014a), in Russia/CIS[5] and Eastern Europe, (Berg Insight 2014b), and in China (Berg Insight 2015).

5.1.1 Fleet management in Europe

According to official European statistics there were over 36 million commercial vehicles in what Berg Insight refers to as "EU23 +2"[6] in 2011. The 5.9 million medium/heavy trucks accounted for more than 75% of all inland transports, worth €250 billion. There were 0.8 million buses and 29.5 million light commercial vehicles, the latter mainly used by mobile workers and for parcel distribution.

Berg Insight believes that the European fleet management market will have an average annual growth rate of 14.2% from 3.65 million units at the end of 2013 to 7.10 million by 2018. Penetration in non-privately owned commercial vehicles will increase from 12.4% in 2013 to 22.9% in 2018. There are a number of international aftermarket solution providers, including Masternaut, TomTom Telematics, Transics, and other European and international companies; the field has seen numerous mergers and acquisitions. All major truck manufacturers supplying the European market offer OEM telematics solutions. The trend is to standard fitment of fleet management solutions, often bundled with a service subscription. In most cases mobile 2G/3G networks are used, though satellite communication and other networks are also found. The key technical parameters of area coverage, network latency and data bandwidth are all covered adequately by GPRS; 3G and 4G technologies will bring improved uplink speeds and latency, improving the end-user experience.

5. CIS is Commonwealth of Independent States - former Soviet Republics including Russia.

6. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, the United Kingdom, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia plus Norway, and Switzerland.

5.1.2 Fleet Management in Russia/CIS and Eastern Europe

The Berg Insight report covers 30 Eurasian countries: the CIS plus Eastern European countries, eleven of which are now part of the European Union. As in Western Europe, commercial vehicle fleets play a crucial economic role in the CIS and Eastern Europe, including in important pan-European transport corridors. There are 10 million HGVs in the region, accounting for 70% of inland transport in Russia. Again, most of the 14 million light commercial vehicles are used by mobile workers and for distribution of goods and parcels.

Berg Insight forecasts a growing fleet management market, driven by cost savings, regulatory developments such as ERA-GLONASS (the Russian equivalent of eCall) and the Russian tachograph mandate. Fleet management systems will grow at 15.7% per year, from 2.9 million units in 2013 to 5.9 million by 2018. Penetration within non-privately owned vehicles will increase from 12.1% in 2013 to 21.7% in 2018. The Russian market alone will grow from 1.3 million units in 2013 to 2.6 million by 2018.

Belarus-based Gurtam is the leading fleet management software provider active in most of the region, covering more than 300,000 commercial vehicles, followed by the Russian ENDS, NIS and TechnoKom groups, and Arvento Mobile Systems from Turkey. The European and CIS fleet management markets are expected to converge in terms of system functionality and service models. Cloud services are being adopted, as is factory-fitment of OEM truck telematics. Again, most fleet management systems use the 2G/3G/GPRS wireless networks, though coverage is not available in some remote parts, so satellite communication is used but has long latency and limited bandwidth.

5.1.3 Fleet Management in China

As in Europe and the CIS, commercial vehicle fleets are essential to the Chinese economy and its future development. Road transport represents 75% of the freight total by weight - around 31 billion tonnes in 2013. There were almost 17.9 million vehicles in 2011, plus 2.5 million buses. Berg Insight expects steep growth in the Chinese market, and renewal of the vehicle fleet to combat pollution. Fleet management systems will grow at 22.9% annually, from 2.1 million units in 2014 to 5.9 million by 2019. Penetration will increase from 9.0% 2014 to 19.8% in 2019. Track & trace systems dominate the market and the installed base includes low-end systems with limited functionality. Once again, most fleet management systems use the 2G/3G/GPRS wireless networks, with satellite communication in unpopulated areas. The major fleet management suppliers are Chinese, including E6GPS and Etrans. Some Chinese commercial vehicle OEMs have introduced telematics systems, notably Foton and Shaanxi Automobile Group. Automotive suppliers are expected to equip new commercial vehicles with telematics systems following government initiatives.

With the predominance of GSM/GPRS communications only set to increase with the move towards 3G and 4G, and the consequent improved service to end-users, MNOs can expect to see increasing revenues from the fleet management market.

5.2 PAYDI & UBI

Pay As You Drive Insurance (PAYDI), also known as Usage-Based Insurance (UBI) is a hot topic, with increased interest in the US and Europe as insurance companies seek to reduce costs and to acquire more sophisticated tools to categorise drivers, especially with developments such as the EC ban on charging by the sex of the driver. Studies have shown there are dramatic variations in accident rates among drivers:

- **A study in the US state of Virgina found that the 12.5% most dangerous drivers had over 100 times the crash risk of the 12.5% safest drivers.**
- **An Israeli study found that aggressive drivers were responsible for 17 times the crash costs of the safest drivers.**
- **A Swedish test of incentives to reduce speeding led to a decline in its frequency from 15% to 8% of driving time.**

Although the percentage of UBI policies is still small (8% in the US in mid-2014), it has doubled since early 2013. Drivers' privacy concerns have also declined, from 42% to 35%, at least according to some reports, though others dispute this. Certainly there are concerns about the "dongles" used in these applications, and the extent to which they may compromise security and privacy (section 4.2). Dongles usually plug into the OBD port on a vehicle, and typically contain a processor and memory, a GPS receiver to determine location, an accelerometer to identify periods of harsh acceleration and braking, and a SIM card to relay data back to a control centre via a GPRS link. Thus dongles can provide valuable information to insurance companies and fleet managers, including:

- **Start and stop times and locations**
- **Idling time**
- **Journey duration**
- **Roads used and mileage covered**
- **Use of seatbelt**
- **Use of accelerator and brakes**
- **Time, direction and severity of impact**
- **Driver and number of passengers, if camera is installed in vehicle**

It appears that 80% of smartphone owners are willing to download apps to their phones that would track their driving. In the US in 2014 the Allstate insurance company began testing a smartphone app called Drivewise Mobile, which is available in 19 states and Washington, D.C. The UK Automobile Association also has a free-to-download usage-based insurance app for smartphone users. This is important because dongles are relatively expensive. The Progressive insurance company, based in Ohio, announced that it was comparing results of the mobile app with data from its "Snapshot" device in the same car.

Android and iPhone smartphone apps can cut up-front costs, tracking driver habits such as mileage and braking in exchange for reduced policy costs. Google and Apple also have other advantages, including being accepted as big data collectors. Apple's "CarPlay" allows iPhone users to make calls, use Apple Maps, listen to music and access messages by touch or voice commands. The iPhone is connected to the car through a cable, and CarPlay can then be controlled from the car's built-in display or by using Siri, Apple's iOS voice system. Google has introduced the similar Android Auto. Vehicle manufacturers including Audi, Honda, Nissan, Subaru, Jeep, Dodge, Chrysler, Chevrolet, Mazda and Volvo have said they will support both CarPlay and Android Auto.

In early 2015 AT&T and LoJack Corporation, a leader in vehicle theft recovery and advanced fleet management solutions, announced a collaboration to power LoJack's current and future telematics solutions. Both companies are committed to providing machine-to-machine and telematics solutions to the automotive and fleet industries, giving better operational efficiency, improved customer service and increased profitability.

In June 2012 Verizon Communications Inc. bought Hughes Telematics for $612 million, thereby moving into the automotive-technology market. Hughes is involved in GPS tracking, communications and safety features in cars, and M2M applications.

Thus telematics and UBI are new sources of growth as the mobile phone voice market saturates.

5.3 Parking

5.3.1 Parking objectives, principles and practice

Studies have shown that a large percentage of urban traffic (from 8% to 74% at different times and places) may be drivers cruising around looking for a parking space. Facilitating their task – and tailoring the parking charge appropriately, will help to minimise congestion and pollution. The price should be set so that one or two curb spaces are usually vacant on every block so that drivers can always find convenient parking, but with 85% of spaces occupied all the time. Prices can be variable, with new rates sent wirelessly to meters. Public acceptability is increased if the revenue is spent on local infrastructure (Shoup 2011).

5.3.2 New York City

Following this principle, New York City Department of Transportation (NYC DOT) implemented three “Park Smart” parking pricing pilots, and subsequently expanded and made permanent two of them. In Park Slope, peak hour parking was $2.00/hour, and $1.00/hour off-peak. In Greenwich Village, charges were $5.00/hour (peak) and $3.00/hour off-peak. It was found that 18% more vehicles were able to find legal metered spaces compared to the previous year, and traffic volumes declined by 7 % because drivers spent less time circling. These schemes are being extended to other areas and augmented by making real-time parking information available via smartphone and the Internet. Similar initiatives were carried out in Seattle and San Francisco, including “pay by phone”.

In December 2014 NYC requested proposals to develop a cell phone payment option to speed up collection of fines for parking and traffic camera violations. The city issues up to 10 million parking tickets annually, generating $600 million a year in penalties. It thinks that that emerging technologies may provide a convenient way for motorists to pay their parking tickets using a mobile device.

According to Cisco (2013), the field of “smart parking” is valued at $41 billion worldwide.

5.3.3 Westminster, London

In 2013/14 Westminster City Council installed more than 3,000 parking bay sensors which detect whether a bay is vacant; drivers can use a smartphone app to view a real-time map of parking spaces, updated every minute, showing where there are empty bays, and directing to the nearest one. This award-winning “ParkRight” app will reduce the time spent driving around looking for a parking space and the congestion on Westminster’s roads. The scheme is attracting world-wide attention. Installation of a further 7000 sensors will be considered in 2015. The number of PaybyPhone (PbP) transactions increased by 4.7% in 2013/14, to 669,343, whereas the number of transactions for card-only Pay and Display parking remained constant (Westminster (2014).

FIGURE 2: WESTMINSTER PARKRIGHT PARKING APP

Source: Westminster City Council.

5.3.4 Other parking schemes and apps

An advanced parking technology system was installed in Barcelona in 2013 by Streetline and Cisco, as part of the Internet of Things World Forum held in the city. Similar to the Westminster scheme, wireless sensor technology embedded in the parking bays indicates occupancy, parking patterns and trends, not only helping motorists to find parking, but also facilitating management of parking in the city. Barcelona has seen a $50 million annual increase in parking-fee revenues due to use of smart parking technology.

The city of San Antonio, Texas, recently partnered with Pango, a company whose app shows available parking spots. Pango accesses data from parking pay stations and uses information on past parking trends to inform app users through maps with streets and parking lots highlighted green, yellow or red to denote where parking is available, nearing capacity or full. The app also shows how much parking will cost. Though not currently used in San Antonio, the app can be used to pay for a parking space in advance or refill the meter. Before the parking time expires, a warning text message is sent so drivers can get back to their vehicle or extend the parking time. Pango Mobile Parking is in use in Israel, the Czech Republic, Germany, Greece and Poland, with more than 1,300,000 Pay-by-Phone transactions per month and 700,000 customers. See **www.mypango.com** . While Pango and other parking apps such as ParkMe focus on on-street parking, a third app, SpotHero, addresses off-street parking.

A number of MNOs and cities are using or trialling SMS to pay parking charges, including Telstra in Sydney and Melbourne, Lithuanian operators Omnitel, and Bite GSM in Vilnius and Kaunas, Sonera in Helsinki, Eircell Vodafone in Dublin, Etisalat in the cities of Abu Dhabi, Dubai and Sharjah in the United Arab Emirates.

6. Road Pricing

Road Pricing incorporates Tolling, Road User Charging, Congestion Charging, Electronic Fee Collection (the EC term) and Value Pricing (in the US). This is an important topic in the ITS area – though commercially progress has been slow, except in certain sectors.

According to Sir Rod Eddington's transport report for the British Government, 'the potential for benefits from a well-designed, large-scale road pricing scheme is unrivalled by any other intervention' (Eddington, 2006). This view was endorsed by the UK Department for Transport in 'Towards a Sustainable Transport System' (DfT, 2007a), where it states: 'The Government accepts the Eddington analysis regarding the exceptional case for exploring the potential of road pricing'.

Although road pricing can benefit the environment as well as reducing road traffic congestion, thereby benefiting the economy, governments worldwide have not implemented it on a large scale, because it is seen as a vote-loser. However, there is evidence that road pricing is acceptable to the public, under certain conditions, as follows:

- **it is equitable;**
- **it is revenue-neutral (i.e. other taxes are reduced by the same amount) or that revenues are reinvested in transport;**
- **it does not have a high cost overhead – people don't like the idea of scheme operators lining their pockets at the public's expense;**
- **people who are likely to be affected have experience that road pricing works;**
- **people are given a choice of the charging mechanism – see the Oregon trials below (section 6.2.2.1).**

Some aspects of road pricing are surprising or counter-intuitive.

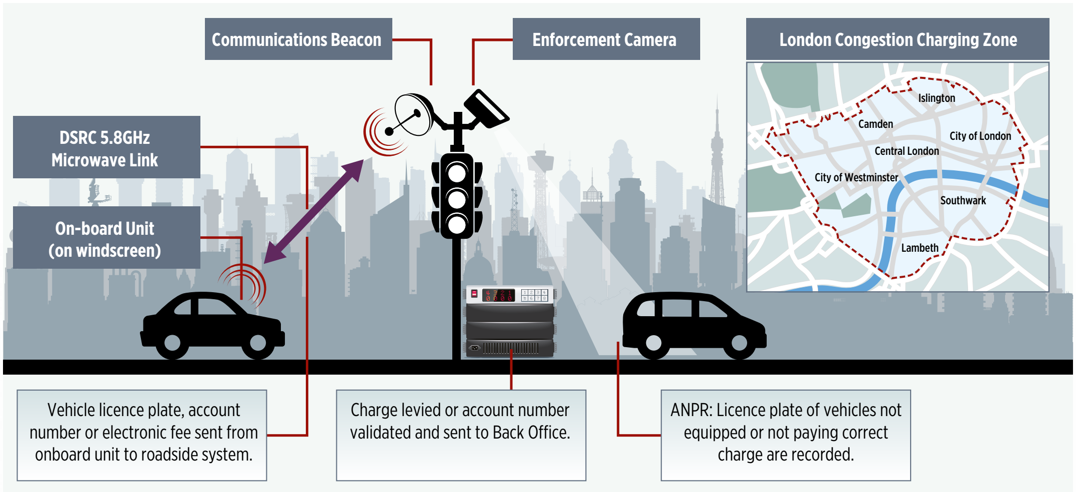
- **People voted for the introduction of road pricing in Stockholm.**
- **Ken Livingstone was elected as Mayor of London on a manifesto which included the introduction of congestion charging.**
- **Significant traffic reductions can be achieved with minimal charges. In Stockholm, charges of Swedish Kronor (SEK) 10, 15 or 20 (1-2€) reduced traffic more than 20%.**
- **There is no traffic diversion onto other routes.**

6.1 Technology of road pricing

6.1.1 Microwave tag-and-beacon

Microwave tag-and-beacon (also known as Dedicated Short-Range Communications or DSRC) operates as illustrated in Figure 3, where a vehicle equipped with a battery-powered on-Board Unit (OBU) communicates with a transponder on an overhead or roadside gantry to register its passage through the charge point. (Note that 5.8GHz is the European standard frequency, but other frequency bands are used in for example Singapore (section 6.3.1) and the United States). Unequipped users would have their number plate recorded by a camera and identified via Automatic Number Plate Recognition (ANPR) (aka Automatic License Plate Recognition - ALPR) either at the roadside or at a remote back office. The microwave technology is virtually 100% efficient in detecting equipped vehicles.

FIGURE 3: MICROWAVE TAG-AND-BEACON CHARGING TECHNOLOGY WITH CAMERA ENFORCEMENT



Source: Transport Operations Group at Newcastle University

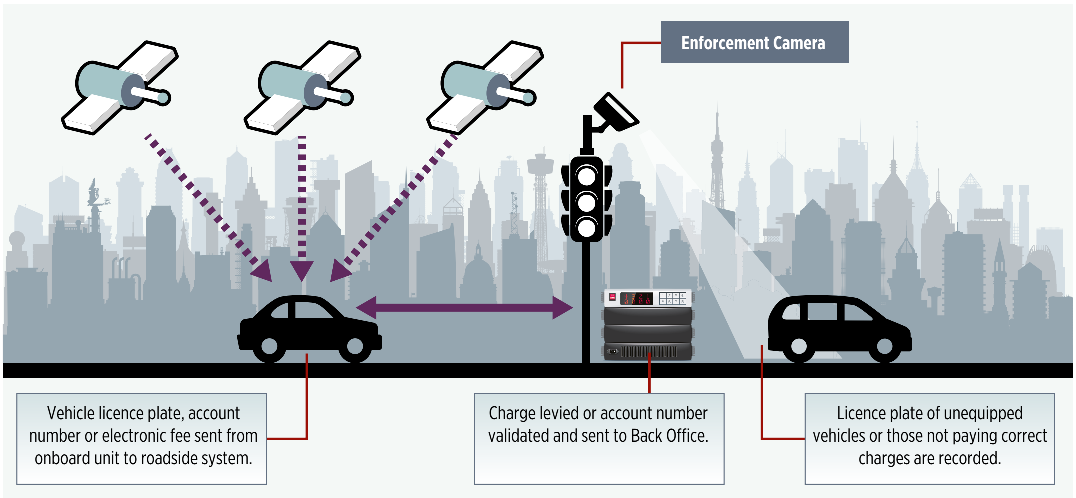
In some cases, for example London and Stockholm, only the ANPR system is used; it is somewhat less efficient at detecting vehicles but has the advantage that no additional in-vehicle equipment is needed. It is also being increasingly used in the United States, where it is known as “video tolling”, as one way of getting round the problem of incompatible regional microwave systems.

6.1.2 Satellite-based charging

An alternative scheme which dispenses with DRSC beacons is shown in Figure 4. A GPS receiver in the vehicle, combined with a digital map of the road network, enables the vehicle to calculate which road it is on – exactly like a satnav. If a charge applies to that road at that time of day, it can be calculated either in the vehicle or sent via a mobile radio link to the back office, which calculates the charge – the so-called 'Thick Client' (aka 'Intelligent Client') or 'Thin Client' approaches respectively. There are pros and cons to each approach. The Thick Client needs a more powerful OBU containing a digital map, which needs to be kept up to date, as does the road tariff data; but privacy of the vehicle's location is easier to maintain. The Thin Client is a much simpler, cheaper unit, and only the digital road map and tariff data in the back office need to be updated; but maintaining privacy is more complicated – though it can be done.

Smartphones are also starting to be used as on-board units – for example in the Oregon trials – section 6.2.2.1.

FIGURE 4: SATELLITE-BASED CHARGING TECHNOLOGY



Source: Transport Operations Group at Newcastle University

Although GPS technology on its own may not be able to accurately identify which of two adjacent roads a vehicle is on, the use of 'map-matching' (i.e. comparing a series of locations with the digital map) significantly improves the accuracy. The availability of other GNSS (Global Navigation Satellite Systems) such as the Russian Glonass, the European Galileo and the Chinese Beidou, as well as upgrades to GPS, will further increase the reliability and accuracy of this charging technology. Augmentation technologies such as heading sensors can also improve positioning accuracy, although they may increase the complexity and cost of the OBU. There may be a role for smartphones in this respect.

6.1.2.1 Time-Distance-Place (TDP) based charging

The most recent and most sophisticated variant of road pricing is 'Time-Distance-Place' (TDP) based charging, where charges are related to distance travelled, to time of day and to location, so that charges are higher at certain times of day (e.g. peak traffic hours) and in certain places (e.g. town centres). *Satellite-based technology with mobile communications is currently the only realistic way to achieve true Time-Distance-Place (TDP) charging – an opportunity for MNOs.*

6.2 Road tolling

6.2.1 Road tolling in Europe

The only city-tolling/congestion charging schemes currently in operation are Singapore, London, Stockholm, Gothenburg and the Norwegian toll rings, all of which use ANPR, microwave tags or a combination of both – though a number of other cities, including Beijing, Hong Kong, Jakarta, Tehran and New York are actively considering it.

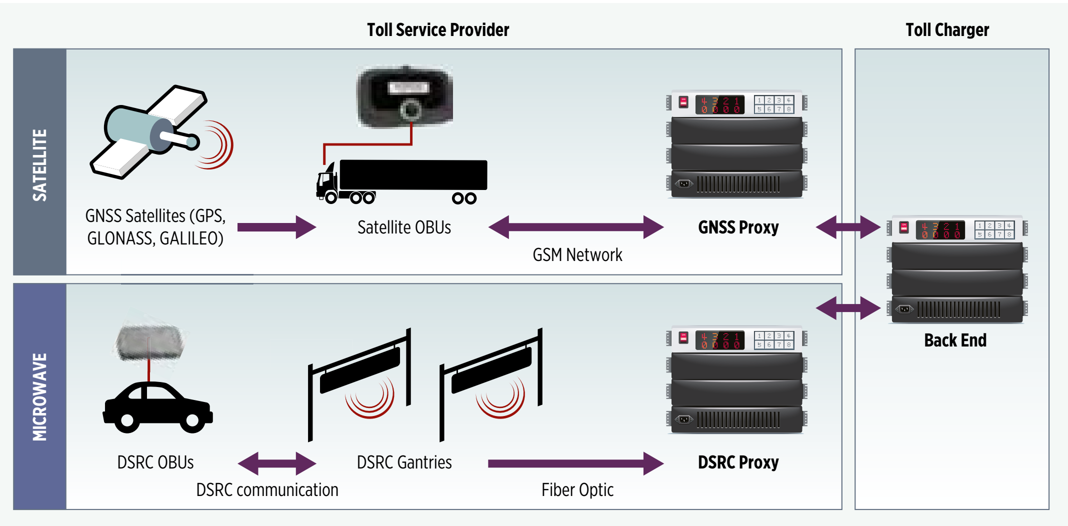
There are many truck-tolling schemes implemented or planned, in Austria, Germany, Russia, Switzerland, the Czech Republic, Hungary, Poland, Slovakia, and the UK. The intention is usually to make "foreign" vehicles contribute to the cost of road maintenance, particularly of strategic routes, and to ensure a "level playing field" with local carriers. Germany and Slovakia use GPS/GSM-based schemes.

6.2.1.1 The European Directives and the European Electronic Toll Service (EETS)

There are two pertinent European Directives on tolling and charging, namely:

- **the Directive on the interoperability of electronic road toll systems (EU Directive 2004/52/EC), which mandates the use of one or more of satellite positioning, mobile communications using the GSM/GPRS standard, (or more generally the GNSS/Cellular Networks - GNSS/CN) and 5.8 GHz microwave technology. EU (2004). See Figure 5.**
- **Directive 2006/38/EC of the European Parliament and of the Council of 17 May 2006 Amending Directive 1999/62/EC on the Charging of Heavy Goods Vehicles for the Use of Certain Infrastructures. European Council. EU (2006).**

FIGURE 5: THE TWO MAIN TECHNOLOGIES OF EETS



Source: Siemens Electronic Tolling, Austria

Following on from the 2004 Directive, the Commission has mandated the European Electronic Toll Service (EETS) to enable road users to pay tolls throughout the European Union (EU) with just one contract with one service provider and one single on-board unit (EC 2009b).

Although electronic toll systems were introduced in several European countries in the early 1990s, they were usually incompatible, creating a barrier to international road transport. For example, a truck travelling from Portugal to the Netherlands might needed five different OBUs, and contracts with five road operators, each with their own invoicing and billing procedure. This creates time-consuming paperwork for transporting goods across the EU (see Figure 6).

FIGURE 6: THE WINDSHIELD OF A TOLL-COMPLIANT TRUCK TODAY

Image courtesy of Siemens Electronic Tolling, Austria

Within EETS there are three main partners:

- **Users,**
- **EETS providers,**
- **Toll Chargers.**

The EETS provider concludes contracts with users and grants them access to the EETS within the EU. The toll charger levies tolls on the road network or other infrastructure. Tolling policies are decided by Member States in compliance with EU legislation. It is intended that EETS will be available on all electronically tolled infrastructure such as motorways, tunnels, bridges and ferries, ensuring the interoperability of electronic toll systems, limiting cash transactions at toll plazas and minimising paperwork.

Interestingly, the Commission does not consider cameras and ANPR to be electronic toll services, so these are exempt from the Directive.

6.2.1.2 Truck tolling in Europe

As indicated above, Germany and Slovakia use GPS/GSM-based schemes, and are likely to be of particular interest to the GSMA. Belgium, Bulgaria and Russia are investigating similar schemes.

The proposed Russian scheme is potentially the world's largest, applying to vehicles weighing more than 12 tonnes, on 50,000 km of Federal Roads. Initially 1 million trucks would be equipped with GNSS-based OBUs. The use of GLONASS (GLObalnaya NAvigatsionnay Sputnikovaya Sistema) - the Russian version of GPS) will be mandatory – probably in combination with GPS, with an optional microwave interface on the OBU.

Belgium is a small country with a large transit of Heavy Goods Vehicles (HGVs). Partly for this reason it is planning a zone-based EETS-compatible tolling scheme for trucks greater than 3.5 tons in weight, starting in 2016, using up to 800,000 GPS+GLONASS OBUs. Charges will be based on time of day, direction of travel, road and vehicle categories. The preferred bidder is a consortium led by T-Systems, with Belgacom as telecommunications partner. The initial contract will be for 12 years' operation with an optional extension of 3 more years. The OBU will be mandatory when the truck enters the country, even if not on a tolled road. 3,853 km of roads will be tolled, with plans to expand to all 15.000 km of Belgian roads. The scheme is called Viapass. **http://www.viapass.be/en/**

A charging scheme aimed at traffic reduction is also under consideration for light vehicles (less than 3.5 tonnes) in the Brussels region – either a zonal scheme with a limited charge (3€/day), enforced by ANPR, or a kilometre charge of 7 eurocent/km.

6.2.1.2.1 Germany

GNSS/GSM-based charging of HGVs greater than 12 tonnes in weight has been used in the German motorway tolling scheme since 2005 (Kirchmann, 2008; Estiot, 2008), originally covering 12,500 km of motorways; it was extended in 2007 to 40 km of Federal Highways to counter local diversion, and in 2012 to 1100 km of dual-carriageway Federal Highways. Around 800,000 lorries are equipped with OBUs as of 2014, generating €4.4 billion in revenues per annum.

The objectives were to raise funds for road infrastructure, to implement the user-pays-principle, and to incentivise a shift to cleaner vehicles, all of which have been achieved.

2015 will be an interesting year for the scheme: from 1st July it will be extended to trucks between 7.5 and 12t maximum laden weight (about 150,000 more vehicles); from 1st October it will cover an additional 1,000km of dual-carriageway; on 31st August Toll Collect's scheme operator contract ends, though there is an option to extend it until 2018.

6.2.1.2.2 Slovakia

GNSS/GSM-based charging has also been used in Slovakia since January 2010, for lorries of over 3.5 tonnes on 600 km of motorways and 1,800 km of first class roads. The objectives are to finance the operation of the motorway network, and to charge 'through-traffic'. Again, it is not true TDP charging; it uses zones (1132 road sections), though this makes it simpler to implement. A quarter of a million OBUs have been issued; a GNSS/GSM OBU is mandatory for all trucks.

The Slovakian system claims to be the first based only on GNSS, for all major roads, and was relatively cost-effective to implement, taking only 11 months to build up the 2,400km toll network. Updates of the "geomodel" of the road and zone network are performed over the air using secure GPRS data communication, allowing new roads and other infrastructure to be incorporated quickly and easily. In early 2014 the scheme was extended significantly over a period of 3 months, adding 15,315 km of new tolled roads, comprising 3162 new road sections, increasing the tolled network 7-fold.

The ease of extending a GNSS/CN scheme is likely to influence other potential adopters and upgraders; another example is Singapore – see section 6.3.1.

6.2.2 Road tolling in the US

Moves to make existing US Schemes (E-ZPass, SunPass, FasTrak etc) interoperable through multi-protocol tags and readers and by "video tolling" are gaining momentum, as is the proposed replacement of fuel duty (gas tax) by Vehicle Miles Travelled (VMT). There are also a number of interesting R&D projects in the US, including trials in Oregon and Minnesota. The Oregon trials are entering a new major phase starting 1st July 2015, and involving 5,000 voluntary taxpayers, including 8 state legislators, plus 44 additional participants from Washington DOT and Nevada DOT.

6.2.2.1The Oregon Road Usage Charge Program

Oregon has a long history of innovation in roads; it was the first US state to introduce a "gas tax" (in 1919). It will be the first to have a per-mile road usage charge, under its Senate Bill 810, which directs Oregon DOT to implement an operational program by July 1, 2015 – though only for 5000 volunteers in the first instance. The scheme must be flexible, scalable and geographically unlimited, must have an open architecture to allow for evolution of technologies, and must provide motorists with choices for mileage reporting. The scheme is driven by declining fuel tax revenue as alternative-fuel vehicles become more common, and do not pay the gas tax, and as diesel and petrol vehicles become more fuel-efficient – for example the US CAFE standard mandates 54.5 MPG by 2025.

Oregon's previous (second) pilot, from 2012-2013, involved 44 volunteer participants from Oregon, including 8 state legislators, plus 44 participants from Washington and Nevada DOTs. Users had a choice of 3 mileage reporting methods (electronic reporting from the odometer (the basic OBU), electronic reporting from an OBU with vehicle location capability plus wireless transfer of mileage (Advanced OBU), or a flat annual tax); they paid a road usage charge of 1.5 cents per mile and received a fuel tax credit.

The 2015 trials will have additional choices of reporting method:

- **Basic reporting from odometer**
- **Advanced reporting using vehicle location (which may cover all miles driven or just public roads in Oregon; there will also be a smartphone option).**
- **Manual reporting option for mileage driven off Oregon public roads.**

In January 2015 Oregon's Department of Transportation (ODOT) chose SANEF, Verizon and telematics company Azuga as preliminarily suppliers to the 2015 trials. SANEF will provide mileage reporting and account management. Verizon and Azuga will be Commercial Account Managers for the program, offering mileage tracking devices and other services such as insurance discounts. Participants will pay 1.5 cents per mile instead of Oregon's 30 cents per gallon gasoline tax. Verizon will run its part of the trial through "In-Drive", a service it sells through insurance company State Farm, using its existing equipment.

State DoTs with an expressed interest in these trials include Arizona, California, Colorado, Florida, Hawaii, Idaho, Minnesota, Montana, Nevada, New Mexico, Oklahoma, Texas, Utah and Washington – some of which have formed a "Western Road Usage Charge Consortium". There has also been interest from 38 commercial organisations.

California has passed a State Senate Bill mandating an RUC pilot starting January 2017 and reporting by June 2018. Washington State's RUC steering committee has determined that a business case exists for further study, and suggested 4 methods of road use charging; legislation is needed but a demonstration scheme could take place by 2017.

6.2.3 HOV and HOT lanes

High-Occupancy Vehicle (HOV) lanes, much used in the United States, are restricted lanes on a highway which can be used only by vehicles with at least one (or, in some cases, two) passengers in addition to the driver – the objective being to reduce the number of cars on the roads by encouraging car sharing. However, many HOV lanes are under-utilised and are being converted to High Occupancy Toll (HOT) lanes, which can be used by HOVs free of charge, and by Single-Occupancy Vehicles (SOV) on payment of a toll. HOV and HOT lanes are often referred to as Managed Lanes or Express Lanes in the USA; HOT lanes now operate in California, Colorado, Florida, Georgia, North Carolina and Washington State amongst others.

One problem with HOV/HOT lanes is identifying that there are actually 2 or 3 people in the vehicle and therefore whether a charge is payable. Enforcement of this is usually by the local police force, which is expensive and difficult. Camera technology has been used, but does not seem to work well and is not in commercial use. Cellphone technology has been suggested as another option, provided it is possible to distinguish between 2 or 3 people in a vehicle each with their own cellphone, and an SOV whose driver possesses 2 or 3 cellphones. *This would seem to be an opportunity for MNOs, if they could come up with a solution.*

6.3 City congestion charging

The existing city congestion charge schemes use either microwave DSRC technology (Singapore), or cameras plus ANPR (London, Stockholm, Gothenburg).

6.3.1 Singapore

Singapore operated a manual road pricing scheme called the Area Licensing Scheme (ALS) from June 1975, using a paper licence to permit entry to a restricted zone. The charge was higher in the morning and evening peak hours, and also depended on the type of vehicle. The ALS was a very useful traffic management measure, but was cumbersome, labour-intensive and inflexible, and was replaced by an automatic Dedicated Short Range Communication (DSRC) system called the Electronic Road Pricing (ERP) scheme in 1995.

An ERP control point uses two overhead gantries 15 metres apart and 6 metres above road level, with two 2.45 GHz DSRC microwave beacons and two cameras per lane on the first gantry. Optical sensors on the second gantry detect the passage of vehicles. The initial contract was worth SGD 196 million - half for the gantries, the other half for 1 million OBUs. There were originally 33 gantries, subsequently increased to 66. In 2004 the annual revenue was SGD 80 million, with running costs of SGD 16 million.

Being an 'active' system, with charges deducted from a smart card in the OBU, the central computer system does not need to keep track of vehicle movements. Transaction records are stored on the smart card, but are erased once payments are secured – typically within 24 hours. Speeds on road sections are monitored; charges are increased if there is congestion and lower speeds, or reduced to encourage traffic if speeds are high.

However, the cost of gantries is now 50% more than in the 1990s, and system operation costs have increased by 80%, so Singapore will replace the scheme with a GNSS/CN system, which has advantages including the ability to implement distance-based pricing, which is more equitable – charges will be proportionate to the distance travelled on the congested roads. Value-added services will also be possible, including real-time location-based traffic information and electronic payment for parking, The Singapore Land Transport Authority (LTA) has short-listed three consortia to supply the new system: NCS Pte Ltd & MHI Engine System Asia Pte Ltd, ST Electronics (Info-Comm Systems) Pte Ltd, and Watchdata Technologies Pte Ltd & Beijing Watchdata System Co Ltd. Bids close on 2nd March 2015; the system implementation contract will be awarded in 3Q2015, with "go-live" in 2019.

In its 2014 "Infrastructure 100: World Markets report" KPMG says that:

"Thanks to its Intelligent Transport System, Singapore is one of the least congested major cities in the world despite a growing urban population and limited physical space. This integrated pay-as-you-use system maximises the capacity of the road network with vehicle quotas, sophisticated electronic road pricing (ERP) tolls that vary according to traffic flows, and alerts to drivers, all controlled in real time from an operations center. Consequently, average car speeds of 27 km/hour compare favorably to 16 km/hour in London and 11 km/hour in Tokyo. The judges considered this a clever system that encourages motorists to change their mode of transport, travel route or time of travel." (KPMG 2014).

Although probably not connected to Singapore's road pricing plans, it is worth noting that Singtel and Ericsson announced in January 2015 a partnership to explore the future of 5G communications in Singapore, including the Internet of Things (section 9) and "cloud-based computing" (section 2.4), supporting Singapore's vision of itself as a "Smart City."

6.3.2 The London Congestion Charge

The central London congestion charge went live on 17 February 2003. The charge was originally £5, but is currently (January 2015) £10.50 per day using the Auto Pay automated payment system, £11.50 if paid in advance or on the day of travel, and £14 if paid by midnight the following charging day.

Transport for London is currently consulting on an Ultra-Low Emission Zone (ULEZ) which would require all vehicles driving in central London (the same area as the Congestion Charging Zone) to meet new exhaust emission standards including particulate matter and nitrogen oxides (NOx). The ULEZ would take effect from 7 September 2020, and apply 24 hours a day, 7 days a week. A vehicle that does not meet the ULEZ standards could still be driven in central London but a daily charge would have to have been paid - £12.50 for cars, £100 for trucks and buses. There is currently a Low Emission Zone (LEZ) covering a much larger area, out to the M25 orbital motorway, and policed by ANPR cameras. It applies only to diesel trucks; If the ULEV and the congestion charge zone were extended to this larger area, thereby massively increasing the revenue, it would be natural to consider the use of GNSS/CN, following Singapore's lead; this is not part of TfL's current plans, but it has trialled GNSS/CN technology in the past and shown that it is viable in London.

6.3.3 The Stockholm and Gothenburg Congestion Tax

Road pricing had been under discussion for many years, and following the success of London, Stockholm introduced a permanent scheme in August 2007, following a successful trial in 2006 (Figure 7). Public acceptability increased throughout the trial period and in the subsequent referendum Stockholmers voted to implement the scheme permanently. Public acceptability has continued to rise since, reaching 74% in 2010, and the scheme is no longer a political issue.

FIGURE 7: THE STOCKHOLM CONGESTION CHARGING SCHEME BOUNDARY.

Image by permission of the Swedish Transport Agency. The dotted line shows the scheme boundary, the red dots are the locations of the charging stations.

The scheme is cordon-based (Figure 8), with cameras on gantries at all entry and exit points. Initially, alternative-fuel vehicles were exempt, but the numbers grew significantly following the introduction of the scheme, and since they contributed to congestion if not to pollution, the exemption has been removed.

Stockholm is important because it demonstrates that despite initial opposition, people will accept road pricing once they are familiar with it and see that it works.

The Gothenburg scheme, which began in 2013, was modelled on Stockholm and used the same technology & charges. It aimed to raise revenues for investments, to reduce congestion and to improve the environment. Traffic across the cordon was reduced by 12% during the charged hours. However, in a consultative referendum held in September 2014, 57% voted against the scheme. Despite this, the City Council will probably retain the scheme since its revenues leverage a major financial package from the national Government (Börjesson & Kristoffersson 2015).

FIGURE 8: A STOCKHOLM CONGESTION CHARGING SCHEME GANTRY.

By permission of the Swedish Transport Agency; Photographer: Mikael Ullén

6.3.4 New York

New York is an instructive case study of the failure of a proposed scheme (Schaller 2010). A congestion pricing proposal was introduced in 2007 by New York City (NYC) Mayor Bloomberg as part of a wider sustainability plan. NYC residents supported the proposals by 67% to 27%, provided the revenue was used to expand public transport. The proposal also had the support of the NY City Council and State Senate, though crucially not of the NY State Assembly. A number of organisations were proponents of congestion pricing, as part of a larger sustainability plan (PlaNYC) to create a 'greener, greater New York', using the E-ZPass electronic tolling system, or other payment channels, with compensating reductions in bridge and tunnel tolls. Overall press and public reaction was positive, probably because of the wider sustainability plan; it was supported by the Mayor, the State Governor, 135 civic, business, labour, environmental and advocacy groups, and all four major newspapers, though there was opposition from the four NYC boroughs outside Manhattan. The NYC council voted 30 to 20 to adopt the Commission plan; but congestion pricing needed authorisation under state law; this was blocked (without a vote) by Democrats, who controlled the State Assembly, so the plan failed to meet the Federal funding deadline, and was abandoned. Schaller (2010) asks why the broad support for sustainable transport and congestion pricing failed to gain approval. 'The short answer is that a relatively small group of auto users believed that congestion pricing was against their best interests... The intensive interests of one group were thus able to overcome widespread public support'.

More recently, a new plan, “Move NY” has been proposed by Sam Schwartz, a former NYC Department of Transportation Chief Engineer and First Deputy Commissioner. He describes it as “fair pricing” rather than “congestion charging”; it would be a unified scheme covering tolled bridges as well as traffic within the city, using E-ZPass microwave technology (Schwartz 2013), at least initially. A quarter of the revenues would be used to improve roads and bridges — an incentive for drivers who opposed the earlier plan - the rest would go to transit. Although it has much local support, it will have to bring on board the State Legislature.

6.3.5 Other cities

Jakarta is hoping to implement Electronic Road Pricing by the end of 2015 - a very ambitious time-scale. Studies have been carried out since 2006 and there were trials in 2014 by Kapsch and Q-Free, two well-known road pricing suppliers. The proposed scheme will replace the existing HOV lanes on some Jakarta roads.

A number of Chinese cities are considering introducing urban congestion charges, including Beijing, Shenzen and Chongqing, to combat air pollution, and congestion. The Beijing Metropolitan Commission for Transport (BMCT) commenced a 12-month technology trials programme in November 2014 including GNSS (probably based on Beidou2), ANPR, radio-frequency identification (RFID) and DSRC as the four primary means of identification and charging.

The Iranian press has reported that Tehran is considering electronic charging of three tunnels and an elevated highway in the city, using adhesive electronic sticker tags on wind-screens. The aim is to combat congestion and pollution and encourage the use of public transport. Electric and hybrid cars will be exempt from charges.

6.4 National/regional/wide area charging

Other than the truck charging scheme referred to above, and tolled highways, bridges and tunnels, there are no wide-area charging schemes in existence commercially as yet, but some schemes have been proposed and extensive studies carried out – see especially Oregon (section 6.2.2.1).

6.4.1 The Dutch Pay Per Use Scheme

In 2007 the Dutch Government proposed to introduce a national road pricing scheme to improve accessibility and the quality of the living environment (ABvM – Anders Betalen voor Mobiliteit – Different Payment for Mobility). The principle was that payment should be made for using rather than owning a car. Motorists would be expected to pay per kilometre driven, instead of paying through motor vehicle tax, purchase tax and fuel duty. Charges would depend on the time and place of driving and the environmental characteristics of the vehicle, and would use GNSS and cellular radio technology, with Vodafone and T-Systems amongst others as potential suppliers.

However, the Government fell, for quite unrelated reasons, and the new Government did not proceed with the ABvM, although there seemed to be public acceptability. A large majority of the members of the biggest Dutch motoring organisation, the Royal Dutch Touring Club, accepted the principle that high-mileage drivers should pay more than low-mileage ones; in the current Dutch system, due to the high tax on car ownership, those who seldom drive subsidise those who drive a lot. But the Dutch Government seems to have no plans to resuscitate the ABvM project.

6.4.2 China and Hong Kong

China adapted a National Standard for ETC, based on DSRC, in 2007, and the first scheme opened in 2008. It now covers 15 Provinces, more than 1,300 ETC lanes have been built covering around 15000km and there are more than 800,000 ETC users. A national unified system is expected to be launched in 2015 to reduce freeway congestion, and reduce transport costs and emissions. China has successfully trialled GNSS-based ETC on 143 km of the Jing-jin-tang highway, using 300 test vehicles, 22 virtual toll stations and 6 enforcement points. (Wang D et al., 2012). The toll and route information were sent to a management centre by GPRS/GSM. As reported in section 6.3.5 Beijing is trialling GNSS and other technologies for identification and charging.

Hong Kong has been contemplating road pricing for 20 years, and carried out technology trials in the 1990s. A recently published study (HKTAC 2014) recommends, amongst many other measures, a pilot congestion charging scheme in the Central District.

6.4.3 The future for Road Pricing – and opportunities for MNOs

The UK Office for Budget Responsibility (OBR) says that because of improved fuel efficiency and use of alternative fuel vehicles, there will be a £13.2B pa revenue loss from motor taxes by 2030 for the UK Treasury; fuel duty will fall from 1.7% to 1.1% of GDP, and Vehicle Excise duty (VED) from 0.3% to 0.1%. In the US there are similar concerns about reducing revenue from the "gas tax", and HOT lanes are receiving driver approval; the road pricing trials in Oregon and California are being followed by a number of western US states. Other countries undoubtedly have the same fiscal problems.

Increasing use of PAYD insurance is likely and HGV charging will spread further in Europe and elsewhere – though there were problems with the GPS-based scheme in France – it was abandoned because of protests from French hauliers and others.

Germany plans to introduce a controversial scheme in 2016 aimed at foreign drivers using German autobahns. German drivers would also pay the toll, but would be compensated with a reduction in existing automobile taxes. The German government and the EU are in dispute about whether this is compatible with EU law, though the UK truck tolling scheme introduced in early 2014 adopted a similar approach without apparent legal problems

As the GSMA (2013a) points out, mobile operators have a track record of keeping large volumes of sensitive data secure. This makes them ideally placed to play a role in road pricing, where mistrust of Governments is endemic. It would seem to be in their interests to lobby for and get involved in the wider adoption of road pricing.

7. Public Transport

There is a perception in some circles that public transport is "green", sustainable and environmentally friendly, and that cars and trucks are the opposite, so there are moves to get drivers out of their cars, and to transfer freight from road to rail. The reality is much more complex; public transport vehicles, which are typically older, may emit more pollutants than private cars; and if they travel empty or nearly so, they are less efficient than even a single-occupancy vehicle. Typically the road network carries ten times the people and ten times the freight that rail does, so a small transfer from road may cause overload on what is often a rail network running at capacity. And public transport operates best in high-density urban environments, and less well in suburban areas or sparsely populated rural environments.

Nonetheless, public transport is crucially important, especially in urban and suburban areas – and the world-wide trend is towards increasing urbanisation. By 2020, 80% of Europeans will be living in urban areas; in some countries the proportion will be 90% or more.

Another trend is the use of mobile technology. It is normally assumed that commuters want to minimise their travel time—and are willing to pay for the privilege. But with tablets, laptops and smart phones, travel time can be used productively, unlike in a car; this undoubtedly makes some commuters to choose transit rather than car—even if the journey takes longer – *a trend that MNOs would do well to encourage.*

A journey may include more than one mode of transport. Research identifies four areas that can make public transport easier and more convenient (DfT 2014):

- **Improving the quality and availability of information;**
- **Smart and integrated ticketing;**
- **Improved and reliable connections in multi-modal journeys;**
- **Safe, comfortable and easily accessible transport facilities, meeting the needs of passengers.**

An important part of this is making data available for app and other developers; see **www.data.gov.uk** - and case studies below.

7.1 Bus, Metro, Train

As the GSMA (2012) White Paper: "Mobile NFC in Transport" indicated, Near Field Communication (NFC) is a contactless radio technology that can transmit data between two adjacent devices. Mobile phones are increasingly being equipped with NFC capabilities, enabling new digital services that could greatly improve the passenger experience of public transport. The combination of NFC with mobile connectivity enables many benefits in the transport sector, including:

- **Enhanced value and functionality of existing contactless infrastructure;**
- **Greater passenger convenience - ability to buy NFC tickets via a mobile connection and avoid queuing;**
- **Lower sales and distribution costs, fewer plastic cards, paper tickets and their associated physical infrastructure, and concomitant environmental benefits;**
- **Fast, accurate and transparent ticket validation;**
- **More flexible and interoperable ticket systems - NFC handsets can support multiple ticketing standards, creating a seamless passenger experience;**
- **Personalised communication with passengers and promotion of public transport.**

This could pave the way for complete, integrated solutions covering different modes of transport.

Potential benefits of mobile NFC for mobile operators include:

- **Greater usage of mobile services - NFC interactions can prompt more usage of the mobile network;**
- **Spur adoption of mobile NFC and accelerate upgrade of handsets and UICCs;**
- **A platform for mobile commerce services, such as targeted advertising.**

Three years later, these predictions are coming to pass. Transit agencies are adopting new payment options for travelers including mobile ticketing. According to Juniper Research, mobile ticketing across all forms of transit will triple between 2013 and 2018; one in eight North American smartphone users are expected to use it as a public transport ticket by 2016.Transit fares are typically low-value; handling cash is expensive, and prone to fraud and theft, as well as potentially delaying transport services. Mobile technologies minimise these risks; passengers can use smartphones to buy their ticket or pass anytime, anywhere, minimising boarding delay and improving the passenger experience. For public transit operators the benefits include increased ridership; cost reductions and better management of their operations, especially with integrated ticketing of different transit modes. A Smart Ticketing Alliance was set up in Brussels n 2014 to work towards a single transport specification for NFC phones across Europe facilitating the implementation and deployment of NFC-enabled devices.

7.1.1 Dubai

In 2013 Dubai became the first city in the Middle East to allow mobile phones to access public transport (GSMA (2014d). The “Smart Nol” service (“Nol” means “fare” in Arabic) enables a passenger to open a ticket barrier by tapping their handset against a reader. The NFC technology connects to the handset to validate the passenger’s virtual Nol account, stored on the SIM card. The handset can be used to check in and out of buses, metro stations and water taxis, with the appropriate fare deducted from the Nol credit, obviating the need to use a conventional Nol plastic card.

FIGURE 9: THE DU TRANSPORT APP AND THE ETISALAT MOBILE NFC APP

The “Smart Nol” service was developed by Dubai’s Roads and Transport Authority (RTA) and the Emirate’s mobile operators Etisalat and Du. Removing the need for a separate physical card, of which there are six million in use in Dubai, will reduce the RTA’s costs and environmental impact. The service also reinforces the high-tech, forward-looking image of Dubai’s public transport, thereby increasing patronage. Passengers can review their Nol usage on their handset at anytime, anywhere, rather than having to use a machine in a metro station. They can use an Etisalat or Du app (Figure 9), or a special SIM toolkit menu, to check their current balance, the amount and date of their last balance recharge, the date and cost of their most recent journey, whether they have reached the daily fare cap, and their tag ID and expiry date, which they need to contact the RTA call centre.

Passengers need a NFC handset and NFC SIM card to use the Smart Nol service.

- **Smart Nol can be managed using Du’s Android-based transport app. It can also recharge their Salik road toll account, find the closest metro station, book a taxi and pay for parking.**
- **Etisalat’s NFC Android appcan access the Nol card, view credit and check transaction history.**

7.1.2 Dallas Area Rapid Transit (DART)

After investigating contactless smart cards and credit/debit cards, DART opted for mobile ticketing in its Texas-based public transit services, as its customers increasingly used smartphones, including ones with NFC. Mobile ticketing gives benefits of reduced capital costs (less need for ticket vending machines), flexibility for the future, new payment options and convenience for customers. DART’s mobile ticketing app, GoPass, allows flexible ticket validation, including screen animations and ultimately NFC. Several types of payment are available including bank cards and Pay Pal. Mobile ticketing has advantages for customers; the app includes a trip planner, disruption alerts, and estimated times of arrival for buses and trains. An SMS text service alerts travellers to the next scheduled bus or train service at their stop. GoPass also has a link to buy a ticket in advance, and people feel safer because they don’t have to get out their wallet at a ticket office. DART also operate a car-pooling service and has partnered with the Zipcar car-sharing organisation (see 7.2.1). **http://www.dart.org/**

7.1.3 JustRide in Athens

Transport for Athens and Masabi, a UK-based transit mobile ticketing organisation, announced in January 2015 the deployment of a mobile ticketing scheme, JustRide, for public transit in the city, following a pilot in December. This digital ticketing system supplements the existing paper ticket and cash-based operation; it has previously been deployed in Boston, London, San Diego and shortly New York. Customers can conveniently buy and display tickets for immediate or future travel using their smartphone. Transport for Athens will experience reduced costs of handling cash and printing paper tickets. **www.masabi.com**

7.1.4 Other smart-ticketing operations

Maryland Transit Administration (MTA) “My MTA Tracker for Bus”, enables customers to determine the estimated arrival time of their Local Bus via computer, tablet, smartphone and standard phone. Users can receive SMS or email alerts for their particular route.

Following in the footsteps of several other US cities, the San Francisco Municipal Transportation Agency (SFMTA) is piloting a scheme to allow transit users to buy tickets using their smartphones. It may scale down other fare collection mechanisms if mobile payments prove popular and cost-effective.

7.1.5 Matatus - Nairobi

Nairobi commuters can now access the routes of over 20,000 matatus (public buses) – see Figure 10) in the city, using the "Transit App" developed by the University of Nairobi, Columbia University's Center for Sustainable Urban Development, Groupshot, and MIT's Civic Design Lab in a collaborative research project called "Digital Matatus". As well as a trip planner the app includes bus schedules, stops and routes, so a network connection is not essential. Real-time updates on bus movements or routes are not currently available but may be added later. To get the data, volunteers with GPS-tracking cellphones travelled on the matatus, compiling a list of routes, arrival times, and stop locations – which turned out to be surprisingly coherent and logical (Figure 11). They then converted the data into GTFS (Google's General Transit Feed Specification - a standard format for public transport schedules and related geographic information). The Transit App developers say they are confident the methodology can be applied to any informal transit system worldwide. The app can be downloaded from the App Store or Google Play. **http://www.digitalmatatus.com/**

FIGURE 10: A MATATU (PUBLIC BUS) IN NAIROBI

Image courtesy of the Digital Matatus project

FIGURE 11: NAIROBI MATATU ROUTES

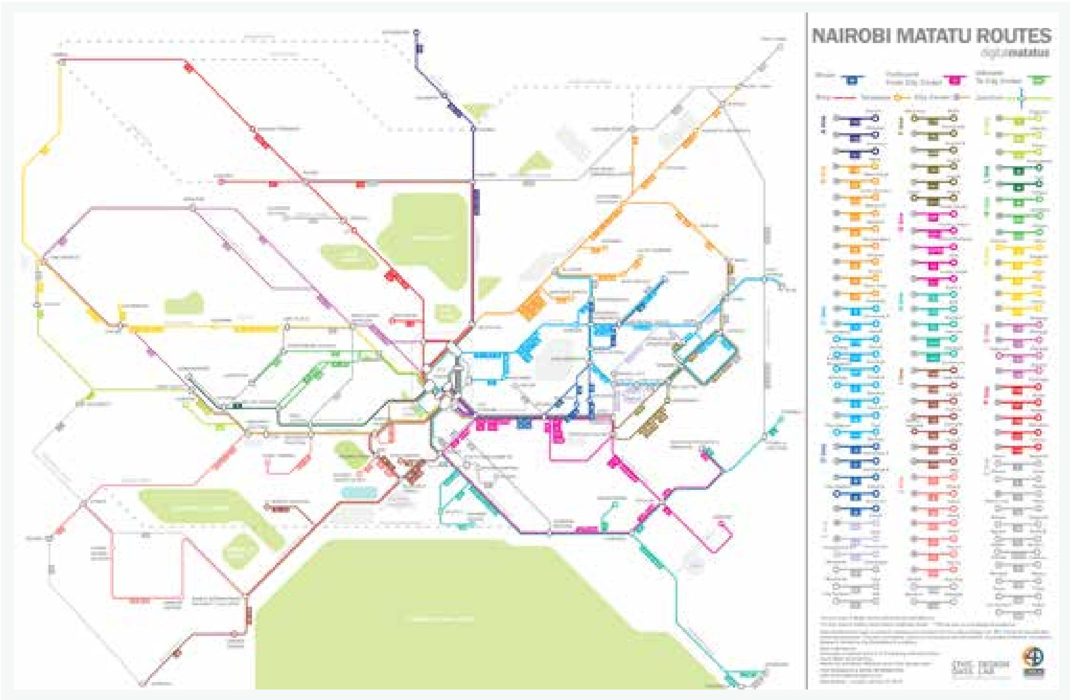


Image courtesy of the Digital Matatus project

It would be in the interests of MNOs to encourage similar developments in other "informal transit systems".

7.2 Car sharing and car clubs

Car-pooling and car sharing began in the late 20th century, as a mechanism for Travel Demand Management (TDM) to reduce congestion and environmental damage. They also gave cost and time savings, especially for commuters. They could be formal – managed and encouraged by an employer – or informal amongst family and friends. A car club provides its members with flexible access to the hire of vehicles, which are parked in reserved spaces, close to homes or workplaces and used on an hourly, daily or weekly basis (DfT 2005).

In some places, particularly the US, High Occupancy Vehicle (HOV) lanes (section 7.2.3) were built on freeways, usable only by multi-occupancy vehicles, in order to encourage car-pooling – though vehicles were often multi-occupancy for other reasons, such as a family going on holiday. They also gave rise to the curiously named practice of "slugging", where people "hitching" lifts would queue at certain points, particularly in the vicinity of 3+ HOV lanes (at least 3 people in the vehicle); it was in drivers' interests to pick them up because 3+ car-pools were more difficult to create and maintain.

Dynamic ridesharing was a subsequent development, again particularly in the US, encouraged by technology and social networking – minimising the "management overhead" of formal car-pools. Commuters decide to drive or take the bus, depending on how flexible they need to be and whether the bus is running on time. If they drive they can pick up riders anywhere along a route; potential riders can contact drivers through smart phones and GPS information. Riders may make micro-payments to drivers, who also gain by using HOV lanes.

US Federal and State Governments have funded pilot rideshare programmes, including software to facilitate them; it reduces vehicle-miles traveled, congestion and pollution, and the need for new infrastructure. It also provides socially-necessary transportation for senior citizens, students and dial-a-ride users.

7.2.1 Zipcar

Zipcar claims to be the world's leading car sharing club, covering the United States, Canada, the UK, Spain, Austria and France, offering more than 30 makes and models of self-service vehicles by the hour or day to people who don't want to own a car, or occasionally need a second car or a larger vehicle. Zipcar is a subsidiary of Avis Budget Group, Inc.

A Zipcar can be reserved on the website or via a free-of-charge app. On joining, you get a credit-card-sized "Zipcard", which unlocks the vehicle via a card reader in the windscreen. Subsequently customers can use either their smartphone or Zipcard to lock and unlock the vehicle. A car-key, if needed (some cars have start buttons instead of keys), is stored inside the car, attached to the steering column. The app allows customers to book and locate the car. Customers can sign up for Zipcar Text Alerts - reminders about reservations, and whether they can be extended. A Zipcar hired in the US or Canada can drive in both countries, but not Mexico. If hired in France, Spain, Austria or UK it can be driven into some but not all European countries, though permission may be needed in advance from Zipcar. **www.zipcar.com**.

7.2.2 DriveNow

DriveNow, a joint venture of BMW and car rental firm Sixt, started operations in 2011 in Munich. It now has over 400 BMW 1 Series, Mini Convertible and Mini Clubman vehicles, with a choice of manual or automatic transmission, diesel, petrol or electric drive. It operates in five German cities (Munich, Dusseldorf, Cologne, Berlin, Hamburg) plus Vienna, San Francisco and London; registered customers can use the service in any of these cities and countries, using their credit card, and cars can be reserved in advance. Unlike traditional car clubs, DriveNow members can leave their car in most public parking in the area. The London scheme operates in the boroughs of Hackney, Islington and Haringey; the charges are a £29 registration fee, a basic car hire rate of 39p per minute, capped at £20 per hour. **https://uk.drive-now.com/#!/carsharing/international**

7.2.3 London: the Car Club Coalition and Westminster

A draft strategy to boost car club use in London was published by the Car Club Coalition, which was established in September 2014 and represents car club operators, London Councils, the Greater London Authority (GLA), Transport for London (TfL) and other stakeholders (London 2014).

As mentioned earlier (5.2.3) the Westminster Car Club was launched in May 2009 by Westminster City Council to provide greener modes of transport in response to the growing pressure on residents' parking and help tackle congestion and poor air quality. It offers 'pay as you go cars' to those who only use their cars occasionally or don't want the expense of their own vehicle. In 2013 the contract was successfully re-let to the existing contractor for a further 2 years.

A previous point-to-point car club operator, Car2Go, a pioneer of "free-floating" car sharing, withdrew from the UK in 2014, citing the UK's tradition of private vehicle ownership, but continues to operate in 25 cities world-wide, including 12 other European cities.
https://www.car2go.com/en/london/

7.2.4 Uber, Lyft and other ridesharing businesses

A number of companies, of which the best-known is Uber (**www.uber.com**) have turned dynamic ride-sharing into a successful business, using the Internet and apps to connect drivers with potential travelers. It is a kind of unlicensed taxi service, and consequently has aroused significant opposition from taxi companies and the licensing authorities in cities and countries world-wide.

Uber was founded in 2009 in California. Its success has spawned similar companies in many countries - including China, especially with the merger of Kuaidi Dache and Didi Dache. Even Google is reported to be entering the business, despite being an investor in Uber, perhaps related to its driverless car project – eliminating drivers would reduce costs. This could be problematic for Uber because its smartphone applications for drivers and riders use Google Maps. Conversely, Uber has linked up with Carnegie Mellon University to develop its own autonomous vehicle technology.

Lyft (**www.lyft.com**) also began in California as a spin-off from a (largely campus-based) ride-sharing service called Zimride. There are even lessons for public transport and freight. A US company called TransLoc (**www.transloc.com)** helps public transport operators to offer "demand-responsive transport" – a concept that has been around for many years but has yet to take off in a big way; it has also applied the concept to freight companies, optimising deliveries.

Cargomatic has been described as "Uber for trucks". Also based in California, it addresses the inefficiency and fragmentation of the local trucking industry by connecting shippers with hauliers who have empty trucks in the vicinity, via a website and smart-phone apps. The company even gives smartphones to terucker swho don't have them. **www.cargomatic.com**

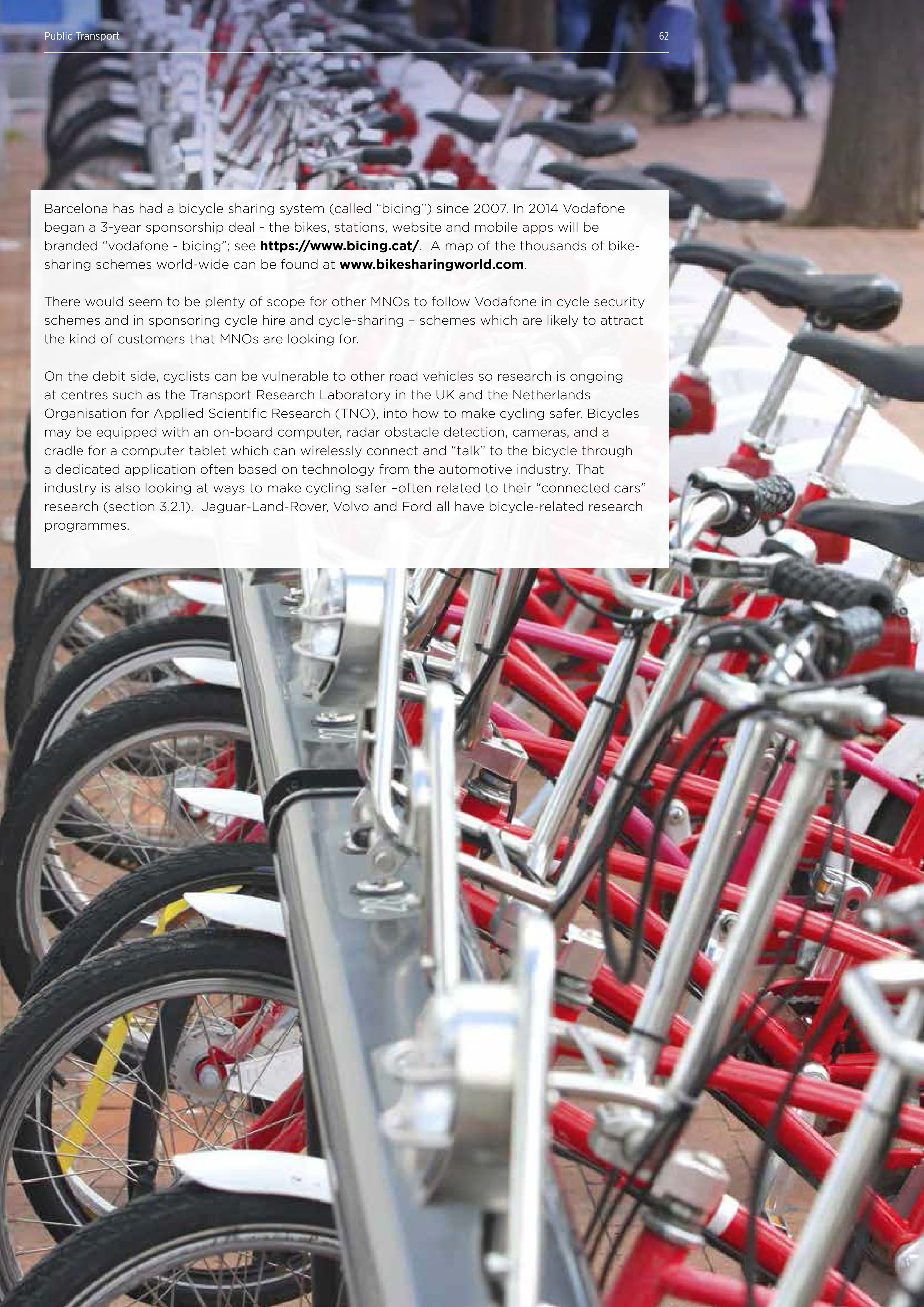
Car sharing and car clubs are already fertile ground for MNOs, but there is still a great deal of unexplored potential, including in freight.

7.3 Cycling and Scooter hire

Cycling is a realistic choice for quick, reliable and convenient short journeys within cities, as an alternative form of public and private transport, as a supplement to existing transport modes (such as cycling to railway stations) and as a cost-effective way to reduce congestion and pollution and improve quality of life. It has health benefits at a time when developed countries in particular are facing declining levels of physical activity. It has grown significantly in many cities and countries world-wide over the past few years, including London ("Boris-bikes"), Barcelona, Brussels, Paris (vélib), New York and Tokyo. According to Transport for London its cycle hire scheme had more than ten million hires in 2015, 5% up on 2012 (the previous high) and 25% up on 2013; cycling levels in London are the highest since records began in 2000. London is also planning to introduce "cycle superhighways" segregated from other traffic – though there is opposition from some quarters due to the costs of the scheme and the apparent dis-benefits to other transport modes.

Cycle-hire schemes may be subscription-based or require a debit or credit card; customers can use the Internet and smart-phones to check out availability and other cycle facilities for example at railway stations. Electric bikes and scooters may be available as well as conventional bikes.

One interesting electric bike is supplied by the Dutch VANMOOF company. It wanted GPS connectivity in its e-bike to combat bike theft and map commuter routes. It uses Vodafone Global M2M SIMs, integrated in the bike frames, to provide world-wide connectivity, managed from the Vodafone platform. The SIM can roam to a secondary network if necessary. The bikes are available world-wide through agents, with dedicated shops in Amsterdam and Taipei.
www.vanmoof.com



Barcelona has had a bicycle sharing system (called “bicing”) since 2007. In 2014 Vodafone began a 3-year sponsorship deal - the bikes, stations, website and mobile apps will be branded “vodafone - bicing”; see **https://www.bicing.cat/**. A map of the thousands of bike-sharing schemes world-wide can be found at **www.bikesharingworld.com**.

There would seem to be plenty of scope for other MNOs to follow Vodafone in cycle security schemes and in sponsoring cycle hire and cycle-sharing – schemes which are likely to attract the kind of customers that MNOs are looking for.

On the debit side, cyclists can be vulnerable to other road vehicles so research is ongoing at centres such as the Transport Research Laboratory in the UK and the Netherlands Organisation for Applied Scientific Research (TNO), into how to make cycling safer. Bicycles may be equipped with an on-board computer, radar obstacle detection, cameras, and a cradle for a computer tablet which can wirelessly connect and “talk” to the bicycle through a dedicated application often based on technology from the automotive industry. That industry is also looking at ways to make cycling safer –often related to their “connected cars” research (section 3.2.1). Jaguar-Land-Rover, Volvo and Ford all have bicycle-related research programmes.

8. Travel information and Traffic management

Although traffic and traveler information is normally regarded as separate from traffic management and from environmental issues within the ITS field, the three are increasingly closely related – and increasingly affected by social media, so we are addressing them together here.

8.1 Public Transport Information

Public transit passengers want information on timetables, how long will the whole journey take (the wait time, the in-vehicle time, any delays), and route information (does it go where I want?). The information must be accurate, timely and (ideally) personalised and real-time; at times of disruption information is also needed on alternatives. Real-Time Passenger Information (RTPI) empowers passengers – tells them the situation and the options available. And it is important that systems are designed from a user not a supplier viewpoint.

The traditional sources of information, apart from paper maps and timetables, are large indicator displays at bus and train stations, and on platforms. Even this traditional technology can benefit MNOs. Under a joint agreement with Southeastern Pennsylvania Transportation Authority (SEPTA) Verizon provided three video indicator boards at Philadelphia's Suburban Station, allowing SEPTA to deliver improved customer service and generate new advertising revenue. Verizon has a long-term relationship with the Titan advertising agency, which sells advertising at SEPTA stations and vehicles. The video screens provide riders with information about train schedules, travel updates and weather reports. Verizon benefits from branding and has also opened a wireless retail store at the station.
http://www.septa.org/media/releases/2015/01-23.html

So even the supply of traditional technology in public transport can benefit MNOs.
But the traditional technology is being supplemented by additional services enabled by mobile technology.

8.1.1 User needs in public transport information systems

8.1.1.1 Commuters in Boston and San Francisco

In order to minimise congestion and pollution, public policy in many cities and countries is to getting people out of their cars and onto mass public transit – a policy that has had only limited success so far. However, smartphone apps could be key in future. A study of commuters in Boston and San Francisco by the Latitude consultancy found that drivers are more willing to switch to transit if they can manage their commutes effectively. The study asked 18 people to travel by transit rather than by car for one week; the participants found that the autonomy lost by giving up the automobile could be regained through smartphone apps providing real-time information about transit schedules, delays and shops and services along the routes. There is no substitute for frequent and punctual service, but there is nothing worse than waiting for buses that may be late or not arrive at all; real time transit information makes travellers feel more in control. Latitude chose Boston and San Francisco for the study because of the availability of information about public transit. And provision of third-party apps is much cheaper than electronic display boards at bus-stops.
http://latd.com/2010/09/22/latitude-42-tech-for-transit-designing-a-future-system/

8.1.1.2 The Informed Rural Passenger project in Scotland

A similar project, but in rural areas, the "Informed Rural Passenger project", is under way at the University of Aberdeen in Scotland, and demonstrates that mobile devices and crowd-sourcing can help to fill in missing information. Again people felt more in control of their situation, found the bus services easier to use, reduced their waiting times (or their perception of waiting times) and increased satisfaction with their journeys - though they didn't change their travel behaviour or feel safer. An SMS service allowed them to request the time of the next bus at their stop. Future developments will include integration of social media (twitter). **www.dotrural.ac.uk/irp**
So mobile technology and social media can improve the passenger experience and benefit the transport operator and the MNO.

8.1.1.3 The New Zealand Transport Agency

The New Zealand Transport Agency studied traveller information needs using focus groups and online surveys. It confirmed that information must be of high quality, timely, accurate, relevant to the specific journey, customisable, easy to understand; it must be possible to save "favourite" routes. Users will soon stop using sources which do not meet their expectations. They also want comprehensive information from robust and user-friendly websites. They will not check multiple websites. Information needs to be suitable for both novices and experienced travelers, in both digital and paper formats. Indirect payment mechanisms (e.g advertising) were preferred over direct costs. In general the results confirm the Boston, San Francisco and Aberdeen studies. Considerably more detail will be found in the paper by Chang et al. (2014).

The benefits of mobile technology apply in both urban and rural areas.

8.1.2 London buses

Transport for London (TfL) manages one of the largest bus networks in the world: 8,500 vehicles travelling 500 million kilometres per year, 50 bus stations, 19,500 bus stops and two billion passenger trips per year – half the UK total. Most London bus services are run by private operators under contract to London Bus Services Ltd, a TfL subsidiary, which plans routes, specifies service levels and monitors service quality. TfL operate a system called iBus on all routes; using satellite tracking and other technologies, iBus locates the buses and relays information between driver, garage and central control point. "Countdown" (live bus arrival information via signs at bus stops) is available at 2,500 stops. Real-time bus information is also available online for all bus stops via smartphones and SMS. Interactive bus maps allow people to search by postcode, street name, route number or place of interest. "Oyster" smart cards are used for more than 85% of bus passenger journeys; fewer than 2% are paid for in cash. The "London River Service" boats use the same iBus equipment, delivering the same operating cost reductions and fleet management benefits.
http://www.tfl.gov.uk/corporate/about-tfl/what-we-do/buses

8.1.3 App Quest: New York State and AT&T

In November 2014 New York State's Metropolitan Transportation Authority (MTA) and AT&T launched their third "App Quest" - a competition to develop an app using real-time MTA data sets and APIs, with a total of $50,000 in prize money (contributed by AT&T) for the winning apps. The competition includes the use of wireless beacons set up at Grand Central-42nd Street subway station to allow apps to locate people within the subway station, benefitting travellers with disabilities and those unfamiliar with the subway. App platforms can include smartphones, tablets, desktops and wearable technology. Prize-winners will be announced on 19th March 2015. The 2013 AppQuest first prize of $20,000 was won by "Citymapper" - a journey planner with real-time information on subways, buses (including when to get off) and hire bikes across all five NY boroughs, plus information on disruptions, and weather. The app "Embark NYC", a transit navigation app with trip planning, service advisories, interactive maps and schedules won the 2012 Grand Prize.
http://www.mta.info/press-release/mta-headquarters/att-and-mta-open-public-voting-best-apps-designed-improve-commutes

App Quest has generated a lot of interest worldwide. The current competition attracted more than 40 app developers from Australia, Europe and Morocco as well as the US. MNOs could partner with cities or other administrations to set up their own version of App Quest, thereby generating good publicity, branding opportunities, and network traffic - and not just in the transport domain – see section 10.1.

8.1.4 My MTA Tracker

The Maryland Transit Administration (MTA) recently launched My MTA Tracker for Bus, a GPS-based system that enables customers to determine the estimated arrival time of their local bus via computer, tablet, smartphone and standard phone. The website MyMTAtracker.com also gives access to journey planners for commuter rail and local Light Rail services. E-notifications can be pre-set to send notifications for particular routes at specified times during the day, via SMS or email to a mobile phone, tablet or computer.
http://mta.maryland.gov/news/my-mta-tracker-bus-rolls-out-arrival-time-convenience

8.2 Traveller & Traffic information

The "traditional" sources of road traffic information are the Radio Data System and more recently TPEG (section 2.2.1), plus roadside Variable Message Signs (VMS). Mobile technology with location information has added more powerful, and more user-friendly, options, at lower costs.

8.2.1 The Singapore Land Transport Authority (LTA)

Penetration of smart-phones is high in Singapore - 72% in 2013 – just behind the United Arab Emirates , South Korea and Saudi Arabia, but ahead of Norway, Australia, Sweden, Hong Kong and the UK. The LTA has taken various initiatives to use smart-phones as sensors for traffic management and to deliver real-time traffic information to motorists. (Wong Sook Kwan et al., 2014).

A smartphone traffic app was developed with a local company, BuUuk Pte Ltd, acting as a crowd-sourced traffic data collection channel with low maintenance cost. It learns users' regular travel routes and sends personalised traffic information to them, based their location and regular routes, with minimal user intervention. It also sends the phone's location to a server anonymously, using a randomly generated ID, preserving user privacy. LTA can analyse this crowd-sourced data which is complementary to existing infrastructure-based traffic data. The benefit for the user is a more pleasant commute – the app takes a week to establish the regular travel route, which is then displayed on the screen; users can chose to have real-time traffic alerts not just about their current location but also from elsewhere along the route.

Using the crowd-sourced data the LTA can estimate journey times, the different routes from a trip origin to its destination, and related travel patterns. Over time, the change in travel patterns provides insights into motorists' behaviour in response to traffic advisories, change in charges for the Electronic Road Pricing system (section 6.3.1), new road connections and other factors.

The data gathered can be quite detailed. Study of users travelling from Tampines, in the east of Singapore, to the Central Business District (CBD) showed that there were two alternative routes – the Pan-Island Expressway (PIE) which is charged during morning peak hours and the uncharged Upper Changi Road. The difference in travel times was only 5 minutes on average during the morning peak and users did not seem to have a preference between those two routes.

With more in-depth analysis it is possible to calculate average travel times at different times of the day, and on different days of the week; for example, commuters have a longer travel time from Tampines into the CBD on Mondays and Wednesdays. Such information is very useful to transport planners, allowing them to distribute traffic more evenly, optimising road network usage, and also benefiting travellers. Feedback on the app from motorists has been very positive.

On the debit side, data analysis can be difficult and time-consuming and manual intervention and verification are essential. Future development of the app would permit the data be used to validate household travel surveys, measure waiting time at bus stops and count queues at taxi stands in real-time.

8.2.2 Waze

Waze (**https://www.waze.com**) is owned by Google. As in the Singapore example above, after typing in their destination address, Waze users drive with the app open on their phone to contribute traffic, mapping and other road data in background mode; but they can also be pro-active by sharing reports on accidents or disruptions on the road network, and fuel prices at gas stations, benefitting other drivers and users. There are also online freelance map editors who ensure that the data in their areas is as up-to-date as possible. As anyone with a satnav knows, road networks change on both short-term and long-term bases, due to incidents, road-works, construction of by-passes and other road- building; keeping a road network database up-to-date is time-consuming and expensive – at least in the absence of Waze - its app and use of the online data are both free of charge.

In October 2014 Waze launched its "Connected Citizens" program with a number of city partners who had agreed to share their data, including Boston, Los Angeles, Miami and New York in the USA, San Jose in Costa Rica, Rio de Janeiro in Brazil, Jakarta in Indonesia, Tel Aviv in Israel and Barcelona in Spain. The objective is to set up a 2-way information exchange, where the authorities provide their road traffic and transport data which Waze aggregates and makes available to users, who in turn supplement and update the data by crowd-sourcing. This aggregated and updated data can then be used by a city's traffic management centre as well as by users of the app. There are obvious links with smart and connected cities – section 9.1.

8.3 Traffic Management

8.3.1 Managed Motorways & Smart Motorways

Managed Motorways,aka Smart Motorways, are a means of getting more traffic capacity out of a road, especially motorways and Interstate Highways, at lower cost, without increasing physical capacity, using ITS. These “strategic roads” are a small percentage of the network, but carry most of the traffic; according to the UK Highways Agency (aka Transport England), the 4400-mile Strategic Road Network makes up 2.4% of English roads, but carries 33% of all traffic and 67% of all freight traffic. Counter-intuitively, despite changing the “hard shoulder” into a running lane (with refuges/laybys every km), smart motorways are safer motorways. On the UK M42 around Birmingham, the smart motorway that has been in operation for several years, has not only reduced congestion and improved journey time reliability, but has improved safety - frequency of accidents has fallen by more than half.

8.3.2 Smart Maintenance of Dublin’s ITS Infrastructure

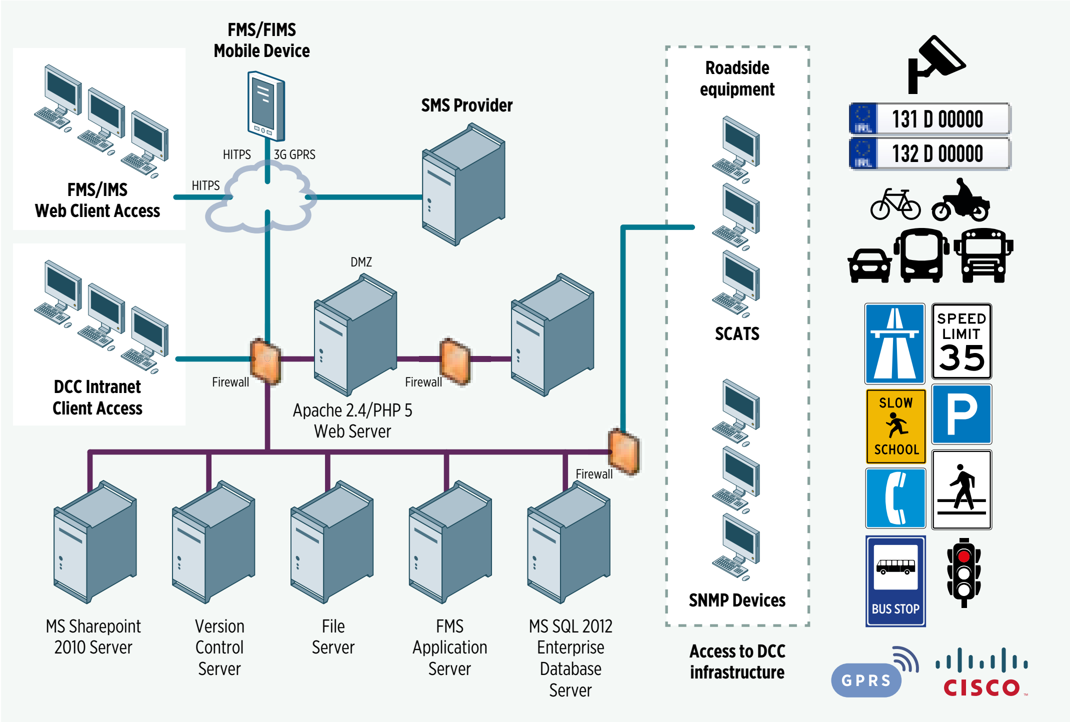
Nicander, a UK-based software and IT consultancy, recently developed an Internet and smart phone-based integrated fault, repairs and inventory management system commissioned by Imtech Traffic & Infra for Dublin City Council and its third party maintenance contractors (Platt 2014). ITS field staff access it from their smart phones, providing the following benefits:

- **Ability to respond quickly to faults and avoid infrastructure downtime while minimising travel time, costs and carbon emissions, and maintaining the infrastructure to the highest standard.**
- **Optimising maintenance team size and utilisation, and minimising time-consuming and bulky paper-based systems.**
- **Maximising first visit fault rectification and optimising repair activity.**
- **Facilitates the identification of poorly performing technology, and improves stock control.**
- **Time consuming fault/repair recording tasks are automated and all activity is logged.**

Dublin City Council is the largest Irish local authority. It has invested heavily in ITS for many years, including urban traffic control systems, CCTV, automatic number plate recognition, vehicle detection, emergency telephones, access and lane control, and variable message signs; this infrastructure investment supports economic growth throughout Ireland so its continuing availability is crucial.

The Fault Management System (Figure 12) manages the life cycle and maintenance of ITS equipment by in-house staff and third party contractors. Faults in roadside devices are diagnosed automatically; management services are delivered through internet based connectivity including mobile applications. Secure access from Android smart phones or tablets allows field engineers to view and enter information directly from the roadside. The system went live in January 2014 and is working well; faults are cleared more quickly and more and better management information is available. The ITS infrastructure must be available 24/7; managers receive alerts via email and SMS. The open architecture, standard internet connectivity and smart phone technologies allow upgrade and integration as new technologies emerge.

FIGURE 12: INTEGRATING THE MANAGEMENT OF DUBLIN'S ITS ASSETS THROUGH WEB-BASED AND ANDROID APP SOLUTION



Source: Nicander Ltd

8.3.3 BMW ConnectedDrive: regular automatic navigation map updates

BMW's Navigation System Professional, paired with ConnectedDrive, enables regular automatic navigation map updates, keeping the system informed of new roads and modified traffic layouts. Using the vehicle's built-in SIM card, the data is transmitted over the air via the mobile phone network, with no licensing fees or transmission costs for the end user. Real Time Traffic Information (RTTI), used to optimise route calculations, can also be transferred over the same communications link.

8.4 Smart Environment – traffic pollution management

Pollution and noise due to road traffic is an increasingly important issue. Transport is a major source of CO_2 and other emissions, and with current concerns about global warming there is considerable interest in transport aspects of this field. Topics include:

- **Emission & pollution detection and control**
- **Low Emission Zones (as in London)**
- **Environmental monitoring**

Because they emit less CO_2, diesel vehicles were seen as relatively friendly environmentally. However, now there is concern about the NO_x they emit, which is injurious to health, so the pendulum may swing back to petrol – as well as to alternative fuel vehicles.

Mobile technology can contribute environmentally by making transport more efficient, via travel information apps and navigation systems. If smart-phones were equipped with suitable sensors, they could also act as a crowd-sourced pollution monitoring system, similar to the traffic monitoring schemes described above.

8.5 Social Media in Transport

In 2013 there were 680 million active monthly mobile users of Facebook, 120million users of Twitter and 46 million users of LinkedIn (GSMA 2013b). These and other social media, especially twitter and crowd-sourcing, have become an increasingly important source of transport information and even of control. People may learn about a road traffic accident or transport problems through twitter before they hear about it from their traffic information service; for example, Transport for London asks people to follow @TfLTrafficNews to get live travel news and avoid disruption. Car-sharing has been found to be more acceptable with “Facebook Friends” than it is with strangers.

Social media allow transport users to communicate and share intelligence with each other as distinct from the traditional relationship of communication between transport system providers and end users, as we have seen above.

8.5.1 Moovit

Moovit is a public transport version of Waze. Its free local transit planner shows live arrival & departure times, updated time-tables, local station maps, service advisories that affect your trip, with crowd-sourced supplementary data from other travellers. It notifies you when you are getting close to your stop. Moovit is available in more than 500 cities world-wide including New York, Los Angeles, London, Paris, Madrid, Barcelona, Rome, Sao Paulo, Rio de Janeiro, Bogota, Santiago de Chile, Sydney, Toronto, and Tel Aviv, and it is planning to expand particularly in Asia-Pacific. It also plans to include bike, taxi, and car-sharing services. The app is available free of charge for Apple, Android and Windows phones. **http://www.moovitapp.com/**

8.5.2 AASHTO and social media

For five years the American Association of State Highway and Transportation Officials (AASHTO) has surveyed the use of social media and mobile app tools by state DOTs (Departments of Transportation), including the types of tools used, agency policies and the development of mobile smartphone apps. It has found a continuing trend toward social media adoption and changes in public engagement strategies. In 2010, less than half of state DOTs used Facebook and only 26 states had Twitter accounts. The 2013 survey found that 90 percent of state DOTs use both Twitter and Facebook to share information about traffic incidents, construction projects, safety initiatives and public involvement opportunities. Mobile apps are an increasingly important area; one DOT added 100,000 mobile app users in just six months. Half of the States offer mobile apps and 73% percent have mobile-friendly web sites. Another growth area is the use of social media to gather information such as pothole locations. But there is some ambivalence because of the potential of mobile apps to distract drivers, and there are ongoing challenges in keeping up with public expectations on the supply of information (a potential opportunity for MNOs).
http://communications.transportation.org/Documents/Social%20Media%20Survey_final_Oct2013.pdf

8.5.3 Gamification in transport

"Gamification" is the use of gaming concepts (e.g., challenges, discovery, levels, rewards, scores, leaderboards, status) and gaming technology (e.g. 3D animation tools) in non-game contexts – adding fun to a real-word task. There are a number of examples in the transport domain.

- **A trial in Singapore aimed to improve commutes and optimise the efficiency of the transport network by persuading commuters to switch to off-peak hours to earn credits, which can be traded for cash. It seemed to be effective in that 11% of users shifted to off-peak, - enough to make a difference to traffic flow.**
- **Chromaroma was a gamified approach to transport, encouraging the use of public transport in London, turning daily journeys into a series of missions and competitions. It was based on the Oyster travel card and the "Boris-bike" cycle rental scheme. Although it no longer seems to be available, its developer is working on follow-up projects (http://www.chromaroma.com/).**
- **The California Department of Transportation (Caltrans) with the Office of Traffic Safety and the California Highway Patrol launched an interactive, mobile and online game called "Distraction Zone" to educate young drivers about safe driving - avoiding distractions, being alert, and slowing down when approaching road-works. The game is available in both mobile and online format. (www.BeWorkZoneAlert.com).**

Gamification is not new, but it has become fashionable, based partly on the "nudge" philosophy and the enormous commercial success of the computer games industry. Other applications in transport include driving feedback and transport planning (Polak et al 2014).

A report by research company Markets and Markets in 2013 predicted that the gamification market would be worth $5.5 billion by 2018, up from $421 million in 2013, though it is not clear how much of that would be in transportation. The Gartner group predicted that by 2014, 70% of large companies would use gamification in their organisations, driving much of their innovation.

There are opportunities for MNOs in this new field of gamification, such as real-time journey monitoring, particularly based on smart-phone apps.

9. Smart cities and the Internet of Things (IOT)

9.1 Smart cities

A smart city uses intelligent technology to sustainably enhance the quality of life in urban environments, saving money, minimising waste, measuring domestic water usage and managing transport routes, the latter being relevant here. ICT links and strengthens networks of people, businesses, infrastructures, resources, energy and spaces, as well as providing intelligent organisational and governance tools.

According to the "Guide to Smart Cities: The Opportunity for Mobile Operators" (GSMA 2013a), the global mobile addressable market in smart cities, transport, utilities and intelligent buildings will amount to USD67.1bn in 2020, up from USD22.8bn in 2012, according to Machina Research. By 2020, security in intelligent buildings, (which includes connected security alarm systems, fire alarms, CCTVs, intercoms and building access control) will account for 52% of the total addressable market for mobile operators. Smart meters will be the second largest addressable revenue category, with 22% of the total, followed by environment and public safety sector applications with 14% in 2020. These figures exclude the potentially significant revenues that mobile operators could earn from the data generated by smart city services.

Other commentators project the smart cities industry to be worth more than $400 billion globally by 2020. Mobile operators are already involved in smart city projects. Of the 150 smart cities the GSMA tracks, more than 100 have deployed services (beyond smartphone apps) that use mobile networks. The GSMA has identified 232 mobile products and services that cover a variety of smart city sectors, of which transport accounts for 99 worldwide, such as ticketing applications, intelligent transport systems and traffic information.

Deutsche Telekom is rolling out services developed in its test-bed in Friedrichshafen to other German cities.

The Amsterdam Smart City project aims to turn the city into the smartest in the world. Initiated by the city, its Economic Board, and KPN Telecom amongst others, it now has over 70 partners. The suburb of IJburg has become a "Living Laboratory" with free Wi-Fi and a new optical fiber network. One partner, TrafficLink, is developing "The Digital Road Authority" to shorten the response time of emergency services by controlling traffic lights and bridges. It also provides IJburg residents with personalised travel advice, and reduces emissions by guiding trucks to available unloading zones. **http://amsterdamsmartcity.com/about-asc**

£50 million over 5 years has been earmarked by "Innovate UK" for the new Future Cities Catapult centre established in London and the Future Cities Demonstrator Project in Glasgow. The UK DfT is working with the nine largest English cities outside London through the Smart Cities Partnerships to support them in delivering smart, integrated ticketing schemes; the principal bus operators have committed to deliver smart multi-operator tickets in 2015 (DfT 2014). The Borough of Greenwich (London) Smart City is a test site for one of the UK's Driverless Cars project (section 3.2.3).

In Singapore, the Land Transport Authority's mytransport.sg portal has prompted the creation of 23 mobile apps since it was set up in 2010. NCS, the IT arm of SingTel, and its partners have an Urban Mobility initiative using advanced technologies to improve urban mobility.

The Indian government has announced a plan to build pollution-free smart cities at each at the country's 12 major ports, including Mumbai and Chennai, by 2020, starting in 2015. They will be built to international standards and use green energy: bio fuels, solar energy and wind power.

According to GSMA (2013a), mobile operators can play a role in four key elements of smart city services:

- **Connectivity: connecting city infrastructure and individuals' handsets to central servers and databases;**
- **Data aggregation/analysis: combining data from multiple sources to produce new insights;**
- **Service delivery: delivering real-time information to people and machines that will enable them to adapt and respond to events in the city;**
- **Customer interface - providing customer support operations, such as call centers and web portals, as well as delivering messages to subscribers.**

9.2 M2M and the Internet of Things

The Internet is evolving from connecting people to connecting things – the so-called "Internet of Things" (IoT), enabled by Machine to Machine (M2M) communication. By 2020, handsets will constitute only 72% of cellular connections, from 92% in 2014, with an estimated 14.5 Billion connected M2M devices (GSMA 2014e).

In his Keynote Speech at the 2015 Consumer Electronics Show (CES) in Las Vegas, the Samsung Electronics CEO said that the IoT represented the most promising of all markets in the technology industry. Samsung believes that openness is key to IoT development, as is collaboration between the technology industry and the industries that IoT will revolutionise. By 2017, all Samsung televisions, and by 2020 all Samsung hardware, will be IoT devices.

The connected car (3.2.1) is one instantiation of the IoT. Also at CES 2015, the Ford CEO indicated that the company plans to become a transportation data analytics organisation, absorbing data from cars and people and turning it into a business, related to vehicle quality, insurance costs, car sharing, driving patterns, parking apps, transportation analysis and societal problems – not just smarter cars, but smarter roads and smarter cities. Ford sees data as a major asset.

According to a recent UK report, the IoT can deliver significant benefits to citizens and consumers across healthcare, energy and transport, where collecting information from vehicles can help to improve traffic flow, allow drivers to avoid traffic accidents, find parking spaces and provide information for better vehicle design (Ofcom 2015). This will considerably increase cellular network traffic but Ofcom concludes that making spectrum available at 870/915MHz and liberalising licence conditions for existing mobile bands, plus spectrum at 2.4 and 5GHz, should meet the short to medium term demand, though there may be a need for additional spectrum in future. Ofcom also notes the increasing importance of network resilience and data security and privacy. The European Union will soon require all vehicles to have eCall (section 1.4.1) on board - a start for M2M communication.

Satellite communications may be best for delivering IoT services in rural areas, as well a backup for terrestrial services. IoT will not be a single network or technology but a heterogeneous collection of technologies operating on both licensed and licence-exempt bases.

Thus the IoT is a major opportunity for MNOs in providing mobile network connectivity – though a prerequisite is the adaptation of the cellular network standards to facilitate these new services.

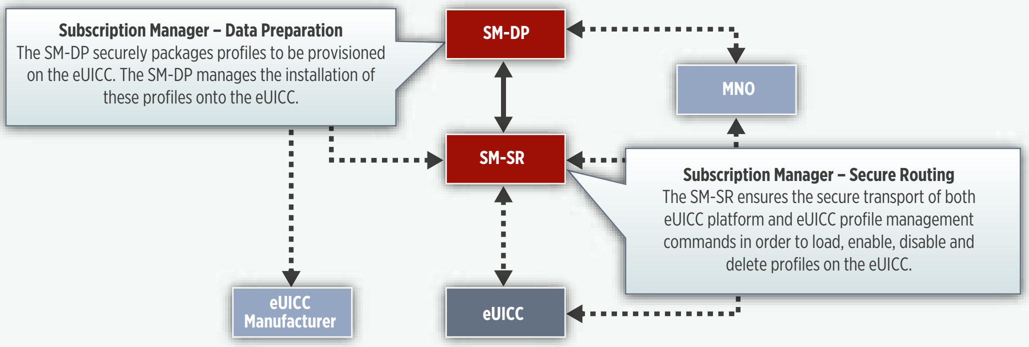
9.3 The embedded Universal Integrated Circuit Card - eUICC

So a new type of mobile network user will emerge; automobile, consumer electronics, energy companies and others will see their devices used by millions world-wide. M2M communication will become standard, primarily using mobile networks.

However, there is an issue with the SIM card in these M2M applications. One of the benefits of the SIM is that customers can easily change the SIM and network operator if they wish. But for M2M applications a change of SIM is impractical for a number of reasons; it may be inaccessible, or soldered in to prevent fraud and damage from vibrations. Operators recognised this and developed “GSMA Embedded SIM” technology to allow change of operator, subject to any contractual conditions, if required. The eUICC is an embedded SIM. The GSMA has produced an embedded SIM Specification to accelerate growth in M2M (GSMA 2014e). The specification provides a standard mechanism for remote management of M2M connections, allowing “over the air” provisioning of an initial operator subscription, and a change to other operators subsequently, while maintaining the same level of security as with traditional removable SIMs. See http://www.gsma.com/connectedliving/embedded-sim/.

Figure 13 shows the eUICC Subscription Manager architecture. Operators use the Data Preparation entity to securely encrypt their operator credentials for over the air installation within the SIM. The Secure Routing entity delivers the encrypted operator credentials to the SIM and remotely manages the SIM thereafter to enable, disable and delete the credentials as necessary during the product’s lifetime. Use of the eUICC could minimise some of the security problems outlined in section 4.2.

FIGURE 13: EUICC SUBSCRIPTION MANAGER ARCHITECTURE



The GSMA Embedded SIM provides tremendous benefits to OEMs, including late-stage provisioning during manufacture, therefore those Operators who can supply this capability will win market share. Additionally the technology improves traditional Operator M2M business, including reduced costs in handling M2M SIM products and low integration and testing costs. And all this with minimal impact to existing systems and network infrastructure.

So the eUICC provides new business opportunities for MNOs, with reduced logistical costs but retaining existing SIM security levels, with minimal impact to the network infrastructure (non-standard proprietary devices have been insecure and have been known to cause network problems).

The eUICC can also be used with removable M2M SIMs – for example a vehicle may have its infotainment provided via one MNO and its remote engine monitoring by another.

10. Conclusions and recommendations

ITS is a very diverse subject, with a variety of communications needs that MNOs can address.

10.1 General recommendations

A good way of keeping up-to-date with the ITS field is attending and exhibiting at ITS conferences. The annual ITS World Congress Conference and Exhibition rotates between Asia-Pacific, Europe and North America; the next ones are in Bordeaux (October 2015), Melbourne (October 2016), Montreal (October 2017), and Copenhagen (2018). There are European ITS conferences in years when the World Congress is in North America or Asia-Pacific, the next being in Glasgow (2016). The 13th ITS Asia Pacific Forum met in New Zealand in April 2014 and the 14th will be in Nanjing, China in April 2015. The IEEE organises similar ITS and Intelligent Vehicle conferences in the US.

Standards are crucial; MNOs and the cellular industry have extensive standards experience and should be involved in ITS standards development, such as C-ITS in Europe. Interoperability is crucial – GSM is a good model for ITS in general and tolling in particular.

National and multi-national collaborative R&D programmes such as Europe's "Horizon 2020" programme are good ways of getting exposure to the field, gaining exposure to new areas and trialling relationships with potential new partners.

Whilst the future of driverless cars is still uncertain, there is an enormous amount of R&D activity in the field, and there will undoubtedly be big spin-off benefits whether or not the promise is delivered. Connected cars are here today. In both cases mobile communications are crucial.

One of the most promising areas in the long-term, though uncertain in the short-term because of adverse public opinion, is road user charging using GNSS/CN (Global Navigation Satellite System/Cellular Network) - the only way to achieve true distance-based charging. There are signs, in the western US, in Europe, in China and in Singapore, that it is becoming standard – though users ideally need to be given a choice of technology.

- **Germany and Slovakia use GPS/GSM-based truck tolling schemes, with Belgium following shortly, and other European countries evaluating the technology. Deutsche Telecom is heavily involved in the German scheme.**
- **Singapore will replace its microwave road pricing scheme by GNSS/CN by 2020.**
- **The 2015 Oregon large-scale trials, which have a GNSS/CN option, are being closely followed by 14 other Western States. California will run a similar trial in 2017. Verizon and telematics company Azuga are suppliers to the Oregon trials.**
- **Beijing is trialling GNSS/CN amongst other technologies for urban congestion charging. China has also trialled GNSS/GSM electronic toll collection on the Jing-jin-tang highway.**
- **Mobile operators have a track record of keeping large volumes of sensitive data secure (GSMA 2013a), making them well-placed to play a role in road pricing, where privacy is an issue and mistrust of Governments is endemic. MNOs should work with Local and National Authorities to encourage the further development of wide-area road user charging and to ensure they are involved.**
- **Augmentation technologies such as heading sensors can improve positioning accuracy, and it is possible that there may be a role for smartphones in this respect.**

Many recommendations from the GSMA report on Smart Cities (2013) apply in the ITS field:

- **A MNO should partner with ITS-aware international technology companies or systems integrators to facilitate solutions across national borders, avoiding starting from scratch with new partners in each country or region. For example, in the Smart City arena, Vodafone Global Enterprise and AT&T have partnered with IBM, and KT with Cisco. Clearly, the MNO must ensure that such partnerships allow it to capture significant value.**
- **Alternatively a mobile operator can partner with a systems integrator within the same telecoms group as do Deutsche Telekom (with T-Systems) and Telefonica (with Telefonica Digital).**
- **Another option is to acquire an ITS-aware organisation, or buy a stake in one; Verizon bought Hughes Telematics in 2012.**
- **The ITS field is changing rapidly, largely because of mobile communications, which are of intrinsic importance in the field. Users will also pay for real-time data on traffic flows and incident detection, useful for transport planning as well as for traffic information broadcasting. MNOs should highlight to National and Local Authorities the benefits of mobile-based transport services. The GSMA could run summits for transportation organisations and authorities. And mobile operators must develop appropriate marketing messages.**
- **Mobile operators must invest in market intelligence and acquiring knowledge of transportation customers. MNOs need to understand the transport agendas of Governments, municipalities and transport operators.**
- **There is already a shift to cloud-based services and solutions (section 2.4), where the authorities no longer own the assets, but pay to use them. These cloud-based services depend on connectivity, authentication and billing – core telco competences.**
- **Mobile operators need a mix of vertical, M2M and cross-functional skills (e.g. cloud-based services and dealing with open data) to work successfully with transport teams.**

10.2 Specific recommendations

The following recommendations have been made earlier, but are collated and summarised here.

Average speed zones need communications between cameras, and/or to a control centre; intelligent urban traffic control systems need communications links to traffic lights, variable message signs, cameras and other sensors; land-lines have traditionally been used but increasingly could be replaced by a mobile network.

A problem with High Occupancy Vehicle and High Occupancy Toll lanes is identifying how many people there are in a vehicle and therefore whether a charge is payable. Cellphone technology could provide a solution, if it is possible to distinguish between 2 or 3 people in a vehicle each with their own cellphone, and a single-occupancy vehicle whose driver has 2 or 3 cellphones. This would be an opportunity for MNOs, if they could find a solution.

Security is an issue in autonomous and connected vehicles and in telematics applications, and could be improved by using eUICCs. The eUICC also provides new business opportunities for MNOs, with reduced logistical costs while retaining existing SIM security levels. MNOs can also play a wider role because of their expertise in authentication and security.

Fleet management and PAYDI/UBI are expanding marketplaces, with increasing opportunities for MNOs, especially with the move to 3G and 4G.

The routes, bus-stops and timetables of Nairobi's 20,000 matatus (public buses) have been established by GPS-enabled smart-phones, and commuters can now access them using the "Transit App". The same could be done in any "informal transit system", of which there must be many world-wide, with increased revenues for MNOs.

Car sharing and car clubs are already fertile ground for MNOs, but there is still a great deal of unexplored potential – including load-sharing in freight. Similarly, other MNOs could emulate Vodafone in cycle security schemes and in sponsoring cycle hire – schemes which are likely to attract the kind of customers that MNOs are looking for.

Mobile technology and social media can improve the passenger experience of public transport and benefit transport operators and MNOs, in both urban and rural areas. Real-time bus information and arrival times at bus stops can be accessed via smartphones and SMS. There is evidence that availability of such information increases ridership.

New York City's App Quest has generated interest worldwide. MNOs could partner with cities or other administrations to set up their own version of App Quest, generating good publicity, branding opportunities, and network traffic - and not just in the transport domain.

Mobile technology can supplement or replace the "traditional" sources of road traffic information, and be more user-friendly for travellers. Conversely, crowd-sourced data from smart-phones can supplement the infrastructure-based traffic sensors used by administrations. MNOs know the details of the daily commuter journey of their subscribers and could offer a service to send them information on transport disruptions and propose more efficient or cheaper journey option. Such schemes have been trialled in Singapore. Waze supplies a similar service through its "Connected Citizens" program with city partners worldwide. Moovit is akin to a public transport version of Waze.

Mobile technology can contribute environmentally by making transport more efficient, via travel information apps and navigation systems. Furthermore, if smart-phones were equipped with suitable sensors, they could act as a crowd-sourced pollution monitoring system, similar to the traffic monitoring schemes described above – a useful service to administrations who have to observe air quality standards.

Social media have changed the traditional communications between transport system providers and end users. US State Departments of Transportation increasingly use Twitter and Facebook to share information about traffic incidents, construction projects, safety initiatives and public involvement opportunities. Mobile apps are increasingly important; one DOT added 100,000 app users in six months. But there are ongoing challenges in keeping up with public expectations of the supply of information - a potential opportunity for MNOs.

Mobile operators can play a role in four key elements of smart city services:

- **Connectivity: connecting city infrastructure and individuals' handsets to central servers and databases;**
- **Data aggregation/analysis: combining data from multiple sources to produce new insights;**
- **Service delivery: delivering real-time information to people and machines that will enable them to adapt and respond to events in the city;**
- **Customer interface: providing customer support operations, such as call centers and web portals, as well as delivering messages to subscribers.**

The Internet of Things is a major opportunity for MNOs in providing mobile network connectivity – though a prerequisite is the adaptation of the cellular network standards to facilitate these new services. In January 2015 Singtel and Ericsson announced a partnership to explore the future of 5G communications in Singapore, including the Internet of Things and "cloud-based computing", supporting Singapore's vision of itself as a "Smart City."

11. References and further reading

11.1 References

Berg Insight (2014a) "Fleet Management in Europe", M2M Research Series, October 2014,
www.berginsight.com

Berg Insight (2014b) "Fleet Management in Russia/CIS and Eastern Europe" , M2M Research Series, July 2014,
www.berginsight.com

Berg Insight (2015) "Fleet Management in Europe", M2M Research Series, January 2015,
www.berginsight.com

Börjesson, M. & Kristoffersson, I (2015) "The Gothenburg congestion charge. Effects, design and politics", Transportation Research Part A: Policy and Practice. To be published.

Chang J, Pretorius H, Rive G & Thomas, J, (2014) "Multi-modal Information Provision for New Zealand – What to do next?", 13th ITS Asia Pacific Forum, Auckland, New Zealand, 28-30 April 2014.
http://www.itsasiapacificforum2014.co.nz/final-papers/

Cisco (2013) "Internet of Everything: A $4.6 Trillion Public-Sector Opportunity".
http://internetofeverything.cisco.com/sites/default/files/docs/en/ioe_public_sector_vas_white%20paper_121913final.pdf

DfT (2005), "Making Car Sharing and Car Clubs Work: A Good Practice Guide", March 2005,
http://www.civilservice.gov.uk/wp-content/uploads/2012/02/makingcarsharingmarch2005.pdf

DfT (2014), "Door to Door Action Plan: Progress Report December 2014".
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/391159/dft-door-to-doort-action-plan-3.pdf

EC (2008), "The ITS action plan", COM(2008) 886:
http://ec.europa.eu/transport/its/road/action_plan_en.htm

EC (2009a), "Intelligent transport systems: A smart move for Europe".

EC (2009b), "The European Electronic Toll Service".

Estiot, A. (2008). The German GNSS Toll System: lessons learned in ITS and environmental fields. In ASECAP 36th Study and Information Days, Marrakesh, 20 May 2008.

EU (2004), "Directive 2004/52/EC of the European Parliament and of the Council

of 29 April 2004 on the interoperability of electronic road toll systems in the Community".

EU (2006), "Directive 2006/38/EC of the European Parliament and of the Council of 17 May 2006 Amending Directive 1999/62/EC on the Charging of Heavy Goods Vehicles for the Use of Certain Infrastructures".

EU (2014), "Gap Analysis: What is to be done for C-ITS Deployment". European Commission document.
http://ec.europa.eu/transport/themes/its/news/doc/c-its-platform-deployment/draft-work-programme.pdf

Evensen K & Schmitting, P (2014), "D3.5b – Standardisation Handbook", iMobility Support, 9Dec2014.
http://www.imobilitysupport.eu/

GSMA (2012), White Paper: "Mobile NFC in Transport", September 2012, amended April 2013.

GSMA (2013a), "Guide to Smart Cities: The Opportunity for Mobile Operators", February 2013.

GSMA (2013b), "The Mobile Economy 2013"

GSMA (2014b), "The Mobile Economy 2014"

GSMA (2014c), "Smartphones &Mobile money: The Next Generation of Digital Financial Inclusion", GSMA July 2014. http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2014/07/2014_MMU_Smartphones-and-Mobile-Money-The-Next-Generation-of-Digital-Financial-Inclusion_Web.pdf

GSMA (2014d), "Smoother, Smarter Transport in the UAE", January 2014.

GSMA (2014e), "GSMA Embedded SIM Specification - A single, common and global specification to accelerate growth in M2M", GSMA,12 October 2014. http://
www.gsma.com/connectedliving/wp-content/uploads/2014/10/GSMA-Embedded-SIM-Specification-flyer.pdf

HA (2014), "Smart motorways",
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/363993/Smart_motorways_-_Fact_Sheets.pdf

HKTAC (2014), "Report on study of road traffic congestion in Hong Kong", Transport Advisory Committee, December 2014.
http://www.thb.gov.hk/eng/boards/transport/land/Full_Eng_C_cover.pdf

Kirchmann, H. K. (2008). Satellite based tolling: built for the future. In 15th ITS World Congress on Intelligent Transport Systems, New York, 16–20 November 2008.

Wong Sook Kwan et al., (2014), "A self-learning smart traffic mobile app" . 13th ITS Asia Pacific Forum, Auckland, New Zealand, 28-30 April 2014
http://www.itsasiapacificforum2014.co.nz/final-papers/

KPMG (2014), "Infrastructure 100: World Markets report",
http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/infra100-world-markets/Documents/infrastructure-100-world-markets-report-v3.pdf

Markey, E, (2015) "Tracking & Hacking: Security & Privacy Gaps Put American Drivers at Risk". A report written by the staff of Senator Edward J. Markey (Democrat - Massachussetts). February 9, 2015.
http://www.markey.senate.gov/news/press-releases/markey-report-reveals-automobile-security-and-privacy-vulnerabilities

London (2014), "A Car Club Strategy for London", (draft) The Car Club Coalition.

Ofcom (2014) "The Communications Market Report". Published 7 August 2014.
http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr14/2014_UK_CMR.pdf

Ofcom (2015), "Promoting investment and innovation in the Internet of Things; Summary of responses and next steps", 27 January 2015. http://stakeholders.ofcom.org.uk/binaries/consultations/iot/statement/IoTStatement.pdf

Onishi, H, (2014), "Guidelines to Protect Society Against Enlarged Vehicle Cyber Risks", Embedded Security in Cars (ESCAR) Conference, 18-18 November 2014, Hamburg.

Platt, T, 2014), "Smartly Maintaining Dublin's ITS Infrastructure", 13th ITS Asia Pacific Forum, Auckland, New Zealand, 28-30 April 2014
http://www.itsasiapacificforum2014.co.nz/final-papers/

Polak, J, Zolfaghari, A & Daina, N, (2014), "Gamification in Transport: What's all the fuss about?", IET Road Traffic Information & Control Conference, 6-7 October, 2014, London.
http://tv.theiet.org/technology/transport/index.cfm

Shoup, D (2011), "The high cost of free parking". FHWA webinar 23 February 2012. See also his 2005 book The High Cost of Free Parking", (ISBN 978-1-884829-98-7).

Siviak & Schoettle (2015) "Road Safety with Self-Driving Vehicles: General Limitations and Road Sharing with Conventional Vehicles", University of Michigan-Transportation Research Institute Report No. UMTRI-2015-2, January 2015.

Schwartz (2013), "Managing traffic through fair pricing",
http://www.samschwartz.com/Portals/0/PDF/Managing%20Traf%20Thru%20FP%20051313.pdf

USDoT (2014), "ITS Strategic Plan 2015-2019", FHWA-JPO-14-145, May 15, 2014. www.its.dot.gov

Walker, J (2011), "The Acceptability of Road Pricing".
http://www.racfoundation.org/research/economics/road-pricing-acceptability

Wang D et al. (2012), "The experimental system of GNSS-based ETC applied in China", 19th ITS World Congress, Vienna, Austria, 22/26 October 2012, AP-00357

Westminster (2014), "Westminster Annual Parking Report 2013/14", Westminster City Council's Annual Parking Review for 2013/14
http://transact.westminster.gov.uk/docstores/publications_store/parking/annual_report_2013_14.pdf

11.2 Further reading

11.2.1 Relevant GSMA publications

GSMA (2012), White Paper: "Mobile NFC in Transport", September 2012. Amended April 2013.

GSMA (2013a) "Guide to Smart Cities: The Opportunity for Mobile Operators", February 2013.

GSMA (2013b), "The Mobile Economy 2013"

GSMA (2013c), "Connected Car Forecast: Global Connected Car Market to Grow Threefold Within Five Years", February 2013.
http://www.gsma.com/connectedliving/wp-content/uploads/2013/06/cl_ma_forecast_06_13.pdf

GSMA (2014a), White Paper: "The Value of Mobile Commerce in Transport". February 2014.
http://www.gsma.com/digitalcommerce/wp-content/uploads/2014/01/GSMA-The-Value-of-Mobile-Commerce-in-Transport-Feb14.pdf

GSMA (2014b), "The Mobile Economy 2014"

GSMA (2014c), "Smartphones &Mobile money: The Next Generation of Digital Financial Inclusion", GSMA July 2014.

GSMA (2014d), "Smoother, Smarter Transport in the UAE", January 2014.

11.2.2 Other publications

Automotive Council UK. (2014), "Connected and cooperative transport: for a safe, efficient and sustainable transport system". Technology Roadmaps. Sept. 2014.
https://www.transportinnovation.se/system/files_force/dokument/roadmap_for_connected_and_cooperative_transport.docx?download=1
Beecham Research (2014), "Benefits analysis of GSMA Embedded SIM specification on the Mobile Enabled M2M Industry". Beecham Research Ltd and GSMA, September 2014.
http://www.gsma.com/newsroom/wp-content/uploads/BRL-Benefits-Analysis-GSMA-Embedded-SIM-Specification-2014.pdf

Begg, D. (2014), "A 2050 vision for London: what are the implications of driverless transport". (Commissioned by Clear Channel).

Berthelsen, E, (2015) "Movement analytics delivers an untapped revenue opportunity for mobile operators", Machina Research White Paper for INRIX, February, 2015.
https://machinaresearch.com, www.INRIX.com

KPMG (2012) "Self-driving cars: The next revolution", KPMG & the Center for Automotive Research, 2012.
www.kpmg.com , www.cargroup.org

McKinsey (2013) "Disruptive technologies: Advances that will transform life, business, and the global economy", May 2013.

USDoT (2015a) "2015 Pocket Guide to Transportation", US Department of Transportation, Bureau of Transportation Statistics.
http://www.bts.gov/publications/pocket_guide_to_transportation/2015/

USDoT (2015b) "Beyond Traffic: Trends and Choices 2045", Draft, US DoT, February 3, 2015. www.dot.gov/beyondtraffic.

Walport, M, (2014) "The Internet of Things: making the most of the Second Digital Revolution". A report by the UK Government Chief Scientific Adviser. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/389315/14-1230-internet-of-things-review.pdf

11.2.3 Useful websites

All the national ITS associations, including, ITS America, ERTICO and ITS Japan, have useful web-sites, and in some case newsletters that can be subscribed to.

13th ITS Asia Pacific Forum, Auckland, New Zealand, 28-30 April 2014
http://www.itsasiapacificforum2014.co.nz/final-papers/

C-ITS web sites: http://its-standards.info
http://its-standards.info/Feeds/cits.rss
http://release1.its-standards.eu/
http://calm.its-standards.info
http://coopsys.its-standards.info
http://pt1601.its-standards.info
http://stf455.its-testing.org

Telematics: http://analysis.tu-auto.com/

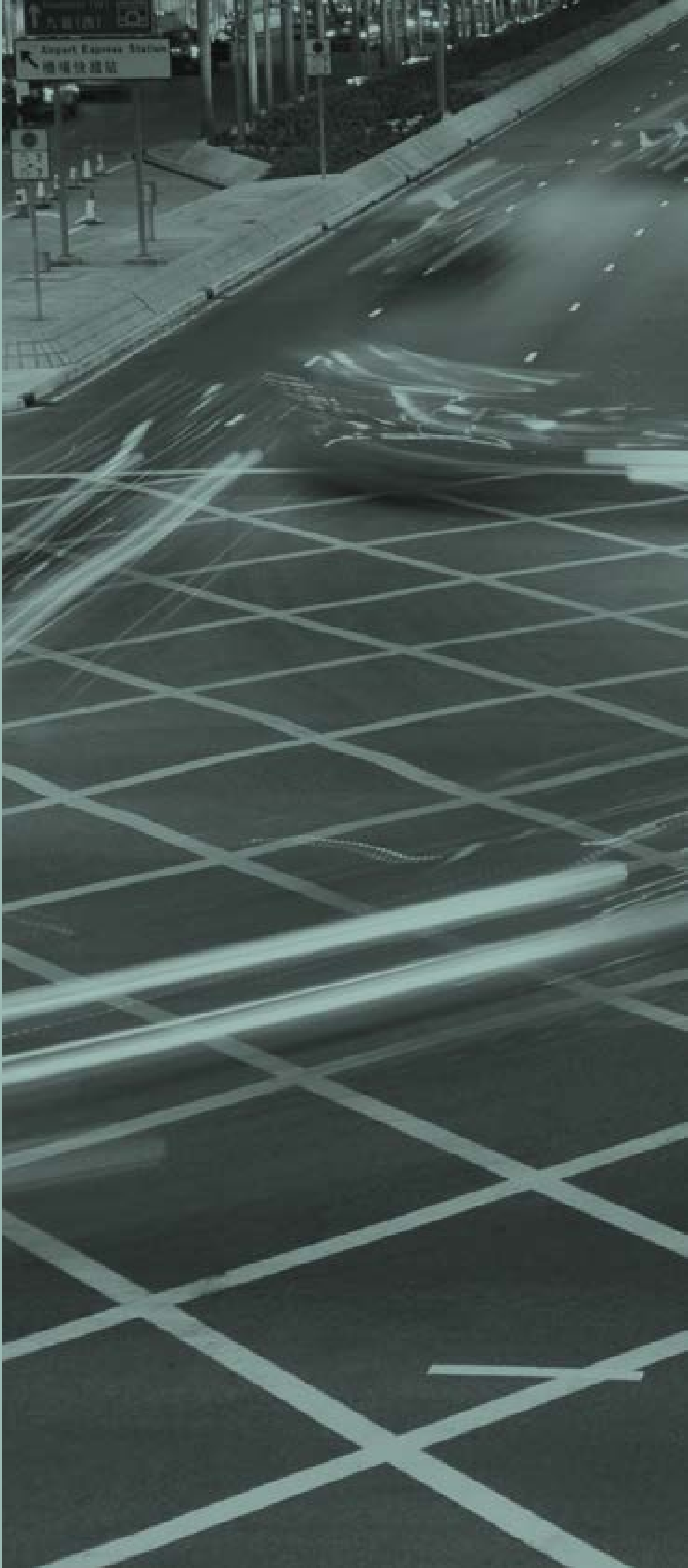
12. Appendix - Glossary of acronyms and terminology

3GPP	3rd Generation Partnership Project for cellular telecommunications standards development
ABvM	Anders Betalen voor Mobiliteit – Different Payment for Mobility
AASHTO	American Association of State Highway and Transportation Officials
ACC	Autonomous Cruise Control
ADAC	Allgemeine Deutsche Automobil Club, the German motoring organisation
ADAS	Advanced Driver Assistance Systems
AEB	Autonomous Emergency Braking
ALPR	Automatic License Plate Recognition
ALS	The Singapore Area Licensing Scheme – its original paper-based road pricing scheme
ANPR	Automatic Number Plate Recognition
API	application Programming Interface
ALV	Carnegie Mellon University's Autonomous Land Vehicle project
APTS	Advanced Public Transportation Systems
ASIG	Automotive Special Interest Group – a GSMA initiative to enable dialogue between mobile operators and vehicle manufacturers
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Traffic Management Information Systems
BEIDOU	The Chinese version of GNSS. Beidou-1 with 3 satellites had limited coverage, mainly of China. Beidou-2, when completed in 2020, will have global coverage.
BMCT	The Beijing Metropolitan Commission for Transport.
BRAiVE	BRAin-drIVE – VisLab's autonomous vehicle.
CAFE	The US "Corporate Average Fuel Economy" standards/regulations, operated by the NHTSA
CAGR	Compound Annual Growth Rate
CBD	Central Business District
CEN	Comité Européen de Normalisation – the European Committee for Standardisation
CES 2015	The Consumer Electronics Show in Las Vegas, January 2015
C-ITS	Cooperative ITS – an EC initiative
CIB	Collision Imminent Braking
CIS	Commonwealth of Independent States (as allied to Russia)
CN	Cellular Networks (usually as GNSS/CN)
CVO	Commercial Vehicle Operations
DAB	Digital Audio Broadcast
DART	Dallas Area Rapid Transit, Texas, USA
DG CNECT	EC Directorate General for Communication Networks Content & Technology
DG ENTR	The EC Directorate General for Enterprise and Industry
DG MOVE	The EC's Directorate General for Transport and Mobility
DG RTD	The EC Directorate General for Research and Innovation
DOT	Department of Transportation
DRIVE	Dedicated Road Infrastructure for Vehicle safety in Europe
EC	European Commission
EDGE	Enhanced Data rates for GSM Evolution
EETS	the European Electronic Toll Service
EFC	Electronic fee collection
ERP	Electronic Road Pricing – especially the Singapore scheme

ERTICO	The European ITS organisation
ETC	Electronic toll collection
ETSI	European Telecommunications Standards Institute
EU	European Union
eUICC	embedded Universal Integrated Circuit Card – an embedded SIM
Euro NCAP	European New Car Assessment Programme
EVI	Electronic Vehicle identification
FHWA	(US) Federal Highway Administration
FM	Frequency Modulation
Galileo	The European version of GPS.
GERAN	The GSM EDGE Radio Access Network
GLA	Greater London Authority
GLONASS	GLObalnaya NAvigatsionnay Sputnikovaya Sistema) - the Russian version of GPS
GNSS	Global Navigation Satellite System – the generic term for GPS, Galileo, GLONASS etc
GNSS/CN	Global Navigation Satellite System/Cellular Network. The terms are used together like this when both technologies are used in combination for road user charging.
GNSS/GSM	Global Navigation Satellite System/Global System for Mobiles. As for GNSS/CN above, but where GSM is sued rather than some other cellular network.
GPS	Global Positioning System
GPRS	General Packet Radio Service
GSM	Global System for Mobiles
GTFS	Google's General Transit Feed Specification - a standard format for public transport/transit schedules and related geographic information
HGV	Heavy Goods Vehicle; truck
HOV	High-Occupancy Vehicle lanes
HOT	High Occupancy Toll lanes
HSPA	High Speed Packet Access
HTTPS	HyperText Transfer Protocol Secure system - as used in Internet browsers
iOS	The Apple iPhone Operating System
ISA	Intelligent Speed Adaptation
ISO	International Standards Organisation
IT	Information Technology
ITS	Intelligent Transportation Systems
KT	KT Corporation, formerly known as Korea Telecom, an integrated mobile and land-line telecommunication service provider.
LDW/LKA	Lane Departure Warning/Lane Keep Assist
LEZ	Low Emission Zone
LIDAR	Light Detection And Ranging; originally coined as a combination of "light" and "radar". Alternatively, "Laser Illuminated Detection And Ranging".
LTA	The Singapore Land Transport Authority
LTE	Long Term Evolution – cellular radio 4th generation
M2M	Machine-to-Machine
MPG	Miles per Gallon
MNO	Mobile Network Operator
MTA	"Metropolitan Transportation Authority" (New York) or "Maryland Transit Administration"
NFC	Near Field Communications

NHTSA	National Highway Traffic Safety Administration
NOx	Nitrogen Oxides – vehicle emissions which are injurious to health
NY	New York
NYC DOT	New York City Department of Transportation
OBD	On-Board Diagnostics port on a vehicle
ODOT	Oregon's Department of Transportation
PAYDI	Pay As You Drive Insurance (aka Usage-Based Insurance -UBI)
POI	Points-Of-Interest
RDS	Radio Data System
RDS-TMC	Radio Data System – Traffic Message Channel
RFID	Radio-Frequency IDentification
ROW	Rest Of the World
RTA	Dubai's Roads and Transport Authority
RTPI	Real-Time Passenger Information
RTTI	Real Time Traffic Information
RTTT	Road Transport and Traffic Telematics – the term applied before ITS came into common usage
RUC	Road User Charging – or sometimes, more recently, Road Usage Charging
SANEF	Société des Autoroutes du Nord-Est de la France – the French motorway operator and systems house
SAS	Speed Assistance Systems
SEK	Swedish Kronor
SEPTA	Southeastern Pennsylvania Transportation Authority
SGD	Singapore Dollars
SIM	Subscriber Identity Module
SOV	Single-Occupancy Vehicle
TDM	Travel Demand Management
TDP	Time-Distance-Place road usage charging
TfL	Transport for London
TISA	The Traveller Information Services Association
TNO	The Netherlands Organisation for Applied Scientific Research
TRL	The UK Transport Research Laboratory
TPEG	Transport Protocol Experts Group
TTI	Traffic and Travel Information (services)
UBI	Usage-Based Insurance
UICC	Universal Integrated Circuit Card – usually a SIM
ULEZ	Ultra-Low Emission Zone
UMTS	Universal Mobile Telecommunications Service - the ETSI third generation mobile radio standard;
USD	US Dollars
USDOT	US Department of Transportation
UTMC	Urban Traffic Management and Control
V2V	Vehicle to Vehicle systems
V2I	Vehicle to Infrastructure systems
VED	Vehicle Excise duty – the UK road tax
VMS	Variable Message Signs

Intelligent Transportation Systems
Report for Mobile
by Dr John Walker



Floor 2, The Walbrook Building
25 Walbrook, London EC4N 8AF UK
Tel: +44 (0)207 356 0600

connectedliving@gsma.com
www.gsma.com