Newcastle University e-prints

Date deposited: 20th December 2012

Version of file: Author final

Peer Review Status: Unknown

Citation for item:

Hübner Y, Blythe PT, Hill GA, Neaimeh M, Higgins C.ITS for Electric Vehicles – An Electromobility Roadmap.*In: Road Traffic Information and Control (RTIC)*. 2012, London: Institution of Engineering and Technology (IET).

Further information on publisher website:

http://conferences.theiet.org/rtic/

Publisher's copyright statement:

Use Policy:

ITS for electric vehicles – an electromobility roadmap

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Keywords: Electric vehicles, intelligent transport systems

Abstract

This paper sets out to discuss how barriers to the uptake of electric vehicles (EVs) can be overcome using intelligent transport systems and will draw up a roadmap and action plan for the implementation of those services. Both, the roadmap and action plan have been designed in collaboration with the ERITCO Electromobility Task Force and the smartCEM project partners. The paper will discuss the need for future regulations and standards and take a strategic view on which stakeholders need to take a lead for the development and production of those services.

1 Introduction

ElectroMobility has long been a priority in the Community Research Programme and figures prominently in the European Economic Recovery Plan [1]. According to the Recovery Plan, a broad range of technologies on the vehicle side and smart energy infrastructures are needed. Under the European Green Cars Initiative research into low carbon transport technologies and energy infrastructures are funded. The European Commission (EC) states that EVs should first be deployed in demonstration projects to assess their feasibility and economic viability. It also stated that that public intervention will be needed at various stages of the development of the infrastructure.

At the end of 2008, the EC agreed to set a target for each Member State, such that renewable energy sources (including biofuels, hydrogen and electricity) should account for at least 10 % of all fuel used within the transport sector by 2020. However, uptake of low carbon transport still remains low. According to Eurostat, the average share of renewable energy sources across Europe was 3.5 % in 2008 [2].

The European Commission adopted the White Paper Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system [3]. The aim of the roadmap was to build a competitive transport network whilst reducing the dependence on fossil fuels. Key goals include:

- To cut carbon emissions by 60% by 2050
- To halve the use of 'conventionally-fuelled' cars in urban transport by 2030
- To establish a framework for a European multimodal transport information, management and payment system by 2020

The EC in its document "A sustainable future for transport: towards an integrated technology-led and user-friendly transport system" [4] also advocates achieving its policy objectives for sustainable transport by keeping the EU at the forefront of transport services and technologies and developing a fully integrated and interoperable transport system that is safe and secure and will enable reductions in the use of non-renewable energy sources. One of the challenges the report highlights is to create the necessary framework conditions to introduce electric vehicles commercially on the market. It calls for policymakers to set open standards, ensure interoperability, increase R & D expenditure on technologies, define a clear legal and regulatory framework and promote best practice examples.

The ElectroMobility Task Force therefore believes that is important to encourage the uptake of low carbon vehicles more. Research has shown that the majority of people still think that electric vehicles are not suitable for their mobility needs [5]. Electric vehicle drivers state that the main barriers included the high purchasing price, limited range, time required to recharge and limited availability of charging points.

Many of those barriers are perceived challenges rather than real problems. In Europe, for example, 50% of trips are less than 10 km and 80% of trips are less than 25 km in length, which is well within the range of electric vehicles [6]. Drivers charged their car for 2 hours 55 min per charge event in real world trials in the UK and were over 90% of the time driving within 5km of a charging point [5]. ITS services can be used to remove some of those uncertainties for EV drivers by giving them relevant information before and during a journey and when the EV is charging.

The SWITCH-EV trial is a large scale electric vehicle demonstrator trial, funded through the Technology Strategy Board's Ultra Low Carbon Vehicle Demonstrator Programme which monitors 44 electric vehicles in the North East of England for three years. Since the beginning of the trial, the vehicles drove a total of 271,452 km, with an average journey length of 9 km. As part of the SWITCH-EV trial, the driving and charging behaviour of drivers of 44 electric vehicles are monitored throughout the North East of England. Those data are correlated with attitudinal data from questionnaires and focus groups to understand the need for public infrastructure and the effects of EV charging on the national grid. Intelligent transport systems were used to record journey start, journey length, GPS and state of charge of the battery on a second-by-second basis through data loggers that were fixed to the vehicles. Those records are combined with energy statistics from over 300 public charging points and 8 fast chargers in the region. The vehicles were placed with both individuals and as part of company fleets.

According to responses from 107 electric vehicle drivers, the top four barriers to the widespread uptake of electric vehicles are: high purchasing price of the vehicles, limited driving range, limited availability of public charging infrastructure and time required to recharge the vehicle. Using the data from the trial, the Transport Operations Research Group (TORG) set out to study those barriers. According to the 2009 DfT Carbon Pathway Analysis [7], 55% of journeys undertaken with internal combustion engine cars are under 5 miles and only 7% of journeys are over 25 miles long, which is well within the range on an electric car. Analysis of the driving behaviour of the EV drivers showed, that 60% of all journeys were under 5 miles and 95% of all journeys were under 25 miles. Furthermore, the high density of charging points in the North East of England meant that drivers were within 5 km of the nearest charging point 90% of the time. Average charging time was 3 hours 5 minutes. Those results show that concerns about lack of charging infrastructure and limited range are exaggerated.

Yet these perceived barriers are still hampering a widespread uptake of electric vehicles. According to DfT statistics, 1543 electric vehicles were registered in 2010 in the UK. Uptake is still slower than predicted and has fallen short of the BERR/DfT forecast from 2008, which estimated that 3000 EV should have been registered under a business as usual scenario by now. smartCEM, a project funded by the European Commission under the CIP-ICT-PSP.2011.1.3 - Smart Connected Electro-Mobility Programme, has therefore taken on the challenge to use ICT technologies to encourage the use of EVs as part of everyday life. To demonstrate the value of five advanced electromobility services (EV-navigation, EV-efficient driving, EV-trip management, EV-charging station management and EV-sharing management) smartCEM will demonstrate their use in four pilot sites across Europe (Barcelona, Gipuzkoa-San Sebastian, Newcastle and Turin). The services are designed to give better advice to EV drivers and to allow the public to test EVs as part of a vehicle sharing club.

This roadmap covers the development of ITS services and applications that are relevant for the mass deployment of electric vehicles (EVs). It focuses on four areas:
(1) ITS and vehicle operation and usage: In this section, technologies are discussed that give advice to the EV driver on energy usage, available driving range, eco-driving and EV navigation.
(2) ITS and connection with the power grid: In this section, technologies are discussed that give information on EV charging to either the driver, charging post operator or the electricity provider. Services include information on the state of charge of the battery, amount of energy drawn from the grid, the design and architecture of interfaces between the cars and the charging infrastructure.
(3) ITS and safety: In this section, ITS services are described that can help overcome some of the safety related issues with electric vehicles; for example services for emergency handling and waning systems for vulnerable road users.
(4) ITS and integration with traffic systems: EVs have different drive cycles to conventional cars and thus create new challenges and opportunities for sustainable urban traffic management. Those services can be classed in three wider groups: new traffic management tools, tools for the freight industry and tools for EV sharing and multimodal transport.

2 Methodology

This study has followed an iterative approach to determine likely ITS services and applications in ElectroMobility over the next 15 years. It gives an overview of likely time frames for R&D, mass production and wider market uptake as well as time needed to create new regulatory and policy frameworks for those services.
The aim of the ElectroMobility Work Plan is to create a strategic research plan that sets out a clear vision for ITS services and applications in ElectroMobility.

2.1 Scoping

A core group of ERTICO – ITS Europe partners and Newcastle University devised a list of services based on existing CAPIRE roadmaps and internal discussions. This scoping phase concluded with a provisional list of ITS services and applications which was used as a basis for industry consultation and to identify necessary enabling technology/technologies. Enabling technologies were defined as systems that would support the introduction of services and applications. Services were grouped into four groups:
- ITS and vehicle operation and usage
- ITS and connection with the power grid
- ITS and safety
- ITS and integration with traffic systems

2.2 Roadmap Workshops

This list of ITS services, applications and enablers was then discussed with stakeholders from ERTICO Task Force "ITS for ElectroMobility" including representatives of the automotive industry, ITS sector, research sector and service provision sector. At two workshops, the services and their enablers were re-defined and the time estimated for necessary work in R&D, production and market introduction was discussed. Furthermore, time horizons for establishing regulatory frameworks and standards were included.

2.3 Work Plan Workshop

As a last step of this methodology, members of the ERTICO Task Force "ITS for ElectroMobility" were asked to prioritise the implementation of the services based on the final roadmap, Each member was given three votes for their first, second and third priority. Starting at the most important service, the members were then asked to identify barriers and enablers for the introduction of that service. The Task Force members were then asked to identify enablers that the group wanted to discuss in more detail.

3   Results

3.1 ITS and vehicle operation and usage

A number of EV manufacturers have now started to provide more accurate information on the range of their vehicles. Examples of range estimators exist both as web tools (for example on the Nissan US website) and as on-board units (for example Nissan Carwings, TomTom for Renault Fluence Z.E). In-car navigation systems estimate the available range of the vehicle based on information on the battery state of charge. The range is estimated based on previous driving style, weather, speed, climate control use and battery usage. However, it does not yet take into account topology. Most of the systems also do not take into account driving style on a particular route or destination, but base the algorithms on previous miles driven, which often gives a distorted range prediction. A number of research projects have been funded in this area. ELVIRE for example aims at reducing range anxiety and SWITCH-EV monitors driver behaviour to help understand real world driving range better.

EV route planning is available for most EVs which allows planning via charging posts. Most on-board units also show the nearest available charging post on the maps. However, none of those EV route planners take into account the state of charge of the battery, different driving styles, topology or weather conditions.

Most EVs give information on energy usage to the driver through the dashboard, where drivers can see how much energy they are using or whether they are regenerating energy. Car manufacturers also give eco-driving advice to drivers on their websites and driver training is available from organisations like the Carbon Savings Trust in the UK. A number of research projects are working on creating eco-driving platforms and new energy management systems for EVs (for example eFuture, OpEneR and EcoDriver) and developing new advanced driver assistance systems that use machine-learning functions for their on-board units (for example ECOGEM).

The first mobile phone applications have been designed by Nissan to give advice on the state of charge of the battery and BMW announced that it will release a new mobile phone app for the BMW i8 plug-in hybrid sports car by 2013. Functions will include information on the driving range, state of charge of the battery, multi-modal trip planner and the ability to pre-set charging times. Priorities for the future implementation of services for vehicle operation and usage:

Priority	Service
9	Implement revised ICT architecture and middleware / Standardisation of ABI
3	Accurate range prediction
4	EV route guidance and EV navigation
5	EV eco-driving
9	Semi-automatic driving (eco-adaptive cruise control)
11	Nomadic device (i.e. mobile phone app) for information on charging status

3.2 ITS and connection with the power grid

A number of charging infrastructure trials are currently on-going across Europe. The majority of trials rely on RFID cards to access charging posts, but other technologies such as pay-as-you-go schemes are tested in some locations. Many European Governments have created trial regions where different charging technologies and back office structures are tested and demonstrated. As a result, few of those charging schemes are interoperable.

The UK's Office for Low Emission Vehicles has for example funded eight pilot projects installing and trialling up to 8,500 charging points in Central Scotland, the East of England, Greater Manchester, London, the Midlands, Milton Keynes, the North East of England and Northern Ireland. Most of these schemes currently use a membership model where with EV drivers can access charging points using a RFID card after they paid a membership fee. The Northeast of England is the first region to implement a pay-as-you-go scheme for some of the charging posts.

Similar plans exist in German. The German Government has funded close to 2,000 charging points across eight model regions by 2011. Charging posts in the different model regions are designed differently. They can be accessed through RFID tags, keys, text messages or PIN codes. Payment systems range from flat rates, payments related to the energy use or for the time spent plugged into the charging point.

Portugal and Ireland are developing their electric vehicle infrastructure with a closer relationship to the national grid. In Ireland, the ESB ecars started to roll out of charging infrastructure for electric cars and vehicles on a national scale

in 2010. Ireland's target is to install 2,000 home charge points, 1,500 public charge points and 30 fast charge points nationwide and for 10% of the Irish motoring fleet to be electric by 2020. The ESB's plan is to integrate a payment system by 2012. EV drivers can access a charging point through a pre-pay RFID card and drivers can choose an energy supplier check their balance and top-up at any time online.

Portugal had plans on installing 1,300 normal charging stations and 50 fast charging stations by the middle of 2011. There is an extensive charging point management system that allows grid managers to control the electric vehicles charging process, transferring consumption from peak to low demand periods. Further plans include vehicle-to-grid capabilities. Electric vehicle drivers will be able to search for charging posts, select charging locations, plan routes and know the charge level of their vehicles through a web login or a mobile phone application.

Priorities for future ITS services for connection with the power grid are:

Priority	Service
6	Standardisation of communication protocols
1	Electric vehicle charging management and services
8	Nomadic device (i.e. mobile phone application) for information on grid/energy
11	Nomadic device (i.e. mobile phone applications) for charging point management
11	Advanced information on charge status to driver
11	Charging point access management and payment systems
10	Standardized interfaces (Open platform development that allows many services to operate from that one platform)
11	Advanced charging point access management and payment systems (i.e. inductive charging)
9	Standardized services, billing and use concepts - pay as you go (alternative payment, incl. credit cards) - membership schemes - roaming between schemes

3.3 ITS and safety

ITS services for safety of EV drivers are very similar to those for conventional cars and will need only little adaptation. eCall services for example will have to include information for the emergency services on how to recover a driver or passenger of the different EV models. Otherwise, the information will be handled in a similar manner.

Since EVs are silent, they can pose more of a risk to vulnerable road users. ITS services could be developed to warn cyclists or pedestrians of approaching EVs.

Priorities for safety related ITS services for ElectroMobility include:

Priority	Service
11	Setup standards for emergency handling

	including roadside and tunnel safety
5	ITS to warn vulnerable road users, cyclists, pedestrians of approaching EVs
9	ITS for emergency handling including roadside and tunnel safety
11	Smart handling of energy saving measures

3.4 ITS and integration with traffic systems

Since the uptake of EVs has remained relatively low, little work has been done in developing cooperative systems for EVs or other traffic management tools. However, managing energy demand according to mobility demand could be an area for future development.

A number of cities have started deploying EVs as part of car sharing clubs, such as Zen-Car in Brussels, Mobecpoint, Mobera, IfRenting and Cochele in Spain. For most of those schemes, users enrol online to receive a RFID card which allows them to access the vehicles. Once a driver has booked a car either through a website or a phone service, he or she can pick up the car from a designated parking spot for the vehicle. At the end of the booking, the driver has to return the car to its original parking spot. In order to maximise the use of the EVs, additional for ITS services are now being developed that allow booking of vehicles depending on the route chosen and the state of charge of the battery of the different vehicles.

As part of smartCEM, Barcelona is developing a sharing 2.0 platform, where the driver is monitored and dynamically charged for the service. In order to maximise the usage of the vehicles, drivers will be encouraged to drive in an eco-friendly way (thus consuming less battery). The management platform will validate whether the user has made a booking of a given motorcycle. The driver then has to specify the intended route via an online tool or smartphone app before being allocated a specific motorbike. A GPS system records the exact position of the vehicle during the journey. Once the user has reached his/her destination and correctly parked the electric motorcycle, it is automatically made available to another user taking into account the available range for future journeys.

Services for fleet operators will have similar features. Drivers and fleet managers will need advice on available range based on vehicle loading, route, driving style and state of charge of the battery.

Priorities for the implementation of new traffic management systems for EVs include:

Priority	Service
2	New traffic management tools for large scale introduction of EVs into the road network
11	Standardisation for new traffic management tools for large scale introduction of EVs into the road network
5	Last mile delivery service for urban distribution centres using electric vehicles4
6	Fleet management systems for the fleet manager(incl. mixed car fleets management)

7	Multi modal trip planning	
10	Advanced ITS services for EV car sharing	
11	Fleet management systems for the driver	
6	Cooperative systems V2I and V2G (energy storage and management according to mobility demand and management)	

4 Conclusions

Research and development for ITS services is on-going. The highest priorities given for research and development were given around battery management systems and driver information services:

1. Electric vehicle charging management and services: All services that relate to the charging infrastructure of the EV. Those could include: Charging post booking, eBilling, information on energy tariff, CO2 emission of electricity at time of charge, scheduling of charging time, guidance to nearest charging point, etc.
2. New traffic management tools for large scale introduction of EVs into the road network: Traffic management tools could include giving access to bus lanes for EVs, managing priorities for EVs at traffic lights, EV parking guidance based on congestion and energy network capacity, etc.
3. Accurate range prediction: Algorithms that calculate the range accurately of an EV based on driving style, topology, weather conditions and congestion levels, either in real-time or based on predictions.
4. EV route guidance and EV navigation: Route guidance and navigation systems that take into account charging point locations, accurate range predictions based on driving style, state of charge of the battery, topology, weather conditions and congestion levels. (some vehicles already include first generation of EV route guidance)
5. EV eco-driving: Eco-driving tools (either web based or as on-board nomadic device) that gives advice to the driver on driving an EV efficiently taking into account regenerative breaking and the use of A/C, heating, etc.

One of the most important enablers for a number of those services is accurate range prediction. All cars have different and proprietary battery management systems and each vehicle has different energy efficiencies. In-car navigation systems estimate the available range of the vehicle based on information on the battery state of charge. The range is estimated based on previous driving style, weather, speed, climate control use and battery usage. However, it does not yet take into account topology. Most of the systems also do not take into account driving style on a particular route or destination, but base the algorithms on previous miles driven, which often gives a distorted range prediction. It is important to develop better algorithms to take into account the different variables. In order to aid the development of more accurate range prediction systems, it is also important to improve the coverage of accurate altitude data for maps.

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