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A pilot study to address the travel behaviour and the usability of electric vehicles in two Italian provinces

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ABSTRACT

This paper presents the results of a pilot study based on the analysis of driving data of a large sample of vehicles to address the urban travel behaviour and the usability of electric vehicles in real world conditions. The work relies on two databases, containing the anonymous driving patterns of approximately 28,000 conventional fuel vehicles in the Italian provinces of Modena and Firenze during one month (May 2011). From the statistical processing of the data it is possible to depict the urban mobility behaviour in these geographical areas, characterising trips length, average speed and parking duration distributions. Then these results have been used to quantify the urban fleet share suitable to be converted to battery electric vehicles, the modal shift required to meet the e-mobility target of the EU White Paper 2011 and the electric energy demand from the EVs fleet, by assuming overnight recharge.

1. Introduction

Road transport contributes to about one-fifth of the EU's total emissions of carbon dioxide (CO_2), the main Green-House Gas (GHG). CO_2 emissions from road transport increased by nearly 23% between 1990 and 2010, and without the economic downturn, this increase could have been even bigger (European Commission Website, 2013). Being transport the only major sector in the EU where greenhouse gases emissions are still raising (European Commission Website, 2013), it is clear that new technological solutions must be investigated to help reversing this trend, including the electrification of road transportation notably in urban context (European Commission Roadmap, 2012). Under the Kyoto Protocol, the European Union (EU) is committed to reducing its emissions by 20% below 1990 levels by 2020, and by 80–95% by 2050, in order to contribute to keep the global temperature increase below 2 °C (EAA, 2005; United Nations Framework Convention on Climate Change, 2011).

The EC White Paper "Roadmap to a Single European Transportation Area" (European Commission, 2011) proposes ten goals to be achieved in the next twenty to forty years. They include the reduction of the share of conventional fuel cars in urban transport to 50% by 2030, phasing them out in the cities by 2050, and the shifting of 30% of freight road transport over 300 km to other modes (e.g. rail or waterborne transport) by 2030, to be increased to 50% by 2050.

According to this vision, the transportation system should evolve towards cleaner, more energy efficient and sustainable solutions over the next decades. Electric road mobility will likely play a role, being almost ready to exploit its market potential in a short-term perspective. However, although the first generation of battery electric vehicles (BEVs) is already available on the market, it is still unclear whether the public will widely accept e-mobility. This uncertainty is due to the several issues which are still limiting the EVs market, such as relatively limited range of EVs, battery ageing and second-life, scalability of costs and sustainability of the e-mobility model as a whole (Gaines et al., 2011; Sullivan and Gaines, 2010), interface with power grid and future energy cost trend (Salihi, 1973; Cain et al., 2010).

In spite of the recent technological advancements, at the current stage of technology electric vehicles cannot replace one-to-one conventional vehicles. With the current limitations, the Lithium-ion batteries used in EVs cannot perform as the oil tank in terms of range and price. Several studies have assessed the state-of-the-art of the different Lithium-ion technologies, concluding that the range that this battery is likely to provide in real-driving conditions lies between 200 and 300 km (Boston Consulting Group, 2010), assuming the battery to be approximately one-fourth of the curb weight of the vehicle. This limited range,

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Nomenclature

Acronyms

BEV	Battery Electric Vehicles
CATI	Computer-Assisted Telephone Interviews
CDF	Cumulative Distribution Function
EPA	Environment Protection Agency
EU	European Union
EV	Electric Vehicle
GHG	Greenhouse Gas
GPS	Global Positioning System
HDV	Heavy Duty Vehicles
HEV	Hybrid Electric Vehicle
HVAC	Heating, Ventilation and Air Conditioning system
IEC	International Electrotechnical Commission
LDV	Light Duty Vehicles
PD	Probability Distribution
PHEV	Plug-in Electric Vehicle
REEV	Range Extended Electric Vehicle
SUV	Sport Utility Vehicle

compared to the conventional fuel vehicles, is only an apparent limitation, since it covers the large majority of the urban mobility demand. The remaining trips can be covered with other means of transportation, with a consequent modal-shift (Blauwens et al., 2006; Nurdden et al., 2007), or with different technologies, such as Hybrid EVs (HEVs, Plug-in HEVs, and Range Extended EVs). This will involve a change in the habits, choices and behaviour of the drivers, which will take some time. In fact the marketing of EVs is expected to remain fairly low compared to conventional vehicles (Van Essen and Kampman, 2011) in the short-term. Starting from the current 0.1% EU market penetration of BEVs, future predictions suggest an increase between 1.5% and 7% of global car sales in 2020, and between 40% and 95% in 2050 (Pasaoglu et al., 2012). At the same time the electric energy distribution grid and the recharging infrastructure network should also evolve to meet the new energy demand of the electric fleet (Aggeler et al., 2010; Hoimoja et al., 2012).

The public acceptance of e-mobility will be also dependent on the ability to meet the mobility demand of the average vehicle user. Therefore the long-term monitoring of current vehicles can play a key-role to derive a realistic estimate of the travel needs in daily life, as depicted in Noulas et al. (2011) and Gonzalez et al. (2008). To this purpose many different sources of data can be used, as mobile cell data flows as in Sevstuk and Ratti (2010) or national surveys (face-to-face or written surveys) as in Marconi et al. (2004). In particular the surveys have been used to observe mobility paths and corridors in congested areas, with the purpose to optimise traffic flows reducing transportation time, as per Giuli and Zampetti (2008, 2009). However the accuracy of GPS datasets, together with the possibility to automatise the data acquisition and processing, has allowed collecting huge amounts of data that can be used for a number of different objectives, such as the evaluation of public acceptance and usability of EVs (Tamor et al., 2013; Pearre et al., 2011), investigation of the energy distribution infrastructure impact and optimisation (Dong and Zhenhong, 2012; Smith et al., 2011) and market potential of EVs (Khan and Kockelman, 2012).

The scope of this paper is to provide the scientific community with an extensive description of the results derived from the analysis of real-world driving data for two medium Italian provinces: Modena and Firenze. The analysis refers to an area identified by the province boundary, mainly characterised by a number of close urban conglomerates connected by an inter-urban roads network. The text will refer to this as urban mobility.

The urban mobility results have been used as basis to determine the ability of six different types of EVs to cover real urban trips, given the possibility to recharge overnight between 22.00 and 07.00, and by assuming the same driving patterns of the conventional fuel vehicles. The urban fleet share capable to drive only electric and its electric energy demand from the grid has been estimated, quantifying also the urban fleet share affected by a modal shift. This is the number of trips per day/week which must be shifted to other means of transportation, being not possible to cover them with an EV. This text will refer to this assessment as usability analysis.

The authors foresee the extension of this pilot study to different European countries and cities, to explore urban mobility and electrification of the urban vehicles on a continental scale.

2. Background information and methodology of the analysis

2.1. Databases description and mobility analysis

This pilot study is based on the analysis of two databases of driving patterns referring to the Italian provinces of Modena and Firenze, which have been purchased by the private company Octo Telematics (Octo Telematics Italia S.r.l., 2013). Data referring to two provinces have been purchased to compare and benchmark two different sets of results.

The data acquisition campaign involved 52,834 conventional fuel vehicles in Modena and 40,459 vehicles in Firenze (i.e. 12.0% and 5.9% of the fleet in these provinces, respectively), which were equipped with data-logging devices which recorded time, GPS position coordinates, engine status, instantaneous speed and cumulative distance with a variable frequency (in the order of magnitude of 0.01 Hz). The data have been collected with no time-interruption, in order to enable to reconstruct the complete driving pattern in the analysed period of one month (i.e. May 2011). Table 1 provides general data of these provinces (Automobile Club d'Italia, 2012).

A double filtering was applied to the data set in order to delete the vehicles driven for more than 50% of the trips outside the province borders (in order to focus only on those vehicles which show a predominantly local usage) and all the trips with a length less than 30 m and/or duration less than 30 s (not representative of real needs). A trip is defined as an event which starts with the switch-on status of the engine and stops with the switch-off status of the engine. As a consequence of these filters the databases were reduced to 16,263 vehicles for Modena (30.7% of the original size) and 12,478 vehicles for Firenze (30.8% of the original size). For both

Table 1
General data for the provinces of Modena and Firenze.

	Population (total)	Province area	Population (density)	Registered vehicles Vehicles per person	Surveyed vehicles (% of the total)	Analysed sample (% of the surveyed)
Province of Modena	706,509 (31/03/2012)	2688.7 km^2	262.77/km^2	441,609–0.62 (31/12/2011)	52,834 (12.0%)	16,263 (30.7%)
Province of Firenze	1,002,831 (31/07/2011)	3514.0 km^2	285.38/km^2	684,005–0.68 (31/12/2011)	40,459 (5.9%)	12,478 (30.8%)