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Big Data for Supporting Low-Carbon Road Transport Policies in Europe: Applications, Challenges and Opportunities

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ABSTRACT

Big data is among the most promising research trends of the decade, drawing attention from every segment of the market and society. This paper provides the scientific community with a comprehensive overview of the applications of a data processing platform designed to harness the potential of big data in the field of road transport policies in Europe. This platform relies on datasets of driving and mobility patterns collected by means of navigation systems. Two datasets from conventional fuel vehicles collected with on-board GPS systems have been used to perform an initial pilot study and develop its core algorithms. They consist of 4.5 million trips and parking events recorded by monitoring 28,000 vehicles over one month. The presented analyses address: (1) large-scale mobility statistics, (2) potential of electric vehicles in replacing conventional fuel vehicles and related modal shift, (3) energy demand coming from electric vehicles, (4) smart design of the recharge infrastructure and Vehicle-to-Grid, and (5) real-world driving and evaporative emissions assessment and mapping. The developed methodology and the presented outcomes demonstrate the potential of big data for policy assessment and better governance, focusing on the challenges and on the huge opportunities offered for future developments. This paper ultimately aims to show how big data can inspire smart policies together with public and private investments to enable the large scale deployment of the next generation of green vehicles, offering an unprecedented opportunity to shape policies for future mobility and smart cities.

1. Introduction

1.1. The European road transport policy framework and the use of big data for supporting low-carbon road transport policies in EU

In order to enable transport emissions reduction in Europe and to meet the Kyoto protocol objectives, the EC White Paper 2011 sets the de-carbonisation of transport as a priority, defining ten goals to be achieved over the next twenty to forty years, [1]. As far as road transport is concerned, these include:

- Halve the use of conventional fuel cars in urban areas by 2030, phasing them out in the cities by 2050;
- Establishing an European framework for multi-modal information management systems;
- Move towards full application of "user-pays" and "polluter-pays" principles and private sector engagement to eliminate distortions in the taxation, including harmful subsidies.

Moreover, in February 2015, the European Commission has unveiled a Strategy and Action Plan for creating an Energy Union [2], endorsed by the European Council on 19 March 2015, that includes several actions and initiatives in three key areas which can directly or indirectly reduce greenhouse gas emissions from the transport sector: (1) switching towards carbon free or less carbon intensive fuels, (2) improving vehicle efficiency and (3) managing transport demand. All these goals call for the widespread of low-carbon vehicle technologies (i.e. Hybrid and Battery Electric Vehicles, HEVs and BEVs), together with smart systems capable to harness the potential of digital mobile technologies in storing and processing data, in order to provide the user with smart transportation solutions in real-time as well as enable the implementation of a smart taxation system.

Transportation is a complex world. It is a mix of technologies, social behaviours, choices of single users and stochastic events, nested within a geographical, environmental and economic sce-

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Nomenclature

Acronyms

AC	Alternating Current
BEV	Battery Electric Vehicle
CATI	Computer-Assisted Telephone Interviews
CO_2	Carbon dioxide
CS2-JU	Clean Sky 2 Joint Undertaking
DC	Direct Current
EEA	European Economic Area
EU	European Union
EU-ETS	EU Emission Trading Scheme
HEV	Hybrid Electric Vehicle
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GPS	Global Positioning System
ICT	Information and Communication Technology
LDV	Light Duty Vehicle
POI	Point of Interest
SUV	Sport Utility Vehicle
TEMA	Transport tEchnology and Mobility Assessment platform
USA	United States of America
VOC	Volatile Organic Compound
V2G	Vehicle to Grid

nario. For this reason the design of the transportation network and its regional regulatory framework involves know-how from engineering, geography, environmental sciences, economy and social sciences. This process must be supported by harmonised datasets from different sources together with data processing methodologies developed across different scientific fields in order to handle real world complexity. Recent studies prove the potential of big data in this respect, being used to measure commuting efficiency in megalopolis [3], to explore public transport users' behaviours [4], to simulate individual mobility choices in carpooling [5] and to classify activity patterns [6,7], with applications in the fields of mobility networks design and infrastructures [8–10] and multi-modal transportation systems [11]. On one hand these studies constitute interesting advances of big data in transport, but, on the other hand, they are limited to single case studies and applications, mostly grounded on data averaging and data aggregation approaches.

More in general, the potential of ICTs in support of mobility needs is a well-known research topic, funded by a number of European projects under the FP7-ICT call for projects 2011. Among the most relevant projects, we must cite the REDUCTION [12], the PEACOX [13] and the eCOMPASS [14] projects, which addressed novel ICT solutions for optimising driving behaviour, routing and multi-modality for passenger and freight transport fleet in cities, together with the ICT-EMISSIONS project [15], that addressed CO_2 emission estimation at a regional scale via monitoring of vehicle fleets. All these parent applications explore interesting uses of data in transport, and might be interesting data source for future big data studies.

Nowadays big data is applied to a number of different disciplines and in 2013 Forbes.com indicates big data among the "Top 10 Strategic Technology Trends of the Year" and "Top 10 Critical Tech Trends For The Next Five Years", [16] and [17]. The term "data science" dates back to the 1960s, when the newly born information technologies posed the problem of how to store, manage, process and retrieve growing amount of data, in a way which was never experienced before. In 1962, John W. Tukey wrote "The Future of Data Analysis" [18], where he presented a visionary perspective of how mathematics, statistics, data analysis and informatics can be merged in a novel discipline with unprecedented potential. After nearly 50 years, at the beginning of the 21st century, data is become "big". Of course this is related to the "size", but it would be quite reductive to condense the meaning of "big data" solely to its bytes count. The big data means "bits and pieces of the real world puzzle", which, if adequately processed, is capable to offer unprecedented insights on a number of real world phenomena. This is potentially capable to impact social dynamics, choices and behaviours, public response to events, market trends, services and goods' demand, enabling to open the doors to a number of applications, re-inventing and re-structuring existing companies and evolving novel concepts in almost every business segment. This work aims to present how big data can be used for supporting low-carbon transport policies in Europe.

1.2. Transport emissions in Europe

In the European Union (EU), transport contributes to nearly one-third of the carbon dioxide (CO_2) emissions and is the only major sector where emissions increased over the last decade despite the economic downturn [19]. The EU needs to reduce the Greenhouse Gases (GHGs) emissions by 20% below 1990 levels by 2020, and by 80-to-95% by 2050, under the Kyoto Protocol, [20, 21]. Transport, i.e. road, rail waterborne and air transport modes together, will contribute to this goal by reducing its GHGs emissions below 1990 levels by 60% by 2050, [1]. EU accounts of 35.3 billion tonnes CO_2-equivalent emissions in 2013 [22], with approximately 11 billion (i.e. one-third) tonnes coming from transport. Road transport accounts for approximately 72%, rail and waterborne transport account together for 15% while air transport accounts for the remaining 13% of the total transport GHGs emission in EU, as per [23]. Nearly two-thirds of road transport emissions originate from light duty vehicles (LDV), while the remaining one-third originates from heavy duty vehicles (HDV) [24], representing respectively 83.3% of total inland surface passenger transport (LDV) and 9.2% of total inland surface passenger transport (HDV, i.e. buses) plus 74.9% of total inland surface freight transport (HDV). Rail transport only accounts for 7.5% of total inland surface passenger transport and 18.2% of total inland surface freight transport, while waterborne accounts for the remaining 6.9% of the inland surface freight transport, with a passenger share which is negligible, as per [25,26]. By considering carbon-intensity per mode (i.e. CO_2 grams per kilogram of payload per kilometre), rail and waterborne are definitively greener solutions, accounting for nearly one-third of the specific emissions compared to road or air transport [27]. However, despite their high carbon-reduction potential, rail and waterborne are still under-exploited solutions and this is mainly related to the poor inter modality of the networks between the Member States and to their low cost-efficiency compared to road transport, [1]. On top of this, automotive and oil industry still have a very important economic weight in most of the countries and this make a change even more difficult. Recent statistics estimates that the number of worldwide circulating vehicles is approximately one billion units (2013), exhibiting an annual growth rate of 4% till 2020, [28]. Such growth is mainly due to the increasing wealth in emerging countries (i.e. 76% of the 2020 market is forecasted not to be in EU or US, [29]), with a long term growth up to 2.4 billion circulating vehicles in 2050 (i.e. +140% with respect to the 2013 figure, traded off by a worldwide population increase of