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Guiding cities to pursue a smart mobility paradigm: An example from vehicle routing guidance and its traffic and operational effects

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ABSTRACT

The concept of 'smart cities' is rooted on the approach taken by cities to reconcile the three often conflicting objectives of economic efficiency, environmental quality and social equity. The expectation that smart cities may promote the adoption of scalable solutions that take advantage of information and communication technologies (ICT) to increase their effectiveness, reduce costs and to improve the quality of life is great among academia, business and governmental stakeholders. Traffic management systems in its multiple applications (including re-routing) are an example of ICT solutions that can expectably lead to the purpose pursued by 'smart cities'. This paper develops a performance evaluation of re-routing for passenger and commercial vehicles with a case study in the city of Lisbon, Portugal. The paper examines how the provision of guidance information to drivers affects traffic performance, operational costs and environmental conditions at different spatial references, namely route level and urban network level. The simulation results indicate that the re-routing can not only reduce travel times, but also enhance the efficiency of roads in the city network and as well the traffic performance at the route level of analysis. The improvement at local route levels (such as corridor/route) is more significant than at the city network level. For the urban network level, simulation results suggest that re-routing can bring variations in travel and delays that may reach 2% and 6%, respectively, when a 10% drivers' compliance rate is considered. Individual drivers are more likely to comply to deviate than urban logistics drivers and bus drivers.

1. Context

The increasing global urbanization has been associated with problems such as traffic congestion, energy consumption, inefficient resource management and damages to the environment. In order to tackle these problems, the path to pursue a sustainable development must consider the use of innovative ways to manage the complexity of urban living. Consequently, cities are embracing ICT as a development strategy, embedding digital infrastructure and systems and utilizing them to obtain competitive and regulatory effect (Kitchin, 2014). This concept – labelled as 'smart cities' - is emerging not just as an innovative modus operandi for future urban living, but as a key strategy for rethinking and turning them in inclusive, integrated and livable cities. At its core, the 'smart cities' concept is rooted on the approach of reconciling the three often conflicting objectives of economic efficiency, environmental quality and social equity. How public decision-makers at all the government levels can embrace the idea of 'smart cities' as a way of reconciling growth and sustainability is still under discussion. However, among academia, business and governmental stakeholders there is a growing expectation that 'smart cities' may play a part in helping to adopt scalable solutions that take advantage of information and communication technologies (ICT) to increase effectiveness, reduce costs and improve quality of life (Caragliu, Del Bo, & Nijkamp, 2011). Indeed, the adjective 'smart' and the concept 'smart city' are used to relate positive urban-based technological innovation and change via ICT. ICT allows the gathering of massive data, used to provide efficient services to citizens, monitor policy measures, manage and optimize existing infrastructures and

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employ cross-sector collaboration (Kramers, Hojer, Lovehagen, & Wangel, 2014). In such context, 'smart cities' can embrace public issues via ICT based solutions on the basis of a multi-stakeholder, municipally based partnership. In this sense, city administrations are the most likely entities to manage this information and services, but they have as well the complex challenge of integrating different and often conflicting goals. 'Smart cities' may pursue the environmental or social goals, but they must also maintain the same operation efficiency or even improve it (Allwinkle & Cruickshank, 2011) in sectors such as transportation, environment, healthcare, energy, education and safety. Such ambition justifies the definition of a 'smart city' list of characteristics that was developed by the Smart European Cities initiative, which includes smart economy, smart people, smart governance, smart mobility, smart environment and smart living.

Despite the lack of a direct causal relation between smart and sustainable cities, it is clear that ICT have a considerable potential for supporting the transition to more sustainable cities (Kramers et al., 2014). For cities, it is a matter of having a better understanding of in which types of ICT they should invest to provide the best benefits for environment and society. Traffic management systems are a good example of ICT solutions which may lead to beneficial environmental and economic effects, enabling a better real-time management of the available resources. The results from theoretical cases indicate that real time traffic management can lead to the achievement of efficient and sustainable transport schemes (Hancke, de Carvalho, & Hancke, 2013; Lin, Choy, Ho, Chung, & Lam, 2014). Real time traffic management is supported by the provision of guidance information to (and/or by) drivers. The basis for this view is that, when drivers choose their route, the decision is typically influenced by factors such as travel time, travel cost, convenience, travelers' value of time and the level of services offered by each network (Cascetta, 2009). If the driver's decision is supported by guidance information provided by the ICT technologies, the information received will influence the traveler to a more efficient direction that can lead to choose more environmental friendly routes (Morfoulaki, Mitsakis, Chrysostomou, & Stamos, 2011). Additionally, a number of relevant studies confirm that the provision of information can help to improve the network performance and transport service quality (Abdel-Aty & Abdalla, 2004; Jou, Lam, Kiu, & Chen, 2005; Mahmassani & Liu, 1999).

The increasing interest in providing guidance information for drivers in order to reduce congestion, regardless of the specific ICT tools used, has not been followed by a proper quantification of the effects or of its absolute dimensions. The use of ICT tools (namely routing applications) in the particular case of urban logistics operations and public transport scheduling is already a determinant tool being used worldwide to assure the reliability of goods delivery and of bus stops schedules, respectively. These applications are chosen by the operators and assume pre-determined settings, disregarding unexpected congestion incidents. In order to promote a better economic efficiency, environmental quality and equity, local public stakeholders should intervene and promote additional real-time guidance information tools to drivers, which allow them to perform their activities in a more efficient way. Although there are many studies that range from laboratory surveys to field observations on this type of guidance provision, there is a lack of research into practical case studies, which thoroughly evaluate the effectiveness of traffic management tools, including re-routing, in the network performance and transportation quality (Mascia et al., 2016; Ubeda, Arcelus, & Faulin, 2011). Under such context, this paper aims at understanding the effects of re-routing by providing guidance information to drivers and to assess the cities and operators' receptiveness's to this type of intervention. In more detail, this paper contributes with a robust methodology to assess the effects of re-routing of both passenger and commercial vehicles, since it clarifies how the application of re-routing can affect traffic performance, which influence operational costs and environmental impacts, at different spatial levels of an urban network. This is highly relevant in order to quantify the energy efficiency and, consequently, environmental quality, which impacts the transport sector economic efficiency, also assessed in this work.

The remainder of the paper is organized as follows. In Section 2, the scientific relevance of the research is presented. In section 3, the methodology and definition of scenarios are described. Section 4 presents the results and corresponding discussion. Conclusions are stated in Section 5.

2. The importance of providing guidance information to drivers

The main pillars for the development of the 'smart cities' concept are: smart mobility, smart environment, smart people, smart living and smart government. Smart mobility aims to improve the mobility of passenger and commercial vehicles, as well as to reduce environmental impacts and improve the social well-being, as described by Caragliu et al. (2011), Kramers et al. (2014) and Melo and Baptista (2017). The use of ICT solutions to promote this smart mobility concept has already some applications both for public transport and freight (Giannopoulos, 2004; Perego, Perotti, & Mangiaracina, 2011). In the field of public transport, the use of real-world monitoring to provide driving real-time or delayed feedback to bus drivers is emerging (Strömberg & Karlsson, 2013; Wälberg, 2007). Also in commercial vehicles, the provision of guidance information to improve energy efficiency has been widely tested (Hickman et al., 2007; Vagg et al., 2013).

The specific field of urban logistics, as it is inherently related with cities' mobility performance, is also covered by the smart mobility axis, with the objective of minimizing economic and environmental effects. An example to pursue this goal is the implementation of an environmental cost-effective vehicle routing, which means that drivers are re-routed to less congested routes, allowing the implementation of more sustainable transportation schemes (Lin et al., 2014). In spite it is not in the scope of this study to approach the re-routing topic with an operational research perspective, in the field of urban logistics, a reference to the research on the Green Vehicle Routing Problems (GVRP) is mandatory, since it directly applies the environmental concern to the traffic management concept. In the traditional Vehicle Routing Problem (VRP), the focus is on the impact of vehicle routes on operational costs to the operator. Research identifies the VRP application to sustainable transportation in the literature from an operations research perspective and denotes it as Green Vehicle Routing Problems (GVRP). This approach evaluates the transportation route which is based on an estimation of the amount of fuel consumed or on the pollution emitted while it completes the required task, while meeting the environmental concerns and the economic targets.

Considering that this work focuses on the nature of the problem and on the application of VRP itself, the review is based on the problem characterization and of its application scenarios rather than focusing on the algorithms. Multiple examples of GVRP are presented in the literature, with the authors solving the routing problems through the calculation of the “cleanest” routes (Ubeda et al., 2011), presenting and comparing environmentally oriented extensions of the classical VRP (Bektas & Laporte, 2011; Bing, Keizer, Bloemhof-Ruwaard, & van der Vorst, 2014), investigating the impacts of route choice decisions on vehicle energy consumption and emission rates for the different types of vehicles using microscopic and macroscopic emission estimation tools (Ahn &

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