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Exploring the impact of ICT on urban mobility in heterogenic regions

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Abstract

Information and Communication Technologies (ICTs) have been widely applied in the monitoring, operation and management of transport services, while they were proven to have a great potential to increase the efficiency in the use of urban transport infrastructure and at the same time reducing negative impacts on the environment. The aim of this paper is to explore the impact of ICTs applications in reducing carbon dioxide emissions and costs in different regions across Europe: a) Bucharest - Ilfov (Romania), b) Centro Region (Portugal) and c) Extremadura (Spain). Through different scenarios we estimate potential emissions savings and damage costs for carbon dioxide. The total emissions in each scenario were calculated using COPERT 4, while the estimation of the total emission costs was based on the updated values of damage costs (€ per tonne, 2010) that are provided from European Commission's Handbook on External Costs of Transport. Results show that ICT measures can have significant impacts in terms of costs savings and can contribute to the rapidly reduce of carbon dioxide emissions.

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Keywords: Information and Communication Technologies; Intelligent Transport Systems, Urban Mobility, Transport External Costs, Impact Assessment

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1. Introduction

Information and communication technologies (ICTs) have the potential to bring a significant change in the way people move, offering greater flexibility in their travel patterns (Banister, 2008) and contributing in reducing congestion, air pollutants, noise and fatalities (Baptista et al., 2012). Their use can greatly influence people's mobility behaviour as allow better planning and managing of their activities (Line et al., 2011) by providing them with real time information about traffic, delays, available transport modes and services etc. ICTs is already a key component in transport policy and have been widely applied in the monitoring, operation and management of transport services expecting to alleviate urban environmental issues (Cohen et al., 2002).

In many cities and regions of the world, the use of ICT tools in transport systems has brought significant improvement in terms of performance and reduction of congestion, emissions, noise, and road accidents. The Stockholm congestion charging systems decreased traffic around 20% and contributes to the reduction of emissions (Eliasson, 2008), while in the city of San Francisco, greenhouse gas emissions declined by 30% in areas like SFpark, where a smart parking system was installed (SFMTA, 2014). However, the transfer of an indisputable good practice from one area to another with different socioeconomic and environmental characteristics may not has the expected results. For instance, the annual report of Central London Congestion Charging Scheme showed in 2007 an increase of 5% in traffic volumes (Transport for London, 2008), while Percoco (2013) indicated in his study that the emissions reductions were insignificant in the city of Milan after the introduction of the road pricing policy.

In the last decades the extensive implementation of new technologies and tools in urban areas has led to a growing body of research on the impacts of ICT on road transport sector (Baptista et al., 2012). However, limited data on actual results have been published so far and to the best knowledge of the authors, there is no sufficient literature examining the transferability of such measures to different areas. Furthermore, the emissions reduction potential granted by ICT's contribution is rarely assessed economically. This work recognises that each ICT measure could have different effects based on their areas of application and there is need of extensive study (simulations, modelling, data collections, surveys etc.) before their deployment. However, the aim of this paper is not to develop a new or improve an existence methodology that estimates in detail the effectiveness of ICTs applications but to highlight their importance by exploring their potential environmental and economic impacts in a set of cities and regions with heterogenic characteristics.

2. Literature Review

The quantification of the potential environmental and economic impacts of ICT interventions in transport networks is impossible to be based on real world traffic measurements because of the complexity of transport systems (Grote et al., 2016). Various initiatives have tried to developed different approaches to simulate the effects of ICT measures on emissions, although the estimation of road transport externalities has to consider several uncertainties (Korzhenevych et al., 2014) and the existing emissions calculation methodologies have significant limitations in terms of data availability and reliability (Grote et al., 2016). Moreover, several studies have outlined a number of additional shortfalls of the existing traffic and emission models which are used to predict the impacts of ICT on mobility (Samaras et al., 2012) making each methodology more unreliable.

The ICT-Emissions project proposed a methodology based on the integration of various simulation models (vehicle control model, traffic model and emissions model) in order to estimate the impacts of ICT technologies on carbon dioxide emissions (Monzon et al., 2017). The combination of the different models require several sources of information and also data collection to acquire the necessary input data (Samaras et al., 2012) but in most cases governments and transport authorities lack the resources for modelling and data experiments (Grote et al., 2016). The ICT-Emissions methodology is aiming to simulate with great accuracy the effects of the measures (Monzon et al., 2017), although the use of complex models has greater demand of input data in terms details which is more sensitive in regards of estimation and collection (Grote et al., 2016).

In Finland, a transport policy tool for the reduction of carbon dioxide emissions was developed which estimates the impacts of the interventions based on trends and forecasts. Unfortunately, the entire methodology requires also a number of data sources (travel surveys, statistics, trends etc.) (Järvi et al., 2015) subjected the whole procedure depends on data quality and availability.

3. Methodology

In this study, two common ICT deployments from different areas that have contributed in promoting sustainable mobility and reducing carbon footprint are assessed. In the next step, through different scenarios we try to examine their effects in a set of cities and regions across Europe. The three case studies are the region of Bucharest - Ilfov in Romania, the Centro Region in Portugal and the region of Extremadura in Spain (Figure 1). Through different scenarios, we analyze the impacts of the potential implementation of the three ICT applications in these areas by estimating emissions savings and costs. This study focuses on carbon dioxide emissions and costs because it is the largest constituent of road traffic greenhouse gas emissions (Grote et al., 2016).

Fig. 1. (a) Centro Region; (b) Bucharest - Ilfov; (c) Extremadura (Google Maps, 2017)

3.1. ICT Applications

The two ICT applications that are examined in this paper are an urban congestion charging system and the impacts of the use of eco-routing navigation system.

Congestion charging is one of the most important public policy instruments in the world (Grisolía et al., 2015), mainly because is a cost-efficient and effective measure to mitigate traffic congestion in the city centers (Börjesson et al, 2015) and funding infrastructure maintenance. Moreover, it can also bring environmental benefits by contributing in the reduction of carbon dioxide emissions (Grisolía et al., 2015; Nocera et al., 2016). Nocera et al. (2016), in their study examined the impacts of road pricing measures in terms of carbon emissions by analysing a significant number of European case studies, stating that these interventions grab the potential to decrease carbon dioxide levels more than 10%.

The Congestion Charging System of Stockholm was introduced in 2006 as a trial in the beginning and as a permanent measure in 2007 (Börjesson et al., 2012). The main purpose of the system was to reduce traffic congestion in and around the city and improve the efficiency of the transport system (Eliasson, 2008). The system was consisted of a cordon around the city centre with a charge from 6.30-18.30 during the week, including exceptions for taxis, buses and alternative fuel cars. The charge was € 2 during peak hours, € 1.5 30 min before and after peak period and € 1 during off-peak while the maximum amount payable per vehicle during a day was € 6 (Eliasson et al., 2009). Eliasson et al. (2009) in their study provide an overview of the impacts that had the deployment of the system during its trial period. Traffic decreased almost 16% inside the cordon, while the total vehicles kilometers travelled declined by 15% in the inner city. The Stockholm Congestion Charging System also contributed to the reduction of air emissions, as carbon-dioxide emissions in inner city decreased by 14% (2-3% in Stockholm County), air-borne pollutants inside the cordon from 10% to 14% and nitrogen oxides by 8.5%. Finally, in terms of road safety the number of personal injury accidents within the tax cordon was estimated that reduced by 9–18%.

Due to the increasing traffic volumes in urban areas, information and communication systems are increasingly present in road vehicles. In-vehicle Information Systems include navigational and traffic information systems which integrates maps with up-to-date traffic information, and can provide drivers with information such as road and traffic conditions, navigation information etc. Recent initiatives focus on developing a new approach called "eco-routing" that provides information about routes that require least amount of fuel and/or produces the least amount of emissions. Eco-routing in recent years became a popular tool in transport policy because of its benefits. Investigations have shown that an eco-routing navigation system can contribute in reducing fuel consumption and emissions by finding the most environmental friendly route and assisting drivers during the trip (Zeng et al., 2016) with reported results ranging from 5% to 40% (Alam and McNabola, 2014). Alam and McNabola (2014), in their paper conducted a comprehensive review of eco-driving policies and practises in relation to their potential environmental effects. In their results, they highlighted that the proved benefits of eco-driving in real world examples ranged from 4.8% to 6.8%.

Ahn and Rakha (2013) in their study estimate also the emissions savings for various pollutants (Table 1) by implementing a dynamic eco-routing system compared to a minimum travel time route strategy in a full level of market penetration in the downtown area of Columbus, Ohio, USA., showing that the expected reduction in carbon dioxide emissions is 5.16%.

Table 1. Eco-routing impact (Ahn and Rakha, 2013)

	Relative Difference (%)
Travel Distance (km)	5.46
Travel Time (s)	-3.21
Average Speed (km/h)	8.40
Fuel (l)	6.12
Hydrocarbon (g)	17.67
Carbon Monoxide (g)	17.59
Nitrogen Oxides (g)	9.49
Carbon Dioxide (g)	5.16

3.2. Case Studies

The three studied areas of this paper are also case studies of the Interreg Europe Project CISMOB (cooperative information platform for low carbon and sustainable mobility. The project focus on improving the implementation of regional policies and local mobility programmers by having a thorough understanding of the different transport-related impacts and identify best practices of sustainable management of urban transport taking advantage of ICT.

Bucharest – Ilfov is a region in Romania that includes the capital of the country (Bucharest) and Ilfov county. Region's population was 2,264,865 inhabitants in 2012 with a total area of 1,821 km² and population density 1,244 inhabitants/km². Bucharest is the largest urban area in Romania with population of 1,924,299 inhabitants, total area of 238,551 km² and a density of approximately 8,090 inhabitants/km² (Stoicescu et al., 2013). The Centro Region is in central Portugal, and its population in 2011 was 2,327,755 inhabitants, and its total area is 28,199 km². The population density of the region is 82 inhabitants/km² (INE, 2012). Extremadura is a region in Spain. Its population was 1,104,499 inhabitants in 2011 with a total area of 41,611km² and a density of 26 inhabitants/km² (INE, 2013).

3.3. Studied Scenarios

In this study two different scenarios were assessed (Table 2). In the first scenario, we examine the potential installment of a congestion charging system in the region of Bucharest - Ilfov. Bucharest is one of the most congested cities in the world with drivers in the Romanian capital expecting to spend an average of 57 minutes of extra travel due to traffic anytime of the day (TomTom, 2017). In this case, we assume that the impact would be similar to The Congestion Charging System of Stockholm in terms of reduction in carbon dioxide emissions. The two regions have almost the same population (Eurostat, 2016) and the same number of registered vehicles (INSSE, 2017; SCS, 2017), while the national fleet composition of Sweden in the year 2006 has more similarities with Romania's in 2014 (Emisia SA, 2017). Furthermore, the expected effect (14% reduction in carbon dioxide emissions) is an acceptable value, as we have already mentioned above.

In the second scenario, the impacts of adopting an eco-routing driving approach in a full level of market penetration are studied in each region. In this case, we assume a 5.16 decrease in the levels of carbon dioxide emissions (Ahn and Rakha, 2013), as it is the only valid value in a context of a full level of market penetration and it is inside the validated values (4.8% - 6.8%) of real world applications. It is worthwhile mentioning that the aim of this paper is no to provide detailed results of the excepted impacts of ICT measures but to highlight the importance of the implementation of such technologies in monetary terms.

For the calculation of the total emissions in each scenario for the year 2014, we used COPERT 4 v11.4, an emission calculation tool developed by Emisia SA. Firstly, we had to estimate the fleet composition of each region. For that purpose, we applied two different approaches: i) for Centro Region and Extremadura, the available data is specified by the number of vehicles of each type, without any information concerning technology. For these two cases, we estimated the fleet composition taking into account the percentage of each vehicle technology in the corresponding national fleets; ii) while for Bucharest-Ilfov, due to the lack of the required data (only the total number of vehicles were available), we estimated the vehicle fleet composition by considering the ratio between the total number of cars in Romania and Bucharest region. In the next step, we calculated the total emission costs for carbon dioxide based on the updated values of damage costs (€ per tonne, 2010) of 90 €/tonne, that are provided from The Handbook on External Costs of Transport (Korzhenevych et al., 2014).

This paper follows a more detailed approach in order to provide a more accurate estimation of the total emissions in each region by taking into account not only the total number of the vehicles and the composition of the fleet but also the discrimination by technology (Euro 1, Euro 2 etc.).

Table 2. Studied scenarios

Scenarios	Measure	Studied Area	Expected Impacts
Scenario 1	Stockholm Congestion Charging System	Bucharest - Ilfov	-14% Carbon Dioxide
Scenario 2	Eco-Routing	Bucharest – Ilfov, Centro Region, Extremadura	-5.16% Carbon Dioxide

4. Results

In Table 3, we present the total emissions and damage costs for the year 2014 of carbon dioxide for each one of the studied regions, while in Figure 2a, we calculated the total emissions of the main transport pollutants in each region and in Figure 2b the costs of each pollutant per kilometre. The numbers demonstrate that carbon dioxide is a major constituent of transport externalities with total emissions over 2 million tonnes in each area, while the costs per kilometre are higher in Bucharest – Ilfov as the fleet vehicle is older compared to the other studied areas. Centro Region produced the most emissions during 2014, while the damage costs of carbon dioxide emissions in the area were 289.8 million euros. Extremadura is the region with the less total emissions but the damage costs per capita is the higher among the study areas.

Table 3. Total emissions and damage costs of carbon dioxide (2014)

Studied Area	Total Emissions (in million tonnes)	Damage Costs (in million euros)	Damage Costs (per capita in euros)
Bucharest – Ilfov	2.521	226.9	100.2
Centro Region	3.220	289.8	124.5
Extremadura	2.011	181.0	163.8

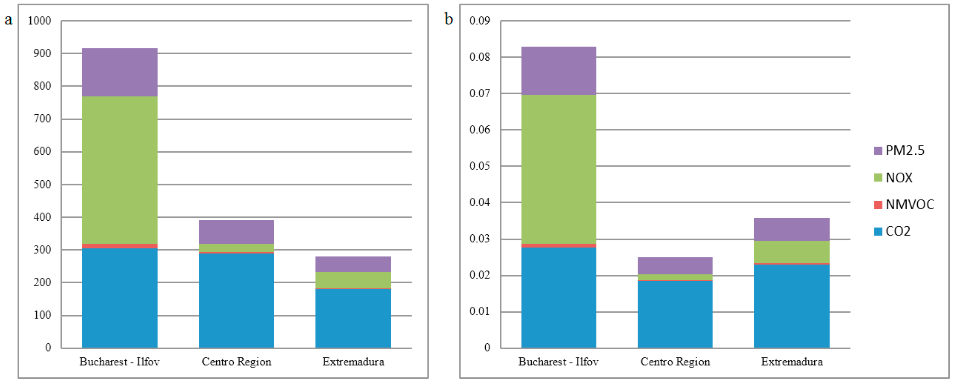

Fig. 2. (a) Total costs in 2014 (in million euros); (b) Costs per kilometre in 2014 (in euros)

Table 4 displays the total emissions and damage costs for each scenario applied to studied areas and finally, Table 5 reports the total emission and cost savings in each scenario. Although the methodology approach cannot provide detailed estimations, the results show significant savings in terms of carbon dioxide emissions. Moreover, in both scenarios the examined ICT measures also resulted in reductions in damage costs proving their great potential. Concretely, the first scenario, related to a congestion charging system in Bucharest – Ilfov region, provides significant improvements, with savings around 32 million euros. Concerning Scenario 2, the region that most benefits with the implementation of an eco-routing driving approach is Centro Region, with a CO_2 emission saving of 0.166 million tonnes, and in terms of costs, these are minimized, representing a reduction of 15 million euros.

Table 4. Total emissions and damage costs of carbon dioxide in each scenario

Scenarios	Studied Areas	Total Emissions (in million tonnes)	Damage Costs (in million euros)	Damage Costs (per capita in euros)
Scenario 1	Bucharest – Ilfov	2.168	195.1	86.1
Scenario 2	Bucharest – Ilfov	2.391	215.2	95.0
	Centro Region	3.054	274.8	118.0
	Extremadura	1.907	171.7	155.5

Table 5. Emission and cost savings in each scenario

Scenarios	Studied Areas	Total Emissions (in million tonnes)	Damage Costs (in million euros)	Damage Costs (per capita in euros)
Scenario 1	Bucharest – Ilfov	0.353	31.8	14.1
Scenario 2	Bucharest – Ilfov	0.130	11.7	5.2
	Centro Region	0.166	15.0	6.5
	Extremadura	0.104	9.3	8.3

5. Conclusions

This study tries to address the estimation of potential environmental and economic impacts of ICT interventions in different areas, and to highlight their importance in reducing carbon footprint and increasing the sustainability of urban areas. From the literature review it is evident the lack of a comprehensive methodology that could estimate in detail and with accuracy the effects of such measures. The use of simulation models contains various uncertainties while combined with the absence of relevant and organized data make the whole procedure costly and lengthy. The methodology of this paper tries to provide more accurate results, by estimating the total emissions not only by considering the type of vehicles for each region, but also their specification in terms of technology and their annual travel activity (kilometres travelled).

From our results, we can conclude that ICT interventions in transport networks can be beneficial in terms of carbon dioxide emissions and costs reductions and they can become an important tool for local authorities and policy-makers. However, further research is required in exploring the potential effects of combining different measures in the same areas and in overcoming the barriers of assessing the implementation of a good practice in a new area. Future work will also include the identification of additional good practices and the collection of more detailed and harmonised data across the studied areas.

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