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Smart city as a tool for sustainable mobility and transport decarbonisation

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ABSTRACT

The sustainable governance of transport systems remains a significant challenge for policy makers worldwide, particularly in cities. Urban areas are developing rapidly from a technological viewpoint, and innovative technologies create new possibilities for smart mobility management. Therefore, this study investigates the relationship between the implementation of the smart city concept and the idea of sustainable transport, particularly with regard to the reduction of transport generated CO_2 emissions. The study estimates CO_2 emissions for different potential scenarios of development for the Warsaw transport system until 2050 using the United Nations' ForFITS (For Future Inland Transport Systems) model. The study also analyses the additional impact on CO_2 emissions of smart city elements as determinants of mobility. The results show that meeting the reduction targets set by the European Union 2011 White Paper on Transport will be challenging, requiring an in-depth transformation of the transport and energy sectors. This study also confirms that smart city solutions can play a crucial role in mitigating transport emissions and meeting reduction goals. The conclusions provide important insights for the design of smart mobility governance and enhance the relationship between transport policy and research.

1. Introduction

Although research on environmentally sustainable transport was initiated more than twenty years ago (OECD, 1996), the implementation and governance of sustainable mobility remain significant challenges worldwide. The constantly-growing transport demand is reflected in traffic congestion, as well as in higher energy consumption and the associated emissions. CO_2 (carbon dioxide) accounts for 75% of global greenhouse gas (GHG) pollution and is projected to remain the largest contributor to global GHG emissions by 2050 (Edenhofer et al., 2014). Transport is also a major source of emissions (22%) (OECD/ITF, 2010), with road transport being the biggest contributor and responsible for about 75% of CO_2 emissions worldwide, 70% in the European Union (EU) (Ribeiro et al., 2007), and a staggering 98% in Poland (KOBIZE, 2014). More importantly, unlike local emission levels, the transport GHG emissions are constantly growing (OECD/ITF, 2011) which makes it an even more serious problem.

According to a 2011 White Paper, titles 'Roadmap to a Single European Transport Area – Towards a competitive and resource-efficient transport system' (henceforth, 2011 White Paper on Transport), by 2050 GHG emissions from transport should be at least 60% lower than in 1990 and move steadily towards zero (EC, 2011a). Cities and local authorities would play a crucial role in achieving this goal. Urban areas are especially vulnerable, and their contribution to transport emissions is continuously rising as they concentrate most urban population and their mobility-related activities. Furthermore, by 2050, more than 60% of the global population will be living in cities (UN, 2014). As such, governance of smart mobility in urban areas become part of the new phase of considering transport as well as climate and energy policies.

The aim of this study is thus to investigate the potential contribution of smart city solutions and their impact on future transport-related GHG emission levels. Smart cities and emerging technologies are important factors in the pollution-mitigation process. Overall, innovative technologies can have numerous applications, not only in improving the energy efficiency of different transport modes, but also in supporting behavioural changes, mobility patterns, and governance of transport systems.

Specifically, this study estimates potential changes in GHG emission levels due to urban road transport in Poland for 2008–2050. A case study estimated these changes based on Warsaw and using the United Nations' For Future Inland Transport Systems (ForFITS) model. The results of these estimations are further compared with the reduction targets set by the 2011 White Paper on Transport. The discussion and conclusions address two critical questions: whether the ambitious reduction goals adopted in 2011 White Paper are achievable and what is the potential

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role of smart cities in this process. The results provide several recommendations for an ongoing debate on better governing and creating smart low-carbon mobility systems.

2. Methodology and literature review

2.1. Methods and data collection

The methods used in this study combine a theoretical review and an empirical investigation, based on the scenarios analysis method and CO_2 emissions estimation (see Fig. 1).

The main sources of macroeconomic data include the databases and publications of both Polish and international institutions: Central Statistical Office of Poland (GUS), Eurostat, European Environmental Agency (EEA), World Bank, Intergovernmental Panel on Climate Change (IPCC), United Nations Economic Commission for Europe (UNECE), and International Transport Forum (ITF) at the Organisation for Economic Co-operation and Development (OECD). Data on the number of vehicles per category and their annual mileages are based on resources from the Central Register of Vehicles and Drivers (CEPiK) in Poland, Internet-Based System for Local Analyses (SAS), and The National Centre for Emissions Management (KOBIZE) in Poland. The data regarding Warsaw's transport system were supplemented with opinions collected through a survey administered to relevant authorities. Average mileage is as per the Motor Transport Institute in Warsaw (ITS) statistical data and market research (Waskiewicz and Chłopek, 2014). The number of passengers has been estimated using the Polish 'Guidelines on Assessment of Economic Efficiency or Road and Bridge Investments' (IBDIM, 2008), and JASPERS Blue Book (JASPERS, 2015), statistics regarding transport performance across different vehicle types in 2008. The fuel consumption in the first year in the analysis is as per available domestic statistical data (GUS, 2009, 2012) and international data (IEA, 2009). The charges and fuel-related tax levy in Poland in 2008 have been determined based on the Excise Tax Act, data from the International Energy Agency (IEA) and the World Bank (IEA, 2013; World Bank, 2012).

2.2. Literature review

GHGs are considered responsible for global warming and climate change. The term 'climate change' has several parallel definitions across literature. According to the IPCC, it refers to 'any change in climate over time, whether due to natural variability or as result of human activity' (Ribeiro et al., 2007). The United Nations Framework Convention on Climate Change uses a slightly different definition: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods' (UN, 1992). The major threats related to global warming include rising sea levels, impact on energy use, and agricultural and water supplies. It can also create negative health effects, influence the functioning of ecosystems and global bio-diversity, and, finally, cause extreme weather conditions and major catastrophic events (Watkiss et al., 2005).

The decarbonisation of transport is an integral part of mitigating climate change, and has been the subject of many research projects and studies. Moreover, there are many reports and guidelines in transport decarbonisation policy published by recognised international institutions (OECD/ITF, 2015a,b; UN, 2016), a large share of which is dedicated exclusively to urban areas (GIZ, 2002; Hickman and Banister, 2014; OECD/ITF, 2016). This growing attention given to urban transport systems can be also justified by the constantly growing role of transport activities in cities.

Possible estimations of transport-related GHG emissions levels and their mitigation measures can be also considered from different perspectives. Some studies focus on macro-scale analysis, covering national and international emission levels (Ajanovic and Haas, 2017; Hao et al., 2014; Jarvi et al., 2015), while others focus on regional and urban scales (Guoa et al., 2014; Li, 2011; Liu and Cirillo, 2016; Ramachandraa et al., 2015) or the various factors of decarbonisation e.g. technological (Oshiro and Masui, 2015; Nocera and Cavallaro, 2016a), economic (Sobrino and Monzon, 2014; Nocera and Cavallaro, 2016b) or social and spatial (Reichert et al., 2016; Zhang et al., 2016; Goeverden et al., 2016).

Estimating transport-related GHG emissions can be conducted using a wide range of methods and tools. Nevertheless, two main methods can be distinguished: top-down and bottom-up approaches. However, some recently developed models combine solutions from both these methods, using a so-called hybrid approach (Böhringer, 1998; Boulter et al., 2007; Van Vuuren et al., 2009). The top-down approach derives from macroeconomic analysis and generally makes use of aggregate models and estimates emissions for an entire economy (Böhringer, 1998; Böhringer and Rutherford, 2007; Van Vuuren et al., 2009). Models from this group use more general data (e.g. overall fuel consumption in transport systems). The input data in top-down emission models are usually expressed in terms of transport activity, that is, in passenger-kilometres (pkm), tonne-kilometres (tkm), vehicle-kilometers (vkm), or overall/average fuel consumption in a transport system. This type of estimations requires less specific inputs, hence their more common use in macro-scale analyses, such as for national GHG inventories.

Models based on the bottom-up approach allow for more accurate calculations, providing insights into individual sources of emissions to cover a larger number of technical characteristics for energy demand. The most accurate models from this group, the so-called instantaneous models, can calculate GHG emissions from vehicles even within one-second intervals (Alkafoury et al., 2013). Nevertheless, they require detailed input data, which are typically difficult and costly to collect. As such, bottom-up models are often used in micro-scale analysis (e.g. regional or even street level), as they more accurately reflect the characteristics of local emissions, which makes them suitable for monitoring urban policies and actions.

For the purpose of this study, the ForFITS model was used to estimate transport-related GHG emissions in Warsaw. The choice of ForFITS model is a result of comparative analysis of 17 models designed for assessing GHG emissions from transport sector. The selection criteria included, inter alia, the ability to create long-term forecasts (2008–2050), specialisation in road transport mode, and ability to perform analysis at both regional (urban) and national scales. An additional goal of this study was the validation of ForFITS as a freely available

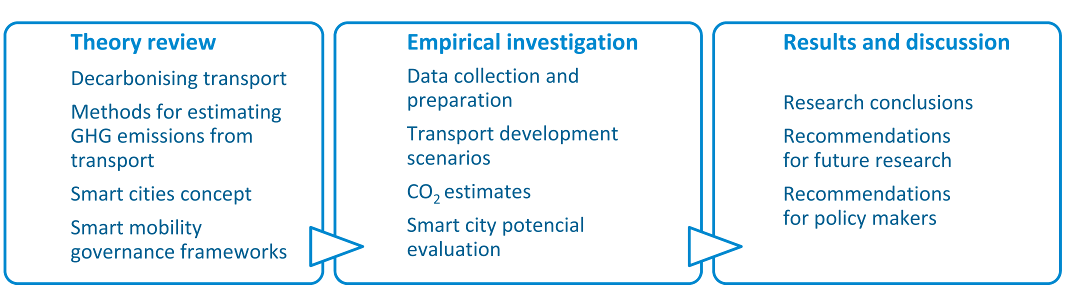

Fig. 1. Research methodology.