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Assessing carbon emissions from road transport through traffic flow estimators

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ABSTRACT

Carbon emissions from road transport are one of the main issues related to modern transport planning. To address them adequately, the acquisition of reliable data about traffic flow is an essential prerequisite. However, the large quantity and the heterogeneity of available information often cause problems; missing or incomplete data are one of the most critical aspects. This paper discusses how technology handles imperfect information in order to obtain more accurate quantification of CO_2 emissions. First, an analysis of single estimators and combination models is provided, highlighting their main characteristics. Then, the TANINO model (Tool for the Analysis of Non-conservative Carbon Emissions In TraNspOrt) is presented, jointly developed at the University of Seville and at the IUAV University of Venice. It consists of two different modules: the first is a combination model that optimizes the results of three traffic flow single estimators, while the second is a macro-model of carbon evaluation, which takes into account road infrastructure, vehicle type and traffic conditions. TANINO is then tested to calculate CO_2 emissions along the ring road of the Spanish city of Seville, showing its more efficient performance, compared to the single estimators normally adopted for such aims. Transport planning can benefit from the adequate knowledge of traffic flows and related CO_2 emissions, since it allows a more reliable monitoring of the progresses granted by specific carbon policies.

1. Introduction

Urban mobility accounts for about 40% of total greenhouse gas (GHG) emissions from road transport in the European Union (EU; Council of the European Union, 2011). The expected growth of urban areas will also result in increasing demand for mobility. If not well managed, this will raise transport externalities, including GHG emissions. Hence, their correct estimation and inclusion into modern transport planning has become a crucial issue, acknowledged by the EU through the development of Sustainable Urban Mobility Plans (SUMPs; Wefering et al., 2013). Despite these issues, GHG emissions are not considered as high-effective impact factors to decision making in several mobility plans, yet their reduction is rather left as an ancillary consequence (Nocera and Cavallaro, 2014).

To overcome such issues, public authorities have promoted specific technologies, tools and standards to deal with CO_2 emissions - the most important of anthropogenic GHGs. For instance, the EU ARTEMIS project (André, 2004) aims at developing a harmonised model for road, rail, air and ship transport, in order to provide consistent estimates of the emissions at (inter)national and regional levels. The Worldwide harmonized Light duty Test Procedure (WLTP) is the United Nations Economic Commission for Europe

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standard for determining the level of pollutants and CO_2 emissions from light-duty vehicles (Tsokolis et al., 2016). On a smaller scale, local authorities have developed Information and Communication Technology (ICT) tools, designed to observe and manage city assets such as traffic flow and its emission levels. Computational intelligence and data mining are valid approaches to analyse and use data for short-time traffic parameter forecasts (Vlahogianni et al., 2014), which can be used as a basis for eco-routing navigation (Zeng et al., 2016).

The volume and speed at which such local data is generated, processed and stored are unprecedented. On the one hand, this can present a formidable opportunity for transport planners (Grant-Muller et al., 2015; Kuflik et al., 2017); on the other hand, it poses new methodological challenges related to the input of massive, often real-time, datasets. The provision of incomplete time series is considered one of the most significant challenges, and new methodologies to address this issue are a priority (OECD/ITF, 2015). Another relevant issue related to these technologies is the harmonization of the datasets in different contexts, in order to allow the benchmarking of results. Indeed, their harmonization in the European regions and cities has not followed the rapid pace of development of the new ICT tools. As a result, in many cases it has not been possible to obtain comparable information (EC, 2017).

This paper analyses the technologies that deal with incomplete information; then it proposes a methodology that uses high-volume information about traffic flows, via road detectors, to quantify related CO_2 emissions. To achieve this aim, the Tool for the Analysis of Non-conservative Carbon Emissions In TraNspOrt (TANINO) models traffic parameters in metropolitan areas, under the presence of data gaps. This method improves the quality of the calculation of CO_2 emissions from transport, by reducing one of the most important sources of uncertainty regarding the carbon economic valuation, i.e. the lack of reliable data about traffic flows (Habel et al., 2016). Furthermore, the use of standards defined by the EU guarantees that datasets are harmonized between different metropolitan areas, thus overcoming the interoperability issues previously mentioned. The paper is organized as follows. Section 2 describes the current methods adopted to deal with traffic flow detection and carbon issues, as well as the main issues. Section 3 provides the theoretical framework of TANINO. Section 4 tests the model for the urban area of Seville and discusses the results. Finally, Section 5 draws some conclusions and practical implications.

2. Transport modelling and CO_2 emissions

2.1. A two-step approach

The quantification of CO_2 emissions from mobility is based on a two-step process: transport modelling and calculation of fuel consumption and emissions related to it. In Nocera et al. (2017), the main characteristics and the link between the two modules were discussed, according to the different geographical scales, temporal horizons, and patterns of drivers' behaviour established by the modellers.

Transport modelling is the first step of this process. It aims at providing policy-makers with adequate information about traffic flows, the origin and destination of the journeys, the selected transport modes and the paths followed by users (Linton et al., 2015). The different levels of detail are distinguished by a micro and a macro approach. The microscale represents the behaviour of vehicular traffic dynamics, considering individual vehicles interacting with each other (Hoogendoorn and Knoop, 2012). The dynamic variables represent microscopic properties like the position and speed of single vehicles and traffic flow is modelled according to individual movements. For instance, traffic network models, behavioural models and agent-based models belong to this class. System dynamic models are on an intermediate scale, since they do not refer to single vehicles, but rather analyse the relationship and mathematical modelling of stocks (Mosterma, 2007). The macro-models consider the relationship between economy, technology and society and provide aggregate values, expressed in terms of flows and the saturation of infrastructures.

As for fuel consumption and CO_2 emissions, the scientific literature is vast[1]. Briefly, the factors that affect fuel consumption and related *CO_2 emissions* belong to four main categories: characteristics of the vehicle, traffic conditions, environmental conditions and driver behaviours (Esteves-Booth et al., 2002). According to these details, a similar distinction between micro and macro approaches can be provided. The micro-level models operate at a high level of complexity. They provide detailed output in terms of fuel consumption and the estimation of emissions for a particular vehicle type according to various driving cycles (Demir et al., 2011). They also include different levels of speed and operational modes, among which acceleration, deceleration, steady-speed cruise and idle. In this group, we include simple modal models, instantaneous fuel consumption models, four-mode elemental fuel consumption models, running speed fuel consumption models and comprehensive modal emission models. These models assess how driver behaviours affects total emissions (Ayyildiz et al., 2017). An interesting approach has been proposed by Zeng et al. (2017), combining the established CO_2 emission and eco-routing models, to compare the original routes selected by travellers and the eco-friendly ones. Results reveal a potential saving of CO_2 emissions up to 11%. The macro level, which is intended for higher geographical and temporal scales, adopts a simplification and aggregation of factors. It includes different models, spanning from aggregated emission factors to traffic situation models. The former provide a value (g/km) for a vehicle type according to the different road types, while the latter express the estimations by the use of emission factors extracted from real-life situations.

Both steps are characterised by a vast number of scientific uncertainties, which make the future evaluation of traffic flows and CO_2 emissions complex. For this reason, mesoscopic models have been proposed as an alternative solution, which simplifies the computation by reducing the number of parameters (Kirschstein and Meisel, 2015). In Nocera et al. (2018), we have described the main issues related to CO_2 models, distinguishing between technical, economic and decisional uncertainties and have proposed a

[1] Interested readers may refer to Nocera and Cavallaro (2017) for a more comprehensive analysis of this topic.