Journal of Cleaner Production 183 (2018) 797–809

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Downscaling national road transport emission to street level: A case study in Dublin, Ireland

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ARTICLE INFO

Article history:
Received 1 June 2017
Received in revised form
14 February 2018
Accepted 20 February 2018
Available online 21 February 2018

Keywords:
Transport
Spatial
Emission
Mapping
Policy

ABSTRACT

Emissions from road transport are routinely prepared at the national scale in many countries under different national and international policies, directives and legislation. Scaling down this emission to the smaller geographical area is considered as a top-down approach. Several methods have been previously applied to scaling down emission, however these have often reported inconsistent findings in comparison with emission distribution using a bottom-up approach. Carbon dioxide and particulate matter (smaller than about 2.5 μm) emissions from a national road transport estimation in Ireland were disaggregated among four counties in the Greater Dublin Area and subsequently distributed at a finer spatial scale (0.5×0.5 km^2). Spatial coverage of the proxy variables, spatial weight distribution and appropriate representation of the fleet characteristics were identified as main sources of difference in distributed spatial emissions between top-down and bottom-up approaches. The first two issues were addressed in this paper by predicting missing or absent traffic volume from limited datasets, and the later was addressed by considering the fleet and mileage data from national annual vehicle test data at county level. A neural network model was applied to predict traffic volume which showed a 51% precision in prediction performance. Emission distribution was also performed for comparison purposes using a more conventional road density-based approach, where a correlation analysis showed an inconsistency between the two approaches. The results of this study highlighted that if the fleet characteristics at county level were not considered, the estimated emission would be different by −1.6 to −8.6% (Carbon dioxide) and −12.6 to 0.03% (Particulate matter) for passenger cars and −3.57–13.6% (Carbon dioxide) and −0.054–16.8% (Particulate matter) for light and heavy duty vehicles, depending on the counties in question. This study revealed that a share of 22.6% and 21.1% of national carbon dioxide and particulate matter emission occurred in Dublin County alone, and Dublin city was attributed to approximately 10.5% carbon dioxide and 9.8% particulate matter of the national total. The particulate matter in Dublin County was 14.3–22.4% higher than surrounding counties, and carbon dioxide emissions in Dublin city were two times higher than that of the towns and urban areas in the surrounding three counties. This study provides a combination of methods for producing finer scale spatial estimation of emission to facilitate abatement strategies and mitigation action plans at county and municipality level for the reduction of emission, better air quality and climate. The study highlights the necessity of reliable spatial distribution methods for assigning emission at a finer scale.

1. Introduction

Emissions of air pollutants and greenhouse gases at national and local level are known to be dominated by transport, domestic and industrial sources. The road transport sector is one of the key sectors for emitting Greenhouse Gases (GHGs) and air pollutants (Duffy et al., 2017). Carbon dioxide (CO_2) is the primary GHG in the Irish road transport sector and Particulate Matter <2.5 μm Diameter ($PM_{2.5}$) is one of the major air pollutants in Ireland having a share of nearly 12% of the total emissions in 2016 (EPA, 2017). $PM_{2.5}$ and CO_2 emissions were chosen together in this study to assist assessing both the health and

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https://doi.org/10.1016/j.jclepro.2018.02.206

climate change impacts of the transport sector at a more local level. This study focused on developing a combination of methods to scale down national level emission to a smaller geographical area or a street level, regardless of pollutant type, so that the developed methods can be applied to impact assessment, air quality mapping, developing effective local level planning, or for policy analysis at city or municipality level for any emission using these methods. Ma et al. (2014) highlighted that understanding of the local factors that shape travel behaviour, and the resulting carbon and air pollution emissions is the key for 21st century planning in low carbon cities. A representation of real world emission distribution at local level will help local or national policy makers to identify the issues of priority to reduce the emission from transport in specific areas.

Emissions from road transport are prepared at the national scale in many countries under different national and international policies, directives and legislation. The countries in European Union (EU) prepare road transport emission estimations for GHGs and air pollutants at the national level under EU requirements MMR 525/2013, the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and EU Directive 2016/2284. Under CLRTAP (ECE/EB.AIR/125), countries prepare emission maps at a grid of 0.1° x 0.1° (approx. 11×11 km^2), every four years. Source data for such emissions maps and/or the national level emission may be used in producing spatially finer emission maps annually to facilitate policy planning, impact assessment and air quality mapping.

For estimating road transport emission at the national level, COmputer Programme for calculating Emissions from Road Traffic (COPERT) software (Ntziachristos et al., 2009) and COPERT based approaches were extensively used at the national and regional level in different countries (Borge et al., 2012; Guevara et al., 2013; Pallavidino et al., 2014; Fameli and Assimakopoulos, 2015; Sun et al., 2016; Alam et al., 2017a). Although COPERT estimates emission at a very disaggregated vehicle category level, their spatial reference is not considered in the process. A segregation of vehicle mileage at highway, rural and urban area was considered in COPERT, however, that does not highlight the difference in vehicle mileage profile at the smaller geographical area level. COPERT estimated a number of emissions including GHGs and air pollutants, and with the help of suitable methods, these emissions can be downscaled to a fine spatially disaggregated level. Thus, the aim of the present study is to develop an appropriate process combining methods in light of the existing literature to scaling down the national level emission estimation to street level.

In previous studies, emissions estimated at the national level or city level were downscaled to a finer scale of spatial mapping following a top-down approach (Sun et al., 2016; Fameli and Assimakopoulos, 2015; Gioli et al., 2015; Pallavidino et al., 2014). These methods employed proxy data such as road length density, road length density by road hierarchy, population density, traffic volume at major roads, and various combinations of these. In comparison to these top-down approaches, road transport emissions can also be estimated using bottom-up approaches where road traffic characteristics at the road link level are used to calculate emission and added for a geographical area (Pallavidino et al., 2014; Nyhan et al., 2016; López-Aparicio et al., 2017).

Several attempts were also made to compare the consistency of these two approaches which provided useful information regarding downscaling emissions. Pallavidino et al. (2014) reported that emission estimated by traffic models using the bottom-up approach and emission from a top-down approach distributed using population density, led to different emissions maps. López-Aparicio et al. (2017) reported a comparison of fine-scale bottom-up emission inventories and regional emission inventories after these were downscaled to the same areas for nitrogen oxides (NO_x), particulate matters that are smaller than about 10 µm (PM_{10}) and $PM_{2.5}$. In scaling down the emissions under that study, emission was distributed based on the modelled data for inter-urban traffic emissions and population density for urban traffic emissions. The differences in emission for different areas were identified as: omission of emission factors for PM_{10}, missing of localised representation of the fleet, and the lack of detailed information about the location of emissions (high traffic volume link vs. urban traffic based on population was underestimated). Similarly, Gately et al. (2013) reported that, using spatial proxies such as population and road density to downscale national emissions introduced errors, and they employed Vehicle Miles Travelled (VMT) as a proxy to tackle this problem. In this process, a limitation of estimating VMT for local roads, was handled by combining two datasets and share of mileage for the local level to the state level.

Requia et al. (2017) found that spatial patterns of traffic emissions at municipal district level were associated with population, length of highways, and four other macro-level variables. When distributing emission at a finer scale use of these variables may be limited, and a spatial proxy must have appropriate spatial coverage and spatial weight. Sun et al. (2016) assigned emission at road network level based on road length density or road length per grid cell. Fameli and Assimakopoulos (2015) estimated emission for entire countries using COPERT and estimated emission spatially following a combination of approaches. For urban areas, urban emission from COPERT output was estimated based on population density grids, similar to Sun et al. (2016). For rural areas, emissions from COPERT were estimated based on the total length of the road per grid cell; while mean daily traffic flow data were applied to distribute highway emissions. Pallavidino et al. (2014) assigned traffic model based emission into a finer scale considering population data. Zheng et al. (2009) estimated emission intensity at a city level based a total emission for multiple cities and road length weighted by traffic information of a city, and the emission intensity of that city was applied with the similar weighted factor for a grid to calculate emissions on that grid. From these studies, road density was found to have the most spatial coverage and was closely related to emission from road transport; however, this does not represent the different spatial weight for emission distribution induced by different levels of traffic volume. Traffic volume is one of the core components of the bottom-up approach (Nyhan et al., 2016; Pallavidino et al., 2014) that can be applied in spatial mapping using the top-down approach instead of the common proxies to achieve a better reflection of emission distribution. Nevertheless, a common problem with this approach may be the lack of availability of traffic volume data on a wider scale (Guevara et al., 2013). Guevara et al. (2013) applied a top-down approach using population density where there was a lack of traffic flow information, and in the latest study, Guevara et al. (2017) applied spatial proxies from traffic counts and road network from Open Street Maps (OSM) to distribute emission. Traffic volume data in all roads provided an appropriate spatial coverage and spatial weight distribution for emission mapping. In order to derive spatial weight from traffic volume beyond traffic modelled area, or traffic count locations, the current study predicted traffic volume data from available sources and applied this to spatial emission mapping. The superiority of the traffic volume data for spatial distribution of emission was also presented by comparing emission distribution from another top-down road length density-based approach.