Commuting carbon dioxide (CO₂) emissions: a study of ten Italian metropolitan cities


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Abstract: Carbon emissions related to daily trips to work/study place have hitherto played an ancillary role in transport problems. This study investigates CO₂ emissions related to commuting in/from/to ten largest Italian metropolitan cities. Not only the flows in the commuting zones defined by the OECD and the European Commission, but all the inbound and outbound flows have been considered. Commuting flows from census data are associated to province-specific car emission factors. Open data are handled in order to build a thorough database. The researchers provide a straightforward methodology to account commuting carbon footprint. The results show that commuting in/from/to the cities considered accounts nearly the 4 percent of total transport CO₂ emissions in Italy: the two-thirds come from the 31 percent of the commuters, which corresponds to a transboundary journey (from/to). The main driver is a significant use of private means of transport with a low occupancy rate. The importance of cities in moving towards sustainable commuting, both for the shorter distance travelled (compactness) and the wider availability of less-emitting modes of transport (walkability, biking, public means) is highlighted.

Keywords: carbon footprint; urban mobility; commuting matrix; CO₂ emission factors; occupancy rate.

1. Introduction

IPCC stated human influence on the climate system is clear and recent anthropogenic emissions of greenhouse gases (GHGs) are the highest in history (IPCC, 2014). Warming of the climate system is unequivocal and, since the 1950s, many of the observed changes are unprecedented over decades to millennia (Francesco I, 2015). Over time, scientific consensus led various nations to undertake initiative for tackling fossil energy consumption and subsequently GHGs emissions. European Union is at the front line of the fight against climate change (Lorenzoni and Pidgeon, 2006; Schreurs and Tiberghien, 2007; Biesbroek et al., 2010). Nevertheless, while emissions from other sectors are generally falling, those from transport have continued to increase until 2008 when transport emissions started to decrease. This is mainly due to the increased efficiency of passenger cars and slower growth in mobility. Transport is still responsible for around a quarter of EU GHGs emissions making it the second biggest greenhouse gas-emitting sector after energy industries (EC, 2015). Urban transport contributes to about one-quarter of the EU’s transport emissions of carbon dioxide and almost 40 percent of the overall urban CO₂ emissions (Glaeser and Kahn, 2010).

Transport deserves greater attention when concerning the reduction of CO₂ emissions because it is far from actively contributing to their reduction (Bresl et al., 2010; Caprosa et al., 2011; Gössling and Cohene, 2014), as required from international agreements such as the Kyoto Protocol (UN, 1998) or the European “20-20-20” targets (EC, 2012).

Policies aiming at reducing transport emissions deal with two main strategies (Albalate et al., 2015). The first focuses on the supply side and attempts to improve the energy efficiency of vehicles (e.g., labelling fuel economy and CO₂ emissions, placing emissions targets for new vehicles (EURO)). The aim is to reduce the carbon content of the energy used and to spread more widely the Intelligent Transportation System (ITS) (Bell, 2006; Demisste et al., 2013). The second strategy is put on the demand side and aims at redirecting demand segments to less impacting transport modes and shifting from private vehicles to public transport. Hitherto, transport policies have been mostly focussed on the supply side at the expense of measures designed to influence travel behaviours (Anable and Bristow, 2007). The studies regarding demand are limited (Libardo and Nocera, 2008). The reduction of carbon emissions deriving from the circulation of private vehicles is considered as one of the most relevant problems in transport planning (Black, 2010). Cities represent an important leverage for the switch to sustainable transport because of higher population density and wide availability of public transport, as well as the option of walking and cycling (Bulkeley and Betsill, 2005; Jabareen, 2006; Goldman and Gorham, 2006). In spite of this, a higher share of travel by private car is still present in Italy’ cities (ISFORT, 2014) mainly due to the highest vehicle ownership rate in Europe (EC, 2014).

A large contribute is given by those people who regular travel between their residence and place of work or full-time study (ISFORT, 2014). Commuting has long been an important target mainly of transport policy and urban planning, because of its regular pattern, its close connection with congestion problems, and its association
with people’s choices about locations of work and housing (García-Serra and van den Bergh, 2014).

However, carbon emissions related to commuting travels has traditionally played an ancillary role (Nocera and Cavallaro, 2014), principally due to the institutional laxness. Italy is a clear example of this. The “Decreto Ronchi” (1998) obliges companies and administrations employing more than 300 workers in a single location or more than 800 overall, to have a company mobility plan and to identify a Mobility Manager, with the aim of reducing private vehicle use by promoting more environmentally-friendly transportation solutions, e.g., carpooling, car sharing, bike sharing, shuttle et cetera. Despite their large number, the role of compulsory mobility managers seems to be rather limited, because an important number of them are not very active (EC, 2010).

1.1. Aim of the study

Against the growing awareness behind carbon footprint of travel behaviour of the commuters, the main goal of this study is to contribute to the literature review by estimating CO₂ emissions generating by ten Italian metropolitan cities during their daily commute. In the study, not only the flows in the commuting zones defined by the OECD and the European Commission in (Dijkstra and Poelman, 2012), but all the inbound and outbound flows have been considered.

Aware of the transport related emissions accounting proposed in the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPCI WRI, 2014) and in the Baseline Emission Inventory (BEI) of Covenant of Mayors (ERC, 2010), this study has not the aim to account the GHG emissions among all the origin and destination cities considered but only to take a picture of the commuting emissions focussing on the chosen metropolitan areas. In Italy about 29 million citizens are commuters: about two-thirds move for work and one-third for study (ISTAT, 2014). In Table 1, commuting statistics, from the last Italian Census of 2011, are disaggregated by purpose mode. As stated in Table 1, road transport is clearly the most used modality, while emissions generating by Italian cities during their daily commuting neglecting other travel purposes. Despite all their large number, the role of compulsory mobility managers seems to be rather limited, because an important number of them are not very active (EC, 2010).

In light of the previous considerations, the study identifies with two objectives: first, to propose a comprehensive methodology for estimating CO₂ emissions generating by Italian cities during their daily commute and secondly, to provide decision makers with a comprehensive view of the issue of commuting carbon footprint.

This paper has been organised as follows: Section 2 establishes a critical overview of state-of-art of commuting research; Section 3 provides a methodology to account commuting carbon footprint with a specific focus on the emission factors; in Section 4 data and results are presented and discussed; finally in Section 5, main findings and suggestions for further research are highlighted.

2. Literature review

In the last decades, in the scientific literature, many authors provided estimates of the GHGs emissions and, as equivalent, the transport energy consumption due to the commuting (Wang et al., 2014).

A first branch (Riou et al., 2012) tries to find, across a group of cities, a correlation between urban form variables, such as city size/density, and transport energy consumption/GHG emissions. In the work of (Newman and Kenworthy, 1989) on land use and motorised journeys, authors found an inverse correlation between population density and urban transport energy consumption, in 32 major cities in the world. For many years European and American policy makers were influenced in their choices by this finding (van de Coevering and Schwanen, 2006). More recently, the findings of (Newman & Kenworthy, 1989) have been highly criticised and many studies have highlighted how the increase in urban density does not generally contribute to energy savings mainly because of the direct correlation between urban density and congestion (Doi and Kii, 2012).

A second branch analyses the effects of different urban forms on transport mobility in terms of distance travelled, time travelled and modal share, estimating the related energy consumption and GHGs emissions. These studies cover many urban areas worldwide, i.e. New York (Transportation Alternatives, 2008), Hamilton (Scott et al., 1997), Montreal (Zahabi, 2012), Flanders (Boussauw and Wirlox, 2009), Wallonia (Pirart et al., 2012), Hong Kong (Loo and Chow, 2011), Vienna (Harl, 2013) Barcelona (Garcia-Sierra and van den Bergh, 2014), and 111 Italian urban areas (Girilli and Veneri, 2014).

In recent years, starting from (Hamilton, 1982), many authors have debated about the CO₂ emissions due to the “excess commuting” (Murphy, 2009). Excess commuting is the additional commute represented by the difference between the actual average commute and the smallest possible average commute given the spatial configuration of workplace and residential sites (Ma & Banister, 2006).

The common denominator among the majority of these studies is the use of census data for the commuters’ estimation. Distances travelled and emission factors are often generalised. As stated in (Pirart et al., 2012), the main weakness about the use of the census data is that information are available only about work and school commuting neglecting other travel purposes. Despite all...
this, home to work/school trips, due to their repetitiveness and systematic nature, are the most organised ones. Further, these travel purposes present the highest one-trip average time duration (Loo, and Chow, 2008), resulting hence more energy consuming than the average trip length for any other purpose.

Also universities and institutions, through detailed surveys, try to estimate their commuting related emissions using however data about means of transport emission factors with high level of aggregation (see for example Mathez, 2013).

3. Methodology

The methodology adopted is based on the interaction processes among open database, at national level, providing distinct but complementary information on the mobility. The proposed methodology consists of three steps: 

- data collection;
- data screening;
- data processing.

Data collection is the first fundamental step. In some cases, e.g., local governments at city or region level, there are national open data that could be used for this purpose. As a rule, census data capture the travel behaviour of the population. For other type of organisations, e.g., corporations, it is necessary to design a basic travel survey, in which employees or staff will be asked to describe their daily trip to the workplace through a series of guided questions. They will be asked to indicate at least the origin and the specification of vehicle type, in case of motorised travel. The more information the organisation is able to collect, the more accurate will be its commuting carbon footprint estimation.

Data screening is particularly important when non-ad hoc data are managed, e.g., census data. Data must be screened in order to ensure the data are usable, reliable, and useful for transportation emission calculations.

Finally, data are elaborated to assess the environmental impact of commuting in terms of CO₂ emissions. Equation 1 is adopted to determine emissions from passenger vehicle commuting travel in terms of vehicle kilometres.

\[ E_z = 2 \cdot \sum_i \sum_j \sum_k x_{ijk} \cdot d_{ij} \cdot EF_{jk} \cdot WD \]  

where:
- \( E_z \) = carbon emissions in/from/to the \( z \)-th city [kgCO₂/year]
- \( x_{ijk} \) = number of commuters from the between \( j \)-th origin to the \( i \)-th destination using the \( k \)-th means of transport [passengers/day]
- \( d_{ij} \) = distance between the \( i \)-th and the \( j \)-th places [km]
- \( EF_{jk} \) = emission factor of the \( k \)-th means of transport related to the province of the \( j \)-th origin [kgCO₂/km-passenger]
- \( WD \) = working days = 250 [days/year]

and:

\( z \) (cities considered) = 1-10 (Rome, Milan, Turin, Genoa, Palermo, Bologna, Florence, Bari, Reggio Calabria, Naples)

\( i, j \) (municipalities) = 1-7670 for the Italian municipalities (excluding Sardinia)

\( k \) (mode of transport) = 1-12 (pedestrian, bicycle, passenger car (as driver or passenger), motorcycle, urban bus, coach, company/school bus, train, tram, underground, others)

Carbon emissions in/from/to the \( z \)-th city are evaluated setting the following restrictions to the \( i \)-th destination and the \( j \)-th origin:

\[ E_{z, in} : z = i = j \] 

\[ E_{z, from} : z = j \ \forall \ i \] 

\[ E_{z, to} : z = i \ \forall \ j \] 

The Italian National Institute of Statistics (ISTAT) organises census data into commuting matrices, estimating the number of commuters \( n \) for each origin \( i \)/destination \( j \) and giving details about their behaviour, such as reason, means of transport \( k \), time and duration (ISTAT, 2014). For the \( j \)-th origin to the \( i \)-th destination, distance \( d \) in [km] between cities has been associated. Distances are calculated using TomTom MultiNet 2013 road network database with the centroids of Italian cities. When \( i = j \), distances are calculated as the ratio of the \( i \)-th average radius and the \( i \)-th compacity index. Compacity index shows how far a city is from a circular form with the same area. It ranges from 0 (highly irregular and less compact form), to 1 (ESPON, 2013).

Section 3.1 gives detailed information about the calculation of emission factors.

3.1. Emission Factors

Car Passenger and Motorcycle

Considering passenger cars and motorcycles, there are many differences among the fleets of Italian provinces. In this case, an average emission factor can be misleading. In order to enable a better estimate of commuting carbon footprint, emission factors are disaggregated by province.

Province fleet emission factors strictly depend on the type of fuel, the engine size and the age. In this study, rough data are drawn from Automobile Club d’Italia (ACI). The ACI makes available data about Italian road vehicles fleet (ACI, 2014). Data are disaggregated by province concerning fuel type, engine size and European emission standard (EURO).

Fuels type (F) considered are:

- gasoline
- diesel
- liquefied petroleum gas
- natural gas
- hybrid electric
Full electric cars are negligible (0.008%).
Engine sizes (ES) are divided into three categories:

- < 1.4 litres;
- 1.4 – 2.0 litres;
- 2.0 litres.

The COPERT methodology provides an average emission factor for each combination of the previous categories (F, ES, EURO), diversifying it for road classes, i.e. rural, urban, highway and average. In the case of passenger car and motorcycle, the analysis takes average and urban road class into account when commuting is transboundary and intra-city respectively.

Considering province’s passenger car fleet, an average emission factor for each province is derived by a weighted mean of the emission factors from COPERT. The calculated emission factors are representative of each province’s “average” passenger car. The 102 values obtained are included between 162.51 [g/km] (corresponding to the Province of Lecce in the Apulia region) and 176.60 [g/km] (corresponding to the Province of Trieste in the Friuli-Venezia Giulia region). The spread is mainly due to the different share of fuel type (almost the 75 percent of Trieste’s passenger cars are powered by gasoline, against almost the 50 percent of Lecce’s ones) and the higher engine size.

As an example, Table 2 shows the calculated emission factors of cars passenger and motorcycles for the Italian metropolitan areas (in the Italian case, the Metropolitan area is composed by municipalities belonging to the same province).

### Table 2: Emission factors for Metropolitan area’s car and motorcycle fleet.

<table>
<thead>
<tr>
<th>Metropolitan area</th>
<th>Car Emission Factors [gCO₂/km]</th>
<th>Motorcycle Emission Factors [gCO₂/km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rome</td>
<td>169.03</td>
<td>87.25</td>
</tr>
<tr>
<td>Milan</td>
<td>175.28</td>
<td>94.30</td>
</tr>
<tr>
<td>Naples</td>
<td>163.83</td>
<td>83.46</td>
</tr>
<tr>
<td>Turin</td>
<td>168.91</td>
<td>96.56</td>
</tr>
<tr>
<td>Genoa</td>
<td>169.35</td>
<td>84.39</td>
</tr>
<tr>
<td>Bologna</td>
<td>172.04</td>
<td>92.86</td>
</tr>
<tr>
<td>Palermo</td>
<td>164.10</td>
<td>85.81</td>
</tr>
<tr>
<td>Bari</td>
<td>162.88</td>
<td>90.71</td>
</tr>
<tr>
<td>Florence</td>
<td>168.74</td>
<td>87.25</td>
</tr>
<tr>
<td>Reggio Calabria</td>
<td>163.63</td>
<td>86.63</td>
</tr>
</tbody>
</table>

Public transport
In the absence of specific data relating to local fleet of public vehicles, i.e. urban bus, coach, train, tram, underground, national data are used (ISPRA, 2015). Emission factors are expressed in grams of CO₂ per vehicle kilometre [gCO₂/vehicle-km]. In order to calculate the amount of CO₂ per passenger kilometre, emission factors per vehicle are divided by their respective passenger load factor. In the case of electric railway transport, emission factors per passenger are calculated following the Equation 5:

\[
EF_i = \frac{EC_i \cdot EEF_{Italy}}{PLF_i}
\]

where:
- \(i\) = electric vehicle (regional train, tram, underground);
- \(EF\) = emission factor per passenger kilometre [gCO₂/pasenger-km];
- \(EC\) = electrical consumption per seat kilometre [kWh/seat-km];
- \(EEF\) = national grid emission factor [gCO₂/kWh];
- \(PLF\) = passenger load factor [passenger/seat].

The resulting emission factors of public transport means are expressed in Table 3.

### Table 3: National load and emission factors for public means of transport.

<table>
<thead>
<tr>
<th>Means of transport</th>
<th>Load Factor</th>
<th>Emission Factor [gCO₂/pasenger-km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban bus</td>
<td>16.154</td>
<td>65.192</td>
</tr>
<tr>
<td>Coach</td>
<td>17.194</td>
<td>39.975</td>
</tr>
<tr>
<td>Train</td>
<td>0.242</td>
<td>43.569</td>
</tr>
<tr>
<td>Tram</td>
<td>0.214</td>
<td>53.470</td>
</tr>
<tr>
<td>Underground</td>
<td>0.227</td>
<td>50.296</td>
</tr>
</tbody>
</table>

1 Load factor expressed in [passenger/vehicle]
2 Load factor expressed in [passenger/seat]

A simplification of the aforementioned considerations is outlined in Table 4. Table 4 summarises, for the kₖ means of transport, on which parameters each emission factor depends ("X" symbol means a matching).

### Table 4: Dependences of the emission factors considered.

<table>
<thead>
<tr>
<th>Means of transport (k)</th>
<th>F</th>
<th>ES</th>
<th>EURO</th>
<th>LF</th>
<th>RC</th>
<th>EEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycle</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban bus</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coach</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tram</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. Results

Commuting carbon footprint in/from/to the ten metropolitan cities considered amounts to 4048 [GgCO$_2$/year], representing nearly the 4 percent of total transport CO$_2$ emission in Italy (104,845 [GgCO$_2$] in 2012, according to (ISPRA, 2014)). Figure 1 shows the total number of commuters in/from/to the ten metropolitan cities considered. The analysis catches about the 18 percent of the total commuters in Italy. According to Figure 2a, most of them commute within the city’s boundaries (69%); only the 7 percent goes outside the city (mainly to their respective suburban areas). Despite of this, the major contribute in terms of emissions is given by commuting to the cities (50%), against the 35 percent of the city dwellers (Figure 2b); this highlights the importance of cities in moving towards sustainability, both for the shorter distance travelled and the wider availability of less-emitting modes of transport. Commuting from/to cities and suburban areas, which is just over the 30 percent of total, accounts the two-thirds of the total emissions. The reason for this is the overuse of private vehicles, which are the best-performing in terms of journey time (ISFORT, 2014).

![Figure 1](image1.png)

**Figure 1:** Commuting in Italy and in/from/to the metropolitan cities considered.

![Figure 2a](image2a.png)

**Figure 2a:** Share of commuting in/from/to the cities

![Figure 2b](image2b.png)

**Figure 2b:** Share of CO$_2$ commuting emissions in/from/to the cities

As shown in Table 5, occupancy rate of passenger cars is very small, even lower for commuting from/to cities. Mobility management, the study of commuters’ trips habits, aiming at improving the current situation through initiatives that sponsor more environmentally-friendly commutes, could promote an increase of the commuters’ cars occupancy rate. The Mobility Manager, defined in the Introduction, is a not widely exploited figure: as stated by ENEA (Lelli et al., 2014), in 2012 in Italy there were 846 Mobility Managers but only about 100 of them had implemented actions that sometimes had resulted even rather superficial.

<table>
<thead>
<tr>
<th>Cities</th>
<th>In</th>
<th>From</th>
<th>To</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rome</td>
<td>1.39</td>
<td>1.11</td>
<td>1.16</td>
<td>1.32</td>
</tr>
<tr>
<td>Milan</td>
<td>1.46</td>
<td>1.08</td>
<td>1.14</td>
<td>1.26</td>
</tr>
<tr>
<td>Naples</td>
<td>1.53</td>
<td>1.24</td>
<td>1.22</td>
<td>1.34</td>
</tr>
<tr>
<td>Turin</td>
<td>1.36</td>
<td>1.09</td>
<td>1.15</td>
<td>1.23</td>
</tr>
<tr>
<td>Genoa</td>
<td>1.32</td>
<td>1.13</td>
<td>1.16</td>
<td>1.27</td>
</tr>
<tr>
<td>Bologna</td>
<td>1.40</td>
<td>1.07</td>
<td>1.13</td>
<td>1.21</td>
</tr>
<tr>
<td>Palermo</td>
<td>1.55</td>
<td>1.13</td>
<td>1.26</td>
<td>1.46</td>
</tr>
<tr>
<td>Bari</td>
<td>1.45</td>
<td>1.12</td>
<td>1.21</td>
<td>1.31</td>
</tr>
<tr>
<td>Florence</td>
<td>1.44</td>
<td>1.09</td>
<td>1.15</td>
<td>1.24</td>
</tr>
<tr>
<td>Reggio Calabria</td>
<td>1.65</td>
<td>1.16</td>
<td>1.24</td>
<td>1.56</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1.43</td>
<td>1.11</td>
<td>1.17</td>
<td>1.30</td>
</tr>
</tbody>
</table>

With the regard to the cities analysed, the major contribute in terms of carbon emissions is given by the city of Rome, accounting alone the 38 percent of total (Figure 3). Figure 3, however, may lead to misleading conclusions: it does not reveal which commuters are “virtuous” among the ten cities. Actually, this percentage roughly follows the share of the commuters (Rome 31%, Naples 11%, Turin 12% etc.). The comparison is possible using suitable metrics, e.g., [kgCO$_2$/commuter] and [kgCO$_2$/km] (see Figure 4).

![Figure 3](image3.png)

**Figure 3:** Cities’ share of CO$_2$ commuting emissions

![Figure 4](image4.png)

**Figure 4:** [kgCO$_2$/commuter] and [kgCO$_2$/km] for the ten cities.
A low value of the parameter \( \text{kgCO}_2/\text{commuter} \) means that the commuting in the area considered is characterised by a useful synergy among the choice of non-motorised transport, high occupancy rate and a widespread use of public transport means (preferably railway). Naples has the 22.6 percent of non-motorised transport and an occupancy rate of 1.34 (see Table 6) (near to the national average value of 1.35 (inferable from Table 1)) has the best performance. Rome has the highest value, mainly because the low modal share of non-motorised transport. Milan, characterised by a noteworthy share in railway transport, is only in the fifth position, but it is leader considering the parameter \( \text{kgCO}_2/(\text{commuter} \cdot \text{km})_{\text{motorised}} \). This parameter, evaluating only the emissions of the motorised transport, “awards” the choice of less-impacting modes of transport. The massive use of private vehicles linked to the poor employment of public means relegate the city of Reggio Calabria to the bottom of the ranking.

**Table 6: Modal share of commuting [%] and their CO2 emissions distribution [%] in/from/to the cities considered**

<table>
<thead>
<tr>
<th>Cities</th>
<th>Non-motorised means</th>
<th>Private motorised means</th>
<th>Public road transport</th>
<th>Railway transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rome</td>
<td>12.5</td>
<td>57.8 (78.8)</td>
<td>14.4 (12.5)</td>
<td>15.1 (8.6)</td>
</tr>
<tr>
<td>Milan</td>
<td>19.9</td>
<td>37.9 (69.9)</td>
<td>10.0 (5.7)</td>
<td>31.9 (24.4)</td>
</tr>
<tr>
<td>Naples</td>
<td>22.6</td>
<td>42.5 (72.4)</td>
<td>16.3 (12.1)</td>
<td>17.9 (15.5)</td>
</tr>
<tr>
<td>Turin</td>
<td>16.3</td>
<td>52.4 (80.0)</td>
<td>17.7 (8.8)</td>
<td>13.5 (11.1)</td>
</tr>
<tr>
<td>Genoa</td>
<td>18.7</td>
<td>46.9 (71.6)</td>
<td>23.3 (16.9)</td>
<td>10.7 (11.5)</td>
</tr>
<tr>
<td>Bologna</td>
<td>15.9</td>
<td>55.9 (79.8)</td>
<td>19.8 (8.1)</td>
<td>8.1 (12.2)</td>
</tr>
<tr>
<td>Palermo</td>
<td>20.8</td>
<td>63.7 (84.9)</td>
<td>13.5 (12.2)</td>
<td>1.9 (2.9)</td>
</tr>
<tr>
<td>Bari</td>
<td>16.8</td>
<td>54.5 (73.9)</td>
<td>15.3 (10.9)</td>
<td>13.2 (15.3)</td>
</tr>
<tr>
<td>Florence</td>
<td>17.0</td>
<td>56.2 (75.7)</td>
<td>12.6 (7.4)</td>
<td>13.9 (16.9)</td>
</tr>
<tr>
<td>Reggio Calabria</td>
<td>12.8</td>
<td>70.3 (85.3)</td>
<td>13.6 (10.4)</td>
<td>3.0 (4.3)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17.1</strong></td>
<td><strong>51.8 (76.6)</strong></td>
<td><strong>15.0 (9.2)</strong></td>
<td><strong>16.0 (14.2)</strong></td>
</tr>
</tbody>
</table>

5. Conclusion, limitations and further research

The study first set out to calculate CO2 emissions generated by commuting in/from/to the largest Italian metropolitan cities. Open data were collected, screened and processed in order to develop a comprehensive database. Cross-section analysis on ten Italian metropolitan cities has validated the hypothesis that daily transboundary commuting from/to cities largely contributes to CO2 emissions. This type of commuting is characterised by an overuse of private vehicles with a very low occupancy rate. This issue reminds of United States urban sprawl, a phenomenon associated with the rapid low-density, mono-functional outward expansion of cities fuelled by the rapid growth of private car ownership. The importance of city in moving towards sustainable commuting, both for the shorter distance travelled (compactness) and the wider availability of less-emitting modes of transport (walkability, biking, public means) is highlighted. In this context, Mobility Managers plays a crucial role. Their potentiality has not been adequately exploited yet. Recently, Italian Government has extended this figure to students commuting issues. Surely, an effective action of this player will promote an increasing modal shift towards more environmentally-friendly transport modes.

Main limitations consist in the emission factors: although province car fleet values have been calculated and used, they do not account speed (congestion is a peculiar issue of intra-city commuting). Furthermore, national load factors for public transport have been considered. Another issue is related to the bias (margin of error) intrinsic in census data.

Further research steps will face previous limitations. Data about trips duration – available on the Italian Census of 2011 – will give information about average speed: this dataset will be appropriately handled to consider the traffic congestion resulting in an increase of CO2 emissions from private road transport. Finally, the straightforward methodology proposed can be extend to any type of organisation, whether local governments or corporations designing an ad-hoc survey. The value of information inherent commuting carbon footprint can be then highlighted, evaluating a range of policies, e.g., telecommuting, carpooling, incentives for lower-emission means of transport, and their impacts.

References


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