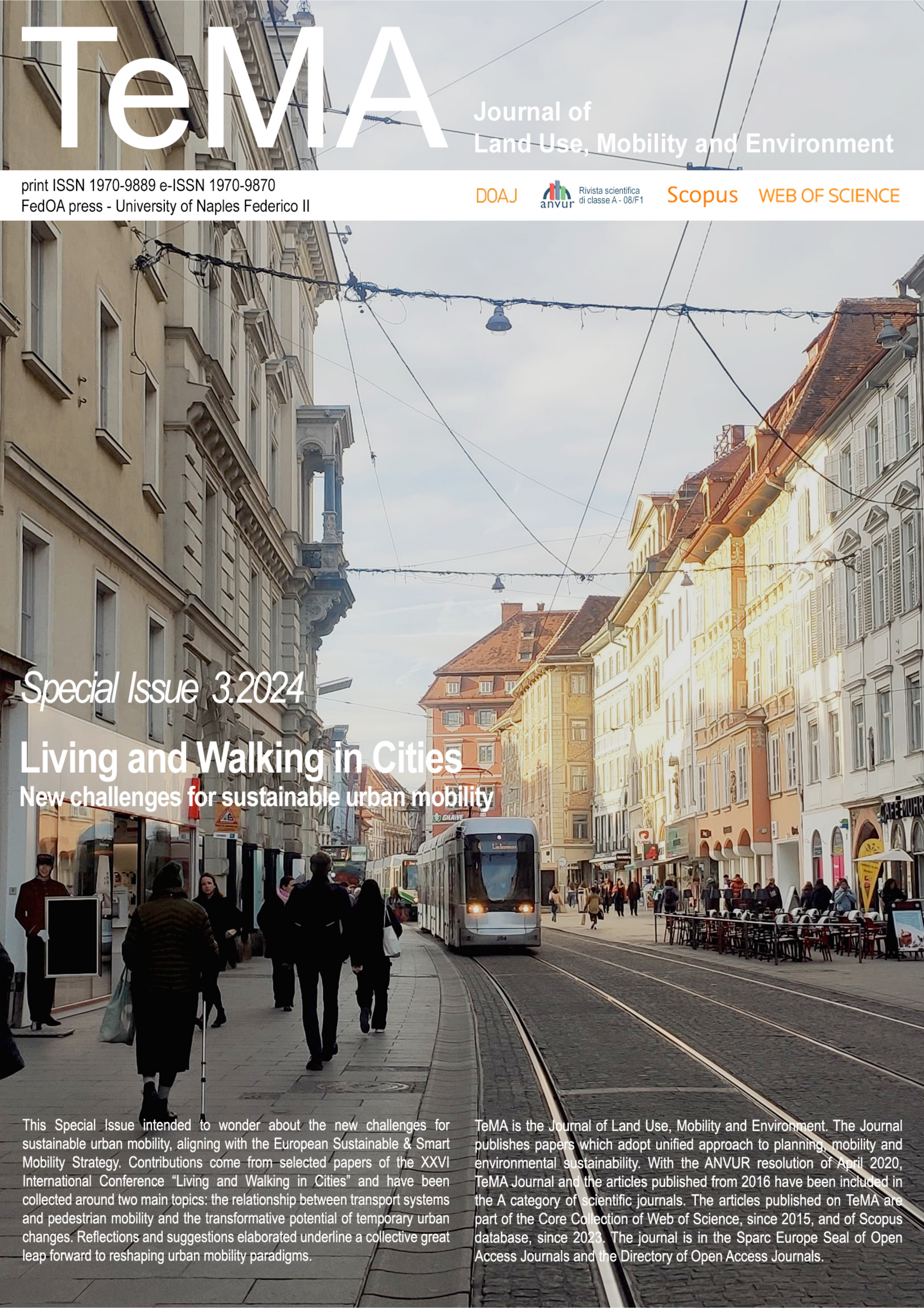

TeMA

Journal of
Land Use, Mobility and Environment

print ISSN 1970-9889 e-ISSN 1970-9870
FedOA press - University of Naples Federico II

DOAJ   anvur Rivista scientifica di classe A - 08/F1   Scopus   WEB OF SCIENCE

Special Issue 3.2024

Living and Walking in Cities
New challenges for sustainable urban mobility

This Special Issue intended to wonder about the new challenges for sustainable urban mobility, aligning with the European Sustainable & Smart Mobility Strategy. Contributions come from selected papers of the XXVI International Conference "Living and Walking in Cities" and have been collected around two main topics: the relationship between transport systems and pedestrian mobility and the transformative potential of temporary urban changes. Reflections and suggestions elaborated underline a collective great leap forward to reshaping urban mobility paradigms.

TeMA is the Journal of Land Use, Mobility and Environment. The Journal publishes papers which adopt unified approach to planning, mobility and environmental sustainability. With the ANVUR resolution of April 2020, TeMA Journal and the articles published from 2016 have been included in the A category of scientific journals. The articles published on TeMA are part of the Core Collection of Web of Science, since 2015, and of Scopus database, since 2023. The journal is in the Sparc Europe Seal of Open Access Journals and the Directory of Open Access Journals.

TeMA

Journal of
Land Use, Mobility and Environment

Special Issue 3.2024

Living and walking in cities: new challenges for sustainable urban mobility

Published by
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"

TeMA is realized by CAB - Center for Libraries at "Federico II" University of Naples using Open Journal System

Editor-in-chief: Rocco Papa
print ISSN 1970-9889 | online ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

Editorial correspondence
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Building and Environmental Engineering
University of Naples "Federico II"
Piazzale Tecchio, 80
80125 Naples

web: www.serena.unina.it/index.php/tema
e-mail: redazione.tema@unina.it

Cover photo: Herrengasse street in Graz (Austria), baroque pedestrian avenue and centre of public life, provided by Michela Tiboni (June, 2024)

TeMA. Journal of Land Use, Mobility and Environment offers researches, applications and contributions with a unified approach to planning and mobility and publishes original inter-disciplinary papers on the interaction of transport, land use and environment. Domains include: engineering, planning, modeling, behavior, economics, geography, regional science, sociology, architecture and design, network science and complex systems.
With ANVUR resolution of April 2020, TeMA Journal and the articles published from 2016 are included in A category of scientific journals. The articles published on TeMA are included in main international scientific database as Scopus (from 2023), Web of Science (from 2015) and the *Directory of Open Access Journals* (DOAJ). TeMA Journal has also received the *Sparc Europe Seal* for Open Access Journals released by *Scholarly Publishing and Academic Resources Coalition* (SPARC Europe). TeMA is published under a Creative Commons Attribution 4.0 License and is blind peer reviewed at least by two referees selected among high-profile scientists. TeMA has been published since 2007 and is indexed in the main bibliographical databases and it is present in the catalogues of hundreds of academic and research libraries worldwide.

TeMA Journal of
Land Use, Mobility and Environment

Special Issue 3.2024

Living and walking in cities: new challenges for sustainable urban mobility

Contents

3 EDITORIAL PREFACE
Michela Tiboni, Martina Carra, Gerardo Carpentieri, Carmela Gargiulo, Giulio Maternini, Michele Pezzagno, Maurizio Tira

7 **Mobility, participation and sustainable regeneration. Urban projects in Liguria Region**
Ilenia Spadaro, Francesca Pirlone

23 **Urban and transport planning integration. A case study in a mid-size city in Italy**
Michelangelo Fusi, Michela Tiboni

43 **Methodologies for estimating emissions from road transport and comparison with the inventory air emissions (INEMAR). The case of Pavia Province**
Marilisa Moretti, Roberto De Lotto

53 **A smart and active mobility assessment protocol for urban regeneration. Application to regeneration projects of medium-sized cities in Emilia-Romagna**
Gloria Pellicelli, Silvia Rossetti, Michele Zazzi

67 **Assessment of urban green spaces proximity to develop the green infrastructure strategy. An Italian case study**
Monica Pantaloni, Francesco Botticini, Giovanni Marinelli

83 **Role of new technologies on pedestrian walking behaviour research**
Araf Öykü Türken, Elisa Conticelli

97 **Coastal roads atlas. Reshaping daily infrastructures for coastline adaptation**
Chiara Nifosì, Federico De Angelis, Rawad Choubassi, Andrea Gorrini, Federico Messa

113 **Evaluating active mobility: enhancing the framework for social sustainability**
Giuseppe Rainieri, Martina Carra, Anna Richiedei, Michele Pezzagno

129 **Redesigning "schools squares" for a public city**
Federica Bianchi, Rossella Moscarelli

149 **Towards more walkable streets. An assessment method applied to school areas in Parma**
Silvia Rossetti, Barbara Caselli, Vincenza Torrisi

159 **Permanently temporary. Street experiments in the Torino Mobility Lab project**
Luca Staricco, Ersilia Verlinghieri, Elisabetta Vitale Brovarone

169 **The exploration of tactical urbanism as a strategy for adapting to climate change. The "SpaziAttivi" program in the city of Brescia**
Stefania Boglietti, Michela Nota, Michela Tiboni

181 **Urban forms interpretation for the car-era spaces reuse. A comparison of walking, automobile, and sustainable cities**
Alessia Guaiani

197 **Capturing city-transport interactions. An analysis on the urban rail network of Palermo (Italy)**
Elif Sezer, João Igreja, Ignazio Vinci

215 **Assessing mobility in sustainable urban regeneration. The GBC Quartieri application to Le Albere neighbourhood in Trento**
Elena Mazzola, Alessandro Bove

TeMA

Journal of
Land Use, Mobility and Environment

TeMA Special Issue 3 (2024) 43-51
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6093/1970-9870/10932
Selection and double blind review under responsibility of "Living and Walking in Cities 2023" Conference Committee.

Methodologies for estimating emissions from road transport and comparison with the inventory air emissions (INEMAR). The case of Pavia Province

Marilisa Moretti [a*], Roberto De Lotto [b]

[a] Department of Civil Engineering and Architecture
University of Pavia, Pavia, Italy
e-mail: marilisa.moretti@unipv.it
ORCID: https://orcid.org/0009-0006-3370-0187
* Corresponding author

[b] Department of Civil Engineering and Architecture
University of Pavia, Pavia, Italy
e-mail: roberto.delotto@unipv.it
ORCID: https://orcid.org/0000-0002-0532-2506

Abstract

According to the actual portrait of emissions (Arpa Lombardia), it is necessary to improve the quality of life and the environment, minimizing emissions into the atmosphere from this sector, implementing specific actions by society and institutions. The population, the population density and the fragmentation of urban centres influence the demand for transport which consequently influences the quantity of emissions to which the populations are exposed. This study focuses on the area of the province of Pavia, one of the most inadequate provinces in terms of air quality in Lombardy Region comparing urban settlements, road system and emissions. Considering the 2019 emission picture from INEMAR (INventory AiR EMissions - Lombardy Region), road transport is responsible for about 13% and residential buildings for about 10 % of total CO_2 equivalent emissions in the province of Pavia. In the paper authors aim to evaluate the inter-scalar relation between Province scale and Municipality scale according to the following analysis: 1) Search regression equation between "settlements" and "pollution" 2) Search regression equation between "road soil occupancy" and "pollution". The emission data resulting from the INEMAR algorithms are compared with the land use's geographical data present on the open-source GIS cartography and on official data (ISTAT and Lombardy Region). The result should highlight in an "emission based" analysis of land use, the opportunities of integrated mobility new systems.

Keywords

Emissions; Inventory; Lombardy Region.

How to cite item in APA format

Moretti, M. & De Lotto, R. (2024). Methodologies for estimating emissions from road transport and comparison with the inventory Air Emissions (INEMAR). *TeMA - Journal of Land Use, Mobility and Environment*, (3), 43-51. http://dx.doi.org/10.6093/1970-9870/10932

1. Introduction

1.1 Study area: Pavia Province

Urban areas have developed over the time, driven by the economic success of cities (Beall & Fox, 2009). This development has led to phenomena such as increased land use and emissions from human activities, in particular production processes, residential combustion, and road transport (Droj et al., 2023; Lo & Quattrocchi, 2003). Urban areas today account for 75% of primary energy consumption and about 60% of carbon dioxide emissions: For this reason, it is increasingly important to develop sustainable intervention strategies to streamline the transport system and increase the energy efficiency of buildings that are affecting the environment (Maranzano, 2022). This study supports the implementation of quantitative analytical tools able to estimate the effects of road traffic and residential combustion in terms of emissions based on geographically detectable data. The Lombardy Region collects a large amount of geospatial data that can be processed through a geographic information software GIS such as, for example, the open-source Q-Gis.
The working assumption is that there is a relationship of close interdependence between land use and emission scenario (Babiy et al., 2003; Bashir et al., 2020; Heres et al., 2011; Hong & Shen, 2013; Janssen et al., 2008; Pezzagno & Rossini, 2015; Wen et al., 2022; Xu et al., 2016; Zimmerman et al., 2020; Zheng et al., 2017). This contribution aims to propose a method that allows to investigate the possible interrelationships between land use and human actions and their potential for CO_2eq emissions, identifying the factors that most influence these processes to outline possible intervention strategies in the perspective of mitigation of risks from climate change.
The study area is the province of Pavia, located in the Po Valley, it is one of the most disadvantaged areas in Europe from the point of view of air quality (Briganti, 2007) because of its geographical and physical characteristics: the closed geographical conformation, the poor ventilation of the area, the frequent thermal inversions and the modest mixing layer height increase the stagnation of pollutants and reduce their dispersion (Caserini et al., 2016; Quality report of the air of the province of Pavia, 2020).
The Pavia province population constitutes the 5% of the Lombard population; its 534,691 inhabitants are concentrated mostly in the cities of Pavia, Voghera and Vigevano (31% of the total). The average population density of the province of Pavia is about 184 inhabitants / sqkm and is lower than the regional average (422 inhabitants / sqkm) (ISTAT, 2022).
In this study the authors describe the state of the art of Pavia province and analyze 6 municipalities: Pavia, Vigevano and Voghera that are the 3 most populated and largest cities of the province and Belgioioso, Mede and Casteggio that are 3 municipalities characterized in having a population about 6,000 inhabitants and having a major road that cross the municipal area.

1.2 INEMAR Database

The inventories of the emissions evaluate the contribution of the various pollutants emitted from various sources and allow us to identify, for each source, the type of pollutant, the quantity emitted and the location. The Lombardy Region inventory of atmospheric emissions INEMAR of ARPA LOMBARDIA, is currently available for the year 2019. Consequently, all the data in this research is derived from this database (INEMAR, 2019). As regards point sources were used collections of already available data, such as emissions reported by companies subject to the IPPC Directive. For diffuse emissions it is not possible to obtain a direct measurement, and it is therefore necessary to estimate them starting from statistical data and appropriate emission factors according to the methodologies adopted at national (ENEA-ANPA) and international (Corinair) level (Corinair, 2019; INEMAR, 2019). In this study we consider the pollutant aggregate CO_2 equivalent since "CO_2eq" emissions represent total greenhouse gas emissions, weighted based on their contribution to the greenhouse effect. The estimated aggregate greenhouse gas emissions based on the following relation (1) (Emission factors INEMAR, 2019).

$$CO2eq. = \Sigma i\ GWPi\ x\ Ei \quad (1)$$

where:

- CO_2eq = CO_2 equivalent emissions in kt/year;
- GWPi = 'Global Warming Potential', coefficient IPCC equal to 1.000, 0.025 and 0.298 for CO_2, CH_4 and N_2O respectively;
- Ei = CO_2 emissions (in kt/year), CH_4 and N_2O (in t/year).

The Province of Pavia from 2003 (the year of which we have the first emission inventory of the Lombardy region) to 2010 saw a 30% increase in emissions from the road transport sector and subsequently saw a decrease of 23% from 2010 to 2019. INEMAR highlights that this gradual rehabilitation is a consequence of the adoption of new technologies and compliance with the regulatory provisions introduced at European and national level and the Regional Plan of interventions for air quality. Emissions from vehicular traffic decreased by an average of 19 % thanks to the renewal of the circulating fleet, also favored by the limitation of the circulation of older euro classes, and the introduction of efficient systems for dust suppression such as the particulate filter. The reduction of the sulphur content in fuels as well as the limitation of industrial emissions as part of the process of issuing Integrated Environmental Authorizations (IEA) have made a significant contribution and domestic heating has contributed to reducing harmful emissions thanks to the increased use of natural gas and energy saving interventions in buildings (Maris & Flouros, 2021).

The INEMAR database (AiR EMission INventory) contains all the data for emission estimates and execution procedures of the algorithms used for these estimates: activity indicators (e.g., fuel consumption, paint consumption, amount incinerated); emission factors; other statistical data necessary for the spatial and temporal distribution of emissions (Methodology INEMAR, 2019).

The emission factor represents the emission related to the activity unit of the source, expressed for example as the amount of pollutant emitted per unit of product processed, or as the amount of pollutant emitted per unit of fuel consumed, etc. Among the most comprehensive bibliographical sources for emission factors are reports by the US Environmental Protection Agency, and in the European context mention the emission factors collected in different versions of the EMEP/EEA Emission Inventory Guidebook, have the best features of completeness and reliability.

The objective of INEMAR's traffic module is to calculate road transport emissions from vehicle exhaust, brake, tyre and road surface wear, and fuel evaporation. The module consists of the calculation of linear traffic which is the one on large arteries and the calculation of diffuse traffic which is that in urban centers.

Linear emissions are emissions from traffic on the suburban and motorway road network and are estimated based on the number of vehicular passages on the different arcs of the network (or graph) evaluated by a traffic allocation model.

Diffuse emissions concern emissions in residential areas (for this reason also called 'urban traffic emissions'), and are estimated from fuel sales data, the composition of the registered fleet (ACI data) and the expected average annual vehicle journeys.

Emissions depend mainly on the fuel, the type of vehicle and its age, as well as driving conditions. The estimation of traffic emissions in Lombardy therefore considers the consistency of the circulating fleet and the average annual mileage of vehicles (Traffic INEMAR, 2019). In the Inemar system they are obviously considered average values for these data, but it should be remembered that a vehicle's emissions depend on its actual maintenance and running conditions. To calculate the amount of co2eq produced by a vehicle in a year, it is sufficient to multiply the distance travelled in km, by the emission factor in g/km of CO_2 of the vehicle as in the formula (2).

$$E = NxLxFE \tag{2}$$

where:

- E = emissions (t/year);
- L = average journey length per vehicle;
- N = number of circulating vehicles;
- FE = emission factor.

The objective of the heating module is to determine the energy needs for the heating of buildings for civil use and to derive the fuel consumption used for thermal needs.

The methodology included in the heating module provides an estimate of energy requirements (in GJ/year), fuel consumption (t/year) in each municipality or census section, category of year of construction, type of fuel used (methane, diesel, LPG, electricity, other, not defined, fuel oil, wood) (heating INEMAR,2019; Inventory INEMAR, 2019). For combustion processes fuel consumption is generally chosen as an activity indicator through the formula (3).

$$E = AxFEi \tag{3}$$

where:

- Ei = emission of the pollutant i (t/year);
- A = activity indicator;
- FEi = pollutant emission factor I.

2. Data and Methodology

2.1 A Multiple Regression Analysis Output

In this paper the authors have focused on the analysis of a static regression model (Berry et al., 1985; Ceylan et al., 2018; Del Giudice, 1995; Irwin, 2001; Negri, 2006; Nordio et al., 2013) between the emissions data resulting from INEMAR algorithms and the demographic and geographical data of ISTAT and derived from DBT files (Lombardy Region Geoportale). The aim is to find a relationship of dependence of emissions (dependent variable Y) on demographic and territorial factors (independent variables X) through the multiple regression model by which from several explanatory variables it is possible to make predictions on a dependent variable through a linear relation (4).

$$E = Y_{\mathrm{i}} = \beta_0 + \beta_1 X_{1\mathrm{i}} + \beta_2 X_{2\mathrm{i}} + \cdots + \beta_p X_{p\mathrm{i}} + \epsilon_{\mathrm{i}} \tag{4}$$

where:

- β_0 intercept;
- β_1 inclination of Y with respect to variable X_1 holding constant variable X_2;
- β_2 inclination of Y with respect to variable X_2 holding constant variable X_1.

The choice to use the regression method derive from a previous study that underline the total lack of correlation between land use and total emissions. The correlation was not only weak, but also negative, and this result was amazing (De Lotto et al., 2022).

2.2 Data and Results

The calculation of emissions is developed in terms of CO_2eq because, as anticipated, it represents the total emissions of greenhouse gases, weighed based on their contribution to the greenhouse effect.

For the first part of calculation the variables considered are:

- CO_2eq.tot (kt/year) = Road transport emissions of each individual municipality i as shown in Tab.1;
- Fe_vi = emission factor for each vehicle type (Emission Factor INEMAR, 2019) as shown in Tab.2;
- Car stock of each individual municipality i (Car stock ISTAT, 2022) as shown in Tab.3.

Municipality	CO_2 eq. (kt/year) from Road transport
Pavia	116.80215
Vigevano	74.07006
Voghera	84.21267
Belgioioso	10.95914
Mede	4.86254
Casteggio	21.57603

Tab.1 Road transport emissions

Vehicle type	Fe CO_2 eq. (g/km)
Car	Fec= 175 g/km
Bus	Feb= 780 g/km
Truck	Fet= 578 g/km
Motorcycles	Fem= 118 g/km

Tab.2 Emission factors

Municipality	Car (Nc)	Bus (Nb)	Truck (Nt)	Motorcycles (Nm)	Vehicle tot.(Nvtot)
Pavia	41,667	275	3,720	8,416	54,078
Vigevano	39,339	100	4,580	6,190	50,209
Voghera	25,565	44	3,106	3,810	32,525
Belgioso	3,759	11	449	503	4,722
Mede	4,354	2	475	526	5,357
Casteggio	4,745	3	892	829	6,469

Tab.3 Car Stock

Dividing the total emissions of CO_2eq. for the number of annual vehicles and their emission factors using the equation (5), the result is an average journey length that each vehicle completes daily in a municipality *i* as shown in Tab.4.

$$L\ vi = (CO2eq\ tot)/(\sum\_i\verb|^|n\ ⟦Fe\_vi\ xNix365⟧\ ) \tag{5}$$

Municipality	L vi	L tot. road lenght (GIS)	% Average journey lenght
Pavia	31.19689616	343.33	9.09%
Vigevano	20.18890757	434.55	4.65%
Voghera	35.0875296	306.23	11.46%
Belgioso	31.21621762	39.41	79.20%
Mede	12.38543464	58.09	21.32%
Casteggio	41.99894233	101.44	41.40%

Tab.4 Average journey length

The average distance of a vehicle in Lombardy is about 30.68 km, so we can consider reasonable the results obtained.

We apply the multiple regression method considering three independent variables (X_1, X_2, X_3) and the dependent variable (Y) where:

- Y_i=CO_2eq tot /year [kt] from the road transport sector of the municipality i;
- X_{1i}=Lvi [km] average daily travel of a vehicle in the municipality i;
- X_{2i}=annual car stock of the municipality i;
- X_{3i}=weighted average of emission factors per vehicle type [g/km] in the municipality.

Municipality	Y	X1	X2	X3
Pavia	116.80 x10⁹	31,2	19,738,470	0.2141
Vigevano	74.07x10⁹	20,27	18,326,285	0.2281
Voghera	84.21x10⁹	35,1	11,871,625	0.2141
Belgioioso	10.96 x10⁹	31,2	1,723,530	0.2281
Mede	4.86x10⁹	12,4	1,955,305	0.2141
Casteggio	21.58x10⁹	41,9	2,361,185	0.2281

Tab.5 Regression model data

The resulting estimated multiple regression model (6) is:

$$Y_i=-61.7574843892764 +0.669540303866588X1_i+7,157,022.21435762X2_i+0.018004428945236X3_i \quad (6)$$

The coefficients in a multiple regression model shall be considered as net regression coefficients. They measure the variation of the response variable Y at one of the explanatory variables when the others are constant.

For a common figure corresponding to an increase of 1 km of the Lvi, emissions would increase by 0.669 kt, for a given vehicle fleet and a given weighted average emission factor.

The coefficient of determination R^2=0.91 means that this relationship is valid for 91% of cases.

For the second part of calculation the variables considered are:

- CO_2eq tot (kt/year) = not industrial combustion emissions of each individual municipality i as shown in Tab.6;
- Gross Floor Area of the buildings for residence, education and health of each municipality, from DBT shapefile (CENED, 2022), as shown in Tab.7;
- Weighted average of the energy performance index = 270.8 kWh/year, calculated through the data on CENED (Energy certification buildings) Lombardy considering buildings with destinations E1 (buildings of all types used as residences and similar) E3 (hospital, clinic or nursing home buildings), E7 (school buildings at all levels and comparable) defined and classified according to D.P.R. 412/93 with energy classes A4 to G. as shown in Tab.8.

Municipality	CO_2 eq. (kt/year) from non-industrial combustion
Pavia	178.36811
Vigevano	122.16594
Voghera	91.95923
Belgioioso	8.96458
Mede	9.9736
Casteggio	12.43398

Tab.6 Not industrial combustion emissions

Municipality	GFA residence (sqm)	GFA health(sqm)	GFA education(sqm)	GFA Total.
Pavia	6,104,130.00	674,983.00	197,241.00	6,976,354.00
Vigevano	5,456,578.00	79,879.00	168,734.00	5,705,191.00
Voghera	3,993,296.00	123,873.00	131,293.00	4,248,462.00
Belgioioso	638,167.00	7,337.00	7,174.00	652,678.00
Mede	788,103.00	14,206.00	10,518.00	812,827.00
Casteggio	1,099,185.00	13,138.00	1,493.00	1,113,816.00

Tab.7 Gross Floor Area

Municipality	KW/smq year	E1 (n)	E3 (n)	E7 (n)
A4	40	1,258	2	4
A3	50	1,234	2	2
A2	70	1,464	7	6
A1	90	1,791	17	8
B	110	2,065	16	10
C	135	3,374	39	30
D	175	6,968	26	92
E	230	10,650	7	65
F	305	17,427	3	28
G	350	31,763	5	4

Tab.8 Energy performance index

We apply the multiple regression method considering one independent variables (X) and the dependent variable (Y) where:

- Y_i= $CO2eq_{tot}$ /year [kt] from the non-industrial combustion sector of the municipality i;
- X_{1i}= GFAi x Weighted average of the energy performance index (270.8 KWh/mq anno) x fuel emission factor (0.1998 kg CO_2eq /kWh) of the municipality i [kg].

Municipality	X	Y
Pavia	178.36811	377,461,493.3
Vigevano	122.16594	308,,684,151.4
Voghera	91.95923	229,866,605.2
Belgioioso	8.96458	35,313,691.44
Mede	9.9736	43,978,687.61
Casteggio	12.43398	60,263,950.29

Tab.9 Regression model data

The resulting estimated multiple regression model (7) is:

$$Y_i = Y_i = -12.9977226904399 + 0.47543265875447 X1_i \qquad (7)$$

The coefficients in a multiple regression model shall be considered as net regression coefficients. They measure the variation of the response variable Y at one of the explanatory variables when the others are constant. The coefficient of determination R^2=0.98 means that this relationship is valid for 98% of cases.

For a common data in correspondence of a decrease of 1 kg of CO_2eq produced by a building effect of a better energy performance and/or use of a renewable source, the emissions would decrease of 0.475 kt.

3. Conclusion and Discussion

In the paper authors developed a methodology that permits to calculate pollution emissions starting from what is freely available from the Lombardy Region portal.

The main reasons of this attempt lay on the extremely complicated methodology that INEMAR utilizes to calculate the comprehensive emissions of all human actions.

Surely the estimation developed by INEMAR is complete and precise even if it does not give any evidence of the geographical distribution of human activities that generate the emissions.

The recognition of certain parameters "BETA" in the linear formula allows to integrate classical urban planning analysis with the environmental ones. As it has been shown in the text, presented data are evaluated as average values in a specific territory.

According to the proposed estimation it is possible to measure the average pollution of a planned transformation basing on the basic data that usually compose the city plan (Zucaro & Morosini, 2018). Compared to the global emissions of a selected city, this estimation can furnish the impact of various urban modifications with the "zero scenario". Moreover, it is the basis to define mitigation and compensation actions to reduce greenhouse gas emissions (measured as equivalent CO_2).

Starting from previous studies, that demonstrated the lack of correlation among territorial data and emissions, with the new results it seems that this connection has been defined.

References

Babiy, A. P., Kharytonov, M. M. & Gritsan, N. P. (2003). Connection between emissions and concentrations of atmospheric pollutants. In *Air Pollution Processes in Regional Scale*, 11-19. Dordrecht: Springer Netherlands

Bashir, M. F., Jiang, B., Komal, B., Bashir, M. A., Farooq, T. H., Iqbal, N. & Bashir, M. (2020). Correlation between environmental pollution indicators and COVID-19 pandemic: a brief study in Californian context. *Environmental research*, *187*, 109652. https://doi.org/10.1016/j.envres.2020.109652

Beall, J. & Fox, S. (2009). *Cities and development*. London, New York: Routledge

Berry, W. D. & Feldman, S. (1985). *Multiple regression in practice*. Thousand Oaks: Sage

Ceylan, H., Baskan, O. & Ozan, C. (2018). Modeling and Forecasting Car Ownership Based on Socio-Economic and Demographic Indicators in Turkey. *TeMA - Journal of Land Use, Mobility and Environment,* 47-66. https://doi.org/10.6092/1970-9870/545

De Lotto, R., Moretti, M., Venco, E. M., Bellati, R., & Monastra, M. (2022). Lack of Correlation Between Land Use and Pollutant Emissions: The Case of Pavia Province. In *International Conference on Computational Science and Its Applications*, 109-124. Cham: Springer International Publishing.

Del Giudice, V. (1995). The analysis of multiple regression in the estimate for typical values in Ce.S.E.T. Evolutionary aspects of estimation science. In *Seminar in honor of Ernesto Marenghi* , 1-10. Firenze University Press

Droj, G., Droj, L., Badea, A. C. & Dragomir, P. I. (2023). GIS-Based Urban Traffic Assessment in a Historical European City under the Influence of Infrastructure Works and COVID-19. *Applied Sciences, 13* (3), 1355. https://doi.org/10.3390/app13031355

Heres-Del-Valle, D. & Niemeier, D. (2011). CO2 emissions: Are land-use changes enough for California to reduce VMT? Specification of a two-part model with instrumental variables. *Transportation Research Part B: Methodological, 45 (1)*, 150-161. https://doi.org/10.1016/j.trb.2010.04.001

Hong, J. & Shen, Q. (2013). Residential density and transportation emissions: Examining the connection by addressing spatial autocorrelation and self-selection. *Transportation Research Part D: Transport and Environment, 22,* 75-79. https://doi.org/10.1016/j.trd.2013.03.006

Irwin, J. R. & McClelland, G. H. (2001). Misleading heuristics and moderated multiple regression models. *Journal of Marketing Research, 38* (1). https://doi.org/10.1509/jmkr.38.1.100.18

Janssen, S., Dumont, G., Fierens, F. & Mensink, C. (2008). Spatial interpolation of air pollution measurements using CORINE land cover data. *Atmospheric Environment, 42* (20), 4884-4903. https://doi.org/10.1016/j.atmosenv.2008.02.043

Lo, C. P. & Quattrochi, D. A. (2003). Land-use and land-cover change, urban heat island phenomenon, and health implications. *Photogrammetric Engineering & Remote Sensing, 69* (9), 1053-1063. https://doi.org/10.14358/PERS.69.9.1053

Maranzano, P. (2022). Air quality in Lombardy, Italy: an overview of the environmental monitoring system of ARPA Lombardia. *Earth, 3* (1), 172-203. https://doi.org/10.3390/earth3010013

Maris, G. & Flouros, F. (2021). The green deal, national energy and climate plans in Europe: Member States' compliance and strategies. *Administrative Sciences, 11* (3), 75. https://doi.org/10.3390/admsci11030075

Negri I. (2006). Multiple regression. In *Probability and statistics for engineering and science* (pp. 420-433). McGraw Hill

Nordio, F., Kloog, I., Coull, B. A., Chudnovsky, A., Grillo, P., Bertazzi, P. A., Baccarelli, A. A. & Schwartz, J. (2013). Estimating spatio-temporal resolved PM10 aerosol mass concentrations using MODIS satellite data and land use regression over Lombardy, Italy. *Atmospheric environment, 74*, 227-236. https://doi.org/10.1016/j.atmosenv.2013.03.043

Pezzagno, M. & Rosini, M. (2015). The Padanian LiMeS. Spatial Interpretation of Local GHG Emission Data*. TeMA - Journal of Land Use, Mobility and Environment, 8* (1), 5-18. https://doi.org/10.6092/1970-9870/2877

Wen, Y., Wu, R., Zhou, Z., Zhang, S., Yang, S., Wallington, T. J., Shen, W., Tan, Q., Deng, Y. & Wu, Y. (2022). A data-driven method of traffic emissions mapping with land use random forest models. *Applied Energy*, 305, 117916. https://doi.org/10.1016/j.apenergy.2021.117916

Xu, G., Jiao, L., Zhao, S., Yuan, M., Li, X., Han, Y., Zhang, B. & Dong, T. (2016). Examining the impacts of land use on air quality from a spatio-temporal perspective in Wuhan, China. *Atmosphere, 7* (5), 62. https://doi.org/10.3390/atmos7050062

Zheng, S., Zhou, X., Singh, R. P., Wu, Y., Ye, Y., & Wu, C. (2017). The spatiotemporal distribution of air pollutants and their relationship with land-use patterns in Hangzhou city, China. *Atmosphere, 8* (6), 110. https://doi.org/10.3390/atmos8060110

Zimmerman, N., Li, H. Z., Ellis, A., Hauryliuk, A., Robinson, E. S., Gu, P., Shah, R.U., Ye, G. Q., Snell, L., Subramanian, R., Robinson, A.L., Apte, J.S. & Presto, A. A. (2020). Improving correlations between land use and air pollutant concentrations using wavelet analysis: insights from a low-cost sensor network. *Aerosol and Air Quality Research, 20* (2), 314-328. https://doi.org/10.4209/aaqr.2019.03.0124

Zucaro, F. & Morosini, R. (2018). Sustainable land use and climate adaptation: a review of European local plans. *TeMA - Journal of Land Use, Mobility and Environment, 11* (1), 7-26. https://doi.org/10.6092/1970-9870/5343

Author's profile

Marilisa Moretti

PhD Candidate. In December 2020 she graduated in Building Engineering-Architecture at the University of Pavia, with the thesis: "Description and quantitative interpretation of territorial sustainability: the DPSIR method for the Lombardy Region" Supervisor: Prof. R. De Lotto. Since March 2021 she has been working on "Soft mobility, reduction of the environmental impact and safety: studies and plans for the mobility of Pavia" dealing with the analysis of flows and critical issues relating to the issue of mobility in the City of Pavia, and in October 2021 she begins the PhD in "Design, Modeling and Simulation in Engineering", XXXIV cycle, at the Department of Civil Engineering and Architecture (DICAr) of Pavia University (Italy).

Roberto De Lotto

Associate Professor in Urban and Regional Planning at University of Pavia (Italy), Department of Civil Engineering and Architecture. He is the President of the Master Degree in "Building Engineering and Architecture" and in 2020 he won a Horizon2020 Grant for the project "RENergetic" - Project ID: 957845. He is Member of the Editorial Board of the "Journal of Urban Planning and Development" of the American Society of Civil Engineers (ASCE), ISI code: 04454J0.From 2015 to 2020 he was Municipality Council Member for City Planning, Municipality of Segrate (Milan, Italy). He has more than 150 scientific publications, Tutor in 6 PhD thesis, Tutor in 170 Master Degree Thesis.