

Development of Transportation Technology to Reduce Air Pollution: A Narrative Review

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Abstract

This narrative review aims to examine the impact of transportation technology on the reduction of air pollution. Airborne pollutants from transportation, including NO_x, CO, VOC, SO₂, and PM, have significant adverse effects on both human health and the environment. Drawing on findings from numerous studies and pollution dispersion models, specific interventions — such as the adoption of fleet public transportation, the construction of ring roads, regular vehicle maintenance, and the provision of essential roadway infrastructure — are projected to reduce transportation-related pollutant emissions by 13% by 2055. In this study, the databases utilized include ISI Web of Science, Scopus, PubMed Central (through PubMed), Science Direct, and Google Scholar. The article's search terms encompassed: "air pollution," "transportation," and "air pollutants." In addition, the integration of functional models, alongside national and international initiatives, is expected to reduce total emissions by 2035 to 30.2%, 24.3%, 18.8%, 5.3%, and 21.4% for NO_x, CO, VOC, SO₂, and PM, respectively. This review highlights the crucial role of transportation technologies, in tandem with individual efforts, in mitigating vehicular pollution, and emphasizes the importance of applying model outputs in achieving significant reductions in emissions.

Keywords: Air pollutants, air pollution, greenhouse gases, transportation

INTRODUCTION

Poor air quality represents one of the most critical global challenges, particularly concerning public health.^[1] According to the World Health Organization (WHO), one in eight deaths worldwide is linked to exposure to polluted air.^[2] The economic consequences of air pollution, both direct and indirect, are negatively significant affecting fertility, motivation, development, and overall workforce productivity and efficiency.^[3] In recent years, various nations have implemented strategic initiatives and research efforts to reduce exposure to air pollution, resulting in changes in individuals' behavior.^[4] However, despite these efforts, air pollution exposure in developing countries continues to have irreversible adverse effects on health and life expectancy, ultimately undermining the economic stability of families.^[5] Contrary to common misconceptions about the emission of pollutants such as PM_{2.5} and PM₁₀, ultrafine particles (UFPs), which are generated by various industrial activities, as well as other contaminants, originate from a range of sources, including

motor vehicles, aviation, rail transport, maritime activities, and port facilities.^[6] The small size of these particles gives them distinct characteristics and behaviors, setting them apart from larger particles.^[7] Empirical studies and surveys have shown a strong correlation between exposure to UFPs and the development of respiratory and cardiovascular disorders, posing a significant public health challenge.^[8] Monitoring assessments conducted near roads, highways, and freeways have recorded high concentrations of UFPs.^[9] The uneven and steep gradients in UFP concentration are due to their widespread distribution around thoroughfares, exacerbated by the

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increasing number of motor vehicles in urban areas, especially in city centers.^[10] Evidence suggests that urban neighborhoods with lower socioeconomic status (SES), along with households with lower income and educational attainment, face a range of challenges related to traffic-related air pollution (TRAP).^[11] Recent advancements in high-resolution mobile monitoring techniques and data-driven exposure assessments have enabled detailed investigations into the complex relationships between unregulated TRAP — such as UFPs and black carbon (BC) and their correlations with socioeconomic variables in urban environments.^[12] In Oakland, a study using mobile phone monitoring found that reducing air pollutant concentrations to the 25th percentile could significantly lower the risk of preeclampsia, especially among Black individuals, who are more vulnerable to complications from BC and nitrogen dioxide (NO₂) exposure.^[13] Recent research has shown that socioeconomic factors greatly influence the mobility and travel behaviors of families, as well as their access to transportation options, thereby affecting commuting distances.^[14] Recently, both national and international organizations addressing air pollution challenges have increasingly focused on improving the equity of extraurban and intraurban transportation systems.^[15] Local and regional bodies are working to reduce the unequal impacts of air pollution that disproportionately affect economically disadvantaged populations.^[16] This shift aims to apply the principles of environmental justice within the transportation sector, emphasizing considerations of mobility and accessibility.^[17]

Given the inadequacy of equitable transportation policies, often constrained by factors such as availability, residential location, and place of employment, it is crucial to implement targeted policies and interventions tailored to specific spatial contexts.^[18] A focused observational study found that children from lower SES backgrounds or those living in areas with higher migration potential faced higher levels of UFPs during their commutes to and from school.^[19] As a result, economically disadvantaged communities may be subjected to prolonged exposure to toxic air pollutants (TRAP), leading to increased health risks.^[20]

Air pollution is a major risk factor for cardiovascular diseases and lung cancer. The release of greenhouse gases (GHGs) from vehicular traffic in urban areas and along major roadways has become a critical concern, as traffic-related pollutant emissions are closely linked to the overall increase in mortality rates and lung cancer incidence.^[21] This harmful pollutant, which disperses in the atmosphere as aerosol particles, is primarily produced by the incomplete combustion of carbon-based fuels.^[19] Within the transportation sector, diesel engines are the primary source of BC emissions. The extent of GHG emissions from diesel engines depends on combustion efficiency, the type and quantity of fuel used, and the effectiveness of the exhaust system.^[22] Empirical studies conducted in various urban areas have shown a direct correlation between the environmental concentration of BC before emissions and the amount of BC released during vehicular activity.^[23] This indicates that the

frequency and concentration of particulate matter (PM) do not always reflect the variations in the impact of road traffic emissions on airborne PM.^[24] However, BC concentration is proportionally related to the levels of traffic-associated gaseous pollutants, including carbon monoxide (CO), NO₂, and nitrogen oxide (NO).^[25] Consequently, based on findings from multiple studies and literature reviews, BC is considered a key indicator for assessing changes in road traffic emissions due to its status as a primary pollutant directly emitted by motor vehicles.^[26] Given the relatively short atmospheric lifespan of BC particles, implementing straightforward strategies to reduce their emissions can lead to rapid improvements in air quality and serve as an effective approach to mitigate the adverse effects of particulate air pollution on public health.^[27] According to the WHO, many developing countries have exceeded standard air quality thresholds for suspended PM and gaseous pollutants.^[28] To reduce these pollutants and protect public health, particularly for vulnerable populations such as the elderly and children numerous air quality initiatives have been implemented, primarily targeting traffic-related emissions. Despite these efforts, high concentrations of suspended PM continue to be recorded in many countries.^[29] Programs and strategies designed to improve air quality place significant emphasis on regulating traffic dynamics and include various initiatives and policies such as promoting public transportation, implementing ring roads around urban areas, optimizing traffic flow in city centers, enforcing reduced speed limits on highways and freeways, and establishing Low Emission Zones LEZs.^[16] However, empirical evidence shows that these localized policies have had limited success in reducing air pollution and consequently improving public health.^[30] From a cost-effectiveness standpoint, it is essential to comprehensively evaluate and potentially revise these policies to determine their overall viability and worthiness.^[31] Panteliadis *et al.* (2014) found in their empirical study that there was a significant reduction in traffic-related pollutants, specifically BC concentrations, following the implementation of the LEZ initiative.^[32] Bogard *et al.* assessed meteorological conditions across various regions of the Netherlands and concluded that LEZ enforcement was insufficiently effective for outdated heavy-duty vehicles (trucks), resulting in no noticeable change in traffic-related pollutant levels, as older trucks represent only a small fraction of the overall transport fleet.^[33] Cyrus *et al.* (2014) documented a 10% reduction in PM₁₀ pollutant concentrations in Germany after the implementation of LEZs in the densely populated urban centers of Cologne, Berlin, and Munich.^[34] In addition, in Munich, Qadir *et al.* (2013) concluded that the introduction of the LEZ initiative effectively reduced the concentration of organic PM. Qadir *et al.* (2013) also reported a 60% decrease in the proportion of PM_{2.5} attributed to traffic sources following the LEZ implementation.^[35] In Chile, Gramesh *et al.* (2013) examined the effects of reconfiguring the public transportation system in Santiago de Chile on BC levels. This reconfiguration, which involved reducing the total number of buses and minimizing the convergence of bus routes, led to a

decrease in BC levels.^[15] Recently, many countries, inspired by the successful air quality management practices of others, have adopted similar strategies to reduce pollution from vehicular traffic. For example, in Ljubljana, Spain, a successful control intervention involved closing primary and central thoroughfares, allowing only public transport vehicles, such as buses and taxis, to access these areas.^[36] The aim of this study is to examine the critical role of using emerging technologies in the transportation sector to reduce exhaust emissions, along with the use of air pollution reduction models.

MATERIALS AND METHODS

A comprehensive review of the academic literature on technological advances in transportation aimed at reducing air pollution was conducted, with a particular emphasis on studies related to vehicular traffic. The research involved identifying published research articles that examined the reduction of air pollution in different modes of transportation (land, air, and sea) using a variety of technologies and methods over the period 2015–2024, based on the standard PRISMA model. Data were collected from multiple online academic sources, including databases such as ISI Web of Science, Scopus, PubMed Central, Science Direct, and Google Scholar. The search used specific keywords related to “air pollution,” “transport,” and “air pollutants.” Inclusion criteria required that studies had one or more of the keywords in the title and were published in English-language journals. Only studies that used transportation-related methods and technologies to reduce air pollution were considered suitable for extraction and further evaluation, and studies that examined the reduction of air pollutants in other organs and sectors were excluded from the search method. Ultimately, 19 articles were identified based on these criteria and selected for review.

RESULTS AND DISCUSSION

Transportation is crucial in modern society, acting as a driver of economic growth, social interaction, and cultural exchange. However, the release of pollutants poses significant environmental challenges, necessitating immediate and sustainable measures to balance societal development with ecological conservation.^[37] Emissions from various transportation modes including land, air, and rail contribute to atmospheric pollution, damage ecosystems, and negatively affect biodiversity. Therefore, there is an urgent need to adopt sustainable alternatives to mitigate these adverse effects.^[38] The rapid growth of urban populations and the increase in vehicular traffic in urban areas have led to the emission of a wide range of pollutants, including particulates, gases, and vapors, which adversely impact both the environment and human health.^[39] Recently, the WHO projected that elevated levels of urban air pollution (UAP) in industrializing nations are responsible for over 2 million deaths annually due to chronic respiratory illnesses. The road transport sector is a major contributor to UAP. Reports from international environmental protection organizations indicate that up to 70%–80% of atmospheric

pollution in major urban centers and developing countries is due to the high number of aged and used vehicles, compounded by poor vehicle maintenance, inadequate roadway infrastructure, and low-quality fuel.^[30] According to Moosmüller *et al.*, (2010), NO_x, sulfur dioxide (SO₂), CO, PM, and volatile organic compounds (VOCs) are the primary pollutants from vehicles that significantly degrade urban air quality.^[40] PM and VOCs are significant components of UAP. These pollutants, primarily originating from vehicular traffic and the wear of automotive tires and brakes, are major contributors to PM emissions in urban areas. The distribution of traffic-related pollutants is nonhomogeneous and asymmetric across urban landscapes, with varying levels and concentrations found in central business districts, intersections, and traffic junctions.^[34] In addition, distinct topographical and meteorological variations within urban environments create complex spatial and temporal fluctuations in pollutant concentrations.^[41] The scope of the Urban Air Quality Management Plan (UAQMP) encompasses macro (national), medium (city), and micro (site-specific) levels. The temporal framework of the UAQMP is based on either long-term or short-term National Ambient Air Quality Standards (NAAQSs).^[42] PM^[43] and VOCs are significant components of UAP. These pollutants, which primarily originate from vehicular traffic and the wear of automotive tires and brakes, are major contributors to PM emissions in metropolitan areas. The distribution of traffic-related pollutants is uneven and asymmetric across urban landscapes, with varying levels and concentrations observed in central business districts, intersections, and traffic junctions. In addition, topographical and meteorological variations within urban environments result in complex spatial and temporal fluctuations in pollutant concentrations. The UAQMP covers a range of scales, from macro (national) to medium (city) and micro (site-specific) levels. The temporal framework of the UAQMP is based on both long-term and short-term NAAQS.^[37] Recognizing the intrinsic link between mobility and varying levels of CO₂ emissions, numerous international organizations have suggested that modifying individual movement patterns could reduce airborne pollutant concentrations and improve overall quality of life. This transformation is crucial for ensuring the welfare and security of individuals.^[43] Research indicates that in countries heavily dependent on tourism for their economic stability, UAP has made major cities less attractive to visitors. It is also possible that, in the near future, tourism may shift toward less densely populated and less polluted areas, except in essential circumstances.^[44] In many societies, due to sociocultural and economic disparities, daily commuting behaviors in low- and middle-income countries heavily rely on motorized transportation. A significant portion of the population shows reluctance to change their travel habits and prefers not to use public transit for their journeys.^[45] From an alternative perspective, empirical research suggests that achieving effective results from climate change mitigation initiatives goes beyond mere awareness; it requires a significant level of public will. This is because reducing BC emissions from automotive sources necessitates substantial changes

in individual behavior.^[24] Nearly all sources emphasize that transforming the transportation paradigm and habitual movement patterns is crucial for advancing environmental sustainability and enhancing energy efficiency. For example, in recent years, the aggregate energy consumption of the road transport fleet has increased from 23% to 29%, thereby exacerbating the burden of air pollution.^[46] Evidence indicates that reducing unnecessary trips by private vehicles and increasing the use of public transportation systems can lead to positive outcomes. Empirical evidence highlights that understanding the societal impacts of pollution from vehicular at neighborhood, municipal, and national levels is crucial for engaging the public and improving outcomes.^[24] Wise *et al.* (2020) found that successful efforts to reduce traffic-related pollution require motivation, individual awareness, and various attitudinal factors. While some studies emphasize reducing essential trips to lower road pollution, other literature suggests increasing the frequency of daily trips to raise public awareness.^[47] Recently, technological advancements in the aviation sector have led to a significant increase in transportation volume and air travel experiences, which have risen markedly since 1980. The aviation industry has created approximately 19.6 million direct and indirect jobs related to tourism. Overall, the aviation sector supports about 45 million jobs and contributes approximately \$1 trillion to the global Gross Domestic Product.^[9]

As the aviation fleet expands, its impact on ecological and environmental conditions becomes a critical global concern. Many scholarly investigations use CO₂ gas concentration as a measure of environmental quality.^[19] According to annual reports by the International Energy Agency, the transportation sector accounts for 24.6% of global carbon emissions, with 80% of these emissions occurring since the 1990s.^[48] Among transportation modes, the aviation sector, following road transportation, contributes the largest share of pollutant emissions compared to other modes. The aviation sector is responsible for 2.4% of global CO₂ emissions from fossil fuels, making CO₂ the primary GHG emitted by aeronautical activities. In 2018, approximately 920 million metric tons of CO₂ were emitted by the global aviation fleet, mainly for commercial purposes.^[49] Researchers project that GHG emissions from the aviation sector will increase by 32% from 2006 to 2050. In addition, the environmental impact of aviation-related GHG emissions is more severe than that of other transportation sectors, as these gases significantly affect atmospheric conditions at high altitudes.^[50]

Modeling

Various methodologies are employed to assess GHG emissions from the transportation fleet. The International Vehicle Emission Model is a structured framework designed to quantify pollutants originating from motor vehicles.^[51] Its primary objective is to estimate pollutant emissions across diverse urban environments, assist in the planning and implementation of control strategies, and formulate effective transportation plans.^[42] In addition, it evaluates the impact of various control strategies on emissions

and monitors progress in mitigating air pollutants over time. This model is specifically used for quantifying air pollutants, GHG concentrations, and hazardous pollutants.^[52] The Motor Vehicle Emissions Simulator (MOVES), developed by the United States Environmental Protection Agency, is another systematic model used to quantify emissions of air pollutants, GHGs, and air toxics from operational moving sources. MOVES investigates pollutant emissions across various scales and assesses strategies for managing air quality, focusing on emissions from vehicles such as cars, trucks, buses, and motorcycles.^[48] Air dispersion models represent another category used to estimate road pollutant emissions. These models determine the concentration or deposition of pollutants emitted from industrial processes (point sources) or roadways (line sources). The results from these models help evaluate the impact of both new and existing pollutants in specific areas, facilitating comparisons of concentrations and deposits against environmental thresholds and air quality standards. In addition, dispersion models are applicable at both short-range (<20 km) and long-range (regional/transboundary >50 km) scales.^[2]

Vegetation impact dynamics assessment model

The vegetation impact dynamics assessment (VIDA) model is specifically designed to quantify the transport-induced air pollution through deposition on vegetation. The VIDA model is an advanced representation of vegetation that can be integrated into future urban air quality dispersion models. In addition, the model serves as a valuable tool for exploring the complex interactions between the processes of deposition, resuspension, and leaching, as well as understanding how meteorological conditions and leaf characteristics affect these processes. The current version of the model focuses on PM and includes a wide range of processes, including deposition on vegetation surfaces, encapsulation in the waxy cuticle, wind-driven resuspension, and leaching. In addition, the model considers dynamic changes in PM particle concentrations at the leaf surface over time, incorporating factors such as the interactions of particle size, meteorological conditions, and leaf characteristics. This comprehensive approach allows for the assessment of different species or groups of species based on their distinctive traits. The VIDA model effectively reproduces measured data, however, ongoing evaluation remains critical as new data emerge. Notably, challenges were encountered due to data scarcity and the lack of standardized methods or characterization of vegetation characteristics. Addressing these challenges and representing the leaching process would enhance the utility of the VIDA model in predicting the dynamic relationship between vegetation and air quality. Introduction VIDA provides a significant advance in modeling the removal of air pollution from transport by deposition.^[52]

CONCLUSION

In light of the growing evidence of the detrimental effects of fossil fuels on the environment and human health, it is essential to develop strategies for transitioning from fossil fuels to cleaner, more sustainable energy sources. Advances in modern

technologies have facilitated the adoption of alternative fuels, such as hydrogen fuel cells and electric vehicles, progressively replacing outdated and polluting vehicles. To achieve significant reductions in pollutants from road transportation, integrating environmentally friendly fuels is a critical strategic initiative. A key objective for environmental and health-focused agencies, as well as international organizations committed to combating air pollution, is to devise strategies that mitigate transportation's adverse impacts. This includes transitioning to intelligent transportation systems, utilizing clean fuels, and reforming infrastructure. In addition, expanding and promoting public transport fleets and ensuring proper vehicle maintenance and repairs are vital components of these strategies.

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Ethical considerations

This is a review article without human or animal participants.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Mason TG, Schooling CM, Chan KP, Tian L. An evaluation of the air quality health index program on respiratory diseases in Hong Kong: An interrupted time series analysis. *Atmos Environ* 2019;211:151-8.
- Obanya HE, Amaeze NH, Togunde O, Otitolaju AA. Air pollution monitoring around residential and transportation sector locations in Lagos Mainland. *J Health Pollut* 2018;8:180903.
- Sueyoshi T, Yuan Y. China's regional sustainability and diversified resource allocation: DEA environmental assessment on economic development and air pollution. *Energy Econ* 2015;49:239-56.
- Landrigan PJ, Fuller R, Acosta NJ, Adeyi O, Arnold R, Basu NN, *et al.* The Lancet Commission on pollution and health. *Lancet* 2018;391:462-512.
- Bueckers J, Stassen K, Panis LI, Hendrickx K, Torfs R. Ten years of research and policy on particulate matter air pollution in hot spot Flanders. *Environ Sci Policy* 2011;14:347-55.
- Wang J, Lin B. The dilemma between economic development and environmental protection: How political leadership turnover influences urban air pollution in China? *Environ Dev Sustain* 2023;134:1-19.
- Luo W, Deng Z, Zhong S, Deng M. Trends, issues and future directions of urban health impact assessment research: A systematic review and bibliometric analysis. *Int J Environ Res Public Health* 2022;19:5957.
- Mazuryk O, Stochel G, Brindell M. Variations in Reactive Oxygen Species Generation by Urban Airborne Particulate Matter in Lung Epithelial Cells-Impact of Inorganic Fraction. *Front Chem* 2020;8:581752.
- Doğan Güzel T, Alp K. The effects of technological developments in transportation vehicles on air pollution mitigation of metropolitan cities: A case study of Istanbul. *Sci Total Environ* 2024;912:168996.
- Babae S, Nagpure AS, DeCarolis JF. How much do electric drive vehicles matter to future U.S. emissions? *Environ Sci Technol* 2014;48:1382-90.
- Amann M, Kiesewetter G, Schöpp W, Klimont Z, Winiwarter W, Cofala J, *et al.* Reducing global air pollution: The scope for further policy interventions. *Philos Trans A Math Phys Eng Sci* 2020;378:20190331.
- Driscoll CT, Buonocore JJ, Levy JI, Lambert KF, Burtraw D, Reid SB, *et al.* US power plant carbon standards and clean air and health co-benefits. *Nat Clim Chang* 2015;5:535-40.
- Roy S, Lam YF, Chan JC, Hung NT, Fu JS. Evaluation of Vietnam air emissions and the impacts of revised power development plan (PDP7 rev) on spatial changes in the thermal power sector. *Atmos Pollut Res* 2022;13:101454.
- Liu J, Mauzerall DL, Chen Q, Zhang Q, Song Y, Peng W, *et al.* Air pollutant emissions from Chinese households: A major and underappreciated ambient pollution source. *Proc Natl Acad Sci U S A* 2016;113:7756-61.
- Gramsch E, Le Nir G, Araya M, Rubio MA, Moreno F, Oyola P. Influence of large changes in public transportation (Transantiago) on the black carbon pollution near streets. *Atmos Environ* 2013;65:153-63.
- Kirchstetter TW, Novakov T, Hobbs PV. Evidence that the spectral dependence of light absorption by aerosols is affected by organic carbon. *J Geophys Res Atmos* 2004;109: 5803-16.
- Czermański E, Cirella GT, Oniszczuk-Jastrzabek A, Pawłowska B, Notteboom T. An energy consumption approach to estimate air emission reductions in container shipping. *Energies* 2021;14:278.
- Baldasano JM, Gonçalves M, Soret A, Jiménez-Guerrero P. Air pollution impacts of speed limitation measures in large cities: The need for improving traffic data in a metropolitan area. *Atmos Environ* 2010;44:2997-3006.
- Castells-Quintana D, Dienesch E, Krause M. Air pollution in an urban world: A global view on density, cities and emissions. *Ecol Econ* 2021;189:107153.
- Calderón-Garcidueñas L, Kulesza RJ, Doty RL, D'Angiulli A, Torres-Jardón R. Megacities air pollution problems: Mexico city Metropolitan Area critical issues on the central nervous system pediatric impact. *Environ Res* 2015;137:157-69.
- Rajagopalan S, Al-Kindi SG, Brook RD. Air pollution and cardiovascular disease: JACC state-of-the-art review. *J Am Coll Cardiol* 2018;72:2054-70.
- Du H, Li Q, Liu X, Peng B, Southworth F. Costs and potentials of reducing CO₂ emissions in China's transport sector: Findings from an energy system analysis. *Energy* 2021;234:121163.
- Duan L, Hu W, Deng D, Fang W, Xiong M, Lu P, *et al.* Impacts of reducing air pollutants and CO (2) emissions in urban road transport through 2035 in Chongqing, China. *Environ Sci Ecotechnol* 2021;8:100125.
- Jacobson MZ. Control of fossil-fuel particulate black carbon and organic matter, possibly the most effective method of slowing global warming. *J Geophys Res Atmos* 2002;107:ACH 16-1-ACH-22.
- Mardones C, Cabello M. Effectiveness of local air pollution and GHG taxes: The case of Chilean industrial sources. *Energy Econ* 2019;83:491-500.
- Andrés L, Padilla E. Driving factors of GHG emissions in the EU transport activity. *Transp Policy* 2018;61:60-74.
- Marcy C, Sanchez B. Power Sector Carbon Dioxide Emissions Fall Below Transportation Sector Emissions. Washington, DC: Energy Information Administration; 2017.
- Organization WH. WHO Study Group On Tobacco Product Regulation. Report on the Scientific Basis Of Tobacco Product Regulation: Ninth Report of a WHO Study Group (WHO Technical Report Series, No. 1047); 2023.
- Chen Z, Wang JN, Ma GX, Zhang YS. China tackles the health effects of air pollution. *Lancet* 2013;382:1959-60.
- Satterthwaite D. The impact on health of urban environments. *Environ Urban* 1993;5:87-111.
- Chen J, Huang S, Shen Z, Song M, Zhu Z. Impact of sulfur dioxide emissions trading pilot scheme on pollution emissions intensity: A study based on the synthetic control method. *Energy Policy* 2022;161:112730.
- Panteliadis P, Strak M, Hoek G, Weijers E, van der Zee S, Dijkema M. Implementation of a low emission zone and evaluation of effects on air quality by long-term monitoring. *Atmos Environ* 2014;86:113-9.
- Boogaard H, Janssen NA, Fischer PH, Kos GP, Weijers EP, Cassee FR, *et al.* Impact of low emission zones and local traffic policies on ambient

- air pollution concentrations. *Sci Total Environ* 2012;435-436:132-40.
34. Cyrus J, Peters A, Soentgen J, Wichmann HE. Low emission zones reduce PM10 mass concentrations and diesel soot in German cities. *J Air Waste Manag Assoc* 2014;64:481-7.
 35. Qadir RM, Abbaszade G, Schnelle-Kreis J, Chow JC, Zimmermann R. Concentrations and source contributions of particulate organic matter before and after implementation of a low emission zone in Munich, Germany. *Environ Pollut* 2013;175:158-67.
 36. Pelko N. Public Transport in the Ljubljana Urban Region: Regional Development Agency of the Ljubljana Urban Region (RRA LUR); 2010.
 37. Navarro O. Social inequality and environmental risk perception. In: *Handbook of Environmental Psychology and Quality of Life Research*. Springer;2017;625:503-18.
 38. Alonso F, Esteban C, Faus M, Useche SA. Sustainable behavior begins with sustainable attitudes: Data to assess the relationships between demographics, concerns about transport-related pollution, and willingness for action. *Data Brief* 2024;54:110446.
 39. Anser MK, Yousaf Z, Nassani AA, Abro MMQ, Zaman K. The role of carbon pricing in the relationship between air freight and environmental resource depletion: A case study of Saudi Arabia. *Clean Technol Environ Policy* 2020. p. 1-12.
 40. Moosmüller H, Chakrabarty R, Arnott W. Aerosol light absorption and its measurement: A review. *J Quant Spectrosc Radiat Transf* 2009;110:844-78.
 41. Alonso F, Faus M, Tormo MT, Useche SA. Could technology and intelligent transport systems help improve mobility in an emerging country? Challenges, opportunities, gaps and other evidence from the Caribbean. *Appl Sci* 2022;12:4759.
 42. Forsberg J, Krook-Riekkola A. Recoupling climate change and air quality: Exploring low-emission options in urban transportation using the times-city model. *Energies* 2021;14:3220.
 43. Lu I, Lewis C, Lin SJ. The forecast of motor vehicle, energy demand and CO2 emission from Taiwan's road transportation sector. *Energy Policy* 2009;37:2952-61.
 44. Shafique M, Azam A, Rafiq M, Luo X. Investigating the nexus among transport, economic growth and environmental degradation: Evidence from panel ARDL approach. *Transp Policy* 2021;109:61-71.
 45. Zaman K, Shamsuddin S. Green logistics and national scale economic indicators: Evidence from a panel of selected European countries. *J Clean Prod* 2017;143:51-63.
 46. Hu H, Zhang Y, Rao X, Jin Y. Impact of technology innovation on air quality-an empirical study on new energy vehicles in China. *Int J Environ Res Public Health* 2021;18:4025.
 47. Wise T, Zbozinek TD, Michelini G, Hagan CC, Mobbs D. Changes in risk perception and self-reported protective behaviour during the first week of the COVID-19 pandemic in the United States. *R Soc Open Sci* 2020;7:200742.
 48. Wang Z, Wu G, Scora G. MOVESTAR: An open-source vehicle fuel and emission model based on USEPA MOVES. *Electrical Engineering and Systems Science* 2008;04986.
 49. Saleem H, Jiandong W, Zaman K, Elashkar EE, Shoukry AM. The impact of air-railways transportation, energy demand, bilateral aid flows, and population density on environmental degradation: Evidence from a panel of next-11 countries. *Transp Res Part D Transp Environ* 2018;62:152-68.
 50. Anser MK, Yousaf Z, Hishan SS, Nassani AA, Sheikh AZ, Vo XV, *et al.* Dynamic linkages between transportation, waste management, and carbon pricing: Evidence from the Arab World. *J Clean Prod* 2020;269:122151.
 51. Viteri R, Borge R, Paredes M, Pérez MA. A high resolution vehicular emissions inventory for Ecuador using the IVE modelling system. *Chemosphere* 2023;315:137634.
 52. Wallace LA, Wheeler AJ, Kearney J, Van Ryswyk K, You H, Kulka RH, *et al.* Validation of continuous particle monitors for personal, indoor, and outdoor exposures. *J Expo Sci Environ Epidemiol* 2011;21:49-64.