Environment International 172 (2023) 107805

Contents lists available at ScienceDirect

Environment International

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

Systematic Evidence Map

Urban policy interventions to reduce traffic-related emissions and air pollution: A systematic evidence map

Haneen Khreis [a,*], Kristen A. Sanchez [b,c], Margaret Foster [d], Jacob Burns [e], Mark J. Nieuwenhuijsen [f,g,h], Rohit Jaikumar [b], Tara Ramani [b], Josias Zietsman [b]

[a] MRC Epidemiology Unit, School of Clinical Medicine, University of Cambridge, Box 285 Institute of Metabolic Science, Cambridge Biomedical Campus, Cambridge CB2 0QQ, United Kingdom
[b] Center for Advancing Research in Transportation Emissions, Energy, and Health (CARTEEH), Texas A&M Transportation Institute (TTI), TX, USA
[c] Texas A&M School of Public Health, TX, USA
[d] Texas A&M University, Center for Systematic Reviews and Research Syntheses, College Station, TX, USA
[e] Institute for Medical Information Processing, Biometry and Epidemiology, Ludwig Maximilian University of Munich, Munich, Germany
[f] Barcelona Institute for Global Health (ISGlobal), Barcelona, Spain
[g] Universitat Pompeu Fabra (UPF), Barcelona, Spain
[h] CIBER Epidemiologia y Salud Publica (CIBERESP), Madrid, Spain

ARTICLE INFO

Handling Editor: Paul Whaley

Keywords:
Urban
City
Policy
Intervention
Emissions
Traffic-related air pollution
Exposure
Health
Climate
Co-Benefits

ABSTRACT

Background: Urban areas are hot spots for human exposure to air pollution, which originates in large part from traffic. As the urban population continues to grow, a greater number of people risk exposure to traffic-related air pollution (TRAP) and its adverse, costly health effects. In many cities, there is a need and scope for air quality improvements through targeted policy interventions, which continue to grow including rapidly changing technologies.
Objective: This systematic evidence map (SEM) examines and characterizes peer-reviewed evidence on urban-level policy interventions aimed at reducing traffic emissions and/or TRAP from on-road mobile sources, thus potentially reducing human exposures and adverse health effects and producing various co-benefits.
Methods: This SEM follows a previously peer-reviewed and published protocol with minor deviations, explicitly outlined here. Articles indexed in Public Affairs Index, TRID, Medline and Embase were searched, limited to English, published between January 1, 2000, and June 1, 2020. Covidence was used to screen articles based on previously developed eligibility criteria. Data for included articles was extracted and manually documented into an Excel database. Data visualizations were created in Tableau.
Results: We identified 7528 unique articles from database searches and included 376 unique articles in the final SEM. There were 58 unique policy interventions, and a total of 1,139 unique policy scenarios, comprising these

Abbreviations: **BC**, Black carbon; **BS**, Black smoke; **CAC**, Catalytic converter; **CARTEEH**, Center for Advancing Research in Transportation Emissions, Energy and Health; **CO**, Carbon monoxide; **DALY**, Disability-adjusted life year; **DOC**, Diesel oxidation catalyst; **DPF**, Diesel particulate filter; **EC**, Elemental carbon; **EGR**, Exhaust gas recirculation; **EV**, Electric vehicle; **GHG**, Greenhouse gas; **HC**, Hydrocarbon; **HEV**, Hybrid electric vehicle; **KonSULT**, Knowledgebase on Sustainable Urban Land use and Transport; **LEZ**, Low emission zone; **MFR**, Maximum Feasible Reductions; **NAAQS**, National Ambient Air Quality Standards; **MOVES**, MOtor Vehicle Emission Simulator; **MPO**, Metropolitan Planning Organization; **NH_3**, Ammonia; **NO**N, itric oxide; **NO_2**, Nitrogen dioxide; **NO_x**, Nitrogen oxides; **OC**, Organic carbon; **OECD**, Organization for Economic Co-Operation and Development; **PICO**, Population, Intervention, Comparator, Outcome; **PM**, Particulate matter; **PM_1**, Particulate matter with an aerodynamic diameter equal to or less than 1 µm; **$PM_{2.5}$**, Particulate matter with an aerodynamic diameter equal to or less than 2.5 µm; **PM_{10}**, Particulate matter with an aerodynamic diameter equal to or less than 10 µm; **$PM_{absorbance}$**, Blackness of PM filters as a representation of BC or EC; **PM_{coarse}**, Difference between PM_{10} and $PM_{2.5}$; **PM_x**, Particulate matter with diameters of mixed sizes; **PPM**, Parts per million; **PRISMA**, Preferred Reporting Items for Systematic Review and Meta-analysis; **ROG**, Reactive organic gasses; **RSPM**, Respirable suspended particulate matter; **SEM**, Systematic evidence map; **SO_2**, Sulfur dioxide; **SO_X**, Sulfur oxides; **SOA**, Secondary organic aerosols; **SPM**, Suspended particulate matter; **TC**, Total carbon; **TOG**, Total organic gasses; **TRAP**, Traffic-related air pollution; **TRID**, Transportation Research International Documentation; **UFP**, Ultrafine particle; **VOC**, Volatile organic compound; **WHO**, World Health Organization.

* Corresponding author.
E-mail addresses: hrk38@medschl.cam.ac.uk (H. Khreis), kris10sanchez19@gmail.com (K.A. Sanchez), margaretfoster@tamu.edu (M. Foster), burns@ibe.med.uni-muenchen.de (J. Burns), mark.nieuwenhuijsen@isglobal.org (M.J. Nieuwenhuijsen), R-Jaikumar@tti.tamu.edu (R. Jaikumar), t-ramani@tti.tamu.edu (T. Ramani), j-zietsman@tti.tamu.edu (J. Zietsman).

https://doi.org/10.1016/j.envint.2023.107805
Received 1 August 2022; Received in revised form 3 February 2023; Accepted 4 February 2023
Available online 7 February 2023

interventions and different combinations thereof. The policy interventions fell under 6 overarching policy categories: 1) pricing, 2) land use, 3) infrastructure, 4) behavioral, 5) technology, and 6) management, standards, and services, with the latter being the most studied. For geographic location, 463 policy scenarios were studied in Europe, followed by 355 in Asia, 206 in North America, 57 in South America, 10 in Africa, and 7 in Australia. Alternative fuel technology was the most frequently studied intervention (271 times), followed by vehicle emission regulation (134 times). The least frequently studied interventions were vehicle ownership taxes, and studded tire regulations, studied once each. A mere 3 % of studies addressed all elements of the full-chain—-traffic emissions, TRAP, exposures, and health. The evidence recorded for each unique policy scenario is hosted in an open-access, query-able Excel database, and a complementary interactive visualization tool. We showcase how users can find more about the effectiveness of the 1,139 included policy scenarios in reducing, increasing, having mixed or no effect on traffic emissions and/or TRAP.

Conclusion: This is the first peer-reviewed SEM to compile international evidence on urban-level policy interventions to reduce traffic emissions and/or TRAP in the context of human exposure and health effects. We also documented reported enablers, barriers, and co-benefits. The open-access Excel database and interactive visualization tool can be valuable resources for practitioners, policymakers, and researchers. Future updates to this work are recommended.

Protocol Registration: Sanchez, K.A., Foster, M., Nieuwenhuijsen, M.J., May, A.D., Ramani, T., Zietsman, J. and Khreis, H., 2020. Urban policy interventions to reduce traffic emissions and traffic-related air pollution: Protocol for a systematic evidence map. Environment international, 142, p.105826.

1. Introduction and rationale

Road traffic is one of the main contributors to air pollution and greenhouse gasses around the world (Guarnieri and Balmes, 2014; McDuffie et al., 2020; McDuffie et al., 2021) and significantly contributes to particulate matter (PM) and nitrogen oxides (NO_x) emissions (European Environment Agency, 2016). In cities worldwide, traffic contributes from 5 % to 61 % of PM, with an average of 27 % (Heydari et al., 2020). In Europe, urban traffic contributes up to 56 % of ambient nitrogen dioxide (NO_2) and approximately 39 % of particulate matter with an aerodynamic diameter equal to or less than 10 μm (PM_{10}) concentrations (Sundvor et al., 2012). For particulate matter with an aerodynamic diameter equal to or less than 2.5 μm ($PM_{2.5}$), urban traffic contributes to 24 % in the USA, 30–34 % in South America and 17 % in Africa, for example (Karagulian et al., 2015). There are broadly two types of traffic emissions: exhaust and non-exhaust. Exhaust emissions result from incomplete fuel combustion, whereas non-exhaust emissions are a result of brake wear, engine wear, tire wear, road surface wear, evaporative emissions, and re-suspended crystal and street dust materials (Frosina et al., 2018; Rubin et al., 2006; Thorpe and Harrison, 2008). For PM, the non-exhaust component is significant and increasing. For example, in the Ruhr area of Germany, exhaust, abrasion, and resuspension (non-exhaust) emissions respectively contribute to 22 %, 22 % and 56 % of PM_{10} levels at an urban background location, and 27 %, 15 %, and 58 % at a streetside location (Weinbruch et al., 2014).

Traffic emissions disperse into the ambient air as traffic-related air pollution (TRAP), which degrades ambient air quality. Humans exposed to TRAP are at a higher risk of developing a wide range of adverse health effects, including, premature mortality, lung cancer, adverse respiratory effects, cardiovascular effects, cerebrovascular effects, reproductive and pregnancy effects, neurological and cognitive effects, metabolic, and bone effects (Khreis, 2020; Health Effects Institute, 2022). There is also an immense financial burden of TRAP which includes the cost of hospitalizations, medical visits, medication, missed school days, loss of earnings from missed workdays, and/or death (Brandt et al., 2014, 2012; Nurmagambetov et al., 2018; Roy et al., 2011). After the Global Burden of Disease Study (2015), the OECD carried out a follow-up study in 2017 that drew on the epidemiological evidence gathered from that study to examine the mortality rates caused by ambient air pollution (AAP) – ambient particulate matter pollution (APMP) – and ambient ozone pollution (AOP) in 41 countries from 2000 to 2015 (Roy and Braathen, 2017). According to the study, in 2015, ambient air pollution (APMP + AOP) cost OECD nations $1.89 trillion, the BRIICS (Brazil, Russia, India, Indonesia, China, and South Africa) $3.18 trillion, and these 41 countries together $5.06 trillion (Roy and Braathen, 2017).

Urban areas are hotspots for human exposure to air pollution originating from road traffic (Kura et al., 2013), and these areas are growing rapidly. Approximately two-thirds of the global population is estimated to reside in urban areas by 2050 (United Nations and Department of Economic and Social Affairs Population Division, 2015). Rapid urban growth and an increasing number of urban residents indicate that a greater quantity of people will be at risk of TRAP exposure. Unfortunately, many cities around the world struggle to meet air quality standards and guidelines despite growing evidence linking traffic, air pollution, exposure, and adverse health effects (World Health Organization, 2014). The World Health Organization (WHO) estimates that merely one in ten people around the globe lives in a city that meets the 2015 WHO air quality guidelines for $PM_{2.5}$ (World Health Organization, 2021). In the United States, many areas exceed National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ (12 μg/m^3 annual mean) and 8-hour ozone (0.070 parts per million) (U.S. Environmental Protection Agency, 2019; United States Environmental Protection Agency, 2016). In 2012, over 20 million people lived in areas failing to meet the $PM_{2.5}$ NAAQS (United States Environmental Protection Agency, 2020a), and in 2015, over 122 million people lived in areas failing to meet the 8-hour ozone NAAQS (United States Environmental Protection Agency, 2020b). In Europe in 2010, 41 % and 7 % of the urban population lived in areas exceeding European Union air quality standards for PM_{10} 24-hour limit value (50 μg/m^3) and NO_2 annual limit value (40 μg/m^3), respectively (European Commission, 2019; Sundvor et al., 2012).

Importantly, the adverse health effects associated with TRAP, and air pollution in general, are observed at relatively low concentrations well below standards and guideline values (Beelen et al., 2014; Belanger et al., 2006; de Castro et al., 2009; Chen and Omaye, 2001; Loxham et al., 2019; MacIntyre et al., 2014; Nishimura et al., 2013; Pedersen et al., 2013; Scoggins et al., 2004; Wei et al., 2019; World Health Organization, 2013). Currently, there is no known “safe” limit for air pollution levels where exposure does not result in adverse health effects (Hitchcock et al., 2014; Khreis, 2020). Notably, ambient pollutant levels from pollutants like ammonia, black carbon (BC), and ultrafine particles (UFP) are unregulated and are not routinely measured or studied even though they are abundant at the local scale due to traffic activity and elicit adverse health effects (Cape et al., 2004; Dennenkamp et al., 2002; Durbin et al., 2001; Khreis et al., 2017a; Luben et al., 2017; Onat and Stakeeva, 2013; Perrino et al., 2003, 2002; Skjøth and Hertel, 2013; Tomlin et al., 2010). Although technologies, such as electric vehicles including hybrid electric vehicles (HEV) and battery electric vehicles (BEV), will aid in reducing traffic emissions and TRAP, there are still challenges regarding their adoption and implementation (Hannan et al., 2014), and concerns that their effect on non-exhaust emissions may be overall negative (Timmers and Achten, 2016).

Reducing traffic emissions and TRAP remains an important issue to address in the existing and rapidly evolving urban context. It is important to document policy interventions (also referred to as "policies", “scenarios”, “measures”, “strategies”, or “practices”) that may be implemented in urban areas to reduce traffic emissions and TRAP, across a wide range of pollutants, thus providing the evidence base for limiting exposures and adverse health effects for urban populations. There is currently limited evidence available on the effectiveness of urban policy interventions to reduce traffic emissions and/or TRAP.

This Systematic Evidence Map (SEM) fills this gap by identifying, describing, and summarizing the global evidence base on policy interventions that may be implemented in urban areas to reduce traffic emissions and/or TRAP. The benefit of conducting this SEM encompassing multiple urban-level policy interventions from around the globe is that it will provide a broad and a high-level overview of the evidence base without restriction on the intervention type, pollutant, or location. Considering studies without geographic restriction provides an opportunity to learn from different countries and become aware of more progressive or atypical policies that may not be implemented in certain areas of the world, in addition to better understanding their potential impacts and initiating discussions about their transferability. Furthermore, understanding the latest information on urban policy interventions is of increasing value especially as new types of policy interventions and technologies continue to emerge and as evidence continues to emerge on the negative consequences of pollution. Proactively collecting and understanding information on emerging policy interventions and technologies may also lead to the early identification and potentially the mitigation of unintended consequences.

Although there are previous reviews (Bigazzi and Rouleau, 2017; Bradley et al., 2019; Burns et al., 2019; Conlan et al., 2016; Henschel et al., 2012; Holman et al., 2015; Slovic et al., 2016; Wagner and Rutherford, 2013), each has limitations in scope and/or methodology. According to Wolffe et al. 2019, SEMs are “queryable databases of evidence applicable to a broader scope of decision-making contexts’’. SEM differ from systematic reviews in that SEMs aim to characterize an evidence base, providing a broad and comprehensive overview of the evidence base, rather than answering a specific research question. In addition, the risk of bias assessment in SEMs is optional and restricted to some extent, depending on the outcome of the SEM. However, study characteristics relevant to the risk of bias assessment can be extracted. As SEMs can identify trends in the literature, they can inform more efficient systematic reviews, or more targeted primary research (Wolffe et al., 2019).

Key differences between previous reviews and the current SEM are listed in Table S.1 in the Supplementary Material and were discussed in more detail in a previously published protocol (Sanchez et al., 2020). Of the note-worthy differences are that only one review reported methods used prior to publication, and none of the previous reviews hosted results in an open-access database or tool. To the best of our knowledge, this SEM is the first to identify and compile international evidence for urban policy interventions together in the context of human exposure and health, in an open-access and query-able Excel database and interactive visualization tool. Therefore, the outputs we provide contain valuable information for practitioners, policymakers, and researchers, and future updates are encouraged by other researchers, following methods explicitly detailed in Sanchez et al. (2020), and this paper.

2. Methods

We previously published a protocol to detail the objective, scope, and methods used to conduct this SEM (Sanchez et al., 2020). This SEM adheres to the preferred reporting items for systematic review and meta-analysis statement (PRISMA) (Moher et al., 2009) with modifications considered for a SEM. The SEM was uploaded to Zenodo (an open access research repository) before the peer-review process, and an updated version will be uploaded after the peer-review process to promote transparency of the changes made. The final accepted SEM version will be uploaded and accessible in Zenodo along with all previous versions (https://doi.org/10.5281/zenodo.6937363).

Table A1
PICO Items.

Population	The population of interest is the urban population. We included populations residing in urban clusters and urbanized areas. Urban clusters are densely settled territories that contain between 2,500 and 50,000 people, and urbanized areas are densely settled territories that contain at least 50,000 people, as defined by the United States Census Bureau (U.S. Department of Commerce, 2012). For the purpose of this SEM, the United States Census Bureau definition was all-encompassing, meaning it was applied to locations outside of the United States as well, following our previously peer-reviewed and published protocol.
Intervention	The intervention refers to urban-level policy interventions to reduce traffic emissions and/or TRAP that can be implemented by urban authorities. For the purpose of this paper, “policy intervention” refers to the set of possible strategies, measures, or practices undertaken to achieve a policy objective. In this case, the objective is to reduce traffic emissions and/or TRAP concentrations originating from on-road mobile sources in urban areas. We consider policy interventions that reduce traffic emissions and/or TRAP concentrations directly (i.e., the specific aim of the intervention is to reduce traffic emissions and/or TRAP) or indirectly (i.e., the specific aim of the intervention is not to reduce traffic emissions and/or TRAP but is still observed – for example, some policies may aim to reduce congestion or improve road safety). “Urban authorities” refer to cities, air agencies, local authorities, including county and district councils, and metropolitan planning organizations (MPOs) or districts.
Comparator	The comparator is the baseline or absence of the urban-level policy intervention of interest.
Outcome	The primary outcomes are traffic emissions and TRAP concentrations. Secondary outcomes are human exposures and health effects or impacts, and secondary items of interest are enablers and barriers to intervention implementation and co-benefits. Secondary outcomes and items of interest will only be reported as available for studies reporting a primary outcome.

2.1. Objective

The objective of this SEM is to examine and characterize the evidence on urban-level policy interventions that can be implemented by urban authorities to reduce 1. traffic emissions 2. and/or TRAP from on-road mobile sources. Such policy interventions may reduce human exposures and adverse health impacts and produce various social, environmental, climate and economic co-benefits.

We also created an open-access, interactive database in the form of a Microsoft Excel sheet to facilitate the identification of relevant trends and gaps in the evidence base and serve as the foundation for future research, practice, and policy recommendations. The Excel database has been uploaded to the CARTEEH Data Hub (Center for Advancing Research in Transportation Emissions Energy and Health, 2020) and can be accessed at (https://carteehdata.org/library/dataset/urban-policy-intervention-f08c). Additionally, the Excel database is included in the Supplementary Material.

2.2. Scope of the SEM

Population, Intervention, Comparator, Outcome (PICO) items are outlined to clearly describe the scope of this SEM (Table A.1), in line with recommended practice for systematic reviews and evidence syntheses.

2.3. Eligibility criteria

The eligibility criteria used to determine whether potential articles were included or excluded in this SEM are described below. We included articles that met all the following criteria:

- Articles that investigate policy interventions implemented in urbanized areas (densely settled territory that contains 50,000 or more people) or urban clusters (densely settled territory that contains at least 2,500 people but fewer than 50,000 people) as defined by the United States Census Bureau (U.S. Department of Commerce, 2012)
- Articles that investigate urban-level policy interventions' impact on traffic emissions (exhaust or non-exhaust) and/or TRAP originating from mobile on-road traffic: BC, elemental carbon (EC), hydrocarbons (HCs), carbon monoxide (CO), nitric oxide (NO), NO_2, NO_x, sulfur dioxide (SO_2), $PM_{2.5}$, PM_{10}, difference between PM_{10} and $PM_{2.5}$ (PM_{coarse}), blackness of PM filters as a representation of BC or EC ($PM_{absorbance}$), particulate matter with diameters of mixed sizes (PM_x), UFP, and volatile organic compounds (VOCs) or other traffic-related air pollutants/pollution
- Articles that investigate past, current, future (hypothetical) or hypothetical changes in traffic emissions and/or TRAP
- Articles reported in the English language
- Articles published between January 1, 2000, and June 1, 2020
- Articles that are peer-reviewed

We excluded articles that met any of the following criteria:

- Articles that exclusively investigate policy interventions implemented at the state/regional or federal/national level or in non-urban areas (e.g., rural areas)
- Articles that exclusively investigate urban-level policy intervention impact on an outcome other than the primary outcomes, traffic emissions and TRAP (e.g., traffic congestion, traffic noise, traffic safety, etc.)
- Articles that exclusively investigate off-road traffic emissions (e.g., boats, planes, trains, construction equipment, etc.)
- Articles that exclusively investigate non-traffic related emissions or non-traffic related air pollution (e.g., wildfires, wood smoke, industrial and indoor combustion emissions, etc.)
- Articles that exclusively investigate human exposures and/or health outcomes because of an urban-level policy intervention (which for our purpose are treated as secondary outcomes)
- Articles that exclusively investigate greenhouse gas (GHG) emissions (which for our purpose are treated as a co-benefit)
- Articles that do not investigate a policy intervention (e.g., source apportionment studies)
- Articles that investigate a policy proxy (e.g., strikes, lockdowns, etc.) or do not investigate a policy intervention (e.g., source apportionment studies)
- Articles that are not original studies or do not provide original data (e.g., reviews)
- Articles that are conference or symposium proceedings, books, book chapters, or reports

2.4. Literature search

We searched the Public Affairs Index (EBSCO, n.d.), Transportation Research International Documentation (TRID) (Transportation Research Board, n.d.), Medline (Ebsco), and Embase (Ovid) for relevant articles published in the English language between January 1, 2000, and June 1, 2020. The concepts of the population (urban), intervention (policies) and outcome (automobile or traffic pollutants in the form of emissions or ambient concentrations) were then developed to match the thesaurus terms in each database, along with keywords. The concept of urban population was not added to the Public Affairs Index search as this is a small database and had the potential to provide many relevant articles. The exact searches used to identify relevant articles in the databases are provided in the Supplementary Material (Table S.2).

In line with our published protocol, gray literature was excluded from the literature search. Due to time and resource limitations, and the large number of papers returned from our electronic searches, it was not possible to consider articles from reference lists, other projects and expert knowledge, and the CARTEEH Literature Library (https://www.carteeh.org/carteeh-literature-library/), which is a deviation from our published protocol (Sanchez et al., 2020).

2.5. Study screening

Results from the literature search were imported into Covidence (Veritas Health Innovation, n.d.) which was utilized to store and screen potential studies for inclusion or exclusion. Covidence automatically identified and removed duplicate records. Then, the screening process was conducted at two levels: 1) title and abstract screening and 2) full-text screening.

KS and HK reviewed the screening process and the data extraction and coding process at the outset and selected papers were reviewed together to ensure all processes were well-defined, similarly understood and agreed upon. Uncertainties were resolved through discussion until consensus was achieved. A third opinion was sought from another reviewer for any disagreements. Titles and abstracts of all identified articles were screened by KS, and a random 20 % was independently screened by JB. Any disagreements were resolved by HK. All articles potentially meeting our inclusion criteria were retrieved, and their full papers were reviewed by KS with a random 20 % independently reviewed by HK. Any disagreements were resolved by JB. Any studies that were not screened in duplicate which were unclear were discussed with HK and any disagreement was resolved by JB. A reason for exclusion was provided for each of the articles that were excluded after the full-text screening, as shown in the Supplementary Material (Table S.3). Additionally, we indicated which articles were among the 20 % screened in duplicate at the title and abstract level and full-text level, and we provided the agreement rate across those articles in the Supplementary Material (Tables S.4 and S.5).

2.6. Data extraction, coding, and storage

Data were extracted and documented manually in Microsoft Excel by KS according to the predefined categories and codes outlined in the Supplementary Material (Table S.6). Three authors, HK, TR, and JB reviewed a total of 20 % of the coded data for consistency. Any discrepancies were noted during the review of coded data and shared with KS to achieve a resolution. If one study included several scenarios, each scenario was considered separately and had its own row in the Excel database. Similarly, if a study packaged more than one policy intervention in a policy package (analogous to a more complex policy scenario), that policy package had its own row in the database. Each row in the database, therefore, represented a scenario, and each scenario is one of the following:

1. A single policy instrument whose impact on traffic emissions and/or TRAP was reported in the included study. For example, the addition of an express bus (this example would be one row in the database)
2. A variation of that single policy instrument. For example, the addition of an express bus with a regular lane (one scenario and therefore one row in the database) versus an express bus with a reserved lane (another scenario and therefore another row in the database) in the same included study
3. A policy package, which is when more than one policy instrument or one intervention is bundled and studied as a whole, and the impact of this package was reported on as a whole in the included study. For example, the addition of an express bus with a reserved lane and that is electric (one package or one scenario and therefore one row in the database).

More detail on data collection and coding, including the level at which data was collected for each category, is specified in the Supplementary Material (Table S.6). If there was missing data from a study, KS

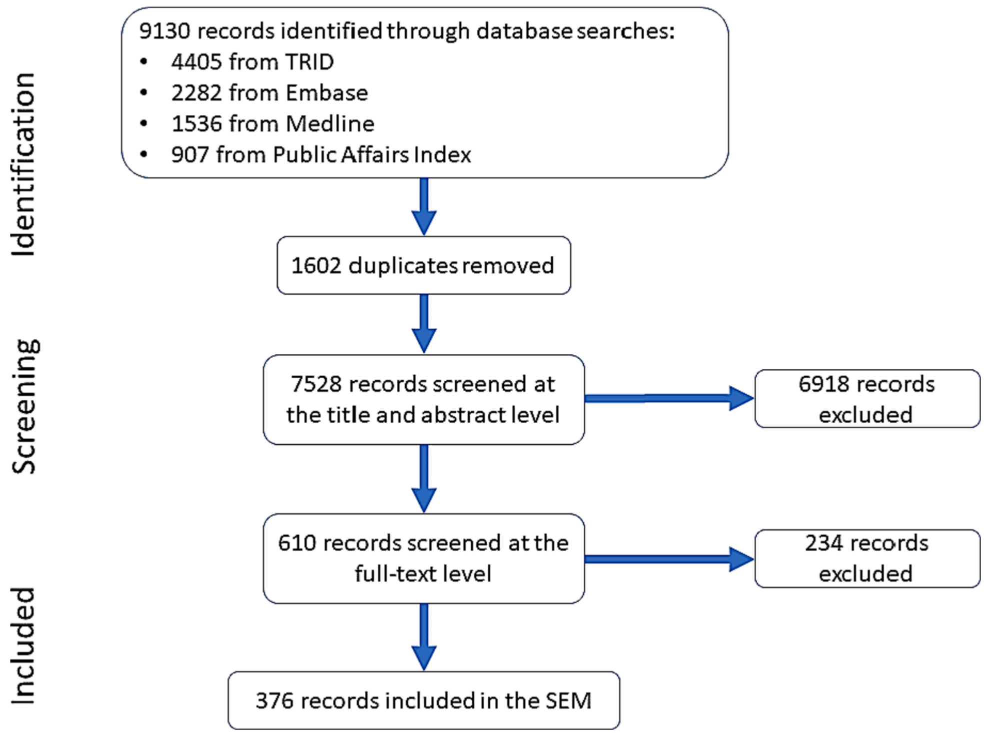

Fig. A1. Study Flow Diagram.

requested information from the corresponding author via email. If no response was received, KS followed up twice via email at one and three weeks. If there was still no response, the missing data was labeled "N/A" for "Not Available". Studies with missing data are documented in the Supplementary Material (Table S.7).

2.7. Interactive data visualization

Interactive data visualization was created by RJ using Tableau Server Version: 2021.1.10. The dashboard helps the user to visualize the locations of policy interventions and filter and visualize the effect of different policy interventions and other characteristics such as health effects or impacts, policy enablers, policy barriers, co-benefits, country of study, analysis start and end years, publication year and scientific journals. The dashboard is hosted on Texas A&M Transportation Institute's tableau server and can be accessed at https://tableau.tamu.edu/t/TTI/views/SEMDataVisualizationV2/SEMVisualizationDashboard?:showAppBanner=false&:display_count=n&:showVizHome=n&:origin=viz_share_link.

3. Results

3.1. Search results

Fig. A.1 is a study flow diagram outlining the number of articles that were retrieved from our database searches and the number of articles evaluated at each screening level. 7528 unique articles were identified after 1602 duplicates were removed. 6918 articles were excluded after the title and abstract screening, leaving 610 to be screened at the full-text level. 234 articles were excluded after the full-text screening. Exclusion reasons for all articles excluded at the full-text level are provided in the Supplementary Material (Table S.3). Notably, ten duplicates remained that were identified at the full-text screening level and were labeled as such for the exclusion reason. Finally, 376 studies were included in this SEM.

Of the random 20 % of titles and abstracts independently screened by JB (1500 records shown in Table S.4), the agreement rate between KS and JB was 92.8 %. Disagreements were resolved by HK. Specifically, of those 1500 titles and abstracts, KS labeled 85 as exclude, while JB labeled as include. The third reviewer, HK, labeled 34 of those as include, which implies a percentage of 2.3 % of titles and abstracts were potentially false negative, i.e., these were excluded when they should have been included. Of the random 20 % of full papers independently screened by HK (120 records shown in Table S.5), the agreement rate between KS and HK was 88.5 %. Disagreements were resolved by JB. Specifically, of those 120 full papers, there was only one paper which KS labeled as exclude, which both HK and JB labeled as include, which implies a percentage of 0.8 % of full papers were potentially excluded when they should have been included. This highlights the limitation of not screening the entire set of returned records in duplicates. In addition, KS and HK met to discuss in detail the disagreements and the resolutions and ensure that consensus on how to screen in similar future instances was achieved. Other studies that were not screened in duplicate which were unclear to KS were discussed with HK and any disagreement was resolved by JB.

3.2. Summary of evidence

Data were recorded for a total of 1,139 policy scenarios from 376 articles since some articles investigated more than one policy scenario. As many as 58 individual policy scenarios were investigated within a single article (Mediavilla-Sahagun and ApSimon, 2003). Policy packaging (i.e., considering the effect of more than 1 policy intervention within a single scenario) was observed 380 times (33.4 %). In those 380 instances, two or more policy interventions were bundled together in a policy package, and the impacts of that package as a whole was reported in the primary data (and was extracted as reported). An example of this is a study that assessed the impact of substitution of leaded gasoline by unleaded gasoline (alternative fuel technology) and conversion of non-catalytic into catalytic vehicles (vehicle retrofitting) and reported the impact of both these intervention as a whole (i.e., the scenario here is a policy package). For the remaining 759 policy scenarios (66.6 %), policy

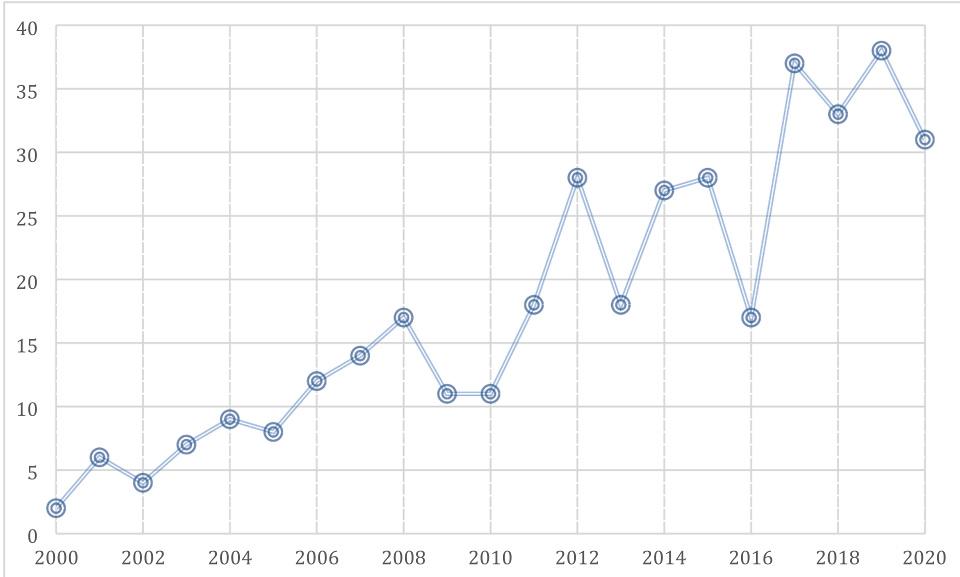

Fig. A2. Number of Studies by Publication Year. Note that the searches were only conducted up to June 1, 2020, so the 31 articles published in 2020 only reflect half of that year.

packaging was not considered, indicating that in those instances, primary data reported on the effect of one specific policy intervention. A scenario that assessed the impact of a vehicle retirement program, only, would be an example of such scenario. Note that the same studies can include policy scenarios with and without packaging, and each scenario is coded in its own row in the Excel database.

The 376 included articles were published across 90 scientific journals, mostly in Atmospheric Environment, followed by Transportation Research Part D, Science of the Total Environment, and Transportation Research Record. Furthermore, included articles were published between the years 2000 and 2020. An increasing trend in the published evidence, especially within the last ten years, supports that there is a growing body of literature on this topic and a need to update this SEM in the future if this evidence base is to be mapped again (Fig. A.2). Most articles were published in 2019 (n = 38), and 31 articles in 2020. Notably, the literature search parameters limited publications up to June 1, 2020, so the 31 articles published in 2020 only reflect half of that year.

Most articles included in this SEM were classified as case study/case series study types at 99.3 %. Cross-sectional studies composed 0.5 % of study types, and case-control studies composed 0.2 % of study types for articles included in the SEM. The study type was classified based on the predefined categories outlined in the protocol and the Supplementary Material (Table S.6). This SEM considered 58 types of unique policies which fell within 1 of the 6 predefined overarching policy categories: 1) pricing, 2) land-use, 3) infrastructure, 4) behavioral, 5) technology, and 6) management, standards, and services as outlined in the Supplementary Material (Table S.6). The 6 overarching policy categories were selected a priori and adapted from the Policy Guidebook of the Knowledgebase on Sustainable Urban Land use and Transport (KonSULT) (University of Leeds, 2016). Management, standards, and services policies were studied most frequently and are documented in 44.1 % of instances followed by technology policies in 22.2 % of instances. Table A.2 outlines the frequency of each policy intervention within the 6 overarching policy categories.

Identified articles reported various outcomes, including traffic emissions (78 %), TRAP (38.0 %), human exposures (12.0 %) and health impacts (13.0 %). However, only 3 % of articles reported all elements of the full-chain (Khreis, 2020) covering an assessment of traffic emissions, TRAP, human exposures, and health impacts. The sections below summarize evidence under the 6 overarching policy categories.

3.2.1. *Pricing policies*

Pricing policies refer to policies that involve a monetary charge, tax, price increase, fee, or incentive. The two most studied instruments being parking charges (55 times) and road pricing (51 times) (Table A.2). Most of the policies in this section are "penalty approaches" that price or tax the purchase and usage of motor vehicles, their fuel or the externalities they generate. One exception is the pricing incentive policy which was studied 27 times and refers to actions such as reducing bus fares and monetary incentives for the purchase of "green" vehicles. We note, however, that other pricing policies documented in the literature are missing from this SEM, for example concessionary fares, which is documented in KonSULT (University of Leeds, 2016).

3.2.2. *Land-use policies*

Land-use policies refer to policies that focus on development and planning. The 6 land-use policies considered in this SEM include development density and mixed developments (policies that support increased centralization and mixed development), parking expansion, superblock development, transit-oriented development, urban sprawl (policies that support increased decentralization including limited land development controls and rapid expansion of utility service areas), and urban transport planning. Development density and mixed developments was studied the most (42 times), followed by transit-oriented development (18 times) (Table A.2). Developer contributions to infrastructure, which is documented as land-use policy in KonSULT (University of Leeds, 2016), is missing from this SEM.

3.2.3. *Infrastructure policies*

Infrastructure policies refer to policies that relate to the built environment. Bus or mass rapid transit were studied the most (43 times), followed by public transportation infrastructure (33 times), while street ventilation and green or blue spaces were studied the least.

3.2.4. *Behavioral policies*

Behavioral policies refer to policies that involve a change in individuals' behavior or practices. The 4 behavioral policies considered in this SEM include flexible work arrangements which includes e- or tele-commuting, the promotion or shift to active/non-motorized transport, public transit, and ride sharing, which includes practices such as car-pooling or car-sharing via services such as Uber or Lyft. In total, behavioral policies were studied 116 times, with public transit

Table A2
Frequency each policy intervention was studied under the 6 overarching policy categories.

Policy Category	Policy Intervention	Frequency Studied
Pricing: 11.8 % (n = 216)	1. Air pollution charging fees	24
	2. Congestion charging	28
	3. Fuel taxes or price increase	26
	4. Mileage-based user fees	4
	5. Parking charges	55
	6. Road pricing	51
	7. Pricing incentives	27
	8. Vehicle ownership taxes	1
Land-Use: 4.2 % (n = 77)	1. Development density and mixed developments	42
	2. Parking expansion	2
	3. Superblock development	2
	4. Transit-oriented development	18
	5. Urban sprawl	8
	6. Urban transport planning	5
Infrastructure: 11.5 % (n = 210)	1. Active transportation infrastructure	26
	2. Bus rapid transit or mass rapid transit	43
	3. Greenspace or blue space	2
	4. Park and ride	9
	5. Public transportation infrastructure	33
	6. Roadway development	23
	7. Solid roadside barrier	8
	8. Speed bump development	18
	9. Street ventilation	3
	10. Unconventional intersection or intersection alteration	22
	11. Vegetative roadside barrier, surface, or roof	23
Behavioral: 6.3 % (n = 116)	1. Active or non-motorized transport (i.e., bike or walk) promotion or shift	31
	2. Flexible work arrangements	26
	3. Public transit promotion or shift	47
	4. Ride sharing promotion or shift	12
Technology: 22.2 % (n = 406)	1. Alternative fuel technology	271
	2. Alternative vehicle technology	12
	3. Electronic toll technology	3
	4. Material coating	6
	5. Real-time passenger information	2
	6. Speed control technology	5
	7. Stop/Start technology	2
	8. Vehicle retrofitting	105
Management, Standards, and Services: 44.1 % (n = 807)	1. Fleet management	59
	2. Fuel regulation or restriction	35
	3. High occupancy vehicle lane	13
	4. Inspection and maintenance program	18
	5. Intelligent transport system	47
	6. Low emission zone	56
	7. Loading, unloading, and/or idling regulation	18
	8. Parking standards, reduction, or regulation	16
	9. Public transportation expansion	47
	10. Public transportation regulation	31
	11. Speed limit regulation or reduction	42
	12. Street cleaning	4
	13. Studded tire regulation	1
	14. Traffic signal optimization	29
	15. Vehicle or manufacturing alteration	4
	16. Vehicle emission regulation	134
	17. Vehicle purchase restriction	7
	18. Vehicle rerouting or route optimization	18
	19. Vehicle retirement or replacement	112
	20. Vehicle shift	2
	21. Vehicle use restriction	114

promotion or shift being studied the most (47 times). While company travel plans were included in this SEM (Nelson et al., 2007, Wall et al., 2017), school travel plans or school mobility management policies, personalized journey planning (which falls under the umbrella of public awareness campaigns), and bike sharing studies did not appear in the SEM.

3.2.5. Technology policies

Technology policies refer to policies that implement innovative and technological advances. The 8 technology policies considered in this SEM include alternative fuel (such as electric vehicles [EVs], biodiesel and hybrid technology) and vehicle technology (such as autonomous and connected vehicles), electronic toll technology, material coating, real-time passenger information, speed control technology, stop/start technology, and vehicle retrofitting. Notably, shared autonomous vehicles were considered as both alternative vehicle technology and ride-sharing promotion or shift policies, where they were presented as such (for example, the study of autonomous taxis or aTaxis presented in Fagnant and Kockelman (2014)). Vehicle retrofitting encompasses diesel particulate filters (DPFs), diesel oxidation catalysts (DOCs), catalytic converters (CACs), and exhaust gas recirculation (EGR). Of note is that other literature considers real-time passenger information as an information provision policy in the same category as, for example, crowdsourcing, in-vehicle and parking guidance systems (University of Leeds, 2016). Technology policies were the second largest overarching category studied (after Management, Standards, and Service Policies, described next), with alternative fuel technology studied the most (271 times).

3.2.6. Management, standards, and services policies

Management, standards, and services policies refer to policies that relate to regulations, restrictions, optimization, or other established rules. The 21 policies considered under this category are shown in Table A.2 and the most studied policy instruments within this category are vehicle emission regulation, vehicle retirement or replacement, and vehicle use restriction. While the least studied policy instruments are studded tire regulations, vehicle shift (i.e. changes in demand due to market restrictions that result in changes to the fleet composition), street cleaning and vehicle or manufacturing alteration which includes the production of more aerodynamic cars (for example, mass and drag reduction), as well as equipping drayage trucks with newer engines.

3.3. Methods used to assess impact

Included articles implemented different methods including measurement or modeling techniques while some articles implemented both methods to assess the impact of policy scenarios. Various modeling methods were implemented including the MOtor Vehicle Emission Simulator (MOVES), COPERT, and coupled Weather Research and Forecasting model with chemistry (WRF/Chem) and biogenic emission from Model of Emissions of Gases and Aerosols from Nature (MEGAN) to name a few. 541 policy scenarios (47.5 %) in 140 unique articles exclusively utilized modeling. 81 policy scenarios (7.1 %) in 43 unique articles exclusively utilized measurement, and 517 policy scenarios (45.4 %) in 193 unique articles utilized both modeling and measurement methods.

3.4. Geographic location

The 1,139 policy scenarios were investigated across a total of 52 countries. Most policy scenarios were investigated in China, followed by the United States, United Kingdom, India, and Spain (Table A.3). A second tier of countries, termed as having moderate frequency, considered less than 60 policy scenarios each, but accounted for more than 1 % of total each. A third category of countries termed as lower frequency, appeared in the SEM but accounted for less than 1 % of policy

Table A3
Studied countries.

Category	Countries
High Frequency (over 7 % of policy scenarios each)	China – 160 policy scenarios (14.0 % of total) United States – 119 policy scenarios (10.4 %) United Kingdom – 93 policy scenarios (8.2 %) India – 91 policy scenarios (8.0 %) Spain – 89 policy scenarios (7.8 %)
Moderate Frequency (between 1 % and 6 % of policy scenarios each)	Portugal, Mexico, Brazil, Italy, Canada, Lebanon, Germany, France, Greece, Iran, Israel, Netherlands, Lithuania, Ireland, Thailand, and Belgium.
Lower Frequency (under 1 % of policy scenarios)	Indonesia, Chile, Japan, Australia, Philippines, Taiwan, Ecuador, Finland, Hong Kong (Special Administrative Region of the People's Republic of China), Sweden, Colombia, Egypt, South Africa, Austria, Denmark, South Korea, Macedonia, Poland, Bangladesh, Switzerland, Norway, New Zealand, Serbia, Vietnam, Czech Republic, Hungary, Jordan, Qatar, Luxemburg, Cameroon and Slovenia.

scenarios each. Notably, 41 policy scenarios (3.6 %) did not have a defined country denoted in the article and were marked as "N/A" in the final Excel database. From a continental perspective, 463 policy scenarios were studied in Europe, followed by 355 in Asia, 206 in North America, 57 in South America, 10 in Africa, and 7 in Australia.

€For city/urban areas, 307 unique locations were documented for the included articles. Fourteen policy scenarios investigated multiple cities simultaneously while the remaining 1,125 scenarios were investigated in one urban area specifically. The urban area studied most was Beijing with 81 scenarios (7.1 %), London where 78 policy scenarios were investigated (6.8 %), Mexico City with 54 scenarios (4.7 %), Madrid with 45 scenarios (4.0 %), Delhi with 45 scenarios (4.0 %), Beirut with 30 scenarios (2.6 %), and Barcelona with 30 scenarios (2.6 %). Notably, 70 policy scenarios (6.1 %) did not have a defined urban area denoted in the article and were marked as "N/A" in the final Excel database. For example, some of these studies modeled a policy scenario using urban data but did not specify which urban area (i.e., New York City, London, etc.). While a specific city was not named, the use of urban data to reflect an urban environment met our inclusion criteria, and hence, those studies were included.

3.5. Analysis years

The start analysis year and end analysis year were captured for each policy scenario. Start analysis years ranged from 1974 to 2030. End analysis years ranged from 1996 to 2050. The longest gap between analysis years was 50 years which started in 2000 and ended in 2050 and occurred in 16 policy scenarios. The shortest gap between analysis years was 0 years indicating the same start and end year which occurred in 288 policy scenarios. Notably, 206 policy scenarios (18 %) did not have defined analysis years and were marked as "N/A" in the Excel database.

3.6. Pollutants considered

Twenty-five traffic pollutants were identified in the included articles: ammonia (NH_3), BC, black smoke (BS), CO, EC, HC, NO, NO_2, NO_X, organic carbon (OC), particulate matter with an aerodynamic diameter equal to or less than 1 μm (PM_1), $PM_{2.5}$, PM_{10}, $PM_{absorbance}$, PM_X, reactive organic gases (ROG), respirable suspended particulate matter (RSPM), secondary organic aerosols (SOA), SO_2, sulfur oxides (SO_X), suspended particulate matter (SPM), total carbon (TC), total organic gases (TOG), UFP, and VOC. Traffic pollutants that were not specified were referred to as "Other" in the final Excel database and represent a twenty-sixth category. For example, one study reported the effect of green roofs on pollutant concentrations but did not specify the pollutants involved (Baik et al., 2012). The most frequently studied pollutants

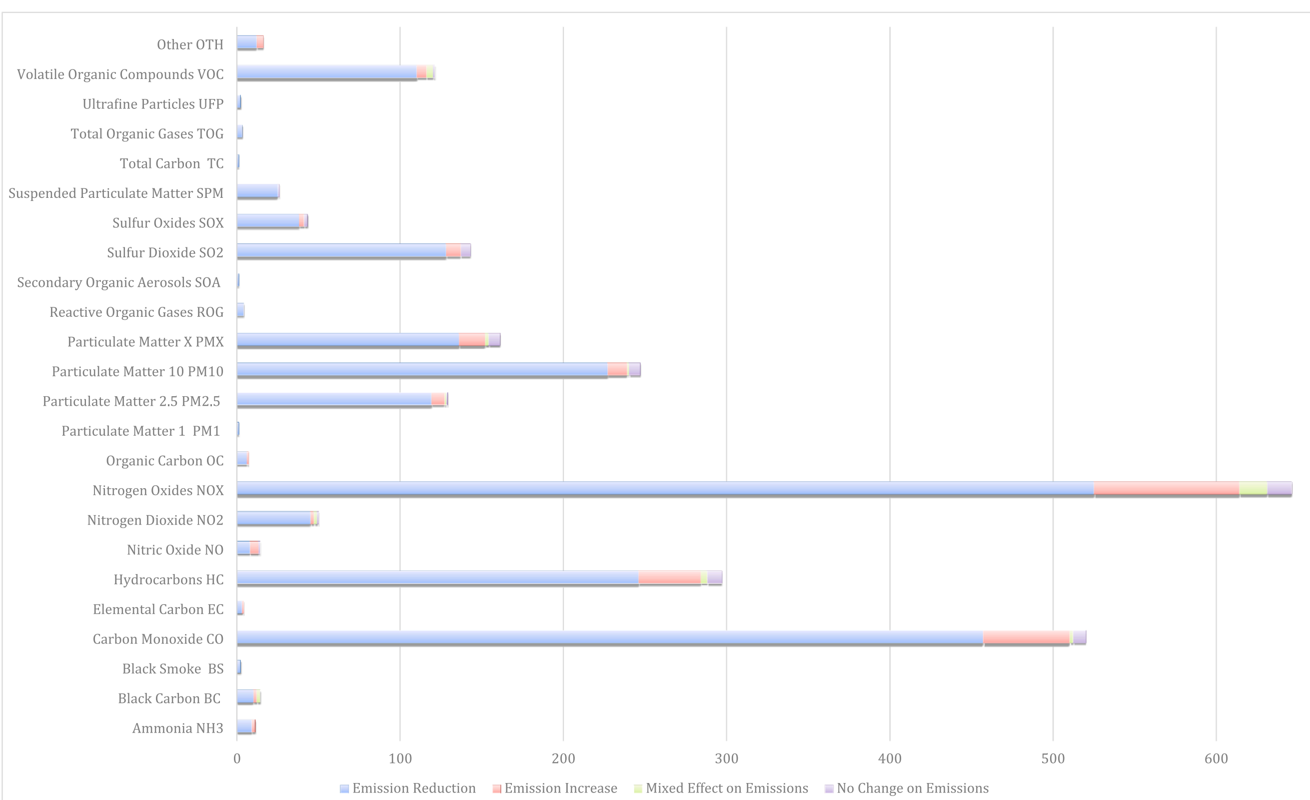

Fig. A3. Traffic Emission Effects and Pollutants Reported.

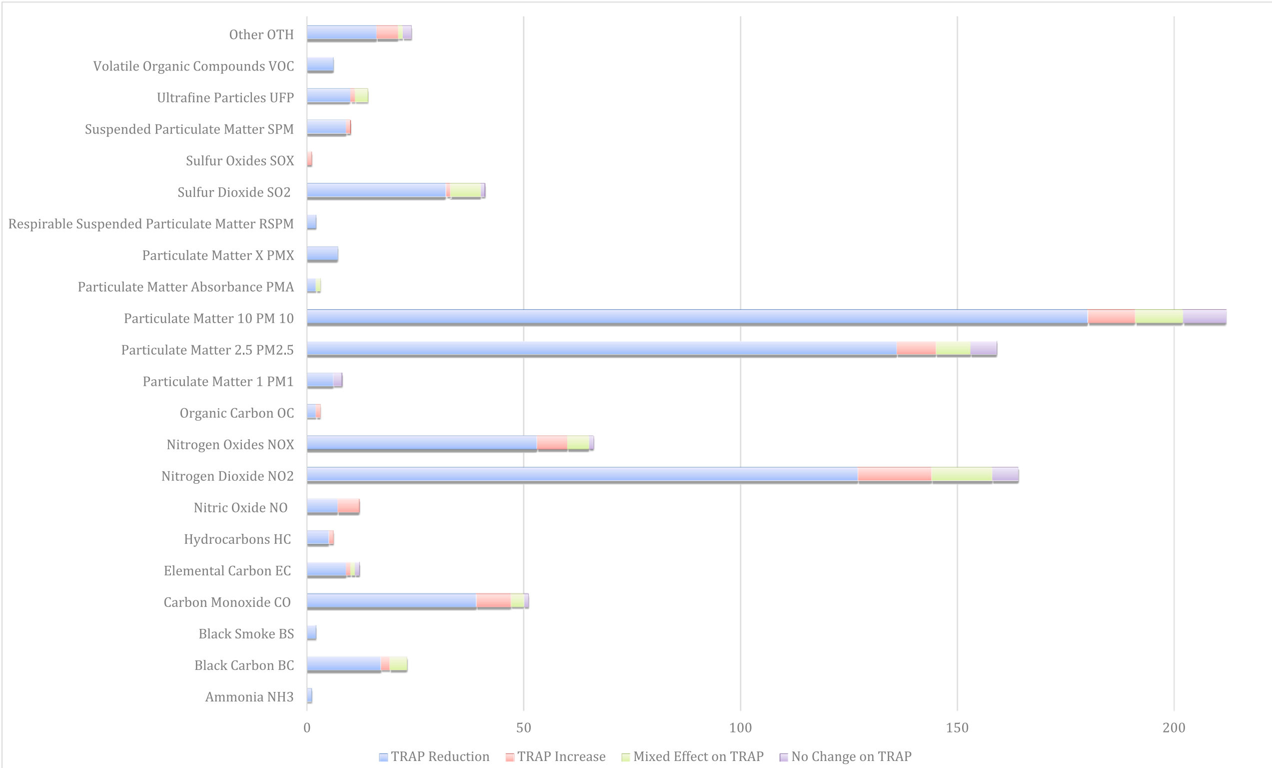

Fig. A4. TRAP Effects and Pollutants Reported.

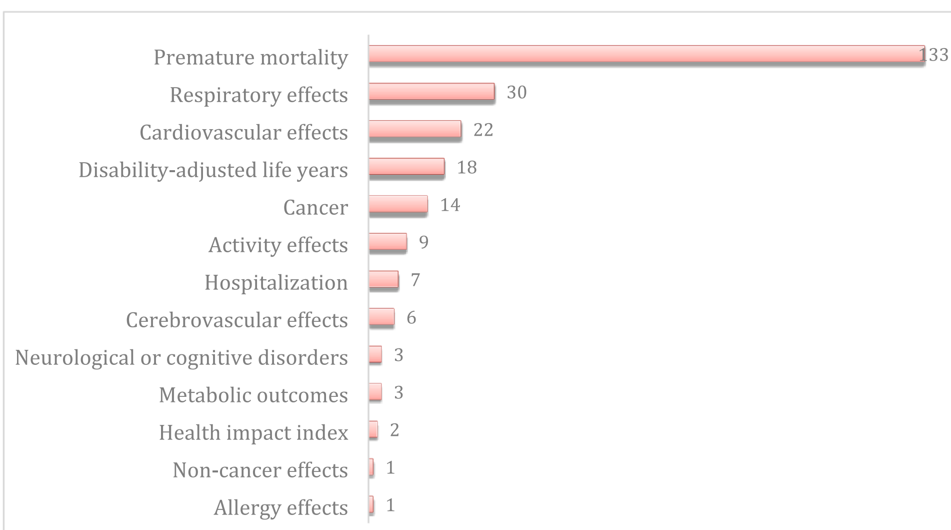

Fig. A5. Frequency of Health Effects and Impacts Recorded.

include NO_X (237 unique articles), CO (181 unique articles), PM_{10} (110 unique articles), HC (103 unique articles), and $PM_{2.5}$ (97 unique articles). The remaining pollutants were studied in less than 20 % of all policy scenarios, most notably NO_2 was studied in 17.5 % of policy scenarios or 67 unique articles. Note that for some studies which differentiated PM components, such as Boogaard et al. (2013), we did not create a separate category for PM_{10} components and considered these pollutants to be part of the PM_{10} category, a minor deviation from our protocol. Future work will address this by adding PM constituents as their own pollutant categories.

3.7. Primary outcomes: changes in traffic emissions and TRAP

The effect on traffic emissions was reported in 892 of the policy scenarios (78.3 %). Fig. A.3 displays traffic emissions effects reported by each pollutant studied in the 892 policy scenarios. The pollutants most frequently studied for traffic emissions effects were NO_X, CO, HC, PM_{10}, PMx and SO_2 at 646, 520, 297, 247, 161, and 143 times, respectively. A reduction in emissions was most frequently reported (2,118 times across all pollutants) although emission increases (251 times), mixed effects (i.e., both reduction and increase observed: 35 times), and no changes (i.e., stayed the same: 59 times) were also observed. Notably, NO_X emissions

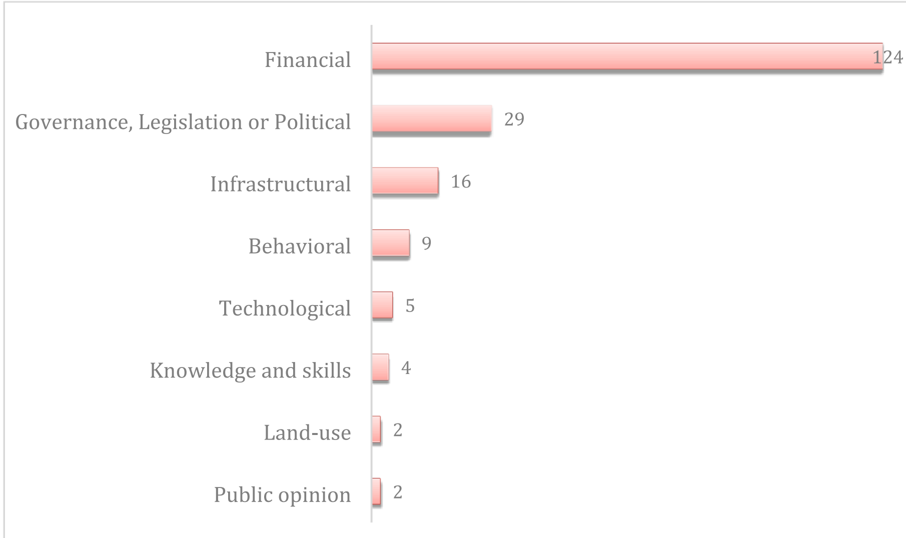

Fig. A6. Frequency of Barriers Recorded.

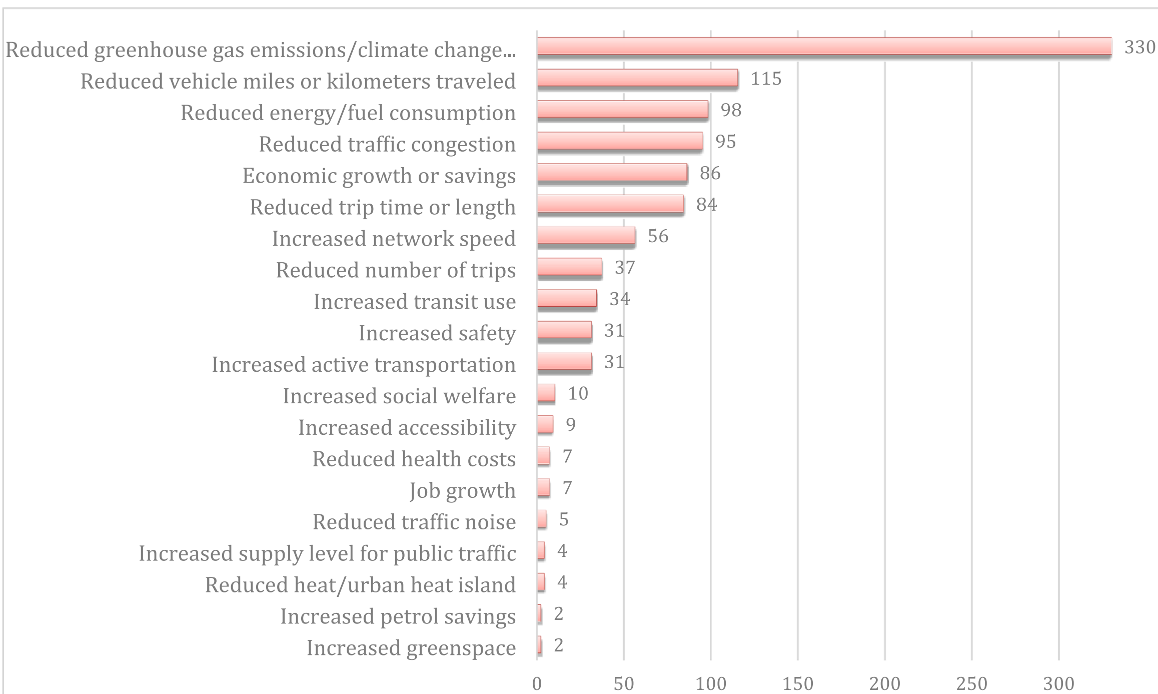

Fig. A7. Frequency of Co-benefits Recorded.

were reported to have increased in 89 policy scenarios, followed by CO and HC; reported to increase in 53 and 38 policy scenarios, respectively. The effect on ambient concentrations of TRAP was reported in 432 of the policy scenarios (37.9 %). Fig. A.4 displays TRAP effects reported by each pollutant studied in the 432 policy scenarios. The pollutants most frequently studied for TRAP effects were PM_{10}, NO_2, $PM_{2.5}$, NO_X, and CO at 212, 164, 159, 66, and 51 times, respectively. A reduction in TRAP was most frequently (668 times across all pollutants) reported although TRAP increases (71 times), mixed effects (i.e., both reduction and increase observed: 58 times), and no changes (i.e., stayed the same: 30 times) were also observed. Notably, NO_2 concentrations were reported to have increased in 17 policy scenarios, followed by PM_{10}, $PM_{2.5}$ and CO; reported to increase in 11, 9 and 8 policy scenarios, respectively.

3.8. *Secondary outcomes: human exposures and health impacts*

Human exposures were reported in 11.5 % of (131) policy scenarios, while most scenarios did not study human exposures (88.5 %). Of the articles that reported human exposure effects, PM_{10} (79 times) was the most frequently studied pollutant, followed by $PM_{2.5}$ (50 times), and only 10 pollutant categories out of the 26 included in the full database were studied. Health impacts were reported in 13.0 % of (148) policy scenarios. Like human exposures, PM_{10} (96 times) was the most frequently studied pollutant, followed by $PM_{2.5}$ (53 times), and only 8 pollutant categories out of the 26 included in the full database were studied for their health impacts. The other pollutants studied for their health impacts in order of frequency were NO_2 (15 times), NO_x (8 times), CO (3 times), EC and SO_2 (2 times each), and VOC (1 time). Both mortality and morbidity were studied, primarily in health impact assessment

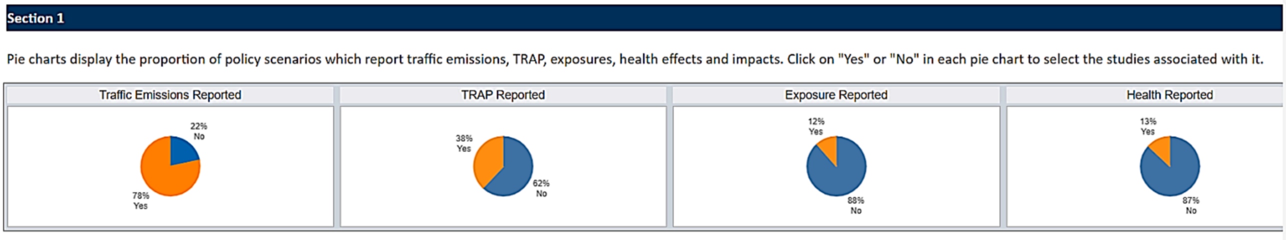

Fig. A8. Screenshot of Section 1 of Tableau Dashboard for interactively visualizing the SEM database.

studies of various scenarios, sometimes combined with economic valuation (e.g., (Rodrigues et al., 2020, Dey et al., 2018, Malina and Scheffler, 2015, Wadud and Khan, 2013). Fig. A.5 shows the reported health impacts.

3.9. Secondary items of interest: policy enablers, barriers, and co-benefits

Enablers to policy intervention implementation were reported a total of 4 times in 4 unique articles, as financial, governance/legislation/political, public opinion, and technological enablers. Barriers to policy intervention implementation were more frequently cited, reported a total of 191 times in 35 unique articles. They included behavioral, financial, Governance/legislation/politics, infrastructural, knowledge/skills, public opinion, land-use, and technological barriers, as shown in Fig. A.6.

Co-benefits were reported a total of 1,047 times in 204 unique articles. The 20 documented co-benefits are shown in Fig. A.7.

3.10. Open-access excel database

The data collected for included studies are hosted in an open-access Microsoft Excel sheet database which is query-able by use of the filter, sort/order, search functions, and the Power Query tool so users may identify and access specific information of interest. Information in the Excel database comes from the 376 included articles and the 1,139 policy scenarios within. This information may be searched across different data items including urban-level policy intervention, publication year, study type, policy packaging, methods used, population characteristics including age, gender, race, and sample size where relevant, geographic location, analysis years, pollutants studied, and primary outcomes (traffic emissions and/or TRAP) and their direction of effect, secondary outcomes (human exposures and health impacts), and secondary items of interest (enablers and barriers to intervention implementation and co-benefits). The Excel database includes 4 worksheets (tabs). The first worksheet is the Introduction which details the purpose of the SEM. The second worksheet is the Codebook which contains information for each variable coded in the database. The third sheet is the Master Sheet which contains all data extracted for the 376 articles included. Note the Entry ID column references the entry number and corresponds to each policy scenario documented (whether policy packaged or not) whereas the Article ID column indicates which unique article the policy scenarios correspond to. For example, entries 1–3 correspond to article 1 which means that the first article listed in the Excel database investigated 3 separate policy scenarios. Finally, the fourth sheet contains ready-to-go queries (i.e., specifically queried information to answer a set of common questions regarding frequency of locations, policy packaging, policies, methods, pollutants, impact on emissions and TRAP, etc.) which users may find helpful. These are ready-to-go queries for ease of use, but users can analyze the data based on their questions of interest. Our intended users are researchers and urban authorities, such as cities, air agencies, local authorities including county and district councils, and metropolitan planning organizations (MPOs) or districts. We encourage this audience to use the Excel database to identify information on various urban-level policy interventions implemented around the world to reduce traffic emissions and TRAP, and potentially yield benefits to human exposures and health and a wide range of documented social, environmental, climate and economic outcomes.

3.11. Open access interactive visualization tool

Finally, the Excel database was used to create interactive data

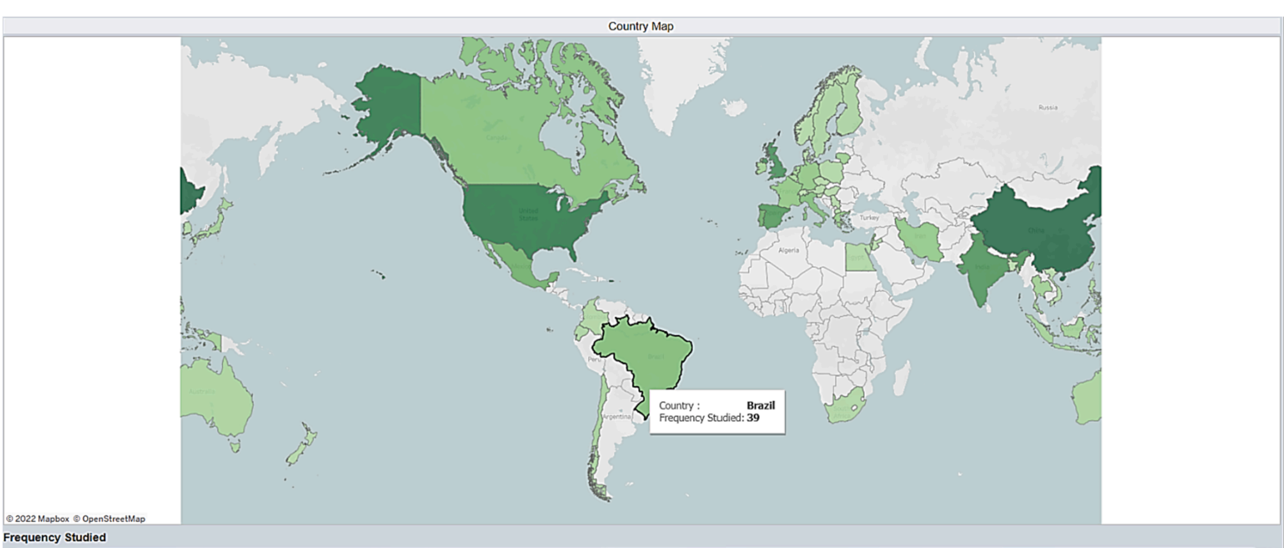

Fig. A9. Screenshot of Section 2 of Tableau Dashboard for interactively visualizing the SEM database.

Fig. A10. Screenshot of Section 3 of Tableau Dashboard for interactively visualizing the SEM database.

visualizations using Tableau. The dashboard represents information for the 376 articles and 1,139 policy scenarios included in the SEM. Users may query the data according to different topics of interest. The dashboard is divided into four sections as described below.

Section 1 is a set of Pie charts displaying the proportion of policy scenarios which report traffic emissions, TRAP, exposures, and health effects and impacts. Click on "Yes" or "No" in each pie chart to filter the studies associated with it as shown in Fig. A.8.

Section 2 is a geographic map which displays the frequency of policy scenarios studied in each country. Click on a country to filter the studies associated with it as shown in Fig. A.9.

Section 3 displays the characteristics selected from a dropdown box. The user can click on specific categories in the dropdown box to filter the studies associated with it as shown in Fig. A.10. The dropdown box lets the user choose a visual based on the following parameters:

1. Policy Interventions: Frequency of each policy intervention reported
2. Pollutants Studied: Frequency of each pollutant reported
3. Health Effects and Impacts: Frequency of each health effect and impact reported
4. Policy Enablers: Frequency of each policy enabler reported
5. Policy Barriers: Frequency of each policy barrier reported
6. Co-benefits: Frequency of each co-benefit reported
7. Analysis Start and End Years: Frequency of each start and end analysis year reported
8. Publication Years: Frequency of articles that were published each year
9. Scientific Journals: Frequency of articles that were published in each scientific journal

Also, in Section 3, on the right is a combination of visuals showing the effect of the selected policy on the traffic emissions and/or ambient concentrations of TRAP for the different pollutants as shown in Fig. A.11. The user can click on a specific direction to filter the studies associated with it (i.e., find the specific policies and studies where reductions, increases, mixed effects or no change in emissions and/or TRAP were recorded for each pollutant or all pollutants).

Section 4 finally lists the articles associated with selected filters in Sections 1 to 3 as shown in Fig. A.12. The user can click on a reference to be redirected to the article page.

The dashboard is hosted on Texas A&M's Transportation Institute's Tableau server: https://tableau.tamu.edu/t/TTI/views/SEMDataVisualizationV2/SEMVisualizationDashboard?:showAppBanner=false&:display_count=n&:showVizHome=n&:origin=viz_share_link.

3.12. *Use of interactive visualization tool to find policy intervention impacts*

This interactive visualization tool can help users dig deeper into the impact of policy interventions on primary outcomes (traffic emissions/TRAP), secondary outcomes (human exposures and health impacts), and explore enablers, barriers, and co-benefits in specific areas. In this section, we will demonstrate two examples. First, we used the dashboard to filter studies which reported TRAP in Section 1 by clicking on "Yes" under the "TRAP Reported" Pie chart. We then clicked on "Poland" in Section 2, and found out that only the policy "vehicle retirement or replacement" was studied in two policy scenarios as shown in Section 3. No health outcomes, policy enablers, barriers or co-benefits were reported on, as shown by selecting the visual to display in the dropdown box in Section 3, and analysis years were 2000 and 2030, in a 2011 publication in Atmospheric Environment. The effect seen in this study was a reduction in ambient concentrations of NO_2 and PM_{10} in both policy scenarios, as shown on the right in Section 3, and no impact on traffic emissions was reported. This was studied in one article: Giannouli et al. (2011), as shown in Section 4. We then clicked on the article in Section 4 and were redirected to its webpage. We found that the authors modeled the impact of a Maximum Feasible Reductions (MFR) scenario which assumes full implementation of the most advanced technical measures to reduce emissions, but their scenario did not consider the retirement of existing equipment before the end of its technical lifetime. This scenario was predicted to reduce NO_2 street increments for narrow canyons from 16 to 53 μg/m^3 (for the reference year) to 7–24 μg/m^3 in the MFR scenario. The corresponding range for PM_{10} was estimated to be 5–15 μg/m^3 for the reference year and 0.2–2.4 μg/m^3 for the MFR scenario. These reductions correspond to 55 %-56 % for NO_2 and for 84 %-96 % PM_{10} in this modeling study. Users can follow these steps to find out more about any policy scenario in any area of interest, including consulting the original paper, to find out about the magnitude of reported impacts.

Second, users can specifically filter studies which show a certain direction of impact on traffic emissions and/or TRAP: reduction, increase, mixed effect, and no change. If users are interested in better understanding what policy scenarios have mixed effects on TRAP, for example, they can directly go to the right panel of Section 3 in the

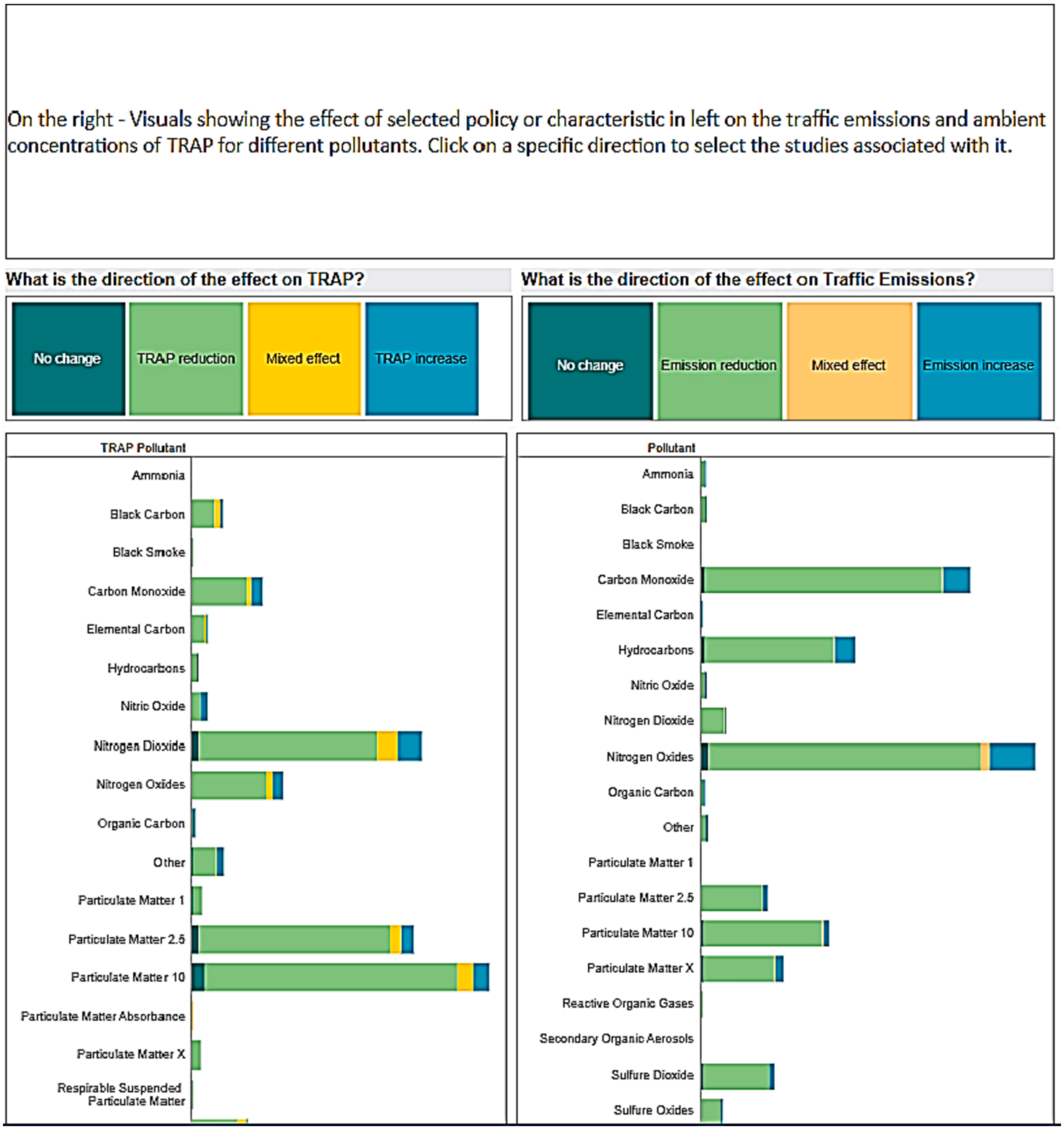

Fig. A11. Screenshot of Section 3 (right panel) of Tableau Dashboard for interactively visualizing the SEM database.

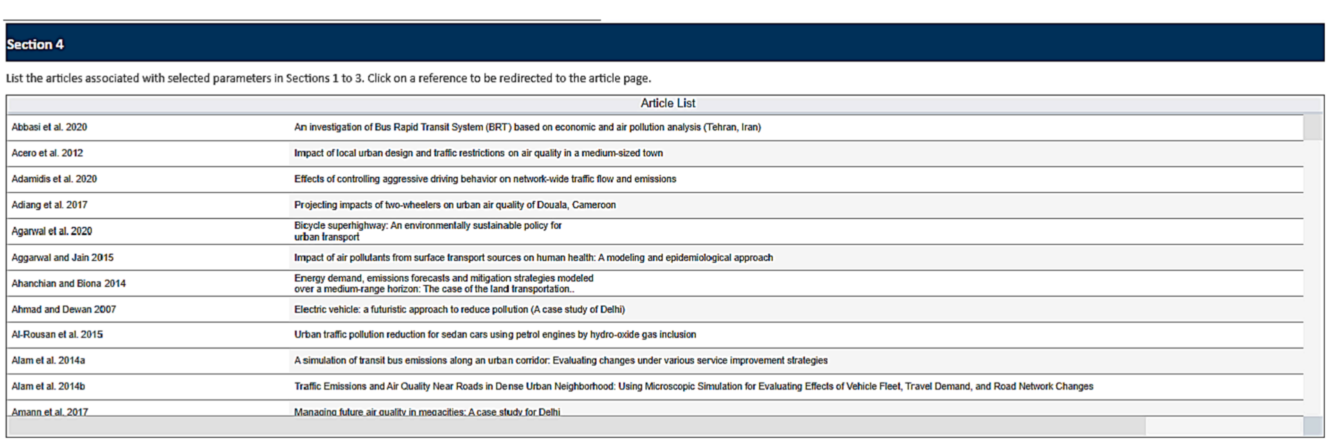

Fig. A12. Screenshot of Section 4 of Tableau Dashboard for interactively visualizing the SEM database.

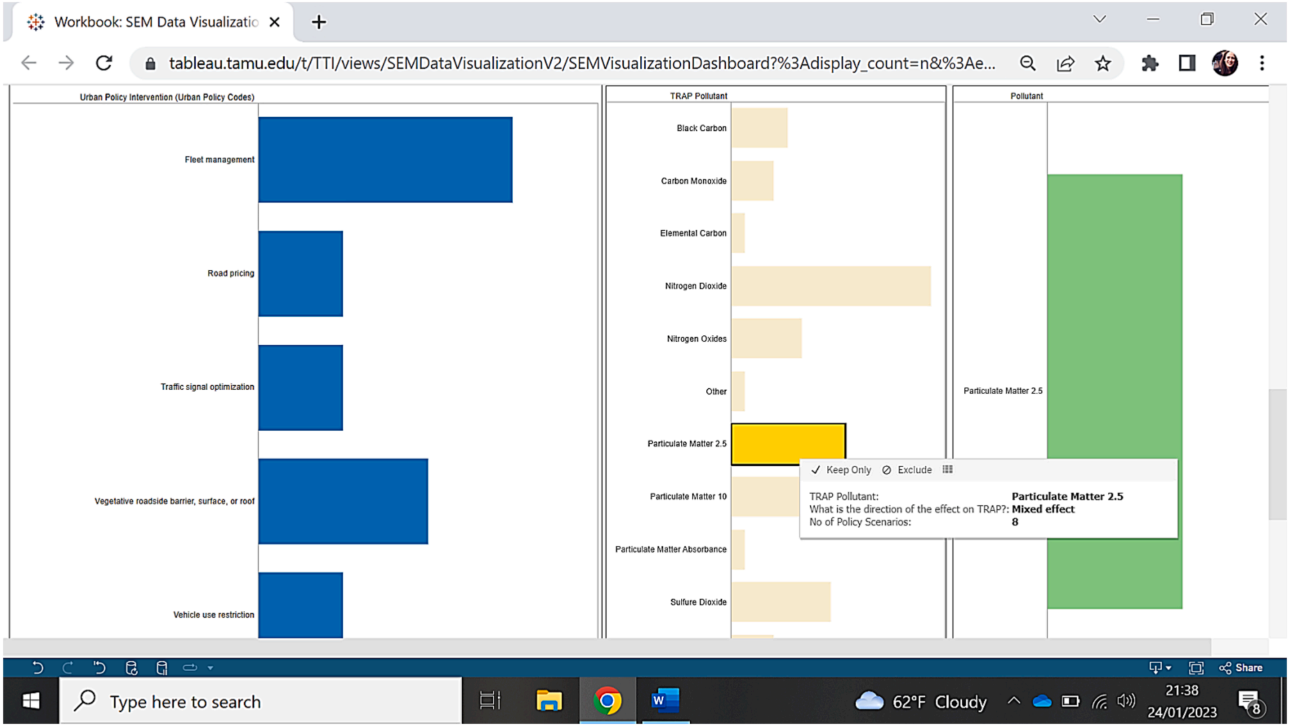

Fig. A13. Screenshot of Filtering of Policy Scenarios which have a Mixed Effect on PM2.5. Scroll down the left panel to show the full list of policy interventions with this impact.

Tableau tool and highlight the mixed effect portion for the pollutant of interest to filter accordingly. For example, highlighting the mixed effect for $PM_{2.5}$ concentrations, shows 8 associated policy scenarios, under 5 policy categories, as shown in Fig. A.13 which are: fleet management (studied 3 times), road pricing (1), traffic signal optimization (1), vegetation (2), and vehicle use restriction (1), which will now be filtered in the left panel of Section 3, and be explored further.

4. Discussion

4.1. Summary and value

Following a published protocol (Sanchez et al., 2020), this SEM synthesizes peer-reviewed studies on urban policy interventions to reduce traffic emissions and/or TRAP from across the globe. The 376 included articles contained within them a total of 1,139 policy scenarios which were examined and characterized in a pre-defined and standardized manner. As such, this SEM:

1. unites a complex and disparate evidence base,
2. facilitates the identification of patterns and gaps in the literature,
3. serves as the foundation for future research, practice, and policy recommendations,
4. provides open-access, query-able and usable products to navigate the results in the format of an Excel database, and an interactive visualization tool. These tools could undergo future development and updates.

Below, we discuss our findings and the strengths and limitations of this work.

4.2. High-level trends and knowledge gaps

Much evidence on this topic has emerged over the last decade and continues to emerge, emphasizing the importance of traffic emission and TRAP mitigation through urban- and city-level policies to combat air pollution and climate change. There were 58 unique policies reported and synthesized which provide a wide range of appropriate options for practitioners and policy makers to consider in their work, including options beyond pre-conceived and trialed ideas or those traditionally deployed in a particular setting. The most frequently studied overarching policy categories were management, standards, and services and then technology while the least studied were behavioral and land-use, indicating research gaps in assessing the impacts of changing behaviors, land-use, and urban development patterns, policies which are long-lasting and can have knock-on impacts.

Notably, there was much less reporting of policy interventions' effects on TRAP (38 %) compared to traffic emissions (78 %). There were even less reports of human exposure (12 %) and health effects or impacts (13 %) in the included studies, indicating that most studies conclude their assessment before assessing human exposure and health implications. Eleven unique articles, or a mere 3 % of articles reported on all elements of the full-chain from traffic emissions, TRAP, human exposures, and health effects or impacts (Khreis, 2020). Increased investigation of human exposures and health effects or impacts in this context is warranted, especially to understand if an emissions reduction policy will ultimately have a beneficial health outcomes.

This relative lack of research and evidence is likely a function of both siloes between transportation and health disciplines in research and practice, as well as the nature of how air quality policy is implemented. While the goal of most air quality improvement policies is to protect and enhance the public's health, it is generally the vehicle emissions that are regulated with the assumption that any emissions reduction will result in a public health improvement. The quantification of health effects or impacts, and their associated economic costs may encourage the adoption of certain policy interventions if they are seen to provide additional incentive beyond environmental improvements of less emissions (or ambient air pollution). In addition, as we show, policies aimed at reducing traffic emissions and TRAP may have mixed effects, no effects, or even increase emissions and concentrations of different pollutants, and our interactive visualization tool allows for their filtering. We found that very few studies utilized measurements, and mostly examined alternative fuel technology, and vehicle emissions regulation. This may be ascribed to the complexity and high costs of measurement campaigns and pre- and post-assessments, and their follow-up, and a lot of the published field is heavily reliant on modeling.

The pollutants studied generally reflected specific markers for traffic activity; for example, NO_x was the pollutant most studied, however, other specific markers like EC, BC, and UFPs are not well-represented in the literature. $PM_{2.5}$, a pollutant with well-established health effects is investigated more than EC and NO_2, which are both emerging as key traffic-related air pollutants, with adverse health effects related to respiratory outcomes in both children and adults, diabetes, and mortality (HEI, 2022). Although traffic emissions and TRAP were predominantly reduced in the policy scenarios studied, the reductions did not result in air quality that always met air quality standards. Some studies may observe improvements in air quality, but air pollution was still above the recommended levels (Taksibi et al., 2020; Tomassetti et al., 2020). Studies also showed emissions and TRAP increases, most notably for NO_x and NO_2, respectively. NO_x emissions and NO_2 concentrations seemed to increase predominantly in studies of alternative fuel technology, speed bump development and intelligent transport systems. It is important to consider that the direction of impacts recorded in the literature may be a result of publication bias where studies showing reduction in traffic emissions and TRAP are more likely to be published, than those showing no changes or increases in these outcomes. We did not formally investigate this issue, but future systematic reviews can.

Another consideration is policy packaging. One-third of policy scenarios were documented as policy packages since the scenario studied the effect of multiple policy interventions at the same time. Different policy combinations may impact traffic emissions and TRAP effects differently than when implemented individually. Such scenarios reflect real-world situations where more than one policy may be implemented in an area at a time; for example, during special events such as the Olympic Games where traffic is anticipated to be much higher than normal in an urban area. Some papers indicated that policy packages tended to be more effective at reducing emissions/TRAP than when policies were considered separately.

Limited evidence was noted for certain policy interventions including vehicle ownership taxes, parking expansion, superblock development, greenspace or blue space, street ventilation, real-time passenger information, stop/start technology, studded tire regulations and vehicle shift. These policy interventions require more research to better understand their effects on traffic emissions and TRAP in an urban setting and may have important implications. For example, passengers using public transit that is often delayed or canceled but are unaware of these disruptions in real-time due to the absence of real-time passenger information may eventually switch to modes with better information and reliability, or where they may have more control over their schedules, such as taxis or private vehicles.

Regarding geographic location, policy interventions were studied least in Africa and Australia. At the country-level, Jordan, Qatar, Cameroon, Czech Republic, Hungary, and Slovenia were studied the least, highlighting a gap in Middle Eastern, Africa and Eastern European urban areas. Most of the literature comes from Asia, Northern Europe, and North America. This is in line with the research on the health effects of TRAP which remains very limited in Africa and the Middle East (HEI, 2022). This is even though most population growth, urbanization and motorization will occur in low- and middle-income countries. Most population growth is currently occurring in China and India, while most projected increases are expected in Africa (Democratic Republic of the Congo, Egypt, Ethiopia, Nigeria, and the United Republic of Tanzania) (United Nations Department of Economic and Social Affairs, 2022). Also, currently, countries in Asia, Africa, and the Middle East experience the highest ambient $PM_{2.5}$ concentrations (HEI, 2020).

Enablers to policy intervention implementation were reported far less frequently than barriers. Potential explanations for this may be that barriers are more easily identifiable, more prominent in policy discourse, or authors may be more willing or interested to report on barriers rather than enablers. Certain enablers, whilst important, are completely missing from this SEM including behavioral, knowledge and skills, legislation, and land-use. GHG emissions/climate change mitigation was the single most reported co-benefit, highlighting its importance in current discourse and its intersection with emissions and air pollution reduction goals. Climate change is expected to further worsen air quality, where increasing intensity and frequency of heat waves and stagnant air can result in poorer air quality and increase susceptibility and adverse health effects. These trends and associated individual studies, and their findings, can be explored in more detail through the supplementary tools developed in this research.

4.3. Limitations

This work has some limitations, some attributable to the high volume of journal articles returned in this area in comparison to other systematic review or evidence mapping efforts. First, study screening was not fully conducted in duplicates due to time and resource restrictions. Only a random 20 % of studies were screened in duplicate, and any disagreements were resolved through a third author. This is in line with our published protocol (Sanchez et al., 2020). KS and HK reviewed the screening process and the data extraction and coding process at the outset and selected papers were reviewed together to ensure all processes were well-defined and agreed upon. We indicated which articles were among the 20 % screened in duplicate at the title and abstract level and full-text level, and we provided the agreement rate across those articles in the Supplementary Material (Table S.4 and Table S.5). Agreement rate was high at the title and abstract level (92.80 %), and relatively lower at the full-text level (88.50 %), with a general trend that KS, the primary reviewer, was more inclusive which indicates a good chance that we did not exclude many studies that should have been included. There were 14 conflicts between KS and HK at the full-text level, 10 of those which KS included but HK chose to exclude (JB decision of these studies was to include 1 and exclude 9). The other 4 studies KS excluded but HK chose to include (JB decision of these studies was to include 1 and exclude 3). These discrepancies were discussed upon identification and the reasons for discrepancies were identified and understood in the hope of a better agreement with future screening. However, this does not eliminate the exclusion of studies which should have been included and is a key limitation of not conducting the screening in duplicates. In addition, as explained in the "literature search" section, we did not attempt to find articles from reference lists, other projects and expert knowledge, and the CARTEEH Literature Library (https://www.carteeh.org/carteeh-literature-library/), a minor deviation from our published protocol (Sanchez et al., 2020). We also plan on doing this in future iterations, which would capture studies that were not captured in our literature search such as Woodcock et al. (2009).

We also excluded gray literature (i.e., books, book chapters, reports, etc.) from our search, due to time and resource limitations, and the large number of returned records (Fig. A.1). Although in line with our published protocol (Sanchez et al., 2020), we acknowledge that this limits the comprehensiveness of this SEM as relevant reports were not considered. In addition, it may exacerbate the potential impact of publication bias which may be less pronounced in the gray literature compared to peer-reviewed journal publications. In line with our protocol, there was no quality assessment of the included studies although the purpose of this SEM was not compromised (Sanchez et al., 2020). Users of our Excel database and interactive visualization tool are recommended to critically assess study methods and findings before applying study findings to their cases of interest. Our last searches were in June 2020. The increasing number of studies in recent years suggests a need to update this SEM periodically to capture new urban policy interventions and understand their impacts in a proactive manner which could benefit policy and practice. While already slightly outdated, the explicit, detailed, and transparent reporting of our methods, and our open-access Excel database, can facilitate updates to this SEM in the future, and we are attempting to secure required resources for this endeavor.

Our database was produced in Excel format rather than a "relational" database that might identify connections between data more efficiently – this was due to time, resource, and skill limitations. However, we think potential users will be more familiar with Excel and how to navigate it/ perform different functions compared to a relational database. We complemented the Excel database with an interactive visualization tool which enables easier and more visual identification of underlying data and trends. There is also some overlap with categories in the Excel database which may lend itself to a distorted picture of the evidence. For example, non-methane hydrocarbons are technically both a HC and a VOC but were documented as only a HC in the database due to Excel limitations and for simplicity. Although there is not much overlap like the one just described, it is important to note this for users who may come across it.

Also importantly, it is difficult to differentiate which specific policy interventions impacted the reported effects of traffic emissions and TRAP when these policy interventions were studied simultaneously within a single scenario (i.e. in a policy package). For example, Boogaard et al. 2013 considers two interventions (a low emission zone: LEZ and a vehicle rerouting: VRR) in one scenario (i.e., policies were considered together or packaged). The authors reported TRAP reductions for five pollutants and other elements of PM_{10} which were considered and lumped under the PM_{10} category. The paper did not directly associate the reductions recorded to the specific policies so the impact and its magnitude per policy is unknown. It is difficult to discern from this paper whether LEZ or VRR were primarily responsible for reductions and in which specific pollutants. This is similar to other papers in the database. Another example is Xu et al. (2017), who investigated Nickel as a subset of $PM_{2.5}$ and reported on the overall impact of policy packages including traffic- and non-traffic related instruments, and therefore did not directly associate $PM_{2.5}$ (and nickel) reductions to specific policies. As such, our database is limited by its underlying studies and the format by which their data was reported.

The lumping of Nickel under $PM_{2.5}$ and the PM_{10} elements (Chromium (Cr), Copper (Cu) and Iron (Fe)) under the PM_{10} category in the way we coded for Xu et al. (2017) and Boogaard et al. (2013) is also limited and something which was only highlighted in the peer review process. This again highlights the limitation of conducting the data extraction by one, and not two independent, reviewers. We decided to keep the $PM_{2.5}$ and PM_{10} categories only and not add the specific elements in separate categories as the lumped coding of PM's elemental components is likely to have been used by KS in other studies which similarly reported elements of PM separately. As we do not have the capacity now to go back, identify and double check the data extraction for each study, we kept the coding as it is and noted this in our amendments. We will revisit this issue in future iterations and developments of this database, in a manner consistent across studies. Three authors reviewed 20 % of the coded data for consistency. The noted discrepancies were shared and discussed with KS to achieve a resolution and an understanding to be applied to future similar instances, however, the reorientation was done after issues were identified. The independent data extraction showed the following as the most recurrent discrepancies: the categorization of studies as measurement, modelling, or both, with increasing the latter category as many studies included an element of both measurements and modelling, a discussion of what sample size means, as in some cases studies sampled not only human population, but trips, trip plans in travel surveys, vehicle numbers and others, which likely resulted in gaps in studies screened earlier than this discussion, missing some reported scenarios and pollutants, missing co-benefits, and an instance where health impacts from air pollution and physical activity in the same article were conflated. The prevalence of these discrepancies and errors is unknown in this map, in addition to other potentially unidentified errors and trends, which further strength the need of duplicate data extraction in the future.

4.4. Strengths

Nonetheless, our SEM provides a valuable picture of the evidence base, searching a variety of databases and producing open-access user-friendly outputs aimed at researchers, practitioners, and policy makers. We followed a published protocol and adhered to it with very minor amendments listed in full in Table S.8 in the Supplementary Material. If there were uncertainties during study screening for any of the 80 % of articles that were not screened in duplicate, another author (HK) was consulted. This allowed for a structured way of discussing any unclear cases with another reviewer and added an extra level of certainty for difficult articles that did not fall within the 20 % of articles screened in duplicate, although does not fully address the limitations of screening and conducting the data extraction by one, rather than two independent reviewers. Discrepancies for data coding were resolved through consensus between KS and three reviewers (HK, TR, JB). We also included "Raw data'' columns in the Excel database as evidence to why certain codes were listed (for example, urban policy interventions have a raw data column in addition to the column with codes so users can have a better understanding of the policy/policies that were coded in the original authors' language). This raw data column provides more detail and nuance to the users.

This SEM can address some of the principal weaknesses in policy option generation and selection: an over-reliance on preconceived ideas; an unwillingness to consider measures for which the responsibility lies with other bodies; a tendency to consider measures which are more easily funded or more likely to be acceptable; a resulting focus on supply-side measures such as infrastructure and management rather than demand-side measures such as regulation and pricing; a lack of awareness of the wider range of policy measures available; and a lack of evidence of the performance of those measures in other contexts (May et al., 2018). This work follows and furthers our previous work which qualitatively and non-systematically assessed the potential health impacts of different transport policies (Khreis et al., 2017b). In this work, however, we focus on one of the pathways between transport and health (Glazener et al., 2021), TRAP, which allows us a much more detailed assessment and the inclusion of some information about effectiveness from global case studies.

4.5. Recommendations for future work

Future works might address items that were beyond the scope of the current SEM. For example, this SEM excluded articles that were proxies for policy interventions like COVID-19 lockdowns (Sharma et al., 2020; Sicard et al., 2020), but we, however, are systematically reviewing these elsewhere with a focus on air pollution changes in low- and middle-income countries (Navaratnam et al., 2022). Additionally, several articles exclusively investigated policy intervention effects on GHG; a secondary item of interest (Souche-Le Corvec et al., 2019). And several articles exclusively focused on exposure and health effects (Estrella et al., 2019), or impacts (secondary outcomes) as related to traffic emissions and TRAP so did not meet our criteria of reporting on our primary outcomes. While these studies were beyond our pre-defined scope, such articles still provide valuable information for traffic emission and TRAP reduction potential as well as exposure and health benefits. Another item for future works to consider is policy intervention disbenefits (i.e., decreased speed, increased GHG, and increased fuel consumption, increase of the cumulative commute time, or reducing the supply for public transport). While this SEM captured co-benefits including GHG reduction and climate change mitigation, reduced travel time, reduced travel congestion, increased safety, etc., various disbenefits were observed within the included studies. However, since disbenefits were beyond the scope of the SEM, disbenefits were not documented. Finally, the Excel database and the interactive visualization tool can be piloted amongst potential users and improved accordingly.

We encourage practitioners and policy makers to use the resulting Excel database and the interactive visualization tool to explore intervention options that can be implemented in their urban areas, including options that they may have been previously unaware of, and explore primary outcomes (traffic emissions/TRAP), secondary outcomes (human exposures and health impacts), and items of interest (for example, what co-benefits might be expected when a particular policy intervention is implemented? What enablers and barriers may impact transferability potential?).

From a research perspective, users can explore the current state of the evidence and formulate future (and more specific) research questions, understand trends (for example, a researcher can use the SEM to understand which interventions/outcomes have been studied most frequently and decide if there is enough evidence available to conduct a systematic review on a particular intervention), and gaps in the literature (for example, a researcher can identify if data is lacking for a certain intervention/outcome). Of importance, only 3 % of the included articles report on all elements of the full-chain (traffic emissions, TRAP, human exposures, and health impacts) which is a gap to fill in and of itself.

A specific set of tasks to improve this work in the short to medium term are:

1. Searching and including eligible studies from reference lists, other projects and expert knowledge, and the CARTEEH Literature Library,
2. Updating the literature searches based on published methods,
3. Documenting disbenefits or unintended consequences,
4. Increasing the percentage of titles and abstracts and full-text papers screened in duplicates and providing new agreement rates,
5. Increasing the percentage of data extraction conducted in duplicates and providing new agreement rates and details on disagreement,
6. Adding new pollutant categories for subsets of PM such as the elements of Ni, Cr, Cu and Fe,
7. Incorporating feedback from potential users and stakeholders.

In the longer term, extracting and documenting the ranges of emissions, TRAP and GHG reductions is recommended. This will enable assigning numerical values as an indication of the effectiveness of different interventions. In addition, assessing the quality of individual studies and the potential for publication bias may be insightful.

5. Conclusion

This SEM represents the results of a challenging exercise to systematize our understanding of which urban transport policies impact traffic emissions, TRAP, exposures, and human health. Our findings provide valuable insight into the literature on urban policies to reduce traffic emissions and TRAP. A total of 1,139 policy scenarios across 376 identified articles were included in the SEM and an open-access Excel database. 58 unique policies were considered and encompass pricing, land-use, infrastructure, behavioral, technology, and management, standards, and services categories. A general finding was that while there are several policies implemented or studied in urban areas that are expected to reduce emissions, and in turn reduce TRAP and improve health outcomes, the associated evidence varies. We found that the body of evidence reduces as we go down the full-chain between emissions, TRAP, exposures, and health impacts. This is a likely related to how the transport sector is mostly regulated based on traffic emissions, and that both pre-implementation and post-implementation studies of effectiveness, and follow-up for health outcomes, are very complex, costly and rare. Several of the findings similarly reinforce where gaps remain. Often the types of strategies that are more interdisciplinary in nature, such as behavioral and land use strategies, are neglected in favor of supply-side measures usually implemented by transport authorities. We also noted gaps in regional coverage of studies, indicating a mismatch between where investigation is most needed (i.e., rapidly urbanizing middle- and low-income nations), and where the studies are currently focused on. To our knowledge, this work is the first of its kind to establish the scope of literature around transport emissions, and TRAP reduction policies and to help answer the question of which ones are shown to meaningfully reduce emissions, improve air quality, and reduce exposures and health impacts. While the volume of studies in this field limited the recency of studies included, and excluded gray literature, the findings, coupled with the user-friendly dissemination tools will remain a valuable resource for academics and practitioners alike.

6. Amendments

This SEM follows a previously published protocol (https://doi.org/10.1016/j.envint.2020.105826). All specific amendments, including the date of each amendment and a description of the change to this SEM, were documented, and are reported in the Supplementary Material (Table S.8).

7. Author statement

HK is the guarantor and conceived the idea of this SEM. HK and KS designed and drafted this SEM paper. MF conducted the literature searches. KS (100 %), HK (10 %), and JB (10 %) screened studies against eligibility criteria. KS (100 %) completed data extraction and coding for the Excel database. HK (7 %), TR (7 %), and JB (7 %) reviewed data extraction and coding. HK and KS analyzed the extracted data. RJ created the interactive data visualization tool. All authors read, provided feedback, and approved the final manuscript.

8. Contributions

HK is the guarantor and conceived the idea of this SEM. HK and KS designed and drafted this SEM paper. MF conducted the literature searches. KS (100 %), HK (10 %), and JB (10 %) screened studies against eligibility criteria. KS (100 %) completed data extraction and coding for the Excel database. HK (7 %), TR (7 %), and JB (7 %) reviewed data extraction and coding. HK and KS analyzed the extracted data. RJ created the interactive data visualization tool. All authors read, provided feedback, and approved the final manuscript.

Funding

This work was conducted with support from the Texas A&M Transportation Institute's Center for Advancing Research in Transportation Emissions, Energy, and Health, a U.S. Department of Transportation's University Transportation Center, College Station, TX. The grant number is 69A3551747128. More information about the Center for Advancing Research in Transportation Emissions, Energy, and Health is available at https://www.carteeh.org/.

Haneen Khreis received funding from the European Research Council (ERC) under the Horizon 2020 research and innovation programme. The grant agreement number is 817754. This material reflects only the authors' views, and the Commission is not liable for any use that may be made of the information contained therein.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Data availability

All data used is in the supplementary material of this article.

Acknowledgements

We would like to thank Anthony May for providing policy expertise and contribution to the protocol and the overall direction of this work over the years, Pam Flanagan for retrieving and importing full-text articles into Covidence for full-text screening, Harry Williams for assisting HK with an ad-hoc review of data extraction, and Paul Whaley and Taylor Wolffe for their constructive and thoughtful comments throughout this project.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envint.2023.107805.

References

Baik, J.-J., Kwak, K.-H., Park, S.-B., Ryu, Y.-H., 2012. Effects of building roof greening on air quality in street canyons. Atmos. Environ. 61, 48–55. https://doi.org/10.1016/j.atmosenv.2012.06.076.

Beelen, R., Raaschou-Nielsen, O., Stafoggia, M., Andersen, Z.J., Weinmayr, G., Hoffmann, B., Wolf, K., Samoli, E., Fischer, P., Nieuwenhuijsen, M., Vineis, P., Xun, W.W., Katsouyanni, K., Dimakopoulou, K., Oudin, A., Forsberg, B., Modig, L., Havulinna, A.S., Lanki, T., Turunen, A., Oftedal, B., Nystad, W., Nafstad, P., De Faire, U., Pedersen, N.L., Östenson, C.-G., Fratiglioni, L., Penell, J., Korek, M., Pershagen, G., Eriksen, K.T., Overvad, K., Ellermann, T., Eeftens, M., Peeters, P.H., Meliefste, K., Wang, M., Bueno-de-Mesquita, B., Sugiri, D., Krämer, U., Heinrich, J., de Hoogh, K., Key, T., Peters, A., Hampel, R., Concin, H., Nagel, G., Ineichen, A., Schaffner, E., Probst-Hensch, N., Künzli, N., Schindler, C., Schikowski, T., Adam, M., Phuleria, H., Vilier, A., Clavel-Chapelon, F., Declercq, C., Grioni, S., Krogh, V., Tsai, M.-Y., Ricceri, F., Sacerdote, C., Galassi, C., Migliore, E., Ranzi, A., Cesaroni, G., Badaloni, C., Forastiere, F., Tamayo, I., Amiano, P., Dorronsoro, M., Katsoulis, M., Trichopoulou, A., Brunekreef, B., Hoek, G., 2014. Effects of long-term exposure to air pollution on natural-cause mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project. Lancet 383, 785–795. https://doi.org/10.1016/S0140-6736(13)62158-3.

Belanger, K., Gent, J.F., Triche, E.W., Bracken, M.B., Leaderer, B.P., 2006. Association of Indoor Nitrogen Dioxide Exposure with Respiratory Symptoms in Children with Asthma. Am. J. Respir. Crit. Care Med. 173, 297–303. https://doi.org/10.1164/rccm.200408-1123OC.

Bigazzi, A.Y., Rouleau, M., 2017. Can Traffic Management Strategies Improve Urban Air Quality? A Review of the Evidence. J. Transp. Heal. 7, Part B, 111–124. https://doi.org/10.1016/j.jth.2017.08.001.

Boogaard, H., Fischer, P.H., Janssen, N.A.H., Kos, G.P.A., Weijers, E.P., Cassee, F.R., van der Zee C., S., de Hartog J., J., Meliefste, K., Wang, M., Brunekreef, B., Hoek, G., 2013. Respiratory effects of a reduction in outdoor air pollution concentrations. Epidemiology 24, 753–761. 10.1097/EDE.0b013e31829e1639.

Bradley, N., Dobney, A., Exley, K., Stewart-Evans, J., Aldridge, S., Craswell, A., Dimitroulopoulou, S., Hodgson, G., Izon-Cooper, L., Mitchem, L., Mitsakou, C., Robertson, S., 2019. Review of interventions to improve outdoor air quality and public health.

Brandt, S., Perez, L., Künzli, N., Lurmann, F., Wilson, J., Pastor, M., McConnell, R., 2014. Cost of near-roadway and regional air pollution–attributable childhood asthma in Los Angeles County. J. Allergy Clin. Immunol. 134, 1028–1035. https://doi.org/10.1016/j.jaci.2014.09.029.

Brandt, S.J., Perez, L., Künzli, N., Lurmann, F., McConnell, R., 2012. Costs of childhood asthma due to traffic-related pollution in two California communities. Eur. Respir. J. 40, 363–370. https://doi.org/10.1183/09031936.00157811.

Burns, J., Boogaard, H., Polus, S., Pfadenhauer, L.M., Rohwer, A.C., van Erp, A.M., Turley, R., Rehfuess, E., Pfadenhauer, L.M., van Erp, A.M., Rohwer, A.C., Rehfuess, E., 2019. Interventions to reduce ambient particulate matter air pollution and their effect on health. Cochrane Database Syst. Rev. 63, 17–28. https://doi.org/10.1002/14651858.CD010919.

Cape, J.N., Tang, Y.S., van Dijk, N., Love, L., Sutton, M.A., Palmer, S.C.F., 2004. Concentrations of ammonia and nitrogen dioxide at roadside verges, and their contribution to nitrogen deposition. Environ. Pollut. 132, 469–478. https://doi.org/10.1016/j.envpol.2004.05.009.

Castro, H.A. de, Cunha, M.F. da, Mendonça, G.A. e S., Junger, W.L., Cunha-Cruz, J., Leon, A.P. de, 2009. Effect of Air Pollution on Lung Function in Schoolchildren in Rio De Janeiro, Brazil. Rev. Saude Publica 43, 26–34. 10.1590/S0034-89102009000100004.

Center for Advancing Research in Transportation Emissions Energy and Health, 2020. CARTEEH Data Hub [WWW Document]. URL https://carteehdata.org/.

Chen, L., Omaye, S.T., 2001. Air Pollution and Health Effects in Northern Nevada. Rev. Environ. Health 16. https://doi.org/10.1515/REVEH.2001.16.2.133.

Conlan, B., Fraser, A., Vedrenne, M., Tate, J., Whittles, A., 2016. Evidence review on effectiveness of transport measures in reducing nitrogen dioxide: exploring and apprasing proposed measures to tackle air quality, Department for Environment Food and Rural Affairs.

Dennenkamp, M., Mehenni, O.H., Cherrie, J.W., Seaton, A., 2002. Exposure to Ultrafine Particles and PM2.5 in Different Micro-environments. Ann. Occup. Hyg. 46, 412–414. https://doi.org/10.1093/annhyg/mef702.

Dey, S., Caulfield, B., Ghosh, B., 2018. Potential health and economic benefits of banning diesel traffic in Dublin, Ireland. J. Transp. Health 10, 156–166.

Durbin, T.D., Wilson, R.D., Norbeck, J.M., Miller, J.W., Huai, T., Rhee, S., 2001. Emissions of Ammonia From Light Duty Vehicles, in: 10th International Emission Inventory Conference. United States Environmental Protection Agency, Denver.

EBSCO, n.d. Public Affairs Index: EBSCO [WWW Document]. URL https://www.ebsco.com/products/research-databases/public-affairs-index Estrella, B., Sempértegui, F., Franco, O.H., Cepeda, M., Naumova, E.N., 2019. Air pollution control and the occurrence of acute respiratory illness in school children of Quito, Ecuador. J. Public Health Policy 40, 17–34. 10.1057/s41271-018-0148-6.

Estrella, B., Sempértegui, F., Franco, O.H., Cepeda, M., Naumova, E.N., 2019. Air pollution control and the occurrence of acute respiratory illness in school children of Quito. Ecuador. J. Public Health Policy 40, 17–34. https://doi.org/10.1057/s41271-018-0148-6.

European Commission, 2019. Air Quality Standards [WWW Document]. URL https://ec.europa.eu/environment/air/quality/standards.htm.

European Environment Agency, 2016. European Environment Agency: Explaining road transport emissions. 10.2800/71804.

Fagnant, D.J., Kockelman, K.M., 2014. The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. Transport. Res. Part C: Emerg. Technol. 40, 1–13.

Frosina, E., Romagnuolo, L., Bonavolontà, A., Andreozzi, A., Senatore, A., Fortunato, F., Giliberti, P., 2018. Evaporative emissions in a fuel tank of vehicles: Numerical and experimental approaches. Energy Procedia 148, 1167–1174. https://doi.org/10.1016/j.egypro.2018.08.025.

Giannouli, M., Kalognomou, E.A., Mellios, G., Moussiopoulos, N., Samaras, Z., Fiala, J., 2011. Impact of European emission control strategies on urban and local air quality. Atmos. Environ. 45 (27), 4753–4762.

Glazener, A., Sanchez, K., Ramani, T., Zietsman, J., Nieuwenhuijsen, M.J., Mindell, J.S., Fox, M., Khreis, H., 2021. Fourteen pathways between urban transportation and health: A conceptual model and literature review. J. Transp. Health 21, 101070.

Guarnieri, M., Balmes, J.R., 2014. Outdoor air pollution and asthma. Lancet 383, 1581–1592. https://doi.org/10.1016/S0140-6736(14)60617-6.

Hannan, M.A., Azidin, F.A., Mohamed, A., 2014. Hybrid electric vehicles and their challenges: A review. Renew. Sustain. Energy Rev. 29, 135–150. https://doi.org/10.1016/j.rser.2013.08.097.

Health Effects Institute, H. E. I. (2022). Health Effects Institute Panel on the Health Effects of Long-Term Exposure to Traffic-Related Air Pollution. Systematic Review and Meta-analysis of Selected Health Effects of Long-Term Exposure to Traffic-Related Air Pollution. Special Report 23. Boston, MA: Health Effects Institute.

Henschel, S., Atkinson, R., Zeka, A., Tertre Le, A., Analitis, A., Katsouyanni, K., Chanel, O., Pascal, M., Forsberg, B., Medina, S., Goodman, P.G., 2012. Air pollution interventions and their impact on public health. Int. J. Public Health 57, 757–768. https://doi.org/10.1007/s00038-012-0369-6.

Heydari, S., Tainio, M., Woodcock, J., de Nazelle, A., 2020. Estimating traffic contribution to particulate matter concentration in urban areas using a multilevel Bayesian meta-regression approach. Environ. Int. 141, 105800.

Hitchcock, G., Conlan, B., Kay, D., Brannigan, C., Newman, D., 2014. Air Quality and Road Transport: Impacts and Solutions.

Holman, C., Harrison, R., Querol, X., 2015. Review of the efficacy of low emission zones to improve urban air quality in European cities. Atmos. Environ. 111, 161–169. https://doi.org/10.1016/j.atmosenv.2015.04.009.

Karagulian, F., Belis, C.A., Dora, C.F.C., Prüss-Ustün, A.M., Bonjour, S., Adair-Rohani, H., Amann, M., 2015. Contributions to cities' ambient particulate matter (PM): A systematic review of local source contributions at global level. Atmos. Environ. 120, 475–483.

Khreis, H., 2020. Traffic, air pollution, and health. In: Nieuwenhuijsen, M.J., Khreis, H. (Eds.), Advances in Transportation and Health. Elsevier.

Khreis, H., Kelly, C., Tate, J., Parslow, R., Lucas, K., Nieuwenhuijsen, M., 2017a. a. Exposure to traffic-related air pollution and risk of development of childhood asthma: A systematic review and meta-analysis. Environ. Int. 100, 1–31. https://doi.org/10.1016/j.envint.2016.11.012.

Khreis, H., May, A., Nieuwenhuijsen, M., 2017b. b. Health impacts of urban transport policy measures: A guidance note for practice. J. Transp. Health 6, 209–227.
Kura, B., Verma, S., Ajdari, E., Iyer, A., 2013. Growing Public Health Concerns from Poor Urban Air Quality: Strategies for Sustainable Urban Living. Comput. Water, Energy. Environ. Eng. 02, 1–9. https://doi.org/10.4236/cweee.2013.22b001.
Loxham, M., Davies, D.E., Holgate, S.T., 2019. The health effects of fine particulate air pollution. BMJ l6609. 10.1136/bmj.l6609.
Luben, T.J., Nichols, J.L., Dutton, S.J., Kirrane, E., Owens, E.O., Datko-Williams, L., Madden, M., Sacks, J.D., 2017. A systematic review of cardiovascular emergency department visits, hospital admissions and mortality associated with ambient black carbon. Environ. Int. 107, 154–162. https://doi.org/10.1016/j.envint.2017.07.005.
MacIntyre, E.A., Gehring, U., Mölter, A., Fuertes, E., Klümper, C., Krämer, U., Quass, U., Hoffmann, B., Gascon, M., Brunekreef, B., Koppelman, G.H., Beelen, R., Hoek, G., Birk, M., de Jongste, J.C., Smit, H.A., Cyrys, J., Gruzieva, O., Korek, M., Bergström, A., Agius, R.M., de Vocht, F., Simpson, A., Porta, D., Forastiere, F., Badaloni, C., Cesaroni, G., Esplugues, A., Fernández-Somoano, A., Lerxundi, A., Sunyer, J., Cirach, M., Nieuwenhuijsen, M.J., Pershagen, G., Heinrich, J., 2014. Air Pollution and Respiratory Infections during Early Childhood: An Analysis of 10 European Birth Cohorts within the ESCAPE Project. Environ. Health Perspect. 122, 107–113. https://doi.org/10.1289/ehp.1306755.
Malina, C., Scheffler, F., 2015. The impact of Low Emission Zones on particulate matter concentration and public health. Transp. Res. A Policy Pract. 77, 372–385.
May, A.D., Khreis, H., Mullen, C., 2018. Option generation for policy measures and packages: An assessment of the KonSULT knowledgebase. Case Studies Transport Policy 6, 311–318.
McDuffie, E.E., Martin, R.V., Spadaro, J.V., Burnett, R., Smith, S.J., O'Rourke, P., Hammer, M.S., van Donkelaar, A., Bindle, L., Shah, V., Jaeglé, L., 2021. Source sector and fuel contributions to ambient PM2. 5 and attributable mortality across multiple spatial scales. Nat. Commun. 12 (1), 1–12.
McDuffie, E.E., Smith, S.J., O'Rourke, P., Tibrewal, K., Venkataraman, C., Marais, E.A., Zheng, B., Crippa, M., Brauer, M., Martin, R.V., 2020. A global anthropogenic emission inventory of atmospheric pollutants from sector-and fuel-specific sources (1970–2017): an application of the Community Emissions Data System (CEDS). Earth Syst. Sci. Data 12 (4), 3413–3442.
Mediavilla-Sahagun, A., ApSimon, H.M., 2003. Urban scale integrated assessment of options to reduce PM10 in London towards attainment of air quality objectives. Atmos. Environ. 37, 4651–4665. https://doi.org/10.1016/j.atmosenv.2003.07.004.
Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., 2009. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med. 6, e1000097.
Navaratnam, A., Williams, H. & Khreis, H. 2022. Determining transportation contribution to air pollutants in low- and middle-income countries: a systematic review on the impact of COVID-19 restrictions. PROSPERO 2022 CRD42022326924 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42022326924 [Online]. [Accessed].
Nelson, P., Safirova, E., Walls, M., 2007. Telecommuting and environmental policy: Lessons from the ecommute program. Transp. Res. Part D: Transp. Environ. 12, 195–207.
Nishimura, K.K., Galanter, J.M., Roth, L.A., Oh, S.S., Thakur, N., Nguyen, E.A., Thyne, S., Farber, H.J., Serebrisky, D., Kumar, R., Brigino-Buenaventura, E., Davis, A., LeNoir, M.A., Meade, K., Rodriguez-Cintron, W., Avila, P.C., Borrell, L.N., Bibbins-Domingo, K., Rodriguez-Santana, J.R., Sen, Ś., Lurmann, F., Balmes, J.R., Burchard, E.G., 2013. Early-Life Air Pollution and Asthma Risk in Minority Children. The GALA II and SAGE II Studies. Am. J. Respir. Crit. Care Med. 188, 309–318. https://doi.org/10.1164/rccm.201302-0264OC.
Nurmagambetov, T., Kuwahara, R., Garbe, P., 2018. The Economic Burden of Asthma in the United States, 2008–2013. Ann. Am. Thorac. Soc. 15, 348–356. https://doi.org/10.1513/AnnalsATS.201703-259OC.
Onat, B., Stakeeva, B., 2013. Personal exposure of commuters in public transport to PM2.5 and fine particle counts. Atmos. Pollut. Res. 4, 329–335. https://doi.org/10.5094/APR.2013.037.
Pedersen, M., Giorgis-Allemand, L., Bernard, C., Aguilera, I., Andersen, A.-M.-N., Ballester, F., Beelen, R.M.J., Chatzi, L., Cirach, M., Danileviciute, A., Dedele, A., van Eijsden, M., Estarlich, M., Fernández-Somoano, A., Fernández, M.F., Forastiere, F., Gehring, U., Grazuleviciene, R., Gruzieva, O., Heude, B., Hoek, G., de Hoogh, K., van den Hooven, E.H., Håberg, S.E., Jaddoe, V.W.V., Klümper, C., Korek, M., Krämer, U., Lerchundi, A., Lepeule, J., Nafstad, P., Nystad, W., Patelarou, E., Porta, D., Postma, D., Raaschou-Nielsen, O., Rudnai, P., Sunyer, J., Stephanou, E., Sørensen, M., Thiering, E., Tuffnell, D., Varró, M.J., Vrijkotte, T.G.M., Wijga, A., Wilhelm, M., Wright, J., Nieuwenhuijsen, M.J., Pershagen, G., Brunekreef, B., Kogevinas, M., Slama, R., 2013. Ambient air pollution and low birthweight: a European cohort study (ESCAPE). Lancet Respir. Med. 1, 695–704. https://doi.org/10.1016/S2213-2600(13)70192-9.
Perrino, C., Catrambone, M., Bucchianico, A.D.M.D., 2003. Gaseous Ammonia From Traffic Emissions In The Urban Area Of Rome. Adv. air Pollut. Ser. 601–609 https://doi.org/10.2495/AIR030591.
Perrino, C., Catrambone, M., Di Menno Di Bucchianico, A., Allegrini, I., 2002. Gaseous ammonia in the urban area of Rome, Italy and its relationship with traffic emissions. Atmos. Environ. 36, 5385–5394. 10.1016/S1352-2310(02)00469-7.
Rodrigues, P., Alvim-Ferraz, M., Martins, F., Saldiva, P., Sá, T., Sousa, S., 2020. Health economic assessment of a shift to active transport. Environ. Pollut. 258, 113745.
Roy, A., Sheffield, P., Wong, K., Trasande, L., 2011. The Effects of Outdoor Air Pollutants on the Costs of Pediatric Asthma Hospitalizations in the United States, 1999 to 2007. Med. Care 49, 810–817. https://doi.org/10.1097/MLR.0b013e31820fbd9b.
Roy, R. and N. Braathen (2017), The Rising Cost of Ambient Air Pollution thus far in the 21st Century: Results from the BRIICS and the OECD Countries, OECD Environment Working Papers, No. 124, OECD Publishing, Paris, 10.1787/d1b2b844-en.
Rubin, J.I., Kean, A.J., Harley, R.A., Millet, D.B., Goldstein, A.H., 2006. Temperature dependence of volatile organic compound evaporative emissions from motor vehicle. J. Geophys. Res. Atmos. 111, 1–7. https://doi.org/10.1029/2005JD006458.
Sanchez, K.A., Foster, M., Nieuwenhuijsen, M.J., May, A.D., Ramani, T., Zietsman, J., Khreis, H., 2020. Urban policy interventions to reduce traffic emissions and traffic-related air pollution: Protocol for a systematic evidence map. Environ. Int. 142, 105826.
Scoggins, A., Kjellstrom, T., Fisher, G., Connor, J., Gimson, N., 2004. Spatial analysis of annual air pollution exposure and mortality. Sci. Total Environ. 321, 71–85. https://doi.org/10.1016/j.scitotenv.2003.09.020.
Sharma, S., Zhang, M., Anshika, Gao, J., Zhang, H., Kota, S.H., 2020. Effect of restricted emissions during COVID-19 on air quality in India. Sci. Total Environ. 728, 138878. 10.1016/j.scitotenv.2020.138878.
Sicard, P., De Marco, A., Agathokleous, E., Feng, Z., Xu, X., Paoletti, E., Rodriguez, J.J.D., Calatayud, V., 2020. Amplified ozone pollution in cities during the COVID-19 lockdown. Sci. Total Environ. 735, 139542 https://doi.org/10.1016/j.scitotenv.2020.139542.
Skjøth, C.A., Hertel, O., 2013. Ammonia emissions in Europe, in: Urban Air Quality in Europe. Springer Berlin Heidelberg.
Slovic, A.D., de Oliveira, M.A., Biehl, J., Ribeiro, H., 2016. How Can Urban Policies Improve Air Quality and Help Mitigate Global Climate Change: A Systematic Mapping Review. J. Urban Health 93, 73–95. https://doi.org/10.1007/s11524-015-0007-8.
Souche-Le Corvec, S., Mercier, A., Ovtracht, N., Chevallier, A., 2019. Urban toll and electric vehicles: The winning ticket for Lyon Metropolitan Area (France). Res. Transp. Econ. 73, 17–33. https://doi.org/10.1016/j.retrec.2018.10.005.
Sundvor, I., Balaguer, N.C., Viana, M., Querol, X., Reche, C., Amato, F., Mellios, G., Guerreiro, C., 2012. Road traffic's contribution to air quality in European cities. ETC/ACM Tech. Pap. 2012/14.
Taksibi, F., Khajehpour, H., Saboohi, Y., 2020. On the environmental effectiveness analysis of energy policies: A case study of air pollution in the megacity of Tehran. Sci. Total Environ. 705, 135824 https://doi.org/10.1016/j.scitotenv.2019.135824.
Thorpe, A., Harrison, R.M., 2008. Sources and properties of non-exhaust particulate matter from road traffic: A review. Sci. Total Environ. 400, 270–282. https://doi.org/10.1016/j.scitotenv.2008.06.007.
Timmers, V.R., Achten, P.A., 2016. Non-exhaust PM emissions from electric vehicles. Atmos. Environ. 134, 10–17.
Tomassetti, L., Torre, M., Tratzi, P., Paolini, V., Rizza, V., Segreto, M., Petracchini, F., 2020. Evaluation of air quality and mobility policies in 14 large Italian cities from 2006 to 2016 1–17. 10.1080/10934529.2020.1752070.
Tomlin, A., Sutton, A., Tate, J., 2010. The Effect of Commuter Route Choice on Particulate Exposure of an Urban Cyclist. The 2010 Annual UK Review Meeting on Outdoor and Indoor Air Pollution Research Meeting.
Transportation Research Board, n.d. Home - Transportation Research International Documentation [WWW Document]. URL https://trid.trb.org/.
U.S. Department of Commerce, 2012. Qualifying Urban Areas for the 2010 Census. Fed. Regist. 77, 1–19.
U.S. Environmental Protection Agency, 2019. Summary Nonattainment Area Population Exposure Report.
United Nations, Department of Economic and Social Affairs Population Division, 2015. World Urbanization Prospects: The 2014 Revision.
United Nations, Department of Economic and Social Affairs Population Division, 2022. World Population Prospects 2022: Summary of Results. UN DESA/POP/2022/TR/NO. 3.
United States Environmental Protection Agency, 2016. NAAQS Table [WWW Document]. URL https://www.epa.gov/criteria-air-pollutants/naaqs-table#3.
United States Environmental Protection Agency, 2020a. PM-2.5 (2012) Nonattainment Area Summary [WWW Document]. URL https://www3.epa.gov/airquality/greenbook/knsum.html.
United States Environmental Protection Agency, 2020b. 8-Hour Ozone (2015) Nonattainment Area Summary [WWW Document]. URL https://www3.epa.gov/airquality/greenbook/jnsum.html.
Veritas Health Innovation, n.d. Covidence Systematic Review Software [WWW Document]. URL www.covidence.org.
Wadud, Z., Khan, T., 2013. Air quality and climate impacts due to CNG conversion of motor vehicles in Dhaka, Bangladesh. Environ. Sci. Tech. 47, 13907–13916.
Wagner, V., Rutherford, D., 2013. Survey of Best Practices in Emission Control of In-Use Heavy-Duty Diesel Vehicles 1–58.
Wall, G., Olaniyan, B., Woods, L., Musselwhite, C., 2017. Encouraging sustainable modal shift—An evaluation of the Portsmouth Big Green Commuter Challenge. Case Stud. Transp. Policy 5, 105–111.
Wei, Y., Wang, Yan, Di, Q., Choirat, C., Wang, Yun, Koutrakis, P., Zanobetti, A., Dominici, F., Schwartz, J.D., 2019. Short term exposure to fine particulate matter and hospital admission risks and costs in the Medicare population: time stratified, case crossover study. BMJ l6258. 10.1136/bmj.l6258.
Weinbruch, S., Worringen, A., Ebert, M., Scheuvens, D., Kandler, K., Pfeffer, U., Bruckmann, P., 2014. A quantitative estimation of the exhaust, abrasion and resuspension components of particulate traffic emissions using electron microscopy. Atmos. Environ. 99, 175–182. https://doi.org/10.1016/j.atmosenv.2014.09.075.
Wolffe, T.A.M., Whaley, P., Halsall, C., Rooney, A.A., Walker, V.R., 2019. Systematic evidence maps as a novel tool to support evidence-based decision-making in chemicals policy and risk management. Environ. Int. 130, 104871 https://doi.org/10.1016/j.envint.2019.05.065.

Woodcock, J., Edwards, P., Tonne, C., Armstrong, B.G., Ashiru, O., Banister, D., Beevers, S., Chalabi, Z., Chowdhury, Z., Cohen, A., Franco, O.H., 2009. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. Lancet 374 (9705), 1930–1943.
World Health Organization, 2013. Health Effects of Particulate Matter. Policy Implications for Countries in Eastern Europe, Caucasus, and Central Asia.
World Health Organization, 2014. Air quality deteriorating in many of the world's cities [WWW Document]. URLhttps://www.who.int/news/item/07-05-2014-air-quality-deteriorating-in-many-of-the-world-s-cities. World Health Organization, 2021. WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide [WWW Document]. URL https://apps.who.int/iris/handle/10665/345329.
World Health Organization, 2021. New WHO Global Air Quality Guidelines aim to save millions of lives from air pollution. 22 September 2021 News release. Copenhagen and Geneva. Available from: https://www.who.int/news/item/22-09-2021-new-who-global-air-quality-guidelines-aim-to-save-millions-of-lives-from-air-pollution.
Xu, H., Ho, S.S.H., Cao, J., Guinot, B., Kan, H., Shen, Z., Ho, K.F., Liu, S., Zhao, Z., Li, J., Zhang, N., 2017. A 10-year observation of PM2. 5-bound nickel in Xi'an, China: Effects of source control on its trend and associated health risks. Sci. Rep. 7 (1), 1–10.