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

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ABSTRACT

Introduction: Cities are the world's engines of economic growth, innovation, and social change, but they are also hot spots for human exposure to air pollution, mainly originating from road traffic. As the urban population continues to grow, a greater quantity of people risk exposure to traffic-related air pollution (TRAP), and therefore also risk adverse health effects. In many cities, there is scope for further improvement in air quality through targeted urban policy interventions. The objective of this protocol is to detail the methods that will be used for a systematic evidence map (SEM) which will identify and characterize the evidence on policy interventions that can be implemented at the urban-level to reduce traffic emissions and/or TRAP from on-road mobile sources, thus reducing human exposures and adverse health impacts.

Methods: Articles will be searched for and selected based on a predetermined search strategy and eligibility criteria. A variety of databases will be searched for relevant articles published in English between January 1, 2000 and June 1, 2020 to encompass the interdisciplinary nature of this SEM, and articles will be stored and screened using Rayyan QCRI. Predetermined study characteristics will be extracted and coded from included studies in a Microsoft Excel sheet, which will serve as an open access, interactive database, and two authors will review the coded data for consistency. The database will be queryable, and various interactive charts, graphs, and maps will be created using Tableau Public for data visualization. The results of the evidence mapping will be detailed via narrative summary.

Conclusion: This protocol serves to increase transparency of the SEM methods and provides an example for researchers pursuing future SEMs.

1. Introduction and rationale

Traffic is one of the main sources of outdoor air pollution in urban areas (Guarnieri and Balmes, 2014). Traffic emissions disperse into the ambient air as traffic-related air pollution (TRAP) that humans are exposed to and their health is impacted by. TRAP can result from direct exhaust emissions or non-exhaust emissions originating from tire wear, brake wear, road surface wear, engine wear, evaporative emissions, and

Abbreviations: BC, Black carbon; CARTEEH, Center for Advancing Research in Transportation Emissions, Energy & Health; CO, Carbon monoxide; EC, Elemental carbon; GHG, Greenhouse gas; HC, Hydrocarbon; MPO, Metropolitan Planning Organization; NO, Nitric oxide; NO_2, Nitrogen dioxide; NO_x, Nitrogen oxides; PM, Particulate matter; $PM_{2.5}$, Particulate matter with a diameter equal to or less than 2.5 μm; PM_{10}, Particulate matter with a diameter equal to or less than 10 μm; $PM_{absorbance}$, Blackness of PM filters as a representation of BC or EC; PM_{coarse}, PM_{10} minus $PM_{2.5}$; PM_x, Particulate matter with diameters of mixed sizes; PRISMA-P, Preferred reporting items for systematic review & meta-analysis protocols; SEM, Systematic evidence map; SO_2, Sulfur dioxide; TRAP, Traffic-related air pollution; TRID, Transportation Research International Documentation; UFP, Ultrafine particle; US EPA, US Environmental Protection Agency; VMT, Vehicle miles traveled; VOC, Volatile organic compound; WHO, World Health Organization

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re-suspended crystal and street dust particles (Frosina et al., 2018; Rubin et al., 2006; Thorpe and Harrison, 2008). Simply put, TRAP refers to traffic activity's contribution to ambient air pollution. In this paper, traffic activity involves the use of light and heavy duty on-road mobile vehicles, including cars, motorcycles, buses, and trucks. Reports estimate that traffic contributed to 14% of all volatile organic compound (VOC) emissions, 38% of all nitrogen oxide (NO_x) emissions, and 34% of all carbon monoxide (CO) emissions in the United States in 2013 (U.S. Department of Transportation, Federal Highway Administartion, 2016). More specifically, in urban areas in the United States, vehicles may contribute up to over a third of the ambient particulate matter with a diameter equal to or less than 2.5 μm ($PM_{2.5}$) (Hammond et al., 2008). Similarly, in Europe, road transport is responsible for significant contributions to particulate matter (PM) and NO_x emissions (European Environment Agency, 2016). Traffic's contribution to urban PM concentrations at traffic sites in Europe averaged 39% and 43% for particulate matter with a diameter equal to or less than 10 μm (PM_{10}) and $PM_{2.5}$, respectively (Sundvor et al., 2012). Additionally, urban traffic's contribution to ambient nitrogen dioxide (NO_2) concentrations ranged from 3% to 56% (Sundvor et al., 2012). The prominence of traffic emissions and TRAP has great implications for human exposure and its wide range of adverse health effects (Buckeridge et al., 2002; Fan et al., 2009; Health Effects Institute, 2010). A non-comprehensive list of adverse health outcomes associated with TRAP is displayed (Table A1). Moreover, the health impacts associated with TRAP have proven costly. The cost of deaths from ambient air pollution in 2010 was over $496,000,000 in the United States, $201,000,000 in Japan, $148,000,000 in Germany, $102,000,000 in Italy and $85,000,000 in the United Kingdom (OECD, 2014). More specifically, the average annual cost for asthma cases attributable to TRAP was estimated to be over $6,000,000 in Long Beach, California and $2,500,000 in Riverside, California (Brandt et al., 2012).

Urban areas are hot spots for human exposure to air pollution, mainly originating from road traffic (Kura et al., 2013). Understanding efforts to curb air pollution in urban areas is particularly critical as the world is currently witnessing its largest urban growth in human history (United Nations and Department of Economic and Social Affairs Population Division, 2015). In fact, two-thirds of the world's population is estimated to reside in urban areas by 2050 (United Nations and Department of Economic and Social Affairs Population Division, 2015), meaning more people will be at risk of exposure to TRAP. Despite growing awareness of the links between traffic, air pollution, exposure, and associated adverse health impacts, many cities across the globe struggle to meet air quality guidelines set to protect public health (World Health Organization, 2014). For example, the United States Environmental Protection Agency (US EPA) reports that many individuals live in "nonattainment areas" (areas that do not meet national ambient air quality standards in the United States) (U.S. Environmental Protection Agency, 2019). In the United States, urban areas exceed national recommended levels of $PM_{2.5}$ (affecting more than 23 million people in 2012) and 8-Hour ozone (affecting over 124 million people in 2015) (U.S. Environmental Protection Agency, 2019). Similarly, in Europe in 2010, 41% and 7% of the urban population lived in areas exceeding the 24-hour limit for PM_{10} and the annual limit for NO_2, respectively (Sundvor et al., 2012). Further, the European Union-funded study ESCAPE revealed nonattainment of World Health Organization (WHO) guideline values for most of the study areas included in the project (Eeftens et al., 2012), and WHO estimates that over 90% of people living in cities globally are breathing air pollution at levels above their guidelines (World Health Organization, 2018).

In many cities, there is scope for further improvement in air quality through targeted urban policy interventions (Nieuwenhuijsen, 2016). 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 we focus on is reducing traffic emissions and/or TRAP concentrations originating from on-road mobile sources in urban areas. There is limited evidence available on urban-level policy interventions that may mitigate traffic-related emissions and TRAP. Few previous articles review policy interventions to mitigate traffic-related emissions and/or air pollution, and even fewer focus on the urban-level despite the emergence of urban areas as hot spots for human exposures. Of the existing 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), none are as broad or comprehensive in nature as this one. For example, some reviews are limited in their scope to only certain types of policy interventions (e.g. only consider low emission zones or transport measures and therefore, exclude, for example, land-use planning or behavioral measures) (Bigazzi and Rouleau, 2017; Conlan et al., 2016; Henschel et al., 2012; Holman et al., 2015). Similarly, other reviews focused on a limited number of traffic-related air pollutants (e.g. only consider NO_2 and NO_x rather than including a comprehensive set of traffic-related air pollutants) (Burns et al., 2019; Conlan et al., 2016; Holman et al., 2015). Some reviews consider a variety of interventions to improve air quality and health but are non-specific to the transportation sector as they lack focus on traffic emissions and TRAP outcomes specifically (Bradley et al., 2019; Burns et al., 2019; Henschel et al., 2012). One of the existing reviews was limited in that it focused on emissions from heavy-duty vehicles exclusively rather than considering a more comprehensive list of on-road traffic modes (e.g. passenger vehicles, light-duty vehicles, motorized bikes, etc.) (Wagner and Rutherford, 2013). Additionally, some reviews differed in geographic considerations. For example, some were not focused exclusively at the urban-level (Burns et al., 2019; Henschel et al., 2012; Wagner and Rutherford, 2013) or did not consider international evidence like the proposed systematic evidence map (SEM) does, but focused on North America *or* European cities only (Bigazzi and Rouleau, 2017; Holman et al., 2015). Slovic et al. (2016) is most similar to the proposed SEM in that it is a systematic mapping review presenting an overview of urban air pollution control policies and programs aiming to reduce air pollution levels in urban areas. However, Slovic et al. (2016) is conducted in the context of climate change, rather than human exposures and health impacts.

Key differences between the previous reviews described above and

Table A1
Adverse Health Outcomes Associated with TRAP: A Non-Comprehensive List.

Health Outcome	Reference(s)
Premature Mortality	(Beelen et al., 2014)
Cardiovascular Effects	(Brook et al., 2010; Cesaroni et al., 2014; Link and Dockery, 2010; Mustafić et al., 2012)
Cancer	(Raaschou-Nielsen et al., 2013)
Cerebrovascular Effects	(Stafoggia et al., 2014)
Respiratory Effects	(Gasana et al., 2012; Khreis et al., 2017; Lindgren et al., 2009; MacIntyre et al., 2014)
Bone Conditions	(Prada et al., 2017)
Reproductive Effects	(Fleischer et al., 2014; Lafuente et al., 2016; Pedersen et al., 2014, 2013; Sapkota et al., 2012; Vrijheid et al., 2011)
Neurological and Cognitive Disorders	(Power et al., 2016; Raz et al., 2015)
Other Metabolic Outcomes	(Eze et al., 2015; Jerrett et al., 2014)

Table A2
Key Differences from Proposed SEM.

Previous Review	Previous Review Scope	Key Differences
Bigazzi and Rouleau 2017	Reviews evidence on traffic management strategies (TMS) to improve urban air quality in context of emissions, ambient air concentrations, human exposure and health.	• Scope does not consider international evidence • Scope does not consider a comprehensive set of interventions to mitigate traffic emissions and TRAP • Results not available in an open access, interactive database
Bradley et al. 2019	Reviews a variety of interventions (vehicles and fuels, spatial planning, industry, agriculture and behavioral change) to improve outdoor air quality and public health.	• Scope lacks focus on traffic emissions and TRAP as primary outcomes • Results not available in an open access, interactive database
Burns et al. 2019	Reviews a variety of interventions' (industrial, residential, vehicular and multiple sources) effectiveness to reduce ambient particulate matter air pollution and their effect on health.	• Scope does not consider a comprehensive set of traffic-related air pollutants • Scope is limited to studies published before September 1, 2016 • Scope is not exclusive to the urban-level • Scope lacks focus on traffic emissions and TRAP as primary outcomes • Results not available in an open access, interactive database
Conlan et al. 2016	Reviews the effectiveness of transport measures in reducing nitrogen dioxide.	• Scope does not consider a comprehensive set of interventions to mitigate traffic emissions and TRAP • Scope does not consider a comprehensive set of traffic-related air pollutants • Results not available in an open access, interactive database
Henschel et al. 2012	Reviews air pollution interventions and their impact on public health where air pollution interventions are defined as events aimed at reducing air pollution or where reductions occurred as a side effect.	• Scope does not consider a comprehensive set of interventions to mitigate traffic emissions and TRAP • Scope is not exclusive to the urban-level • Scope lacks focus on traffic emissions and TRAP as primary outcomes. • Results not available in an open access, interactive database
Holman et al. 2015	Reviews low emission zone (LEZ) efficacy in improving urban air quality in European cities across 5 different countries: Denmark, Germany, Netherlands, Italy and the United Kingdom.	• Scope does not consider a comprehensive set of interventions to mitigate traffic emissions and TRAP • Scope does not consider a comprehensive set of traffic-related air pollutants • Scope does not consider international evidence • Results not available in an open access, interactive database
Slovic et al. 2016	Reviews local air pollution control policies and programs that aim to reduce air pollution levels in urban areas along with evidence measuring their efficacy in the context of global climate change. The primary goal of the review is to identify and discuss articles addressing policies to control air pollution in urban areas, targeting the impacts of vehicle emissions on climate change and local air quality.	• Scope is limited to studies conducted between 2000 and 2015 • Scope lacks focus on traffic emissions and TRAP in the context of human exposure and health impacts • Results not available in an open access, interactive database
Wagner and Rutherford 2013	Reviews ways to reduce the emissions of the in-use vehicle fleet with emphasis on heavy-duty diesel trucks and highlights national, regional and local examples of effective emission control programs.	• Scope does not consider a comprehensive set of on-road traffic vehicles • Scope is not exclusive to the urban-level • Scope lacks focus on traffic emissions and TRAP in the context of human exposure and health impacts • Results not available in an open access, interactive database

Note: Only one of the previous reviews reported the methods used prior to publication (Burns et al., 2014). *Reporting methods a priori in the form of a peer-reviewed published protocol is considered a high standard for undertaking systematic reviews or systematic evidence maps and has been encouraged* (Collaboration for Environmental Evidence, 2013; James et al., 2016).

the proposed SEM are outlined in Table A2. Notably, only one of the previous reviews reported the methods used prior to publication (Burns et al., 2014). Reporting methods a priori in the form of a peer-reviewed published protocol is considered a high standard for undertaking systematic reviews or systematic evidence maps and has been encouraged (Collaboration for Environmental Evidence, 2013; James et al., 2016). A final and key distinction of our review is that it is the only review that will house its results in an open access database, therefore promoting technology transfer and knowledge translation. There are currently no existing databases that compile different policy interventions together in this context, so the database we provide will contain important information for researchers and policymakers in the form of a detailed, interactive Microsoft Excel sheet.

To our knowledge, this will be the first peer-reviewed SEM focused on compiling international evidence on urban-level policy interventions to reduce traffic emissions and/or TRAP from on-road mobile sources in the context of human exposure and health effects. It is important to note that the idea behind conducting this SEM stems from TRAP's adverse impact on health and wanting to unite this disparate literature with emphasis on highlighting where knowledge is clustered and where gaps exist. Understanding this information is of increasing value as new policy interventions and technologies (e.g. autonomous and electric vehicles), which may have unintended consequences, continue to emerge. Therefore, this SEM provides a good opportunity to find

evidence on emerging policy interventions or highlight if there are gaps.

This protocol adheres with the preferred reporting items for systematic review and meta-analysis protocols statement (PRISMA-P) (Shamseer et al., 2016) with modifications considered for a systematic evidence map. All versions of the protocol are available in Zenodo (DOI: https://doi.org/10.5281/zenodo.3780631). Any modification or update to the methods stated in this protocol will be documented and reported in the final SEM paper and registered in Zenodo. The date of each modification, or amendment will be listed and accompanied by a description of the change.

2. 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, such as cities, air agencies, and metropolitan planning organizations (MPOs) to reduce traffic emissions and/or TRAP from on-road mobile sources, thus potentially reducing human exposures and adverse health impacts. Additionally, the evidence synthesis will take the form of an open access, interactive database and facilitate the identification of relevant trends and gaps in the evidence base and serve as the foundation for future research recommendations.

While there have been a number of reviews, a cohesive and comprehensive SEM characterizing the current evidence on the impact of urban policy interventions on reducing traffic emissions and TRAP is needed. No previous existing SEM considers urban-level policy interventions or traffic-related air pollutants in the context of human exposure and health as comprehensively as the proposed SEM. This SEM will encompass multiple urban-level policy interventions aimed toward mitigating traffic emissions *and* TRAP, and it will consider multiple traffic-related air pollutants, rather than just one or two as previous reviews have done. It will also consider international studies, therefore presenting more complete coverage and allowing readers to learn from different countries and assess the transferability of more progressive or unusual policies that may not be implemented in specific regions of the world.

3. Population, intervention, comparator, and outcome (PICO) items

3.1. Population

The population of interest for this SEM is the urban population. In this study, we will include 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) and will exclude rural areas.

3.2. Intervention and comparator

The intervention refers to urban-level policy intervention to reduce traffic emissions and/or TRAP, while the comparator is the absence of an urban-level policy intervention (or the baseline). This SEM will encompass multiple urban-level policy interventions aimed at mitigating traffic emissions and TRAP, and it will consider multiple traffic-related air pollutants. 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 we focus on is reducing traffic emissions and/or TRAP concentrations originating from on-road mobile sources in urban areas. We use the term “policy intervention” to cover specific actions such as the implementation of low emission zones, congestion pricing, increasing car and bike sharing, etc., while noting that they may be referred to as “strategies”, “measures” or “practices” across the literature from different countries. For example, a paper may utilize the term “measure” when discussing low emission zones (Holman et al., 2015), whereas another utilizes “strategy” (Bigazzi and Rouleau, 2017). Additionally, policy interventions in this paper will not be limited exclusively to traffic interventions alone but shall include a variety of interventions (land-use, behavioral, pricing, infrastructure, technology, management, standards, and services, etc.) that may reduce traffic emission and/or TRAP in urban areas. Finally, policy interventions at the urban-level will include both citywide interventions as well as those applicable within cities (i.e. in a corridor).

3.3. Outcome

The primary outcomes include traffic emissions and/or TRAP. Secondary outcomes include human exposures and health impacts (including, but not limited to: premature mortality, cancers, cardiovascular effects, respiratory effects, cerebrovascular effects, reproductive effects, neurological and cognitive disorders, bone conditions and metabolic outcomes). Secondary items of interest include enablers and barriers to intervention implementation and co-benefits, if any.

4. Eligibility criteria

Here we describe the eligibility criteria that will be used to determine whether potential articles shall be included or excluded in this SEM. We will include articles that meet all the following criteria:

- Articles which specifically 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 which specifically investigate urban-level policy intervention impact on traffic emissions (exhaust or non-exhaust) and/or TRAP originating from mobile on-road traffic: black carbon (BC), elemental carbon (EC), hydrocarbons (HCs), CO, nitric oxide (NO), NO_2, NO_x, sulfur dioxide (SO_2), $PM_{2.5}$, PM_{10}, PM_{10} minus $PM_{2.5}$ (PM_{coarse}), blackness of PM filters as a representation of BC or EC ($PM_{absorbance}$), particulate matter with diameters of mixed sizes (PM_x), ultrafine particles (UFPs), and VOCs or other traffic-related air pollutants/pollution
- Articles reported in the English language
- Articles published between January 1, 2000 and June 1, 2020
- Articles that are peer-reviewed

We will exclude articles that meet any of the following criteria:

- Articles which exclusively investigate policy interventions implemented at the state/regional or federal/national level
- Articles which exclusively investigate policy interventions implemented in rural areas
- Articles which exclusively investigate urban-level policy intervention impact on an outcome other than primary outcomes: traffic emissions and TRAP (e.g. traffic congestion, traffic noise, traffic safety, etc.)
- Articles which exclusively investigate off-road traffic emissions (boats, planes, trains, construction equipment, etc.)
- Articles which exclusively investigate non-traffic related emissions or non-traffic related air pollution (wildfires, wood smoke, industrial and indoor combustion emissions, etc.)
- Articles which exclusively investigate greenhouse gas (GHG) emissions (which for our purpose are treated as a co-benefit)
- Articles which exclusively investigate human exposures and/or health outcomes as a result of an urban-level policy intervention

Table A3
Data extraction and coding.

<table>
<tr><th>Data Category</th><th>Data Collected</th></tr>
<tr><td>General Article Information
Data captured at study-level
Required field</td><td>• Reference ID
• Title
• Author(s)
• Publication Year
• Journal
• URL to full-text or abstract
All general article information will be collected as text entry.</td></tr>
<tr><td>Study Type
Data captured at study-level
Required field</td><td>
<table>
<tr><th>Study Type</th><th>Code</th></tr>
<tr><td>Case-Control
Explores connection between outcome and exposure in an observational study where two existing groups differing in outcome are identified and compared (Parab and Bhalerao, 2010).</td><td>CC</td></tr>
<tr><td>Case Report
Explores connection between outcome and exposure in a descriptive study of a single individual or three or fewer individuals (Parab and Bhalerao, 2010).</td><td>CR</td></tr>
<tr><td>Case Series/Case Study
Explores connection between outcome and exposure in a descriptive study of a group (Parab and Bhalerao, 2010).</td><td>CS</td></tr>
<tr><td>Cohort</td><td>CH</td></tr>
</table>
</td></tr>
</table>

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Table A3 (*continued*)

	Explores connection between outcome and exposure in a prospective study where a group of subjects (with a causative factor and free of a condition of interest) is followed up and observed for the occurrence of the condition (Parab and Bhalerao, 2010).	
	Ecological Study *Explores connection between outcome and exposure for different groups, rather than individuals. No individual level information is collected (e.g. zip codes used for comparison) (Parab and Bhalerao, 2010).*	ES
	Quasi-Experiment *Explores connection between outcome and exposure in an empirical interventional study that estimates the impact of an intervention on a target population without random assignment (e.g. participant allocation is done according to date of birth (odd or even) or hospital record number, etc.) (Parab and Bhalerao, 2010).*	QE
	Randomized Controlled Trial *Involves random assignments to either receive an intervention or a control for exploring the connection between outcome and exposure (Parab and Bhalerao, 2010).*	RT
	If a study design other than those already listed occurs, it will be assigned a unique code, and it will be added to the category list for future use.	
Urban Policy Intervention *Data captured at study-level* *Required field*	Urban Policy Intervention / Code	
	Pricing	
	Air pollution charging fee	APC
	Congestion charging	COC
	Fuel taxes	FUT
	Mileage-based user fees	MUF
	Parking charges	PAC
	Road pricing	ROP
	Vehicle ownership taxes	VOT
	Land-use	
	Development density and mixed developments	DMD
	Parking standards	PAS
	Superblock development	SBD
	Transit oriented development	TOD

(*continued on next page*)

Table A3 (*continued*)

	Infrastructure Active transportation infrastructure: ATI Public transportation infrastructure: PTI Electrification infrastructure: ELI Green wall or buffer: GWB Park and ride: PAR Terminals and interchanges: TEI Behavioral Flexible work arrangements: FWA Ride sharing promotion: RSP Bike sharing promotion: BSP Technology Alternative vehicle technology: AVT Alternative fuel technology: AFT Real-time passenger information: RPI Vehicle retrofitting: VER Management, Standards and Services Fleet management: FLM High occupancy vehicle lane: HOV Inspection and maintenance program: IMP Integrated ticketing: INT Low emission zone: LEZ Public transportation expansion: PTE Public transportation regulation: PTR Speed limit reduction: SLR Traffic signal optimization: TSO Vehicle use restriction: VUR Vehicle emission regulation: VER If an urban policy intervention other than those already listed occurs, it will be assigned a unique code, and it will be added to the category list for future use. The urban policy interventions listed here were collected from KonSULT (University of Leeds, 2016), expert knowledge and other relevant reviews.
Data for the categories above will be collected at the study-level.	
Data for the categories below will be collected at the intervention-level.	
Method(s) Used *Data captured at intervention-level* *Required field*	Method(s) Used: Code Measurement: ME Modeling: MO Both Methods: BM Method(s) used refers to whether measurement, modeling or both methods were utilized in the study.
Population Characteristics *Data captured at intervention-*	Age: Code Infant (< 2 years old): INF

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Table A3 (*continued*)

level *Required field*	<table><tr><td>Child (2-12 years old)</td><td>CHI</td></tr><tr><td>Adolescent (13-17 years old)</td><td>ADO</td></tr><tr><td>Adult (18-65 years old)</td><td>ADT</td></tr><tr><td>Elderly (> 65 years old)</td><td>ELD</td></tr><tr><td>All ages</td><td>ALL</td></tr><tr><td>Gender</td><td>Code</td></tr><tr><td>Both genders</td><td>BG</td></tr><tr><td>Female</td><td>FE</td></tr><tr><td>Male</td><td>MA</td></tr><tr><td>Ethnicity</td><td>Code</td></tr><tr><td>African-American</td><td>AA</td></tr><tr><td>Asian</td><td>AS</td></tr><tr><td>Hispanic/Latino</td><td>HL</td></tr><tr><td>Native American</td><td>NA</td></tr><tr><td>Pacific Islander</td><td>PI</td></tr><tr><td>White/Caucasian</td><td>WH</td></tr><tr><td>Baseline conditions</td><td>Code</td></tr><tr><td>Healthy population</td><td>HP</td></tr><tr><td>Sick population</td><td>SP</td></tr></table> All applicable population characteristics across age, gender, ethnicity, and baseline conditions will be selected. If a population characteristic for age, gender, ethnicity or baseline conditions other than those already listed occurs, it will be assigned a unique code, and it will be added to the appropriate category list for future use.
Sample Size *Data captured at intervention-level* *Required field*	Sample size will be captured in numerical form.
Location *Data captured at intervention-level* *Required field*	<table><tr><td>Country</td><td>Code</td><td>Country</td><td>Code</td></tr><tr><td>United Arab Emirates</td><td>AE</td><td>Jordan</td><td>JO</td></tr><tr><td>Afghanistan</td><td>AF</td><td>Kenya</td><td>KE</td></tr><tr><td>Argentina</td><td>AR</td><td>Lithuania</td><td>LH</td></tr><tr><td>Australia</td><td>AS</td><td>Morocco</td><td>MO</td></tr><tr><td>Brazil</td><td>BR</td><td>Mexico</td><td>MX</td></tr><tr><td>Canada</td><td>CAN</td><td>Netherlands</td><td>NL</td></tr><tr><td>China</td><td>CN</td><td>Norway</td><td>NO</td></tr><tr><td>Chile</td><td>CI</td><td>New Zealand</td><td>NZ</td></tr><tr><td>Colombia</td><td>CO</td><td>Peru</td><td>PE</td></tr><tr><td>Cuba</td><td>CU</td><td>Pakistan</td><td>PK</td></tr><tr><td>Dominican Republic</td><td>DR</td><td>Poland</td><td>PL</td></tr><tr><td>Ecuador</td><td>EC</td><td>Panama</td><td>PM</td></tr></table>

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Table A3 (*continued*)

	<table><tr><td>Egypt</td><td>EG</td><td>Portugal</td><td>PO</td></tr><tr><td>Ireland</td><td>EI</td><td>Qatar</td><td>QA</td></tr><tr><td>El Salvador</td><td>ES</td><td>Philippines</td><td>RP</td></tr><tr><td>Ethiopia</td><td>ET</td><td>Puerto Rico</td><td>RQ</td></tr><tr><td>Czech Republic</td><td>ED</td><td>Russia</td><td>RS</td></tr><tr><td>Finland</td><td>FI</td><td>Saudi Arabia</td><td>SA</td></tr><tr><td>France</td><td>FR</td><td>South Africa</td><td>SF</td></tr><tr><td>Ghana</td><td>GH</td><td>Spain</td><td>SP</td></tr><tr><td>Germany</td><td>GM</td><td>Sweden</td><td>SW</td></tr><tr><td>Greece</td><td>GR</td><td>Switzerland</td><td>SZ</td></tr><tr><td>Haiti</td><td>HA</td><td>Thailand</td><td>TH</td></tr><tr><td>Hong Kong</td><td>HK</td><td>Ukraine</td><td>UP</td></tr><tr><td>Honduras</td><td>HO</td><td>United Kingdom</td><td>UK</td></tr><tr><td>India</td><td>IN</td><td>United States</td><td>US</td></tr><tr><td>Iran</td><td>IR</td><td>Venezuela</td><td>VE</td></tr><tr><td>Israel</td><td>IS</td><td>Vietnam</td><td>VM</td></tr><tr><td>Italy</td><td>IT</td><td>Yemen</td><td>YM</td></tr><tr><td>Iraq</td><td>IZ</td><td>Zambia</td><td>ZA</td></tr><tr><td>Japan</td><td>JA</td><td>Zimbabwe</td><td>ZI</td></tr></table> If a country other than those already listed occurs, it will be assigned a unique code, and it will be added to the category list for future use. Additionally, the specific urban area/city will be captured as free text.
Analysis Year(s) *Data captured at intervention-level* *Required field*	Study analysis years will be captured in a four-digit numerical format for the following: • Analysis start year • Analysis end year
Pollutants Studied *Data captured at intervention-level* *Required field*	<table><tr><th>Pollutant</th><th>Code</th></tr><tr><td>Black carbon</td><td>BC</td></tr><tr><td>Carbon monoxide</td><td>CO</td></tr><tr><td>Elemental carbon</td><td>EC</td></tr><tr><td>Hydrocarbons</td><td>HC</td></tr><tr><td>Nitric oxide</td><td>NO</td></tr><tr><td>Nitrogen oxides</td><td>NOX</td></tr><tr><td>Nitrogen dioxide</td><td>NO2</td></tr><tr><td>Particulate matter with a diameter equal to or less than 2.5 micrometers</td><td>PM2.5</td></tr><tr><td>Particulate matter with a diameter equal to or less than 10 micrometers</td><td>PM10</td></tr><tr><td>Particulate matter with diameters of mixed sizes</td><td>PMX</td></tr><tr><td>$PM_{absorbance}$</td><td>PMA</td></tr></table>

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Table A3 (*continued*)

	PM_{coarse} — PMC Sulfur dioxide — SO2 Ultrafine particles — UFP Volatile organic compounds — VOC All applicable pollutants will be selected. If a pollutant other than those already listed occurs, it will be assigned a unique code, and it will be added to the category list for future use.
Traffic Emission Effects *Data captured at intervention-level* *Required field*	Is effect on traffic emissions reported? — Code Yes — Y No — N What is the direction of the effect on traffic emissions? — Code Reduction — ER Increase — EI Mixed effect — EM No change — EN
Traffic-Related Air Pollution (TRAP) Effects *Data captured at intervention-level* *Required field*	Is effect on TRAP reported? — Code Yes — Y No — N What is the direction of the effect on TRAP? — Code Reduction — TR Increase — TI Mixed effect — TM No change — TN The effect on TRAP is measured as air quality concentrations.
Human Exposures *Data captured at intervention-level* *Optional field*	Is human exposure to TRAP reported? (The study went a step further to investigate human exposure to TRAP) — Code Yes — Y No — N Which pollutants were studied for human exposure specifically? — Code Black carbon — BC Carbon monoxide — CO Elemental carbon — EC

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Table A3 (*continued*)

	Hydrocarbons: HC Nitric oxide: NO Nitrogen oxides: NOX Nitrogen dioxide: NO2 Particulate matter with a diameter equal to or less than 2.5 micrometers: PM2.5 Particulate matter with a diameter equal to or less than 10 micrometers: PM10 Particulate matter with diameters of mixed sizes: PMX $PM_{absorbance}$: PMA PM_{coarse}: PMC Sulfur dioxide: SO2 Ultrafine particles: UFP Volatile organic compounds: VOC All applicable pollutants will be selected. If a pollutant other than those already listed occurs, it will be assigned a unique code, and it will be added to the category list for future use.
Health Impacts *Data captured at intervention-level* *Optional field*	Are health impacts reported? (The study went a step further to investigate health impacts related to TRAP) — Code Yes: Y No: N If yes, health impacts will be categorized as follows: Bone conditions: BC Cancer: CN Cardiovascular effects: CD Cerebrovascular effects: CE Metabolic outcomes: MO Neurological/cognitive disorders: NC Premature mortality: PM Reproductive effects: RP Respiratory effects: RE All applicable categories will be selected. If a health impact other than those already listed occurs, it will be assigned a unique code, and it will be added to the category list for future use. Which pollutants were studied for health impacts specifically? — Code

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Table A3 (*continued*)

	Black carbon — BC Carbon monoxide — CO Elemental carbon — EC Hydrocarbons — HC Nitric oxide — NO Nitrogen oxides — NOX Nitrogen dioxide — NO2 Particulate matter with a diameter equal to or less than 2.5 micrometers — PM2.5 Particulate matter with a diameter equal to or less than 10 micrometers — PM10 Particulate matter with diameters of mixed sizes — PMX $PM_{absorbance}$ — PMA PM_{coarse} — PMC Sulfur dioxide — SO2 Ultrafine particles — UFP Volatile organic compounds — VOC All applicable pollutants will be selected. If a pollutant other than those already listed occurs, it will be assigned a unique code, and it will be added to the category list for future use.
Enablers *Data captured at intervention-level* *Optional field*	Enablers will refer to items that facilitate the implementation of an intervention. Enabler Category — Code Behavioral — EB Financial — EF Governance — EG Infrastructural — EI Knowledge and skills — EK Legislation — EL Political — EP All applicable categories will be selected. If an enabler category other than those already listed occurs, it will be assigned a unique code, and it will be added to the category list for future use. Additionally, specific enablers will be documented as text entry.
Barriers *Data captured at intervention-level* *Optional field*	Barriers will refer to items that hinder the implementation of an intervention. Barrier Category — Code Behavioral — BB Financial — BF Governance — BG

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Table A3 (*continued*)

	Infrastructural: BI Knowledge and skills: BK Legislation: BL Political: BP All applicable categories will be selected. If a barrier category other than those already listed occurs, it will be assigned a unique code, and it will be added to the category list for future use. Additionally, specific barriers will be documented as text entry.
Co-Benefits *Data captured at intervention-level* *Optional field*	Co-benefits will refer to other benefits beyond reduction in traffic emissions and TRAP as a result of the interventions. Climate change mitigation: CC Economic growth: EG Greenhouse gas emission reduction: GG Job growth: JG Increased accessibility: AC Increased active transportation: AT Increased equity: EQ Increased greenspace: GS Increased property value: PV Increased safety: SA Increased transit use: TU Reduced energy consumption: EC Reduced stress: ST Reduced traffic congestion: TC Reduced traffic noise: TN Reduced vehicle miles traveled (VMT): VM All applicable categories will be selected. If a co-benefit category other than those already listed occurs, it will be assigned a unique code, and it will be added to the category list for future use. Additionally, specific co-benefits will be documented as text entry.

- Articles that are not peer-reviewed

5. Information sources and search strategy

We will search a variety of databases to encompass the inter-disciplinary nature of this SEM, including Public Affairs Index (EBSCO, n.d.), Transportation Research International Documentation (TRID) (Transportation Research Board, n.d.), Medline and Embase for relevant articles published in the English language between January 1, 2000 and June 1, 2020. Reference lists from the identified articles, our experiential knowledge and relevant articles identified in other projects may be used to identify additional relevant studies. The Center for Advancing Research in Transportation Emissions, Energy and Health (CARTEEH) literature library (https://www.carteeh.org/carteeh-literature-library/) (Khreis et al., 2019) will also be scanned to identify relevant articles that may have been initially missed in other database searches. Grey literature will not be included in the literature search due to time and resource limitations. Excluding grey literature from our search may limit the comprehensiveness of the SEM as relevant reports will not be considered. Nonetheless, our SEM will provide a valuable picture of the evidence base, especially since we are searching a variety of cross-disciplinary databases.

Our search terms are composed with regard to three main topics: (1) emissions and pollutants, (2) traffic and (3) policy interventions, with synonyms for each topic included in the search. We will not specifically search for papers reporting on secondary outcomes or items of interest, and as such we do not include them in the devised search terms or eligibility criteria. Instead, we will only document secondary outcomes or items of interest if the included papers identified any.

The exact searches used to identify relevant articles in the Public Affairs Index, TRID, Medline and Embase databases as well as the number of raw hits returned for each literature search string is provided in the Supplementary Material (Table S.1).

6. Data management and selection process

Results from the literature search will be imported to Mendeley where duplicate records will be identified and resolved. Then, the records will be uploaded to Rayyan QCRI (Ouzzani et al., 2016), which will be utilized to store and screen potential studies for inclusion or exclusion and help screeners efficiently identify and resolve any disagreements. The screening process will be divided into two steps, and two separate Rayyan folders will be used to track screening at the different levels. Titles and abstracts will be screened first, and selected

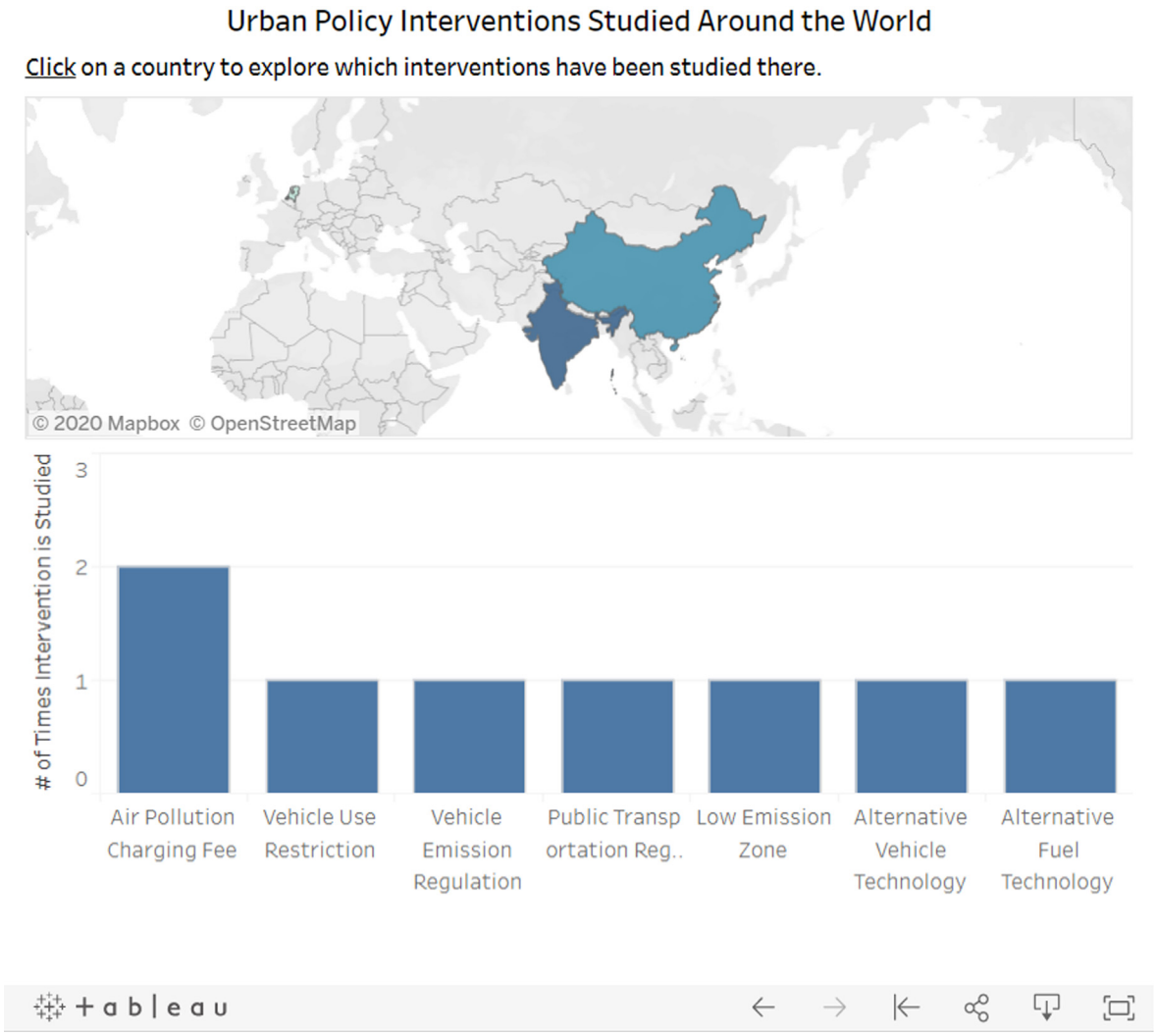

Fig. A1. Example of an interactive map initial user view.

studies will be imported to a second Rayyan folder. Then, studies in the second folder will be screened at the full-text level. A study flow diagram will be created outlining the number of articles that were retrieved from our searches and evaluated at each screening level.

KS and HK will review the screening process and the data extraction and coding process at the outset and select papers will be reviewed together to ensure all processes are well-defined and agreed upon. Uncertainties will be resolved through discussion until consensus is achieved. In the event of a disagreement, a third opinion will be sought from another reviewer. Titles and abstracts of all identified articles will be screened by KS, and a random 20% will be independently screened by HK. Any disagreements will be resolved by another reviewer. All articles potentially meeting our inclusion criteria will be retrieved and their full papers will be reviewed against the inclusion criteria by KS with a random 20% independently reviewed by HK. Again, any disagreements will be resolved by another reviewer. A reason for exclusion will be provided for articles that were excluded after full-text screening, and this information will be provided in a supplemental table. Additionally, we will indicate which articles were among the 20% screened in duplicate at the title and abstract level and full-text level in the final paper and provide the agreement rate across those articles. A limitation of the method described above is that screening is not fully done in duplicate due to time and resource restrictions.

7. Data extraction, coding and storage

Data will be extracted and documented manually by KS according to the predefined categories and codes outlined in Table A3 and stored in Microsoft Excel. Two authors will review the coded data for consistency. The Microsoft Excel sheet will have a section for each data item that will allow screeners to enter extracted information. Data will be collected at the study-level or intervention-level depending on the data item being considered. For example, if one study includes several interventions, certain data items will be considered separately for each intervention in the study. More details on data collection and coding, including the level at which data will be collected for each category, is specified in Table A3. We will further document this information where available. If there is missing data from a study, we will request information from the corresponding author via email or phone. If no response is received, we will follow up twice via email at one and three weeks. If there is still no response, the missing data will be labeled "N/A" for "Not Available". An example of a coded Excel sheet using data from six piloted studies is provided in the Supplementary Material (Fig. S.1). Note that the sheet includes expanded rows to account for multiple interventions in one study (see Article ID 2) and columns for the raw data extracted for urban policy intervention, health impact category, enablers, barriers and co-benefits data categories next to their respective coded cells to promote data transparency. Ultimately, the Microsoft Excel sheet will serve as an open access database with

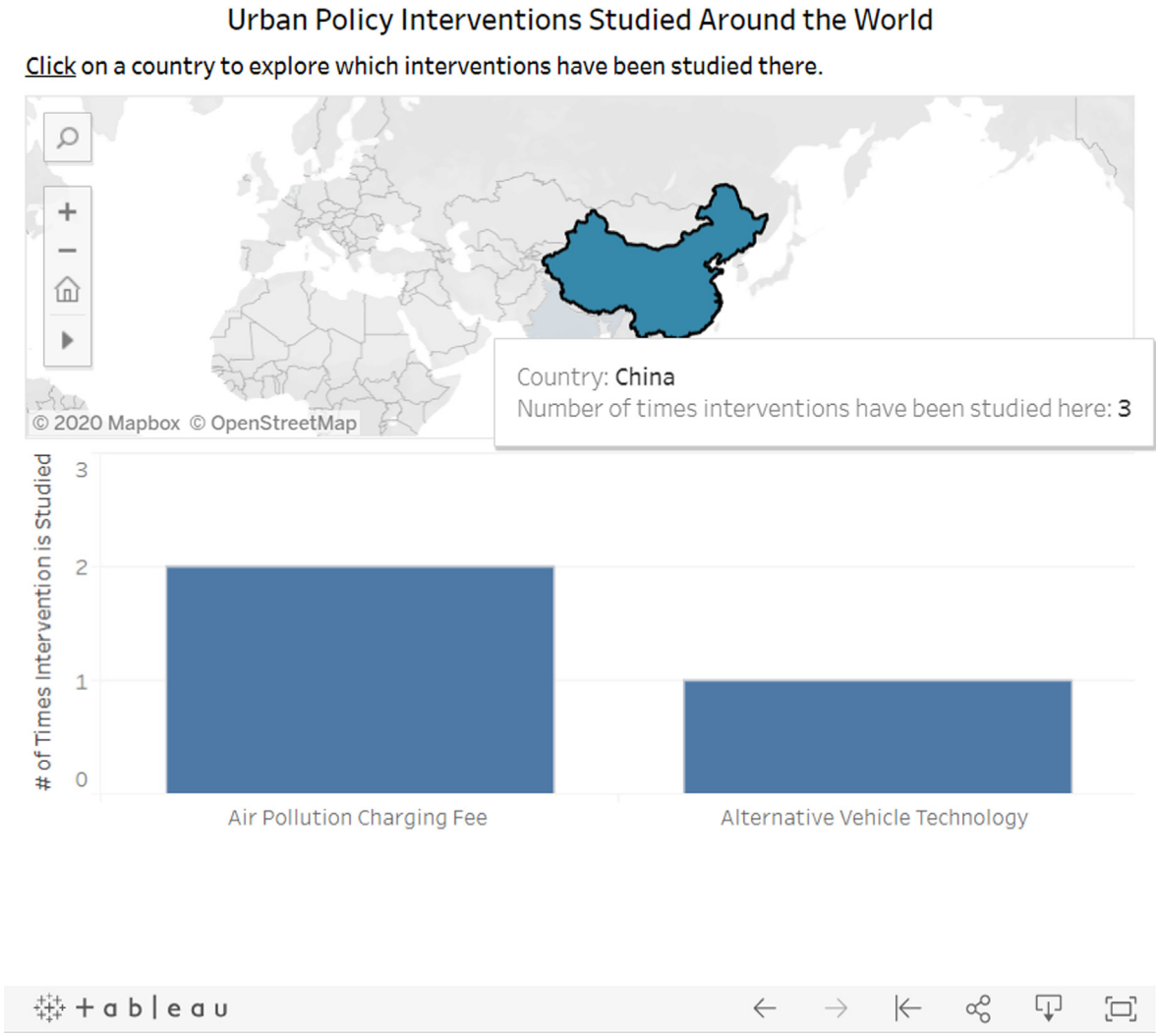

Fig. A2. Example 1 of an interactive map filter function.

information on all extracted data items for included articles. The database will be uploaded to the CARTEEH Data Hub (Center for Advancing Research in Transportation Emissions Energy and Health, 2020), which is a data hub that has already been developed and is maintained in a complementary but separate project. Additionally, the Microsoft Excel sheet will be included in the Supplementary Material of the final paper.

8. Data querying

The open access database will be queryable by use of filter, sort/order, search functions, and the Power Query tool in Microsoft Excel so users may identify and access specific information. Information in the database may be searched for across different data items including publication year, study type, urban-level policy intervention, methods used, population characteristics, location, analysis years, pollutants considered, and primary outcomes (traffic emissions and/or TRAP) along with secondary outcomes (human exposures and health impacts) and secondary items of interest (enablers and barriers to intervention implementation and co-benefits) when available. One example includes querying the database for information on where urban policy interventions have been studied around the world. This query was carried out using data from six piloted studies. The Power Query tool was used to filter information from the database specific to urban policy interventions and geographic location as shown in the Supplementary Material (Fig. S.2). This information may then be used to create data visualizations, which is described more in the next section.

9. Data visualization

The evidence will be displayed on various interactive charts, graphs, and maps, which will be created using Tableau Public software. The charts, graphs, and maps will compose data visualization elements for this SEM, and they will be hosted on the CARTEEH Data Hub along with the database itself. One example of an interactive map is displayed (Figs. A1–A.4). The data for this example originates from six piloted studies as shown in the Supplementary Material (Figs. S.1 and S.2). This example displays where different urban policy interventions have been studied around the world. The initial user view displays a world map highlighting countries where interventions have been studied and a bar chart showing the total number of times each intervention has been studied (Fig. A1). The shade of blue for each country on the map corresponds with the number of records and gets darker with a higher number of records. For example, the Netherlands is shaded light blue because there is only one intervention record, China is shaded medium blue because there are three intervention records, and India is shaded dark blue because it has four intervention records. Users can click on different countries on the map to see which interventions have been studied in each country. Additionally, the tooltip displays information on the total number of times interventions have been studied in each

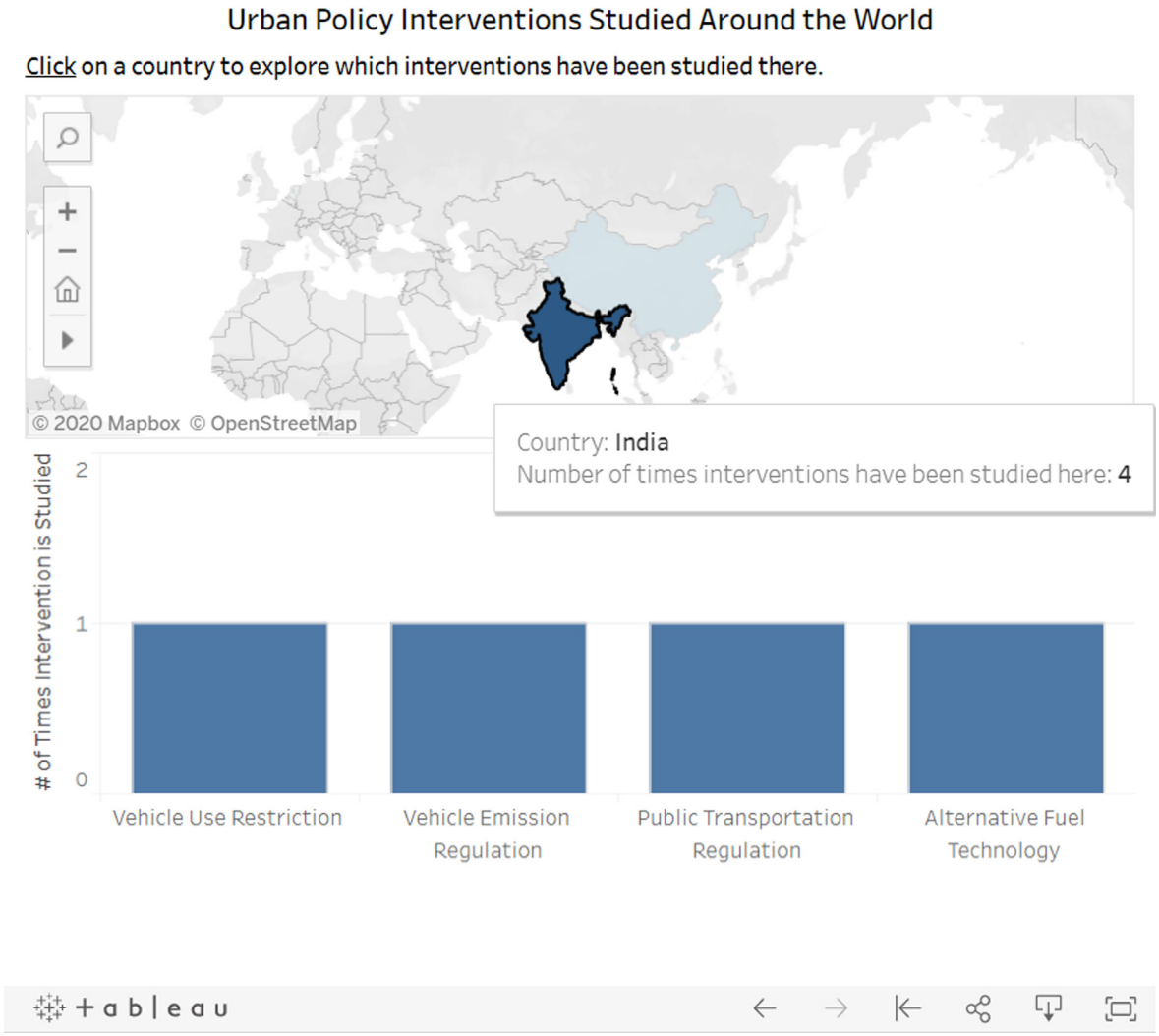

Fig. A3. Example 2 of an interactive map filter function.

country specifically. For example, China was clicked on, and we see that interventions have been studied there three times (Fig. A2). We can use the filtered bar chart to see that "Air Pollution Charging Fee" has been studied twice and "Alternative Vehicle Technology" has been studied once in this country (Fig. A2). Next, India was clicked on, and the tooltip shows that interventions have been studied four times in this country (Fig. A3). "Vehicle Use Restriction", "Vehicle Emission Regulation", "Public Transportation Regulation", and "Alternative Fuel Technology" have each been studied once in India (Fig. A3). Furthermore, if a user wants to see where a particular intervention has been investigated without clicking on the map, they can hover over the intervention in the bar chart, and the tooltip will list applicable countries. We hover over "Low Emission Zone" and see it has been studied in the Netherlands (Fig. A4).

10. Quality assessment

Quality Assessment will not be conducted for this SEM. Nonetheless, the purpose of the SEM will not be compromised as SEM methodology may be adapted while still maintaining its purpose (Wolffe et al., 2019).

11. Synthesis of results

The SEM results will be discussed in a narrative summary format. The following elements from a narrative synthesis guidance will be utilized in the conduct of this narrative summary: developing a preliminary synthesis and exploring relationships in the data (Popay et al., 2006). We will describe trends and gaps identified across the evidence base and highlight any major points from the data mapping exercise. The evidence base will be discussed in terms of the data items collected including publication year, study type, urban-level policy interventions studied, methods used, population characteristics, geographic location, analysis years, pollutants considered, and information on each primary outcome (traffic emissions and/or TRAP), as well as secondary outcomes (human exposures and health impacts) and secondary items of interest (enablers and barriers to intervention implementation and co-benefits), if any. Furthermore, data visualizations will be created using Tableau Public software to promote a better understanding of the results and their distribution. The characterization of the evidence on urban policy interventions to reduce traffic emissions and TRAP will facilitate valuable recommendations for future research in this area.

12. Amendments

This protocol for a SEM is the fourth updated version of a protocol originally geared toward a systematic review. All versions of the protocol are available in Zenodo (DOI: https://doi.org/10.5281/zenodo.3780631), including the original protocol (DOI: https://doi.org/10.5281/zenodo.3250172). All specific amendments will be documented and reported in the final SEM paper. The date of each modification, or

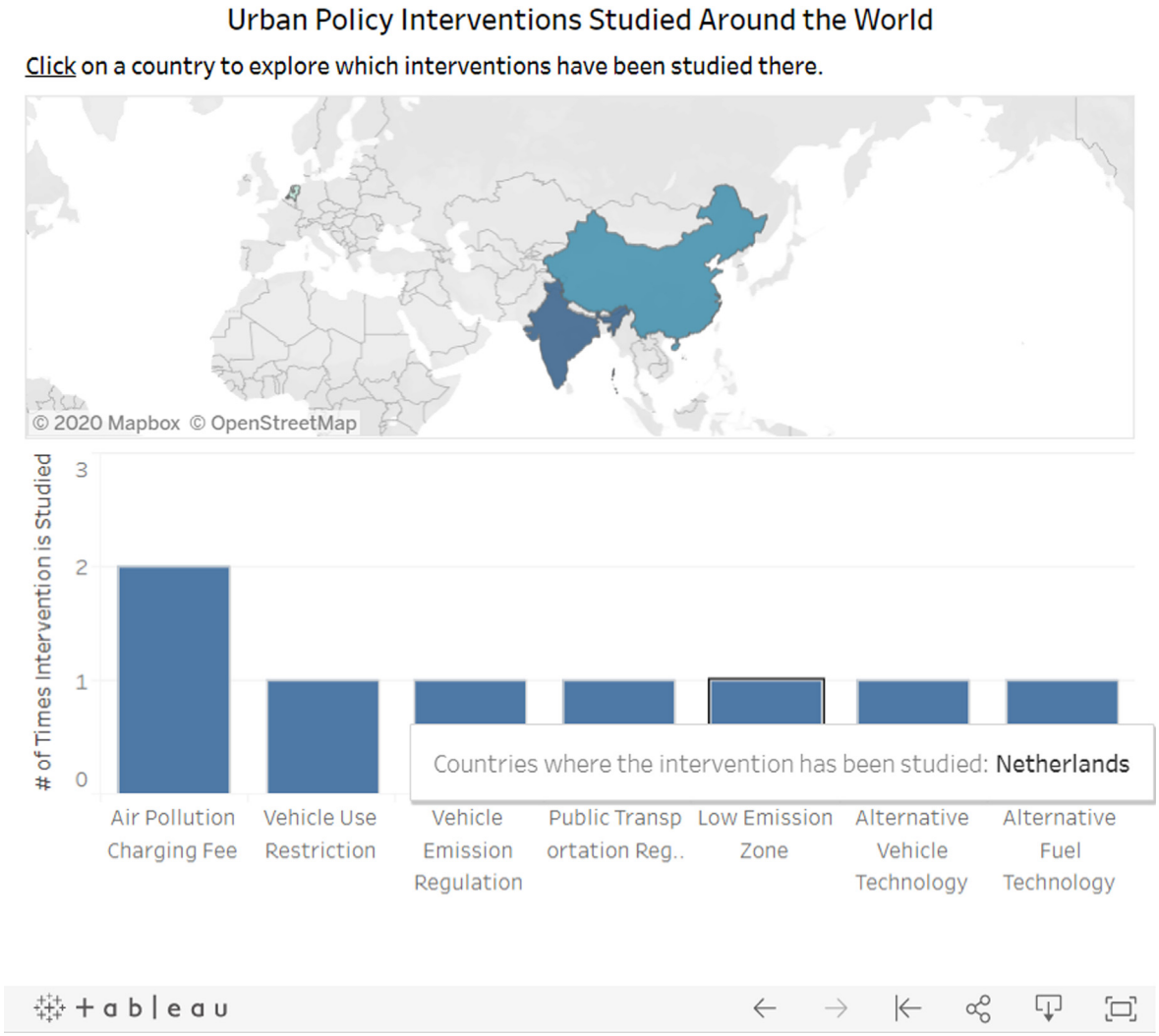

Fig. A4. Example of an interactive map hover function.

amendment will be listed and accompanied by a description of the change.

Acknowledgements

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Declaration of Competing Interest

The authors declare no conflict of interest.

Contributions

HK is the guarantor and conceived the idea of this SEM. KS and HK designed and drafted this protocol. MF developed the Information Sources and Search Strategy section and Table S.1. AM provided policy expertise on policy terminology. All authors read, provided feedback, and approved the final protocol.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envint.2020.105826.

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