Car harm: A global review of automobility's harm to people and the environment

Citation for published version:
Miner, P, Smith, BM, Jani, A, McNeill, G & Gathorne-Hardy, A 2024, 'Car harm: A global review of automobility's harm to people and the environment', *Journal of Transport Geography*, vol. 115, no. February, 103817. https://doi.org/10.1016/j.jtrangeo.2024.103817

Digital Object Identifier (DOI):
10.1016/j.jtrangeo.2024.103817

Published In:
Journal of Transport Geography

Journal of Transport Geography 115 (2024) 103817

Contents lists available at ScienceDirect

Journal of Transport Geography

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

Car harm: A global review of automobility's harm to people and the environment

Patrick Miner [a,b,*], Barbara M. Smith [c,d], Anant Jani [e,f], Geraldine McNeill [b], Alfred Gathorne-Hardy [a,b]

[a] School of GeoSciences, The University of Edinburgh, Old College, South Bridge, EH8 9YL Edinburgh, UK
[b] Global Academy of Agriculture and Food Systems, The University of Edinburgh, Old College, South Bridge, EH8 9YL Edinburgh, UK
[c] Centre for Agroecology, Water, and Resilience, Coventry University, Priory Street, CV1 5FB Coventry, UK
[d] Central Saint Martins, University of the Arts London, 1 Granary Square, N1C 4AA London, UK
[e] Heidelberg Institute of Global Health, Heidelberg University, 1 Grabengasse, 69117 Heidelberg, Germany
[f] Somerville College, The University of Oxford, Wellington Square, OX1 2JD Oxford, UK

ARTICLE INFO

Keywords:
Automobility
Externalities
Traffic fatalities
Pollution
Public health
Social justice

ABSTRACT

Despite the widespread harm caused by cars and automobility, governments, corporations, and individuals continue to facilitate it by expanding roads, manufacturing larger vehicles, and subsidising parking, electric cars, and resource extraction. This literature review synthesises the negative consequences of automobility, or car harm, which we have grouped into four categories: violence, ill health, social injustice, and environmental damage. We find that, since their invention, cars and automobility have killed 60–80 million people and injured at least 2 billion. Currently, 1 in 34 deaths are caused by automobility. Cars have exacerbated social inequities and damaged ecosystems in every global region, including in remote car-free places. While some people benefit from automobility, nearly everyone—whether or not they drive—is harmed by it. Slowing automobility's violence and pollution will be impracticable without the replacement of policies that encourage car harm with policies that reduce it. To that end, the paper briefly summarises interventions that are ready for implementation.

1. Introduction

Cars are the default mode of transportation in thousands of cities, suburbs, and towns around the world. Meanwhile trains, buses, bicycles, wheelchairs, and even our own bodies are discussed as "alternative" transportation. Yet there are just 16 cars for every 100 people on the planet (China Association of Automobile Manufacturers, 2021; International Organization of Motor Vehicle Manufacturers, 2017; Japan National Statistics Center, 2022; World Health Organization, 2018). While some people benefit from the default position of cars, nearly everyone—whether or not they drive—is harmed by it. In other words, human settlements are dominated by automobility, "an interlocking system of cars, highways, fueling infrastructure, automotive companies, government policies, and car cultures" (Sheller, 2018, p. 13).

This review synthesises the negative consequences of the system of automobility, or car harm (Fig. 1). We have grouped car harm into four categories (Fig. 2): violence (crashes and intentional violence); ill health (pollution, sedentary travel, and dependence and isolation); social injustice (unequal distribution of harm, inaccessibility, and consumption of space, time, and resources); and environmental damage (carbon emissions, pollution and resource extraction, and land use).

Car harm ranges from direct physical violence to slow or indirect violence (O'Lear, 2021). Despite the immense scale and severity of these harms, governments, corporations, and individuals continue to facilitate automobility by expanding roads, manufacturing larger vehicles, and subsidising parking, electric cars, and resource extraction. Instead of working to reduce car harm, current policies encourage it (Gössling, 2016). Slowing automobility's violence and pollution will be impracticable without the replacement of policies that encourage car harm with policies that reduce it.

Critiques of automobility started soon after cars were introduced. During the early years of automobility in Europe and North America, critics decried the loss of human and animal life from traffic crashes and the rearrangement of streets and cities to accommodate cars (Norton, 2008; Stoner, 1925). After World War II, as automobility's spread grew in both scope and speed, so did critiques of the system. Jane Jacobs,

* Corresponding author at: School of GeoSciences, The University of Edinburgh, Old College, South Bridge, EH8 9YL Edinburgh, UK.
E-mail address: patrick.miner@ed.ac.uk (P. Miner).

https://doi.org/10.1016/j.jtrangeo.2024.103817
Received 8 June 2023; Received in revised form 1 February 2024; Accepted 8 February 2024
Available online 17 February 2024

Lewis Mumford, and Ralph Nader were vocal critics in the 1960s (Jacobs, 1961; Mumford, 1964; Nader, 1965). Jacobs in particular expanded debates to broader questions around city life, suburbanisation, public housing, segregation, zoning, and safety, among other topics. Numerous authors have built on these arguments in the decades since (Böhm et al., 2006a; Cresswell, 2006; Freund and Martin, 1993; Newman and Kenworthy, 1999; Whitelegg, 1993). 21st-century research relies especially on the work of Mimi Sheller and John Urry who refined concepts related to the "system of automobility" and introduced further directions for critique (Sheller and Urry, 2000). Despite these decades of evidence-building research, automobility continues to expand in the 2020s with an increasing number of cars, and there is increasing industrial and political interest in making electric vehicles the one "solution" despite the social and environmental problems to which they contribute (Henderson, 2020). It is within this context and the context of mobility justice (see Section 2) that this paper discusses automobility (Sheller, 2018).

There are currently about 2 billion motor vehicles in use of which about 1.3 billion are cars (China Association of Automobile Manufacturers, 2021; International Organization of Motor Vehicle Manufacturers, 2017; Japan National Statistics Center, 2022; World Health Organization, 2018). Cars are unevenly distributed around the world (Fig. 3). The number of cars per person, indicated by a darker colour in Fig. 3, is highest in the US, Canada, Europe, and Australia. Per capita car ownership is lowest in Africa and South and Southeast Asia. Although China has recently overtaken the US to have the largest car fleet, there are 4 times as many cars per person in the US as in China. Certain wealthy countries with reputations for widespread cycling and few cars, such as the Netherlands, still have many more cars per person than most countries do; there are more cars in the Netherlands than in Nigeria despite Nigeria's population being 12 times greater. Automobility in the wealthiest countries harms residents within those wealthy countries, but the consequences of automobility also spread across borders and harm populations with the fewest cars—those who benefit least from automobility. For example, depleted lead batteries from cars are dismantled mainly in places with few cars resulting in automotive lead exposure without car ownership (Ericson et al., 2017).

After the methodology (Section 2), the paper continues with a summary of casualties attributable to automobility (Section 3). Sections 4 through 7 detail the four categories of harm identified above: violence, ill health, social injustice, and environmental damage. Section 8 is a brief discussion of interventions and Section 9 concludes the paper.

2. Methodology

This review uses a mobility justice framework (Sheller, 2018) to discuss automobility-related harm across four interrelated categories: violence, ill health, social injustice, and environmental damage. All four of these categories interact with one another, but (in)justice is particularly entangled with the other three topics. Sheller's mobility justice builds on capabilities approaches, egalitarianism, and several other theories of justice (Gössling, 2016; Lucas et al., 2016; Nussbaum, 2011; Pereira et al., 2017; Sen, 1993; Verlinghieri and Schwanen, 2020) but differs from transport justice and spatial justice in part through its basis in a mobile ontology "which not only tracks the effects of inequalities in mobility across various connected sites and scales, but also shows how justice itself is a mobile assemblage of contingent subjects, enacted contexts, and fleeting moments of practice and political engagement" (Sheller, 2018, p. 22). This review follows mobility justice's multi-scalar approach in shifting between micro, *meso*, and macro levels as it discusses mobilities and situations across the planet.

The paper is organised as a narrative review that suggests further reading on each harm topic. Systematic reviews are available for some of the topics, such as the health effects of traffic-related air pollution (Boogaard et al., 2022) or crash deaths and injuries in Africa (Adeloye et al., 2016). While this paper collects many forms of car harm into one resource, it does not attempt to be an exhaustive compendium of all forms of harm related to automobility. We searched the Scopus and Crossref databases up to September 2023 to explore the question "How do cars and the system of automobility harm people and the environment?" Our search combined one term to indicate the topic of automobility ("automobile", "automobility", "car", "parking", "road",

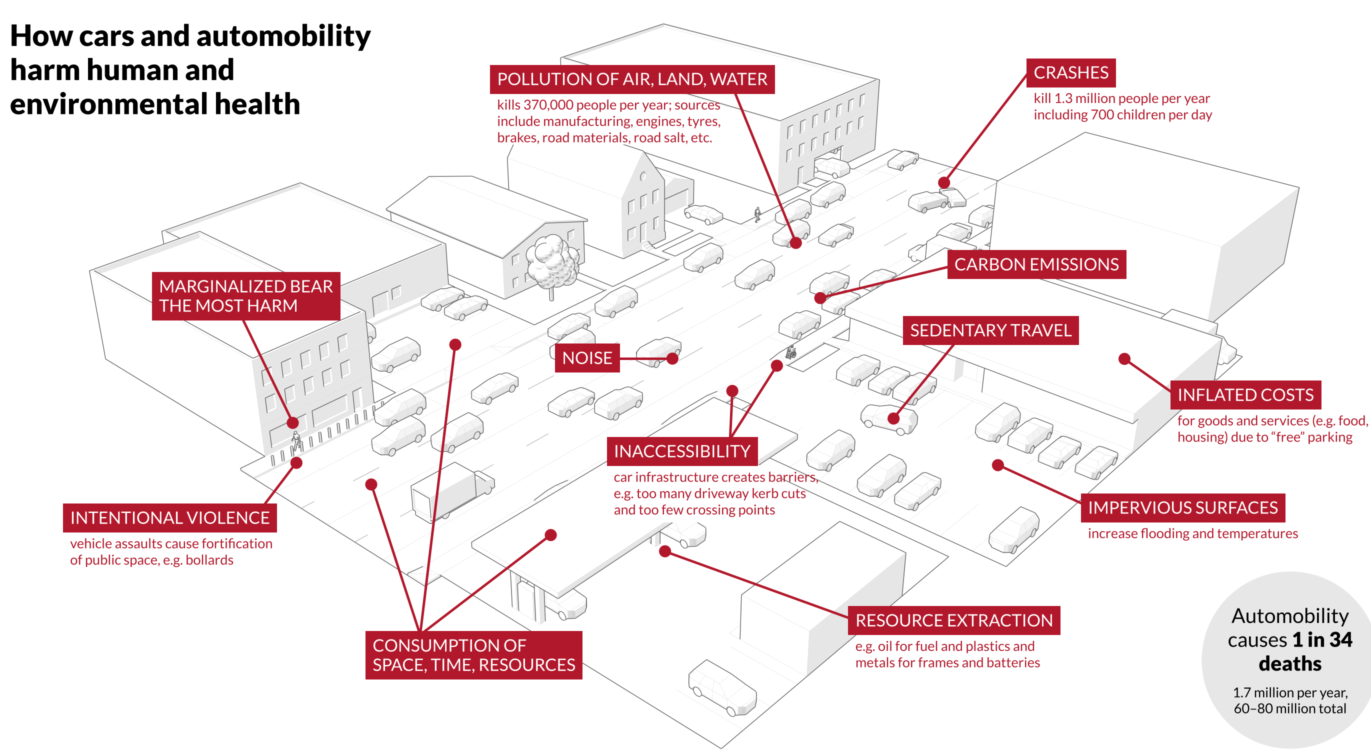

Fig. 1. This illustration gives examples of mechanisms by which automobility harms people and the environment.

"street", "traffic", "vehicle") with one or multiple broader terms, e.g. "accessibility", "assault", "biodiversity", "climate", "crash", "emissions", "environment", "heath", "justice", "land use", "policy", "pollution", "resource". Additional searches for grey literature were performed using non-academic search engines. We reviewed 409 academic articles and books and 78 grey literature reports and documents. In our search of the literature, we focused first on some of the most severe forms of harm as indicated by measurable discrete incidents (particularly deaths and injuries) and by ongoing issues of social injustice.

For our estimates of the annual and cumulative death toll of automobility in Section 3, we collected data from the Global Burden of Disease Collaborative Network, the World Health Organization, and additional sources which are detailed in the supplementary materials. In collecting and analysing data, we follow a critical quantitative approach (Kwan and Schwanen, 2009; Pavlovskaya, 2006; Wyly, 2014). In this case, our critical quantitative methods involve analysing numerical data to help uncover and understand social issues then using those results to encourage "progressive social and political change" (Kwan and Schwanen, 2009, p. 284) in the context of mobility justice.

2.1. Definitions

In this paper, the word "car" is synonymous with automobile and both are used to describe light-duty vehicles that carry people or a small amount of cargo. This includes sedans, SUVs, 4x4s, pickup trucks, vans, and taxis. The use of car does not include heavy-duty vehicles, such as buses and trucks/lorries, nor does it include two or three-wheeled motor vehicles (motorcycles, motorbikes, scooters) or micromobility devices (electric bicycles, electric scooters). The term "motor vehicle" refers to all road vehicles with engines, i.e. cars, buses, trucks, and motorcycles but not micromobility devices. Micromobility devices differ substantially from motor vehicles: they are often at least partly human powered, they operate at slower speeds, and they weigh considerably less.

2.2. Limitations

The paper is intended as a reference for researchers and policymakers who are working on plans and policies that aim to reduce automobility-related harms and subsequently improve human and environmental health and wellbeing. The paper does not explore the benefits of automobility, nor is it an exhaustive summary of all harms. We do not discuss other sociotechnical systems such as aviation or railways—both of which contribute to injuries, habitat destruction, climate change, and other harms (and benefits) albeit on a smaller scale than that of automobility.

While this paper focuses on harm, we recognise that cars and automobility offer important benefits to some people. They connect isolated towns and rural areas. Cars and automobility can provide transportation for people who have physical disabilities (Power, 2016). Car interiors can be sites for conversation, enjoyment of music, privacy, safety, or a respite from the outside world (Dobbs, 2005; Laurier et al., 2008). Cars can influence people's sense of self and fulfil symbolic and affective functions (Steg, 2005). These benefits are important for the people they affect, and interventions to reduce car harm need to take them into consideration.

This paper does not adhere to a utilitarian cost-benefit analysis framework wherein "costs", e.g. harms caused by automobility, are compared with the "benefits" of automobility, e.g. those listed in the previous paragraph. It instead focuses directly on harms, as these have been deprioritised in decades of research and policy that suggest modifications to automobility (e.g. electric or autonomous cars) rather than the more politically controversial option to challenge the system of automobility (Culver, 2018; Sheller, 2018).

3. The death toll of automobility

Since the first car crash death in the late 19th century, car harm has grown to be so ubiquitous that it is socially constructed as normal, accidental, or inevitable (Culver, 2018; Te Brömmelstroet, 2020). Beyond crashes, cars and automobility kill and worsen human health through pollution and several other mechanisms. This section provides an introductory epidemiology of automobility.

Accounting only for crashes and some forms of pollution, approximately 1.67 million people per year die as a result of automobility. This means that cars and automobility cause 1 out of 34 deaths (Global Burden of Disease Collaborative Network, 2020). We estimate that cars and the system of automobility have killed approximately 60 to 80 million people since their invention (see Table 1 and the supplementary

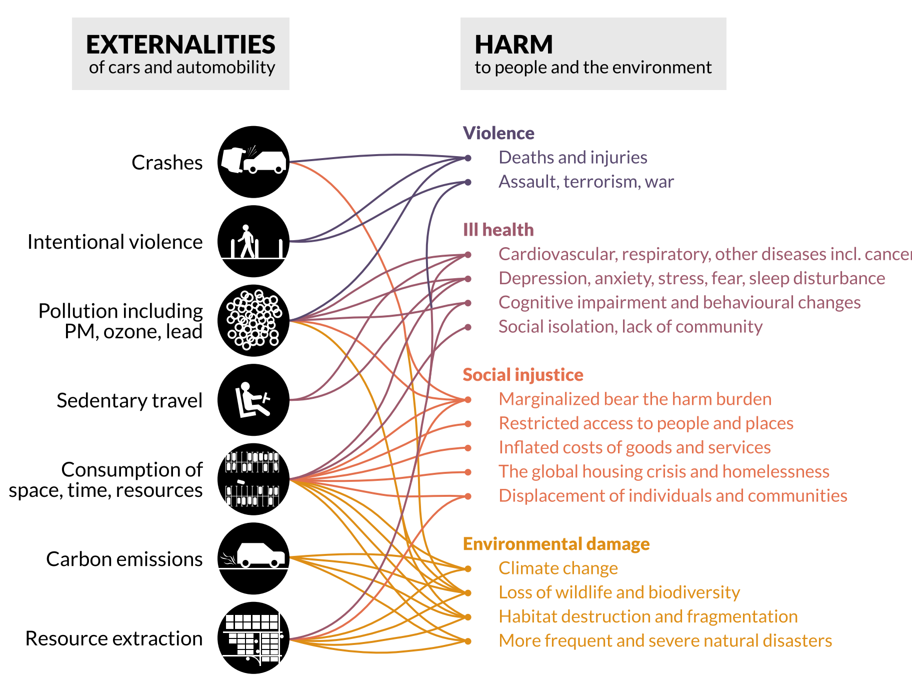

Fig. 2. Externalities of cars and automobility and their connections with harms to people and the environment.

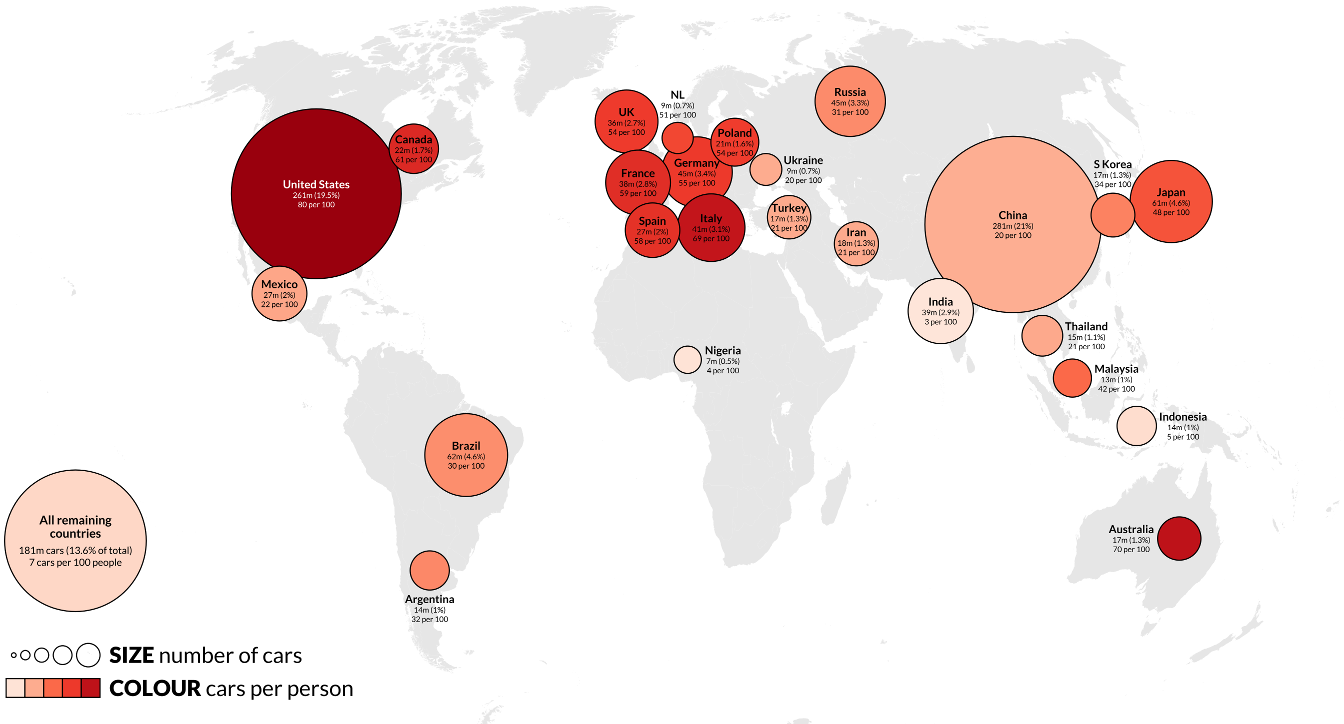

Fig. 3. Number of cars and cars per person in 25 countries. This map highlights the 25 countries with the largest car fleets as of 2016 to 2018. Note that both car fleet and population data for China have been updated to 2020 to reflect the rapid growth of the Chinese car fleet. Other country fleets are changing at a slower pace. Sources: (China Association of Automobile Manufacturers, 2021; International Organization of Motor Vehicle Manufacturers, 2017; Japan National Statistics Center, 2022; World Health Organization, 2018).

materials for details and data). The 60–80 million number is similar in magnitude to the combined 57 to 82 million deaths from the two World Wars (Hughes and Royde-Smith, 2022; Showalter and Royde-Smith, 2022).

Our annual and cumulative death toll figures are conservative estimates mainly due to a lack of data for multiple areas of car harm. The estimates include crash deaths from all motor vehicles (cars, motorcycles, buses, trucks, etc.). These motor vehicles are all part of the system of automobility which prioritises speed over safety. In 2019, 43% of crash death victims were walking, wheeling, or cycling when a motor vehicle driver killed them (Global Burden of Disease Collaborative Network, 2020).

The death toll estimates also include deaths from traffic-related air pollution and some types of vehicle-based lead exposure. Our estimates do not include the contribution of automobility toward illness and death caused by sedentary travel, intentional violence, and forms of pollution not mentioned above, such as noise pollution.

In addition to the immense scale of death caused by automobility, approximately 102 million people are injured in motor vehicle crashes annually (Global Burden of Disease Collaborative Network, 2020). Beyond impact injuries, more than 90% of people live in areas with unsafe levels of outdoor air pollution including vehicle-sourced pollution (World Health Organization, 2021b). Through crashes, pollution, resource extraction, and climate change, automobility has reached—and worsened the health of—nearly every person on the planet.

4. Violence

This section focuses on traffic crashes and intentional violence related to automobility (Fig. 4). The word violence is used here to mean “bodily physical harm” related to motor vehicles (Culver, 2018, p. 147).

4.1. Crashes

Traffic crashes kill 1.3 million people per year or 3500 people per day, and they are the eighth-leading cause of death globally (World Health Organization, 2021c; World Health Organization, 2018). Over the past few decades, the number of crash deaths has not risen as quickly as car ownership—reflecting safety improvements in many places but safety reductions in others. Africa has the highest regional crash death rate per capita, and Europe has the lowest as crash deaths have been declining there for several decades. Importantly, crash deaths in the US were declining but recently began increasing again (National Highway Traffic Safety Administration, 2021; World Health Organization, 2018). This trend has been partially attributed to the growing popularity of SUVs which, due to their heavier and taller forms, are more likely to kill people outside of cars such as those walking (Monfort and Mueller, 2020; Ossiander et al., 2014). A US study found that children were 8 times more likely to be killed when hit by a SUV than by a traditional car (Edwards and Leonard, 2022). As SUVs now account for 46% of global car sales (Cozzi et al., 2023), the US increase in crash death rates could be a warning for other countries.

Globally, traffic crashes are the leading cause of death for children over 4 and for adults under 30 (World Health Organization, 2021c). Crashes kill more than 700 children every day (Zegeer and Bushell, 2012). Except in cases when teenaged children are permitted to drive, children are killed or injured either as passengers or while outside of cars. To facilitate the movement of people in cars, children walking to school or playing with friends must “watch out and make way, or be killed” (Culver, 2018, p. 152).

Crash injuries are, in many cases, permanently life altering (World Health Organization, 2021c). Globally, an estimated 102 million people are injured in crashes annually (Global Burden of Disease Collaborative Network, 2020). This means that in an average year, about 1 in 80 people are injured in a crash. Since 2000, an estimated 2 billion people have been injured in motor vehicle crashes—up to 1 in 4 people alive

Table 1
Estimated annual and cumulative deaths caused by cars and automobility.

Automobility externality	2019 deaths (millions)	Cumulative deaths (millions)	Notes
Traffic crashes, 21st century (2000–2022)	1.30	28–29	Sources: (Global Burden of Disease Collaborative Network, 2020; World Health Organization, 2018, 2021a)
Traffic crashes, 20th century	–	26–40	Sources: (Global Burden of Disease Collaborative Network, 2020; International Federation of Red Cross and Red Crescent Societies, 1998; Organisation for Economic Co-operation and Development, 2021; World Health Organization, 2018, 2021a) and additional data; see supplementary materials
Traffic-related air pollution	0.25	6.3–9	Sources: (Anenberg et al., 2019; Bhalla et al., 2014; Caiazzo et al., 2013; Fann et al., 2017; Frey, 2018; Global Burden of Disease Collaborative Network, 2020; Xiong et al., 2022)
Vehicle-based lead exposure	0.12	0.9–5.7	Sources: (Ericson et al., 2017; Global Burden of Disease Collaborative Network, 2020; Green Cross Switzerland, Pure Earth, 2016)
Other externalities, e.g. other pollution, sedentary travel	–	–	Not included in this study
Total	1.67	61–83	

Traffic crash deaths are counted directly while the health burden of pollution is indirectly estimated; see the supplementary materials for details and data.

today—not accounting for repeat injuries or population change.

4.2. Intentional violence

In car-dependent societies, cars blend into their surroundings and can be inconspicuous weapons. Car bombs were first deployed in the 1920s and have been more frequently used since the 1970s (Davis, 2011). People also use vehicles as weapons without explosives, wherein the force of impact is the weapon. Hundreds of cities have installed bollards to fortify their public spaces against vehicle attacks (Chambers and Andrews, 2019).

Other forms of intentional car-based violence include aggressive driving, driving under the influence of alcohol, and drive-by shootings (Bernardin et al., 2023; Bjureberg and Gross, 2021; Borg et al., 2020; Braly et al., 2018; Carroll and Rothe, 2014). Car-based carbon monoxide (CO) poisoning and intentional crashes are methods for self-harm causing thousands of deaths per year (Carroll and Rothe, 2014; Gunnell et al., 2015; Mott et al., 2002; O'Donovan et al., 2022). In some countries, automobility enables state violence. For US residents, traffic stops are the most common interaction with police, and they are a setting for police violence against Black, Latine/x, and Indigenous people (Carbado, 2015; Engel and Johnson, 2006; Pierson et al., 2020; Seo, 2019; Woods, 2021).

Intentional car-related violence includes armed conflicts over access to resources such as oil and metals. Motor vehicles are by far the largest consumer of oil with the sector responsible for about half of total oil consumption (International Energy Agency, 2020). Wars have complex causes, but one study estimated that 25–50% of interstate wars since 1973 have been connected to oil access (Colgan, 2013). Conflicts within states have also been motivated by access to oil, for example in Nigeria in the 2000s (Schultze-Kraft, 2017).

5. Ill health

Cars and automobility negatively affect physical and mental health through a variety of mechanisms including pollution, sedentary travel, and social isolation (Fig. 5).

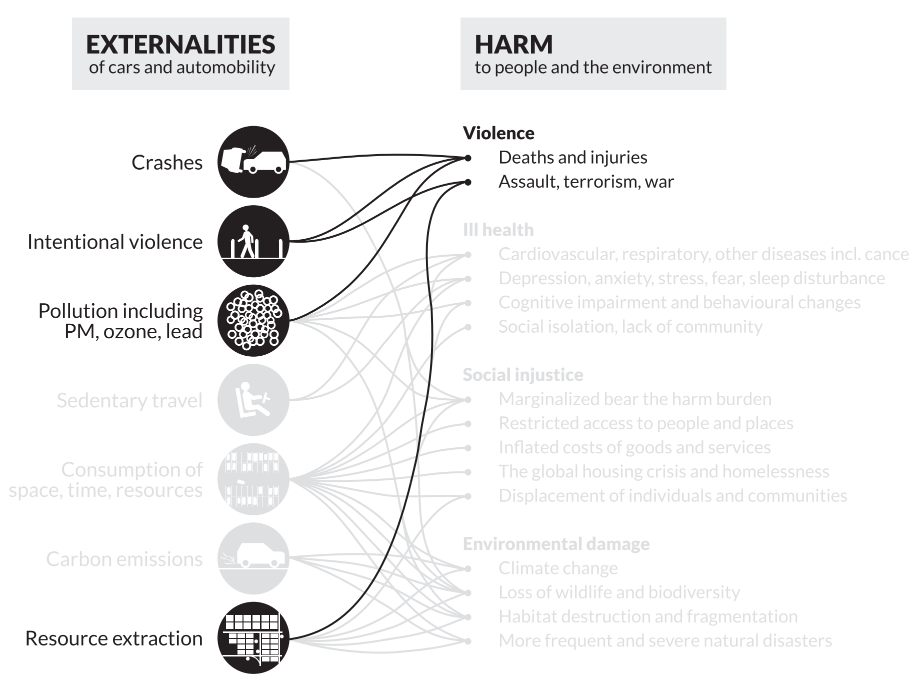

Fig. 4. Externalities of automobility and the violence to which they contribute.

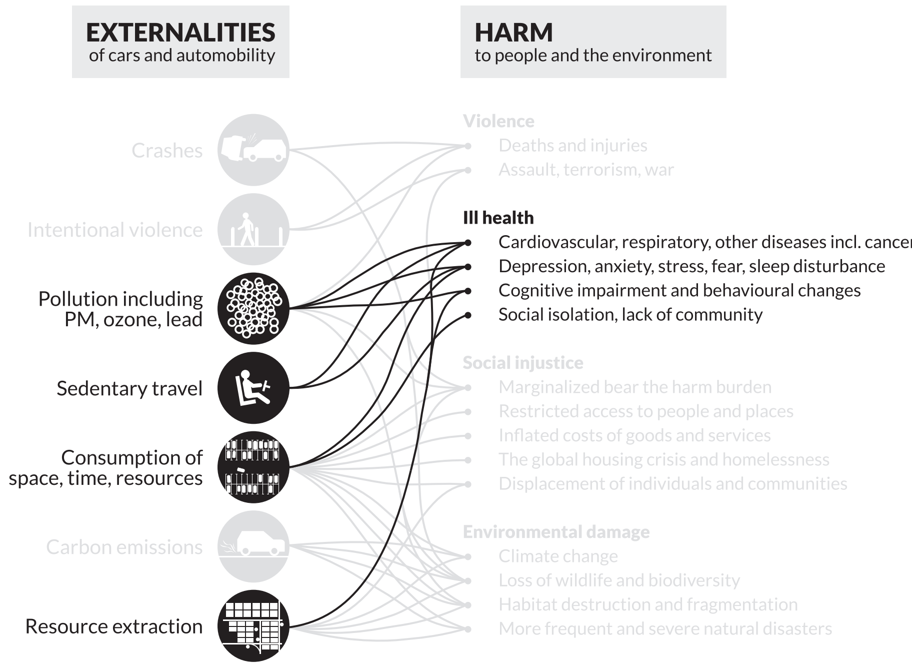

Fig. 5. Externalities of automobility and the ill health to which they contribute.

5.1. Pollution

Automobility contributes to air, land, and water pollution. These forms of pollution are harmful to human health and contribute to hundreds of thousands of premature deaths per year.

5.1.1. Air, land, and water pollution

Traffic-related air pollution is a mix of gases and particles. Gases include nitrogen oxides (NO_x), carbon monoxide (CO), sulphur dioxide (SO_2), and ozone (O_3) (Boogaard et al., 2022; Masiol et al., 2014). Particulate matter (PM) includes “organic and elemental carbon, metals [e.g. lead], and polycyclic aromatic hydrocarbons” (Attademo et al., 2017, p. 55). Particulate matter is typically categorised by particle size. PM_{10} and $PM_{2.5}$ include particles up to 10 μm and 2.5 μm, respectively. Ultrafine particulate matter, $PM_{0.1}$, includes particles up to 0.1 μm (100 nm).

In motor vehicle operations, two processes are responsible for the majority of air pollution: motor running and material abrasion. Motor emissions are produced by the running of a vehicle’s engine. Abrasion emissions are caused by the friction of materials such as tyres, brakes, and road surfaces (Harrison et al., 2021; Smith et al., 2013). The manufacturing and disposal of vehicles also contribute to ambient air pollution. Transitioning to electric vehicles may increase PM abrasion emissions if electric vehicles continue to be heavier than internal combustion engine vehicles (Harrison et al., 2021; Soret et al., 2014).

Among PM emissions, smaller particles tend to be more hazardous to human health. $PM_{0.1}$ “are of great concern… due to their ease to go through biological barriers” (González-Maciel et al., 2017, p. 190). While “up to 90% of PM in urban areas is traffic-related” (Reis et al., 2018, p. 252), certain vehicles produce more harmful particle species and sizes. Diesel engines release 10–100 times as much breathable PM as do gasoline engines (Mazzarella et al., 2007). Stricter regulation of vehicles has led to reductions in PM and NO_x emissions, but these improvements are being offset by increasing numbers of vehicles (Farahani et al., 2021; Xiong et al., 2022).

A systematic review of 353 studies found that traffic-related air pollution is associated with “all-cause, circulatory, ischemic heart disease and lung cancer mortality” (Boogaard et al., 2022, p. 1). Vehicular air pollution may increase risk of neurological conditions including depression, anxiety, dementia including Alzheimer’s, schizophrenia, autism, and cognitive impairment (Attademo et al., 2017; Bakolis et al., 2021; Chen et al., 2017; González-Maciel et al., 2017; Kioumourtzoglou et al., 2017; Newbury et al., 2019; Oudin et al., 2016; Paul et al., 2019; Power et al., 2011; Raz et al., 2015). It contributes to low birth weights and premature births (Dibben and Clemens, 2015; Smith et al., 2017), and in children it contributes to reduced lung volumes and increased risk of diseases, e.g. asthma and leukaemia, and mental health issues (Khreis et al., 2017; Mudway et al., 2019; Newbury et al., 2019; Waygood et al., 2017). Globally, approximately 246,000 annual deaths are attributable to traffic-related air pollution ($PM_{2.5}$ and O_3) (Anenberg et al., 2019; Xiong et al., 2022).

Vehicle tyres and brakes, as well as road markings, shed microparticles including microplastics which become airborne and can contaminate food or water (Blair et al., 2019; Kole et al., 2017). Humans then ingest or inhale these plastic particles. More research is needed to determine the risks of microplastic intake but effects may include inflammation, cellular damage, gastrointestinal issues, and effects from the accumulation of heavy metals that attach to microplastics (Brewer et al., 2021; Chang et al., 2020; Vethaak and Legler, 2021; Wright and Kelly, 2017).

Automobility sources of metals that contaminate environments include exhaust, tyres, brakes, clutches, lubricating oils, vehicle corrosion, road surfaces (e.g. asphalt), and road markings (Adamiec et al., 2016; Ozaki et al., 2004; Sysalová et al., 2012). Studies in Iran and Poland found that road dust was contaminated with up to a dozen metals (Adamiec et al., 2016; Mirzaei Aminiyan et al., 2018). The authors noted that brakes and tyres were especially potent contributors of metal contaminants in road dust. As such, increased uptake of heavy electric vehicles will maintain or increase these levels of metal contamination.

Among vehicle-related metals, one of the most dangerous to human health is lead (Pb). From 1923 to 2021 lead was added to gasoline to improve engine performance (Needleman, 2000; UN Environment Programme, 2021). Before leaded fuel was banned, it “accounted for 80-90% of airborne Pb in cities where it was used” (van der Kuijp et al., 2013, p. 1). Lead depositions persist today and people will be exposed for years to come (Muller et al., 2018). Moving vehicles cause lead-contaminated soils and road dusts to be re-suspended in the air which people then inhale (Laidlaw et al., 2012; Resongles et al., 2021). About

75% of current global lead consumption is for motor vehicle batteries (World Health Organization, 2022). Lead is also found in paint for both new and older vehicles (Ghaffarian-Bahraman et al., 2021; Gottesfeld, 2015; Santosa et al., 2022). Road markings contain high concentrations of lead, especially in yellow paint (Adachi and Tainosho, 2004; Lee et al., 2016; Meza-Figueroa et al., 2018; Turner and Filella, 2023; Zannoni et al., 2016). While it is difficult to determine exactly what proportion of lead deaths are caused by automobility sources (fuel, batteries, and paint), we estimate that automobility causes 120,000 lead exposure deaths annually—see supplementary materials (Ericson et al., 2017; Global Burden of Disease Collaborative Network, 2020; Green Cross Switzerland, Pure Earth, 2016; World Health Organization, 2022).

Oils from streets contaminate land and water, especially in the form of runoff after precipitation events (Byrne et al., 2017; Kuruppu et al., 2019). In addition to deposition on roadways, oil is spilled into water and land systems. People who come into contact with spilled oil, breath its vapours, or eat oil-contaminated seafood are at risk for dizziness, nausea, neurological issues, and cancer (Chang et al., 2014).

5.1.2. Noise pollution

Motor vehicles are the main source of noise pollution in urban areas (Khan et al., 2018). At speeds of under about 30kph (19mph), car noise is dominated by "propulsion noise" from the engine. At higher speeds, noise is dominated by "rolling noise" or tyres rolling on the road surface. For heavy duty vehicles, propulsion noise is the main factor up to speeds of about 75kph (47mph) (Heutschi et al., 2016). Electric engines produce less noise at slow speeds, but the difference becomes less noticeable above 30kph as rolling noise increases.

Certain vehicles and behaviours have an outsized effect on noise pollution. Motorcycles are among the loudest vehicles and are often perceived as nearly twice as loud as cars (Hernandez et al., 2019). Aggressive drivers who rev their engines, use their car horns excessively, or travel at unsafe speeds increase noise pollution. Car alarms, which are frequently false alarms, are another source of automotive noise pollution (Goines and Hagler, 2007).

The negative health effects of vehicular noise pollution include cardiovascular disease, high blood pressure, tinnitus (ringing in the ear), hearing loss, anxiety, stress, sleep disturbance, and cognitive impairment (Allen and Adar, 2011; Caciari et al., 2013; Fritschi et al., 2011; van Kempen et al., 2002). Like many aspects of car harm, it is difficult to separate out the harm that is directly attributable to vehicles, but a World Health Organization study found that at least 1 million "healthy life years are lost every year from traffic-related noise in the western part of Europe" (Fritschi et al., 2011, p. 108). A European Environment Agency report estimated 10,100 premature deaths per year due to road noise pollution in 32 European countries (Peris et al., 2020).

5.1.3. Light and thermal pollution

Automobility contributes to light and thermal pollution through car-centric built environments. Streets and car parks (parking lots) generate light pollution that interferes with human health, e.g. sleep quality (Cao et al., 2023; Cho et al., 2015; Zhong et al., 2023). Paved surfaces such as streets and parking spaces increase local air and surface temperatures. This "urban heat island" effect harms human health by exacerbating heat waves, increasing air pollution, causing heat-related conditions (e.g. heat stress and heat stroke), and worsening existing conditions (e.g cardiovascular or respiratory diseases) (Basu and Samet, 2002; Khosla et al., 2021; Li and Bou-Zeid, 2013; Mora et al., 2017; Santamouris et al., 2015; Ziter et al., 2019).

5.2. Sedentary travel

Sedentary behaviour, including car travel, increases the risk of "all-cause mortality, cardiovascular disease mortality… cancer mortality, and incidence of cardiovascular disease, type 2 diabetes, and cancer" (Bull et al., 2020, p. 1456). Meanwhile, walking, cycling, or wheeling serve not only as transportation but as exercise activities that improve physical and mental health (Bull et al., 2020; Frank et al., 2004; Johansson et al., 2019; Núñez-Córdoba et al., 2013). In car dependent places, many short journeys are made by car when they could be made by physically active modes. Reliance on cars for longer trips can be reduced by using bus and train services. Travelling by public transport is sedentary while passengers are on board, but journeys involve walking or wheeling at the start and end of each trip. One study found that switching from car commuting to public transport commuting with no other behaviour changes increased energy expenditure by 124 kcal per day—about equal to the kcal expended by an average adult walking 2 km (Morabia et al., 2010).

Over the past few decades, children have become increasingly sedentary in their travel, particularly in the most car dependent countries. Children who are driven to destinations are less likely to meet the 60-min daily physical activity recommendation from the World Health Organization (Oliver et al., 2015). In the US, the proportion of children who walk or cycle to school has decreased from about 48% in the 1970s to 10.7% in 2017 (Kontou et al., 2020). One reason for the decline in walking to school across multiple countries is the danger posed by cars: "There is too much traffic for Alex to walk to school, so we drive" (Oliver et al., 2018, p. 323).

5.3. Dependence and isolation

In car-dependent landscapes, individuals are isolated from people and destinations by long distances and physical barriers such as motorways (expressways). Without a car, one cannot access food, healthcare, work, education, family, or friends. Most people on the planet do not drive, including millions in car-dependent places. This results in social isolation, and "isolated individuals are at increased risk for the development of cardiovascular disease, infectious illness, cognitive deterioration, and mortality" (Steptoe et al., 2013, p. 5797). In car-dependent places, people who do not drive must remain in place until someone comes to visit or they can use buses (if available) or taxis (Milton et al., 2015). Emergency services can also be impacted by sprawling car-dependent landscapes as evidenced by fire and ambulance response time delays caused by road traffic and increased travel distances (Lambert et al., 2012; Trowbridge et al., 2009).

Car dependence has shifted social constructions of childhood and especially concepts of independence and safety. Compared to children who walk or cycle, children who travel in cars have less knowledge about their neighbourhoods, have fewer opportunities for outdoor play and exploration, and gain less experience in assessing risk and becoming independent (Bruntlett and Bruntlett, 2021; Karsten, 2005; Mackett, 2002; Oliver et al., 2015; Waygood et al., 2017).

Cars and car spaces dominate urban life. Whether walking, wheeling, cycling, travelling by bus, or simply standing or sitting outside, everyone must negotiate with cars to be allowed their existence. Each time someone prepares to cross a street, they are engaging in a life-and-death decision process. The danger and unpleasantness of traffic reduces rates of walking and cycling and therefore physical activity which is essential to good health (Jacobsen et al., 2009; Mindell and Karlsen, 2012).

6. Social injustice

Automobility is enabled by and produces a long list of social injustices. These include unevenly distributed harm, inaccessibility, and the consumption of space, time, and resources (Fig. 6).

6.1. Unequal distribution of harm

The harm of automobility is unevenly distributed across social characteristics including age, race, ethnicity, sex, gender, wealth, class, and ability. In terms of age, more than 700 children are killed in traffic crashes every day, and children and the elderly are more likely than

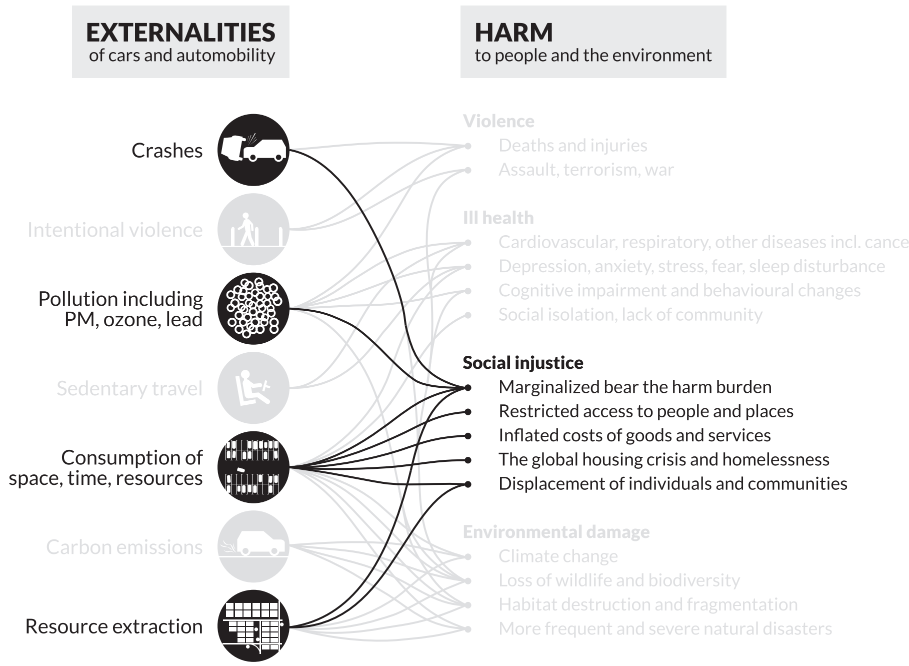

Fig. 6. Externalities of automobility and the social injustices to which they contribute.

other pedestrians to be killed in crashes (Zegeer and Bushell, 2012). Crashes are the leading cause of death for people aged 5 to 29 (World Health Organization, 2018).

Race and ethnicity have been intertwined with car harm for decades. Currently, traffic crash death rates are highest in Africa and Southeast Asia and lower in predominantly white regions despite the presence of more cars per person in predominantly white regions (World Health Organization, 2018). In Brazil and the US, two large racially and ethnically diverse countries, crashes disproportionately kill Black and Indigenous people (Andrade SSCA and Mello-Jorge MHP, 2016; Culver, 2018). A US study found that people were less likely to stop their cars for Black pedestrians than for white pedestrians (Goddard et al., 2015). Automobility played (plays) a key role in colonialism. For example, colonial road building used forced labour and displaced Indigenous communities (Clarsen, 2017; Clarsen and Veracini, 2012; Ponsavady, 2018). Automobility often conflicts with and endangers Indigenous practices of walking as transport (Lucas et al., 2019).

In terms of gender and sex, cars are designed for the "average male" anatomy and.

> when a woman is involved in a car crash, she is 47% more likely to be seriously injured than a man, and 71% more likely to be moderately injured, even when researchers control for factors such as height, weight, seat-belt usage, and crash intensity. She is also 17% more likely to die. (Criado-Perez, 2019, p. 186).

Traffic crashes are "the main cause of injuries and trauma in pregnant women" and "more than half of all pregnancy trauma are due to [crashes]" (Auriault et al., 2014, p. 207). Speeding, risky manoeuvres, revving engines, and other aggressive behaviours have been gendered as masculine activities. This scenario is dangerous for all people on the road, including those perpetuating it as men make up the majority of people killed in crashes caused by risky driving (Braly et al., 2018; Sullman et al., 2017).

Economic status influences one's risk of harm from motor vehicles. Despite lower levels of car ownership and fewer kilometres travelled, the economically poor are more likely than the economically wealthy to be killed in traffic crashes (Culver, 2018; Curl et al., 2018; Lucas et al., 2019; World Health Organization, 2018). Economically wealthy people, especially the "kinetic elite" (Birtchnell and Caletrío, 2013; Sheller, 2018), cause more air pollution through excess driving, but this pollution is disproportionately inhaled by economically poor people and racially minoritised groups (Tessum et al., 2019; Wadud et al., 2022). The least wealthy members of our societies do not have cars but are forced to endure elevated levels of crashes and pollution so that wealthier people can drive.

6.2. *Inaccessibility*

Two meanings of (in)accessibility are particularly relevant for car harm. First, accessibility can refer to physical access to the built environment for people with disabilities. For example, people with mobility disabilities may use wheelchairs or other mobility aids, and people with limited vision or hearing may experience difficulty with travel. Second, accessibility can refer to spatial accessibility. This describes access to places where one interacts with people and accesses essential goods and services (Guimarães et al., 2019).

Buildings, vehicles, streets, and other built environments are not designed to enable physical access for all people. For example, some car infrastructure creates obstacles for people with mobility disabilities, e.g. pavement (sidewalk) clutter such as parking meters, driveway kerb cuts, and bollards to guard against unsafe driving. Kerb cuts for crossing streets, which originated as an "accommodation" for people in wheelchairs, can be a barrier for people who are blind or have limited vision, especially when tactile paving is not used (Hamraie, 2017). More physically accessible streets have raised crossings or speed tables that reduce or eliminate kerb cuts and require cars to slow down to make way for people who are walking or wheeling.

Inaccessibility is not only a matter of equity but also an urgent safety issue. People with disabilities are more likely than others to be killed or injured by motor vehicles despite lower levels of car access and higher levels of public transport use (Aldred and Woodcock, 2008; Kraemer and Benton, 2015; Wilkins et al., 2017). Some people with physical disabilities use dial-a-ride services or taxis, or they may have a vehicle with ability-specific modifications which can cost up to US$190,000 (Darcy and Burke, 2018; Verbich and El-Geneidy, 2016). Currently people with physical disabilities are marginalised by expensive vehicle modification costs, inaccessible infrastructure, and by the assumption that they only move about by a particular mode when in fact they use a combination of modes including cars, public transport, walking, wheeling, and cycling.

Car-dependent environments "disable" people who do not drive by restricting access to essential needs (Urry, 2006).

> Automobility promises the annihilation of distance, but prioritises some people's journeys at the expense of others'. Some distances become larger, as when dual carriageways and fast one-way systems bisect inner-city areas, speeding up commuters while forcing local people to detour. Rather than dissolving space, the car economy redistributes it, and most disabled people are among the losers, along with people in poor neighbourhoods and children. (Aldred and Woodcock, 2008, p. 494).

Physical (in)accessibility and social (in)accessibility overlap and reinforce one another while also interacting with economic inaccessibility. Systems disable people via "social oppression, not a person's impairment" (Aldred and Woodcock, 2008, p. 487). Automobility, like many systems, is organised around the assumption of "able-bodied" movement with too few considerations for physical and social accessibility.

6.3. Consumption of space, time, and resources

Automobility consumes a large amount of space for the operation and storage of motor vehicles including streets, motorways (expressways), car parks (parking lots), residential garages, and petrol stations. Governments, organizations, and individuals invest money and time into building and maintaining these spaces so that the system of automobility can function (Böhm et al., 2006b).

6.3.1. Car-dependent places

Automobility enables the geographical separation of home, work, schools, hospitals, shops, parks, and other places so that motor vehicles are the most convenient way to move between them. In this way, automobility is a solution for a problem that it helps to create (Sheller and Urry, 2000; Urry, 2006). After World War II, dozens of countries built new car-based spaces including suburbs, new towns, wider streets, and motorways. In the US, the federal government incentivised white citizens to move from cities to suburbs with low-cost government-guaranteed mortgages and by subsidising driving with new car infrastructure (Nall, 2018; Sheller, 2018; Trounstine, 2020). This pattern of "white flight" decimated services for those who remained in cities—particularly people who were systematically marginalised such as Black people and the economically poor.

6.3.2. Streets and motorways (expressways)

Streets are, in principle, shared between all people and modes of transport, yet cars consume far more street space than other modes do. While moving, cars consume an estimated 1.39m^2 per hour per person compared to 0.52m^2 for bicycles, 0.27m^2 for walking, and 0.07m^2 for buses (Crist et al., 2022; Héran et al., 2011; Héran and Ravalet, 2008). These estimations vary depending on vehicle size, speed, and number of passengers. One person in a car consumes the space of about 20 bus passengers, and cars are consuming more and more space as vehicle sizes increase. SUVs now account for 46% of global car sales (Cozzi et al., 2023).

Among roadways, motorways are some of the most space and resource-intensive. Not only do they cost millions of pounds per kilometre, they displace residents and destroy communities as they cut paths through the landscape. From 1957 to 2010, construction of US motorways cost at least US$1.4 trillion and required the movement of 38 billion metric tons of earth—equivalent to 116 Panama Canal construction projects. These motorways displaced an estimated 1 million people from their neighbourhoods (Nall, 2018).

6.3.3. Parking

Unlike streets, parking is rarely used by people outside of cars. As such, parking space is distributed more inequitably than street travel lane space. On-street parallel parking consumes approximately 10-19 m^2 per car and off-street parking consumes about 25-33 m^2 per car (Crist et al., 2022; Héran et al., 2011; Héran and Ravalet, 2008; Shoup, 2011; US Department of Transportation, 2022; Willson, 2013). By contrast, a person standing, sitting in a wheelchair, or stationary on a bicycle consumes approximately 1-2 m^2. An empty car in a car park consumes the space of about 20 people.

Outside of city centres, parking often appears to be free. Yet there is no such thing as free parking. Rather, "everyone parks free at everyone else's expense" through increased costs for goods and services (Shoup, 2011, p. 128). Some governments have minimum parking "requirements" or mandates that legally obligate property owners to supply a certain number of parking spaces for each building. These mandates frequently result in car parks (parking lots) that consume more land than the buildings to which they are attached (Shoup, 2011; Willson, 2013). At a supermarket with parking, customers all pay the same inflated price for food since the cost of building and maintaining the car park has been externalised onto the cost of each item. As a result, people who walk to the store are covering part of each driver's bill.

6.3.4. Housing

Automobility increases the cost of goods and services. The global housing crisis is largely a lack of affordable housing in cities, and it has led to high rent burdens, overcrowding, and homelessness (Potts, 2020). Automobility has contributed to this scarcity as one parking space is often larger than a person's living space. One off-street parking space consumes 25-33 m^2 which is about the same size as the average living space per person in China, South Korea, or Spain and larger than the average living space per person in India, Brazil, Mexico, or Poland (International Energy Agency, 2019; Tubelo et al., 2021). Collectively these seven countries are home to 3.3 billion people, meaning that at least 40% of the global population lives in countries where the average living space per person is equal to or smaller than one parking space. Of the European countries that have dwelling size regulations, minimums are set between 14 and 20m^2 per person which is smaller than one off-street parking space (Appolloni and D'Alessandro, 2021).

Homes in car-dependent places are often built and sold with off-street parking in a garage, car park (parking lot), or drive. Bundling parking with housing inflates the cost of housing and obscures the true cost of automobility. In multi-story parking structures, each space costs US$25,000–75,000 to build and maintain (Rivadeneyra et al., 2017; Willson, 2013). In an affordable housing development in California, bundled parking raised construction costs by 38% despite an exception that allowed the construction of fewer parking spaces (Shoup, 2011). Bundling parking with housing creates "free" homes for cars and more expensive homes for people.

6.3.5. Time

For drivers, automobility "consumes" time through multiple processes including traffic congestion, searching for parking, and getting repairs done. As more people drive, the roads fill up thereby making it more difficult for each individual to drive. "The pursuit of individual mobility becomes collective immobility" (Böhm et al., 2006b, p. 9). As Ivan Illich noted in the 1970s, "the typical American male" spends 4 out of 16 waking hours driving or gathering money to pay for a car (Illich, 1974, pp. 18–19). Perceptions of travelling time vary, and for some motorists time spent driving can be enjoyed and thus not "wasted" by congestion and other time-related factors (Kent, 2014). However, people who are walking, wheeling, cycling, or on a bus receive no benefits from the cars around them but their journeys are made slower by traffic congestion.

6.3.6. Financial burden

Car-dependent places force people to own cars so they can access essential destinations (Curl et al., 2018; Mattioli, 2017). The cost of car ownership and use, which ranges from several hundred Euro to more than €1000 per month, can ruin a family's finances. Yet this amount does not cover the full cost of car use (Glazebrook, 2009; Gössling et al., 2022). Even in countries with high tariffs on fuel, motorists cannot cover the cost of automobility. A study in Australia found that 10% of parking was covered by the motorist while the rest was externalised, and the motorist's "out-of-pocket costs" were just one-sixth of the total trip cost (Glazebrook, 2009). A German study estimated the total lifetime cost of one car to be €600,000 to 957,000 of which €250,000 to 280,000 is paid for by government subsidies and higher prices for goods and services (Gössling et al., 2022). In the European Union, a study suggested that cars cost society €0.11 per kilometre while walking and cycling provide a positive benefit (mainly via health effects) of €0.37 and €0.18 per kilometre (Gössling et al., 2019).

7. Environmental damage

In the planetary boundaries framework, six of the nine planetary boundaries have been transgressed (Richardson et al., 2023). Automobility has contributed to the transgression of at least four of these boundaries: climate change, biosphere integrity, land system change, and novel entities. Automobility is a leading source of anthropogenic carbon emissions, and it damages ecosystems and habitats, consumes natural resources, and worsens natural disasters (Fig. 7).

7.1. Carbon emissions

Automobility is one of the leading causes of climate change. In 2019, transport "accounted for 23% of global energy-related CO_2 emissions. 70% of direct transport emissions came from road vehicles," and transport-related carbon emissions are rising (Intergovernmental Panel on Climate Change, 2021, p. 1674).

Tailpipe emissions are just one part of traffic-related emissions. Motor vehicle life cycles usually contain some configuration of the following stages: production; operation; end-of-life; fuel or electricity provision; maintenance; and infrastructure (Chester and Horvath, 2009; Oda et al., 2022). All stages produce carbon emissions, and emissions in each stage vary depending on vehicle type, geography, materials, and policies. For example, internal combustion engine vehicles produce most of their emissions in the operation stage, with 23–32 t of CO_2, and the production stage, with 5–10 t. Electric vehicles produce most of their emissions in the fuel or electricity provision stage, with 11–20 t, and the production stage, with 9–14 t (Oda et al., 2022).

As discussed in Section 6.3, automobility infrastructure includes streets, parking, and other spaces. Building and maintaining this infrastructure generates substantial carbon emissions. A study in Spain estimated roadway life cycle emissions at 8880 to 50,300 t of CO_2e per km (Barandica et al., 2013). Car-based, sprawling land uses can also increase carbon emissions in non-transportation sectors. "Compact and walkable urban form enables effective mitigation while dispersed and auto-centric urban form locks-in higher levels of energy use" (Intergovernmental Panel on Climate Change, 2021, p. 1400). For example, in building heating, densely arranged units produce fewer emissions as they often abut other heated units. Technologies likely to be core to lower-carbon futures such as district heating and cooling systems only operate efficiently in high density areas, e.g. through the use of shared systems such as large-scale heat pumps (Intergovernmental Panel on Climate Change, 2021, p. 1403).

7.2. Pollution and resource extraction

Across multiple vehicle life cycle stages, resource exploitation includes oil extraction and mining for metals. Oil is used to produce fuel and to produce plastics for vehicle manufacturing. The use of plastics in vehicles is increasing due to the low weight of plastics compared to metals. This means that plastics help reduce vehicle weights and therefore the energy needed to move them. However, plastics are made from petrochemicals and are a major source of carbon emissions and pollution (Schönmayr, 2017). In a modern car, about 50% of the vehicle volume is plastic (Fernandez Pales et al., 2019).

Mining activities for metals used in vehicle manufacturing influence several environmental areas of concern including "air quality, water quality / quantity, acid mine drainage, land impacts, [and] ecological impacts" (Jain et al., 2016, p. 53). Some metal mining activities for vehicle manufacturing involve child labour and modern slavery, e.g. cobalt extraction in the Democratic Republic of the Congo (Harper et al., 2019; Kara, 2023). Under current manufacturing practices, electric, hybrid, and hydrogen fuel cell vehicles require more mined material

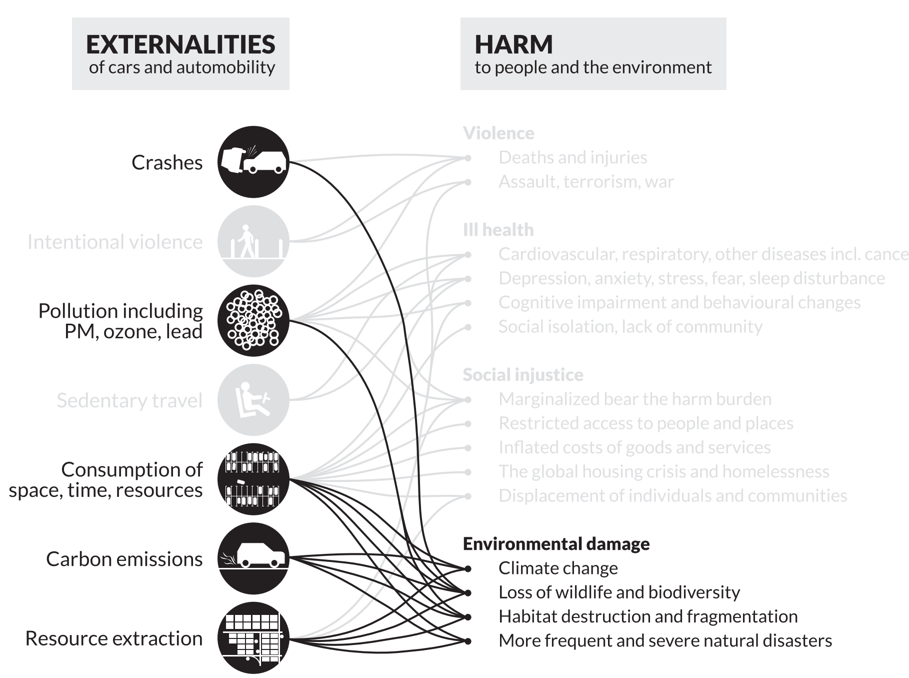

Fig. 7. Externalities of automobility and the environmental damage to which they contribute.

than gasoline-powered vehicles. As automobile markets electrify, metal mining activities are likely to increase unless recycled materials are adopted more widely (Dolganova et al., 2020; Kosai et al., 2021).

In the end-of-life stage, economically valuable (e.g. copper) and hazardous (e.g. fuel) elements are removed from vehicles. The remaining plastic, glass, and other materials are cut into automotive shredder residue. About two thirds of this residue is sent to landfill and most of the remaining is incinerated (Merkisz-Guranowska, 2018; Nakano and Shibahara, 2017).

7.2.1. Tyres

One vehicle component that has a large environmental impact across multiple life cycle stages is tyres. Approximately 2 to 3 billion tyres are manufactured annually and they are not biodegradable (Smithers, 2021; Tian et al., 2021). Tyres are made from (mainly synthetic) rubber, carbon black, silicon dioxide, steel wire, nylon, and polyester (Sun et al., 2016). These materials are mostly derived from fossil fuels. In the end-of-life stage, there are three common outcomes for tyres: they are recycled into new products; they are incinerated; or they are placed in landfills or stockpiles (Bianco et al., 2021).

Metals and microplastics from tyres and brakes pollute terrestrial, marine, and freshwater ecosystems and contribute to the transgression of the novel entities planetary boundary. Among primary microplastics (particles released directly rather than from the breakdown of larger plastics) released into the ocean, tyres and road markings account for an estimated 35%. Road runoff is the main pathway by which microplastics enter both land and water ecosystems (Boucher and Friot, 2017). Plastic particles from tyres and brakes "have been detected already in remote areas… they also absorb light and thereby decrease the surface albedo of snow and ice accelerating melting" (Evangeliou et al., 2020, p. 2). In an Arctic ice (firn) core with a bottom dating back to c. 1966, tyre particles constituted 24% of observed plastic particles (Materić et al., 2022). One of the substances found in tyres has been killing salmon in the northwestern US for several decades. The effects of this tyre substance on other animals needs further investigation (Tian et al., 2021).

7.2.2. Other pollution

Automobility contributes to numerous other forms of pollution. Applying road salt to melt ice and snow is contaminating freshwater ecosystems and making some water sources unsafe for drinking (Dugan et al., 2017; Goodyear, 2015). In Section 5.1, oil spills and noise pollution were mentioned in the context of human health. They also affect ecosystems. A single 2019 oil spill off the coast of Brazil contaminated at least 55 marine protected areas including coral reefs (de Soares et al., 2020). Traffic-related noise pollution harms wildlife through physical effects, e.g. hearing damage, and through behavioural effects, e.g. breakdowns in communication such as birdsong obscured by traffic noise (Derryberry et al., 2020; Slabbekoorn, 2019).

7.3. Land use

The vast global road network affects wildlife through collisions, habitat loss and fragmentation, pollution, and development triggered by road infrastructure (Dolan et al., 2006). Vertebrate deaths from road traffic are difficult to count, but the global number is likely greater than 1 billion per year. In both Brazil and the US, motor vehicles kill an estimated 1 million vertebrates per day for annual totals in the hundreds of millions (Guimarães, 2015; Loss et al., 2014; Seiler and Helldin, 2006).

Roads and sprawl, or car-based low-density development, contribute to deforestation and declining biodiversity. "More than any other proximate factor, the dramatic expansion of roads is determining the pace and patterns of habitat disruption and its impacts on biodiversity" (Intergovernmental Panel on Climate Change, 2021, p. 1191; Kleinschroth et al., 2019; Laurance et al., 2014). Road networks and sprawling developments of low-density housing, retail, offices, and warehouses consume vast amounts of land. These types of development exacerbate natural disasters. Roads and low-density buildings are typically impervious to water infiltration and thus increase both runoff and flooding (Rocheta et al., 2017). Sprawling development also alters the patterns of wildfires, for example by introducing new ignition sources at the periphery of human settlement (Bryant and Westerling, 2014).

8. Interventions

Though not the main focus of this paper, existing interventions are already reducing car harm and improving human and environmental wellbeing in cities and other settlements. This section briefly explores a selection of interventions from research published in the past 20 years. These example interventions are summarised in Table 2.

A study of interventions for reducing car use identified 12 effective interventions including congestion charges, parking reductions, and car-limited or car-free zones (Kuss and Nicholas, 2022). Other studies have explored the public health effects of (partly) car free cities (Nieuwenhuijsen and Khreis, 2016). Some cities are currently working to reduce traffic speeds which in turn reduce crash casualties (Milton et al., 2021). Researchers are evaluating the potential of electric bikes to reduce transport carbon emissions, carry cargo, and travel long distances without a car (Philips et al., 2022). Bogotá, Kigali, and other cities have launched ciclovía events wherein streets are opened up for walking and cycling (Adam et al., 2020). Hundreds of cities are experimenting with changing their minimum parking mandates and in some cases are replacing them with parking maximums or transit-oriented

Table 2
Example interventions to reduce car harm. The format of this table is based on Table 5 from a systematic review of "interventions to reduce car use in European cities" (Kuss and Nicholas, 2022).

Interventions	Example effects	Example locations	Studies / further reading
Congestion charges / road pricing	Reduced pollution; more space for buses, cycles	London (UK), Singapore, Stockholm (SE)	(Goh, 2002; Kuss and Nicholas, 2022)
Reductions to on-street parking	More space for walking, wheeling, cycling	Barcelona (ES), Oslo (NO), Paris (FR)	(Johansson et al., 2022; Kuss and Nicholas, 2022)
Car-free or car-limited areas	Reduced crashes, air pollution, and noise	Fez (MA), Kigali (RW), Venice (IT)	(Kalisa et al., 2022; Nieuwenhuijsen and Khreis, 2016)
Reduced traffic speeds	Fewer crashes deaths and injuries	Belfast (UK), Edinburgh (UK)	(Milton et al., 2021)
Replacing minimum parking mandates with maximums	Lower costs for goods and services (especially housing)	Boston (US), London (UK), Seoul (KR)	(Guo and Ren, 2013; Hess and Rehler, 2021)
Converting parking structures into homes, shops, etc.	Increase in housing availability and affordability	Los Angeles (US), Stockholm (SE)	(Brown et al., 2020; Johansson et al., 2022)
Ciclovía / open streets	Safer spaces for walking, wheeling, and cycling; expanding the commons	Bogotá (CO), Jakarta (ID), Kigali (RW), Nairobi (KE), Pune (IN)	(Adam et al., 2020; Sheller, 2018; Subramanian et al., 2020)
Electric bikes / micromobility	Covering long distances and cargo without cars	Kunming (CN), Shanghai (CN)	(Fishman and Cherry, 2016; Philips et al., 2022)
Car sharing	Reduced car ownership; reduced car idle time	Beijing (CN), Malmö (SE)	(Sun and Ertz, 2021; Svennevik et al., 2021; Vélez, 2023)

development regulations (Guo and Ren, 2013; Hess and Rehler, 2021). Paris and Amsterdam are removing thousands of parking spaces, and in other cities parking structures have been converted into homes (Johansson et al., 2022).

One frequently discussed and politically prioritised car harm intervention is vehicle electrification. Although switching to electric vehicles may be less politically controversial than reducing car use, electrification fails to address a majority of the harms described in this paper, including crashes, intentional violence, sedentary travel, car dependence and isolation, unequal distribution of harm, inaccessibility, land use, or consumption of space, time, and resources. Electrification has the potential to reduce carbon emissions from motor running, but emissions from vehicle production and the end-of-life phase will remain high—or increase. Electric vehicle production will likely increase the extraction of mined metals. Increased energy demand to charge electric vehicles may delay efforts to decarbonise electric grids (Henderson, 2020). In short, political prioritisation of electric vehicles is unlikely to result in large reductions in deaths, injuries, injustices, or the environmental damage caused by automobility.

This paper has discussed the effects of a world organised around the movement and storage of cars, but there are other potential futures. Many of the interventions in Table 2 involve shifting space and budgets away from private cars toward walking, wheeling, cycling, and public transport. These interventions have been successfully implemented in cities around the world. They are ready for implementation in new contexts where they can reduce the human and environmental harm caused by automobility. Such interventions require actions from governments that contradict the current automobility-dominated status quo.

9. Conclusions

This narrative review broadly summarises the harm caused by automobility to people and the environment. The goal of the paper is to describe the scale and severity of car harm. Based on a mobility justice framework (Sheller, 2018), the paper discusses car harm across four categories: violence, ill health, social injustice, and environmental damage.

Regarding violence, or "bodily physical harm" (Culver, 2018, p. 147), automobility causes harm through traffic crashes and intentional violence. Crashes kill 1.3 million people per year including 700 children per day. Traffic crashes injure approximately 100 million people annually. Intentional violence includes, for example, vehicle ramming attacks and armed conflicts over access to resources such as fossil fuels and mined metals.

Automobility can negatively affect physical and mental health through a variety of mechanisms including pollution, sedentary travel, car dependence, and social isolation. Automobility contributes to the pollution of air, land, and water systems through vehicle manufacturing, engine exhaust, road salt, and the abrasion of tyres, brakes, and road surfaces. Counting only air pollution and lead exposure, vehicle-sourced pollution kills 370,000 people per year. Car-dependent places tend to isolate people from their family, friends, and daily needs (such as food) unless they can drive and afford to own a car. When travelling by car instead of walking, wheeling, cycling, or using public transport, people spend more time sedentary and less time moving which negatively affects their physical and mental health.

Automobility creates social injustices and also requires injustice in order to function. The system relies on an unequal distribution of harm, on multiple forms of inaccessibility, and on the over-consumption of space, time, and resources. People with more privilege, such as wealthy people, men, or white people, tend to drive more while the externalities of their driving disproportionately affect those with less privilege, such as economically poor people, women, or racially minoritised groups. Car infrastructure creates barriers for people with mobility difficulties, such as too many driveway kerb cuts or too few street crossing points. Cars consume a vast amount of urban land. For example, one off-street parking space consumes 25-33 m^2, which is similar in size to (or larger than) the average living space per person in many countries. Automobility inflates the cost of goods and services (e.g. food, housing) due to bundled "free" parking.

In terms of the environment, automobility has contributed to the transgression of at least four of the nine planetary boundaries through pollution, carbon emissions, damage to ecosystems, consumption of natural resources, and exacerbation of natural disasters. Carbon emissions from vehicle operation and manufacturing are one of the leading causes of climate change. The sprawling global road network has split habitats, destroyed ecosystems, and increased the frequency and severity of floods and fires.

Since their invention, cars and the system of automobility have killed an estimated 60–80 million people, injured at least 2 billion, created or exacerbated social inequities, and damaged ecosystems in every global region. Governments, corporations, and individuals continue to encourage automobility (e.g. through road expansion and electric vehicle subsidies) despite its status as the leading cause of death of children, a major contributor to climate change and pollution, and a system that forces the economically poor to pay for the convenience of the wealthy. The current status quo prioritises the movement and storage of cars above the safety, health, dignity, and wellbeing of people and the environment. It took just a few decades for nearly every city on Earth to be remade from a pedestrian-centric place to an automobile-centric place. Perhaps in a few more decades, interventions such as those listed above will have once again remade cities—this time into safer, healthier, and more just environments.

Funding

This research was partly supported by a UKRI Natural Environment Research Council (NERC) Doctoral Training Partnership grant NE/S007407/1.

CRediT authorship contribution statement

Patrick Miner: Conceptualization, Data curation, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Barbara M. Smith:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Anant Jani:** Supervision, Writing – review & editing. **Geraldine McNeill:** Supervision, Writing – review & editing. **Alfred Gathorne-Hardy:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no competing interests.

Data availability

The supplementary materials contain text and data describing the calculation of the number of deaths caused by automobility. These data are derived from published sources (i.e. they are secondary data) and are available as a csv file.

Acknowledgements

The authors would like to thank Monica Rico, Jason Brozek, the *Journal of Transport Geography* editors, and the peer reviewers.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jtrangeo.2024.103817.

References

Adachi, K., Tainosho, Y., 2004. Characterization of heavy metal particles embedded in tire dust. Environ. Int. 30, 1009–1017. https://doi.org/10.1016/j.envint.2004.04.004.

Adam, L., Jones, T., te Brömmelstroet, M., 2020. Planning for cycling in the dispersed city: establishing a hierarchy of effectiveness of municipal cycling policies. Transportation 47, 503–527. https://doi.org/10.1007/s11116-018-9878-3.

Adamiec, E., Jarosz-Krzemińska, E., Wieszała, R., 2016. Heavy metals from non-exhaust vehicle emissions in urban and motorway road dusts. Environ. Monit. Assess. 188, 369. https://doi.org/10.1007/s10661-016-5377-1.

Adeloye, D., Thompson, J.Y., Akanbi, M.A., Azuh, D., Samuel, V., Omoregbe, N., Ayo, C. K., 2016. The burden of road traffic crashes, injuries and deaths in Africa: a systematic review and meta-analysis. Bull. World Health Organ. 94, 510–521A. https://doi.org/10.2471/BLT.15.163121.

Aldred, R., Woodcock, J., 2008. Transport: challenging disabling environments. Local Environ. 13, 485–496. https://doi.org/10.1080/13549830802259847.

Allen, R.W., Adar, S.D., 2011. Are both air pollution and noise driving adverse cardiovascular health effects from motor vehicles? Environ. Res. 111, 184–185. https://doi.org/10.1016/j.envres.2010.11.004.

Anenberg, S., Miller, J., Henze, D., Minjares, R., 2019. A Global Snapshot of the Air Pollution-Related Health Impacts of Transportation Sector Emissions in 2010 and 2015. International Council on Clean Transportation, Washington, DC.

Appolloni, L., D'Alessandro, D., 2021. Housing spaces in nine European countries: a comparison of dimensional requirements. Int. J. Environ. Res. Public Health 18, 4278. https://doi.org/10.3390/ijerph18084278.

Attademo, L., Bernardini, F., Garinella, R., Compton, M.T., 2017. Environmental pollution and risk of psychotic disorders: a review of the science to date. Schizophr. Res. 181, 55–59. https://doi.org/10.1016/j.schres.2016.10.003.

Auriault, F., Thollon, L., Peres, J., Delotte, J., Kayvantash, K., Brunet, C., Behr, M., 2014. Virtual traumatology of pregnant women: the PRegnant car occupant model for impact simulations (PROMIS). J. Biomech. 47, 207–213. https://doi.org/10.1016/j.jbiomech.2013.09.013.

Bakolis, I., Hammoud, R., Stewart, R., Beevers, S., Dajnak, D., MacCrimmon, S., Broadbent, M., Pritchard, M., Shiode, N., Fecht, D., Gulliver, J., Hotopf, M., Hatch, S. L., Mudway, I.S., 2021. Mental health consequences of urban air pollution: prospective population-based longitudinal survey. Soc. Psychiatry Psychiatr. Epidemiol. 56, 1587–1599. https://doi.org/10.1007/s00127-020-01966-x.

Barandica, J.M., Fernández-Sánchez, G., Berzosa, Á., Delgado, J.A., Acosta, F.J., 2013. Applying life cycle thinking to reduce greenhouse gas emissions from road projects. J. Clean. Prod. 57, 79–91. https://doi.org/10.1016/j.jclepro.2013.05.036.

Basu, R., Samet, J.M., 2002. Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. Epidemiol. Rev. 24, 190–202. https://doi.org/10.1093/epirev/mxf007.

Bernardin, M.E., Spectorsky, K., Gu, H., Fairfax, C., Cutler, K., 2023. Child firearm injury circumstances and associations with violence intervention program enrollment. J. Surg. Res. 285, 67–75. https://doi.org/10.1016/j.jss.2022.12.032.

Bhalla, K., Shotten, M., Cohen, A., Brauer, M., Shahraz, S., Burnett, R., Leach-Kemon, K., Freedman, G., Murray, C.J.L., 2014. Transport for Health : The Global Burden of Disease from Motorized Road Transport. Institute for Health Metrics and Evaluation at the University of Washington and the World Bank, Seattle.

Bianco, I., Panepinto, D., Zanetti, M., 2021. End-of-life Tyres: comparative life cycle assessment of treatment scenarios. Appl. Sci. 11, 3599. https://doi.org/10.3390/app11083599.

Birtchnell, T., Caletrío, J. (Eds.), 2013. Elite Mobilities. Routledge, London. https://doi.org/10.4324/9780203078532.

Bjureberg, J., Gross, J., 2021. Regulating road rage. Soc. Personal. Psychol. Compass 15. https://doi.org/10.1111/spc3.12586.

Blair, R.M., Waldron, S., Phoenix, V.R., Gauchotte-Lindsay, C., 2019. Microscopy and elemental analysis characterisation of microplastics in sediment of a freshwater urban river in Scotland, UK. Environ. Sci. Pollut. Res. 26, 12491–12504. https://doi.org/10.1007/s11356-019-04678-1.

Böhm, S., Jones, C., Land, C., Paterson, M. (Eds.), 2006a. Against Automobility, Sociological Review Monographs. Blackwell, Malden, MA.

Böhm, S., Jones, C., Land, C., Paterson, M., 2006b. Introduction: impossibilities of automobility. In: Against Automobility. Blackwell, Oxford, UK, pp. 3–16.

Boogaard, H., Patton, A.P., Atkinson, R.W., Brook, J.R., Chang, H.H., Crouse, D.L., Fussell, J.C., Hoek, G., Hoffmann, B., Kappeler, R., Kutlar Joss, M., Ondras, M., Sagiv, S.K., Samoli, E., Shaikh, R., Smargiassi, A., Szpiro, A.A., Van Vliet, E.D.S., Vienneau, D., Weuve, J., Lurmann, F.W., Forastiere, F., 2022. Long-term exposure to traffic-related air pollution and selected health outcomes: a systematic review and meta-analysis. Environ. Int. 164, 107262 https://doi.org/10.1016/j.envint.2022.107262.

Borg, B.A., Krouse, C.B., McLeod, J.S., Shanti, C.M., Donoghue, L., 2020. Circumstances surrounding gun violence with youths in an urban setting. J. Pediatr. Surg. 55, 1234–1237. https://doi.org/10.1016/j.jpedsurg.2019.09.015.

Boucher, J., Friot, D., 2017. Primary Microplastics in the Oceans: a Global Evaluation of Sources. International Union for Conservation of Nature (IUCN), Gland, Switzerland. https://doi.org/10.2305/IUCN.CH.2017.01.en.

Braly, A.M., Parent, M.C., DeLucia, P.R., 2018. Do threats to masculinity result in more aggressive driving behavior? Psychol. Men Masculinity 19, 540–546. https://doi.org/10.1037/men0000135.

Brewer, A., Dror, I., Berkowitz, B., 2021. The mobility of plastic nanoparticles in aqueous and soil environments: a critical review. ACS EST Water 1, 48–57. https://doi.org/10.1021/acsestwater.0c00130.

Brown, A., Mukhija, V., Shoup, D., 2020. Converting garages into housing. J. Plan. Educ. Res. 40, 56–68. https://doi.org/10.1177/0739456X17741965.

Bruntlett, M., Bruntlett, C., 2021. Curbing Traffic: The Human Case for Fewer Cars in our Lives. Island Press, Washington.

Bryant, B.P., Westerling, A.L., 2014. Scenarios for future wildfire risk in California: links between changing demography, land use, climate, and wildfire. Environmetrics 25, 454–471. https://doi.org/10.1002/env.2280.

Bull, F.C., Al-Ansari, S.S., Biddle, S., Borodulin, K., Buman, M.P., Cardon, G., Carty, C., Chaput, J.-P., Chastin, S., Chou, R., Dempsey, P.C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C.M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P.T., Lambert, E., Leitzmann, M., Milton, K., Ortega, F.B., Ranasinghe, C., Stamatakis, E., Tiedemann, A., Troiano, R.P., van der Ploeg, H.P., Wari, V., Willumsen, J.F., 2020. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br. J. Sports Med. 54, 1451–1462. https://doi.org/10.1136/bjsports-2020-102955.

Byrne, D.M., Grabowski, M.K., Benitez, A.C.B., Schmidt, A.R., Guest, J.S., 2017. Evaluation of life cycle assessment (LCA) for roadway drainage systems. Environ. Sci. Technol. 51, 9261–9270. https://doi.org/10.1021/acs.est.7b01856.

Caciari, T., Rosati, M.V., Casale, T., Loreti, B., Sancini, A., Riservato, R., Nieto, H.A., Frati, P., Tomei, F., Tomei, G., 2013. Noise-induced hearing loss in workers exposed to urban stressors. Sci. Total Environ. 463–464, 302–308. https://doi.org/10.1016/j.scitotenv.2013.06.009.

Caiazzo, F., Ashok, A., Waitz, I.A., Yim, S.H.L., Barrett, S.R.H., 2013. Air pollution and early deaths in the United States. Part I: quantifying the impact of major sectors in 2005. Atmos. Environ. 79, 198–208. https://doi.org/10.1016/j.atmosenv.2013.05.081.

Cao, M., Xu, T., Yin, D., 2023. Understanding light pollution: recent advances on its health threats and regulations. J. Environ. Sci. 127, 589–602. https://doi.org/10.1016/j.jes.2022.06.020.

Carbado, D.W., 2015. Blue-on-black violence: a provisional model of some of the causes. Geo. L.J. 104, 1479–1530.

Carroll, L.J., Rothe, J.P., 2014. Viewing vehicular violence through a wide angle Lens: contributing factors and a proposed framework. Can. J. Criminol. Crim. Justice 56, 149–166. https://doi.org/10.3138/cjccj.2014.ES01.

Chambers, P., Andrews, T., 2019. Never mind the bollards: the politics of policing car attacks through the securitisation of crowded urban places. Environ. Plan D 37, 1025–1044. https://doi.org/10.1177/0263775818824343.

Chang, S., Stone, J., Demes, K., Piscitelli, M., 2014. Consequences of oil spills: a review and framework for informing planning. Ecol. Soc. 19 https://doi.org/10.5751/ES-06406-190226.

Chang, X., Xue, Y., Li, J., Zou, L., Tang, M., 2020. Potential health impact of environmental micro- and nanoplastics pollution. J. Appl. Toxicol. 40, 4–15. https://doi.org/10.1002/jat.3915.

Chen, H., Kwong, J.C., Copes, R., Tu, K., Villeneuve, P.J., van Donkelaar, A., Hystad, P., Martin, R.V., Murray, B.J., Jessiman, B., Wilton, A.S., Kopp, A., Burnett, R.T., 2017. Living near major roads and the incidence of dementia, Parkinson's disease, and multiple sclerosis: a population-based cohort study. Lancet 389, 718–726. https://doi.org/10.1016/S0140-6736(16)32399-6.

Chester, M.V., Horvath, A., 2009. Environmental assessment of passenger transportation should include infrastructure and supply chains. Environ. Res. Lett. 4, 024008 https://doi.org/10.1088/1748-9326/4/2/024008.

China Association of Automobile Manufacturers, 2021. 公安部:2020年全国机动车保有量达3.72亿辆 机动车驾驶人达4.56亿人 [Ministry of Public Security]. In: 2020, The Number of Motor Vehicles in the Country Will Reach 372 Million, and the Number of Motor Vehicle Drivers Will Reach 456 Million [WWW Document]. China Association of Automobile Manufacturers. URL. http://www.caam.org.cn/chn/7/cate_120/con_5232881.html (accessed 4.5.23).

Cho, Y., Ryu, S.-H., Lee, B.R., Kim, K.H., Lee, E., Choi, J., 2015. Effects of artificial light at night on human health: a literature review of observational and experimental studies applied to exposure assessment. Chronobiol. Int. 32, 1294–1310. https://doi.org/10.3109/07420528.2015.1073158.

Clarsen, G., 2017. Revisiting "driving while black": racialized automobilities in a settler colonial context. Mobil. History 8. https://doi.org/10.3167/mih.2017.080107.

Clarsen, G., Veracini, L., 2012. Settler colonial automobilities: a distinct constellation of automobile cultures? History Compass 10, 889–900. https://doi.org/10.1111/hic3.12015.

Colgan, J.D., 2013. Fueling the fire: pathways from oil to war. Int. Secur. 38, 147–180.

Cozzi, L., Petropoulos, A., Paoli, L., Huismans, M., Dasgupta, A., 2023. As their Sales Continue to Rise, SUVs' Global CO2 Emissions Are Nearing 1 Billion Tonnes. International Energy Agency, Paris.

Cresswell, T., 2006. On the Move: Mobility in the Modern Western World. Routledge, New York, NY.

Criado-Perez, C., 2019. Invisible Women: Exposing Data bias in a World Designed for Men. Chatto & Windus, London.

Crist, P., Martinez, L., Pritchard, J.P., 2022. Streets that Fit: Re-Allocating Space for Better Cities. International Transport Forum (OECD).

Culver, G., 2018. Death and the Car: on (auto)mobility, violence, and injustice. In: ACME: An International Journal for Critical Geographies, 17, pp. 144–170.

Curl, A., Clark, J., Kearns, A., 2018. Household car adoption and financial distress in deprived urban communities: a case of forced car ownership? Transport Policy, Household transport costs, economic stress and energy vulnerability, 65, pp. 61–71. https://doi.org/10.1016/j.tranpol.2017.01.002.

Darcy, S., Burke, P.F., 2018. On the road again: the barriers and benefits of automobility for people with disability. Transp. Res. A Policy Pract. 107, 229–245. https://doi.org/10.1016/j.tra.2017.11.002.

Davis, M., 2011. The first Car bomb. In: Carrington, K.L., Griffin, S. (Eds.), Transforming Terror: Remembering the Soul of the World. University of California Press, Berkeley, United States.
de Andrade, S.S.C.A., de Mello-Jorge, M.H.P., 2016. Mortality and Potential Years of Life Lost by Road Traffic Injuries in Brazil. Rev. Saúde Pública, p. 50.
de Soares, M. O., Teixeira, C.E.P., Bezerra, L.E.A., Paiva, S.V., Tavares, T.C.L., Garcia, T. M., de Araújo, J.T., Campos, C.C., Ferreira, S.M.C., Matthews-Cascon, H., Frota, A., Mont'Alverne, T.C.F., Silva, S.T., Rabelo, E.F., Barroso, C.X., de Freitas, J.E.P., de Melo Júnior, M., de Campelo, R.P. S., de Santana, C.S., de Carneiro, P.B. M., Meirelles, A.J., Santos, B.A., de Oliveira, A.H.B., Horta, P., Cavalcante, R.M., 2020. Oil spill in South Atlantic (Brazil): environmental and governmental disaster. Mar. Policy 115, 103879. doi:https://doi.org/10.1016/j.marpol.2020.103879.
Derryberry, E.P., Phillips, J.N., Derryberry, G.E., Blum, M.J., Luther, D., 2020. Singing in a silent spring: birds respond to a half-century soundscape reversion during the COVID-19 shutdown. Science 370, 575–579. https://doi.org/10.1126/science.abd5777.
Dibben, C., Clemens, T., 2015. Place of work and residential exposure to ambient air pollution and birth outcomes in Scotland, using geographically fine pollution climate mapping estimates. Environ. Res. 140, 535–541. https://doi.org/10.1016/j.envres.2015.05.010.
Dobbs, L., 2005. Wedded to the car: women, employment and the importance of private transport. Transp. Policy 12, 266–278. https://doi.org/10.1016/j.tranpol.2005.02.004.
Dolan, L.M.J., van Bohemen, H., Whelan, P., Akbar, K.F., O'Malley, V., O'Leary, G., Keizer, P.J., 2006. Towards the sustainable development of modern road ecosystems. In: Davenport, J., Davenport, J.L. (Eds.), The Ecology of Transportation: Managing Mobility for the Environment, Environmental Pollution. Springer, Netherlands, Dordrecht, pp. 275–331.
Dolganova, I., Rödl, A., Bach, V., Kaltschmitt, M., Finkbeiner, M., 2020. A review of life cycle assessment studies of electric vehicles with a focus on resource use. Resources 9, 32. https://doi.org/10.3390/resources9030032.
Dugan, H.A., Bartlett, S.L., Burke, S.M., Doubek, J.P., Krivak-Tetley, F.E., Skaff, N.K., Summers, J.C., Farrell, K.J., McCullough, I.M., Morales-Williams, A.M., Roberts, D. C., Ouyang, Z., Scordo, F., Hanson, P.C., Weathers, K.C., 2017. Salting our freshwater lakes. Proc. Natl. Acad. Sci. 114, 4453–4458. https://doi.org/10.1073/pnas.1620211114.
Edwards, M., Leonard, D., 2022. Effects of large vehicles on pedestrian and pedalcyclist injury severity. J. Saf. Res. 82, 275–282. https://doi.org/10.1016/j.jsr.2022.06.005.
Engel, R.S., Johnson, R., 2006. Toward a better understanding of racial and ethnic disparities in search and seizure rates. J. Crim. Just. 34, 605–617. https://doi.org/10.1016/j.jcrimjus.2006.09.014.
Ericson, B., Landrigan, P., Taylor, M.P., Frostad, J., Caravanos, J., 2017. The global burden of Lead toxicity attributable to informal used Lead-acid battery sites. Ann. Glob. Health 82, 686–689. https://doi.org/10.1016/j.aogh.2016.10.015.
Evangeliou, N., Grythe, H., Klimont, Z., Heyes, C., Eckhardt, S., Lopez-Aparicio, S., Stohl, A., 2020. Atmospheric transport is a major pathway of microplastics to remote regions. Nat. Commun. 11, 3381. https://doi.org/10.1038/s41467-020-17201-9.
Fann, N., Kim, S.-Y., Olives, C., Sheppard, L., 2017. Estimated changes in life expectancy and adult mortality resulting from declining PM2.5 exposures in the contiguous United States: 1980–2010. Environ. Health Perspect. 125, 097003 https://doi.org/10.1289/EHP507.
Farahani, V.J., Soleimanian, E., Pirhadi, M., Sioutas, C., 2021. Long-term trends in concentrations and sources of PM2.5–bound metals and elements in Central Los Angeles. Atmos. Environ. 253, 118361 https://doi.org/10.1016/j.atmosenv.2021.118361.
Fernandez Pales, A., Teter, J., Abergel, T., Vass, T., 2019. Material Efficiency in Clean Energy Transitions. International Energy Agency. https://doi.org/10.1787/aeaaccd8-en.
Fishman, E., Cherry, C., 2016. E-bikes in the mainstream: reviewing a decade of research. Transp. Rev. 36, 72–91. https://doi.org/10.1080/01441647.2015.1069907.
Frank, L.D., Andresen, M.A., Schmid, T.L., 2004. Obesity relationships with community design, physical activity, and time spent in cars. Am. J. Prev. Med. 27, 87–96. https://doi.org/10.1016/j.amepre.2004.04.011.
Freund, P.E.S., Martin, G.T., 1993. The Ecology of the Automobile. Black Rose, Montreal, London.
Frey, H.C., 2018. Trends in onroad transportation energy and emissions. J. Air Waste Manage. Assoc. 68, 514–563. https://doi.org/10.1080/10962247.2018.1454357.
Fritschi, L., Brown, A.L., Kim, R., Schwela, D., Kephalopoulos, S. (Eds.), 2011. Burden of Disease from Environmental Noise: Quantification of Healthy Life Years Lost in Europe. World Health Organization, Regional Office for Europe, Bonn, Germany.
Ghaffarian-Bahraman, A., Taherifard, A., Esmaeili, A., Ahmadinia, H., Rezaeian, M., 2021. Evaluation of blood lead among painters of buildings and cars. Toxicol. Ind. Health 37, 737–744. https://doi.org/10.1177/07482337211042731.
Glazebrook, G., 2009. Taking the con out of convenience: the true cost of transport modes in Sydney. Urban Policy Res. 27, 5–24. https://doi.org/10.1080/08111140802369820.
Global Burden of Disease Collaborative Network, 2020. Global burden of disease (GBD) study 2019 results. In: Institute for Health Metrics and Evaluation (IHME). University of Washington, Seattle, WA.
Goddard, T., Kahn, K.B., Adkins, A., 2015. Racial bias in driver yielding behavior at crosswalks. Transport. Res. F: Traffic Psychol. Behav. 33, 1–6. https://doi.org/10.1016/j.trf.2015.06.002.
Goh, M., 2002. Congestion management and electronic road pricing in Singapore. J. Transp. Geogr. 10, 29–38. https://doi.org/10.1016/S0966-6923(01)00036-9.
Goines, L., Hagler, L., 2007. Noise pollution: a modern plague. South. Med. J. 100, 287–295.
González-Maciel, A., Reynoso-Robles, R., Torres-Jardón, R., Mukherjee, P.S., Calderón-Garcidueñas, L., 2017. Combustion-derived nanoparticles in key brain target cells and organelles in young urbanites: culprit hidden in plain sight in Alzheimer's disease development. J. Alzheimers Dis. 59, 189–208. https://doi.org/10.3233/JAD-170012.
Goodyear, S., 2015. This Winter's Road Salt Has Already Led to Salty Drinking Water Parts of New Jersey. Bloomberg CityLab.
Gössling, S., 2016. Urban transport justice. J. Transp. Geogr. 54, 1–9. https://doi.org/10.1016/j.jtrangeo.2016.05.002.
Gössling, S., Choi, A., Dekker, K., Metzler, D., 2019. The social cost of automobility, cycling and walking in the European Union. Ecol. Econ. 158, 65–74. https://doi.org/10.1016/j.ecolecon.2018.12.016.
Gössling, S., Kees, J., Litman, T., 2022. The lifetime cost of driving a car. Ecol. Econ. 194, 107335 https://doi.org/10.1016/j.ecolecon.2021.107335.
Gottesfeld, P., 2015. Time to ban Lead in industrial paints and coatings. Front. Public Health 3, 144. https://doi.org/10.3389/fpubh.2015.00144.
Green Cross Switzerland, Pure Earth, 2016. The World's Worst Pollution Problems 2016: The Toxins beneath our Feet. Zurich and New York.
Guimarães, T., 2015. A Principal Causa da morte de Animais Silvestres no Brasil. BBC News Brasil.
Guimarães, T., Lucas, K., Timms, P., 2019. Understanding how low-income communities gain access to healthcare services: a qualitative study in São Paulo, Brazil. J. Transp. Health 15, 100658. https://doi.org/10.1016/j.jth.2019.100658.
Gunnell, D., Coope, C., Fearn, V., Wells, C., Chang, S.-S., Hawton, K., Kapur, N., 2015. Suicide by gases in England and Wales 2001–2011: evidence of the emergence of new methods of suicide. J. Affect. Disord. 170, 190–195. https://doi.org/10.1016/j.jad.2014.08.055.
Guo, Z., Ren, S., 2013. From minimum to maximum: impact of the London parking reform on residential parking supply from 2004 to 2010? Urban Stud. 50, 1183–1200. https://doi.org/10.1177/0042098012460735.
Hamraie, A., 2017. Building Access: Universal Design and the Politics of Disability. University of Minnesota Press, Minneapolis, USA.
Harper, G., Sommerville, R., Kendrick, E., Driscoll, L., Slater, P., Stolkin, R., Walton, A., Christensen, P., Heidrich, O., Lambert, S., Abbott, A., Ryder, K., Gaines, L., Anderson, P., 2019. Recycling lithium-ion batteries from electric vehicles. Nature 575, 75–86. https://doi.org/10.1038/s41586-019-1682-5.
Harrison, R.M., Allan, J., Carruthers, D., Heal, M.R., Lewis, A.C., Marner, B., Murrells, T., Williams, A., 2021. Non-exhaust vehicle emissions of particulate matter and VOC from road traffic: a review. Atmos. Environ. 262, 118592 https://doi.org/10.1016/j.atmosenv.2021.118592.
Henderson, J., 2020. EVs are not the answer: a mobility justice critique of electric vehicle transitions. Ann. Am. Assoc. Geogr. 110, 1993–2010. https://doi.org/10.1080/24694452.2020.1744422.
Héran, F., Ravalet, E., 2008. La consommation d'espace-temps des divers modes de déplacement en milieu urbain: Application au cas de l'Ile de France. Ministère des transports, de l'équipement, du tourisme et de la mer, France.
Héran, F., Ravalet, E., Mathon, S., 2011. La consommation d'espace-temps des divers modes de déplacement en milieu urbain: Recherche complémentaire. Ministère des transports, de l'équipement, du tourisme et de la mer, France.
Hernandez, M., Kockelman, K.M., Lentz, J.O., Lee, J., 2019. Emissions and noise mitigation through use of electric motorcycles. Transp. Safety Environ. 1, 164–175. https://doi.org/10.1093/tse/tdz013.
Hess, D.B., Rehler, J., 2021. Minus Minimums. J. Am. Plan. Assoc. 87, 396–408. https://doi.org/10.1080/01944363.2020.1864225.
Heutschi, K., Bühlmann, E., Oertli, J., 2016. Options for reducing noise from roads and railway lines. Transp. Res. A Policy Pract. 94, 308–322. https://doi.org/10.1016/j.tra.2016.09.019.
Hughes, T.A., Royde-Smith, J.G., 2022. World War II - Costs of the War. Encyclopædia Britannica.
Illich, I., 1974. Energy and Equity, Ideas in Progress. Calder & Boyars, London.
Intergovernmental Panel on Climate Change, 2021. Climate Change 2022: Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. United Nations.
International Energy Agency, 2019. Energy Efficiency 2019. International Energy Agency (IEA), Paris.
International Energy Agency, 2020. World Oil Final Consumption by Sector, 2018 [WWW Document]. International Energy Agency. URL. https://www.iea.org/data-and-statistics/charts/world-oil-final-consumption-by-sector-2018 (accessed 10.7.22).
International Federation of Red Cross and Red Crescent Societies, 1998. World Disasters Report 1998. Oxford University Press, Oxford, UK.
International Organization of Motor Vehicle Manufacturers, 2017. Vehicles in Use [WWW Document]. International Organization of Motor Vehicle Manufacturers. URL. https://www.oica.net/category/vehicles-in-use/ (accessed 10.13.22).
Jacobs, J., 1961. The Death and Life of Great American Cities, 50th Anniversary Edition, 2011 Modern Library edition. ed. Modern Library, New York.
Jacobsen, P.L., Racioppi, F., Rutter, H., 2009. Who owns the roads? How motorised traffic discourages walking and bicycling. Inj. Prev. 15, 369–373. https://doi.org/10.1136/ip.2009.022566.
Jain, R.K., Cui, Z. Cindy, Domen, J.K., 2016. Environmental Impact of Mining and Mineral Processing. Elsevier. https://doi.org/10.1016/B978-0-12-804040-9.00001-2.
Japan National Statistics Center, 2022. Number of Cars Owned [WWW Document]. e-stat: 政府統計の総合窓口. URL. https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&toukei=00600700&tstat=000001109495&cycle=1&tclass1val=0 (accessed 10.13.22).

Johansson, M.S., Korshøj, M., Schnohr, P., Marott, J.L., Prescott, E.I.B., Søgaard, K., Holtermann, A., 2019. Time spent cycling, walking, running, standing and sedentary: a cross-sectional analysis of accelerometer-data from 1670 adults in the Copenhagen City heart study. BMC Public Health 19, 1370. https://doi.org/10.1186/s12889-019-7679-z.

Johansson, F., Åkerman, J., Henriksson, G., Envall, P., 2022. A pathway for parking in line with the Paris agreement. Case Studi. Transp. Policy 10, 1223–1233. https://doi.org/10.1016/j.cstp.2022.04.008.

Kalisa, E., Irankunda, E., Rugengamanzi, E., Amani, M., 2022. Noise levels associated with urban land use types in Kigali. Rwanda. Heliyon 8, e10653. https://doi.org/10.1016/j.heliyon.2022.e10653.

Kara, S., 2023. Cobalt Red: How the Blood of the Congo Powers Our Lives, First edition. ed. St. Martin's Press, an imprint of St. Martin's Publishing Group, New York, NY.

Karsten, L., 2005. It all used to be better? Different generations on continuity and change in urban children's daily use of space. Children's Geograph. 3, 275–290. https://doi.org/10.1080/14733280500352912.

Kent, J.L., 2014. Driving to save time or saving time to drive? The enduring appeal of the private car. Transp. Res. A Policy Pract. 65, 103–115. https://doi.org/10.1016/j.tra.2014.04.009.

Khan, J., Ketzel, M., Kakosimos, K., Sørensen, M., Jensen, S.S., 2018. Road traffic air and noise pollution exposure assessment – a review of tools and techniques. Sci. Total Environ. 634, 661–676. https://doi.org/10.1016/j.scitotenv.2018.03.374.

Khosla, R., Miranda, N.D., Trotter, P.A., Mazzone, A., Renaldi, R., McElroy, C., Cohen, F., Jani, A., Perera-Salazar, R., McCulloch, M., 2021. Cooling for sustainable development. Nat. Sustain. 4, 201–208. https://doi.org/10.1038/s41893-020-00627-w.

Khreis, H., Kelly, C., Tate, J., Parslow, R., Lucas, K., Nieuwenhuijsen, M., 2017. 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.

Kioumourtzoglou, M.-A., Power, M.C., Hart, J.E., Okereke, O.I., Coull, B.A., Laden, F., Weisskopf, M.G., 2017. The association between air pollution and onset of depression among middle-aged and older women. Am. J. Epidemiol. 185, 801–809. https://doi.org/10.1093/aje/kww163.

Kleinschroth, F., Laporte, N., Laurance, W.F., Goetz, S.J., Ghazoul, J., 2019. Road expansion and persistence in forests of the Congo Basin. Nat. Sustain. 2, 628–634. https://doi.org/10.1038/s41893-019-0310-6.

Kole, P.J., Löhr, A.J., Van Belleghem, F.G.A.J., Ragas, A.M.J., 2017. Wear and tear of Tyres: a stealthy source of microplastics in the environment. Int. J. Environ. Res. Public Health 14, 1265. https://doi.org/10.3390/ijerph14101265.

Kontou, E., McDonald, N.C., Brookshire, K., Pullen-Seufert, N.C., LaJeunesse, S., 2020. U. S. active school travel in 2017: prevalence and correlates. Prev. Med. Rep. 17, 101024 https://doi.org/10.1016/j.pmedr.2019.101024.

Kosai, S., Matsui, K., Matsubae, K., Yamasue, E., Nagasaka, T., 2021. Natural resource use of gasoline, hybrid, electric and fuel cell vehicles considering land disturbances. Resour. Conserv. Recycl. 166, 105256 https://doi.org/10.1016/j.resconrec.2020.105256.

Kraemer, J.D., Benton, C.S., 2015. Disparities in road crash mortality among pedestrians using wheelchairs in the USA: results of a capture–recapture analysis. BMJ Open 5, e008396. https://doi.org/10.1136/bmjopen-2015-008396.

Kuruppu, U., Rahman, A., Rahman, M.A., 2019. Permeable pavement as a stormwater best management practice: a review and discussion. Environ. Earth Sci. 78, 327. https://doi.org/10.1007/s12665-019-8312-2.

Kuss, P., Nicholas, K.A., 2022. A dozen effective interventions to reduce car use in European cities: lessons learned from a meta-analysis and transition management. Case Studi. Transp. Policy 10, 1494–1513. https://doi.org/10.1016/j.cstp.2022.02.001.

Kwan, M.-P., Schwanen, T., 2009. Quantitative revolution 2: the critical (re)turn. Prof. Geogr. 61, 283–291. https://doi.org/10.1080/00330120902931903.

Laidlaw, M.A.S., Zahran, S., Mielke, H.W., Taylor, M.P., Filippelli, G.M., 2012. Re-suspension of lead contaminated urban soil as a dominant source of atmospheric lead in Birmingham, Chicago, Detroit and Pittsburgh, USA. Atmos. Environ. 49, 302–310. https://doi.org/10.1016/j.atmosenv.2011.11.030.

Lambert, T.E., Srinivasan, A.K., Katirai, M., 2012. Ex-urban sprawl and fire response in the United States. J. Econ. Issues 46, 967–988. https://doi.org/10.2753/JEI0021-3624460407.

Laurance, W.F., Clements, G.R., Sloan, S., O'Connell, C.S., Mueller, N.D., Goosem, M., Venter, O., Edwards, D.P., Phalan, B., Balmford, A., Van Der Ree, R., Arrea, I.B., 2014. A global strategy for road building. Nature 513, 229–232. https://doi.org/10.1038/nature13717.

Laurier, E., Lorimer, H., Brown, B., Jones, O., Juhlin, O., Noble, A., Perry, M., Pica, D., Sormani, P., Strebel, I., Swan, L., Taylor, A.S., Watts, L., Weilenmann, A., 2008. Driving and 'Passengering': notes on the ordinary Organization of Car Travel. Mobilities 3, 1–23. https://doi.org/10.1080/17450100701797273.

Lee, P.-K., Yu, S., Chang, H.J., Cho, H.Y., Kang, M.-J., Chae, B.-G., 2016. Lead chromate detected as a source of atmospheric Pb and Cr (VI) pollution. Sci. Rep. 6, 36088. https://doi.org/10.1038/srep36088.

Li, D., Bou-Zeid, E., 2013. Synergistic interactions between urban Heat Islands and heat waves: the impact in cities is larger than the sum of its parts. J. Appl. Meteorol. Climatol. 52, 2051–2064. https://doi.org/10.1175/JAMC-D-13-02.1.

Loss, S.R., Will, T., Marra, P.P., 2014. Estimation of bird-vehicle collision mortality on U. S. roads. J. Wildl. Manag. 78, 763–771. https://doi.org/10.1002/jwmg.721.

Lucas, K., van Wee, B., Maat, K., 2016. A method to evaluate equitable accessibility: combining ethical theories and accessibility-based approaches. Transportation 43, 473–490. https://doi.org/10.1007/s11116-015-9585-2.

Lucas, K., Akyelken, N., Stanley, J., 2019. Social assessment of transport projects in Global South cities using community perceptions of needs. In: A Companion to Transport, Space and Equity.

Mackett, R.L., 2002. Increasing car dependency of children: should we be worried? Munic. Eng. 151, 29–38. https://doi.org/10.1680/muen.2002.151.1.29.

Masiol, M., Agostinelli, C., Formenton, G., Tarabotti, E., Pavoni, B., 2014. Thirteen years of air pollution hourly monitoring in a large city: potential sources, trends, cycles and effects of car-free days. Sci. Total Environ. 494–495, 84–96. https://doi.org/10.1016/j.scitotenv.2014.06.122.

Materić, D., Kjær, H.A., Vallelonga, P., Tison, J.-L., Röckmann, T., Holzinger, R., 2022. Nanoplastics measurements in northern and southern polar ice. Environ. Res. 208, 112741 https://doi.org/10.1016/j.envres.2022.112741.

Mattioli, G., 2017. 'Forced Car ownership' in the UK and Germany: socio-spatial patterns and potential economic stress impacts. Soc. Inclusion 5, 147–160. https://doi.org/10.17645/si.v5i4.1081.

Mazzarella, G., Ferraraccio, F., Prati, M.V., Annunziata, S., Bianco, A., Mezzogiorno, A., Liguori, G., Angelillo, I.F., Cazzola, M., 2007. Effects of diesel exhaust particles on human lung epithelial cells: an in vitro study. Respir. Med. 101, 1155–1162. https://doi.org/10.1016/j.rmed.2006.11.011.

Merkisz-Guranowska, A., 2018. Waste recovery of end-of-life vehicles. IOP Conf. Ser. Mater. Sci. Eng. 421, 032019 https://doi.org/10.1088/1757-899X/421/3/032019.

Meza-Figueroa, D., González-Grijalva, B., Romero, F., Ruiz, J., Pedroza-Montero, M., Rivero, C.I.-D., Acosta-Elías, M., Ochoa-Landin, L., Navarro-Espinoza, S., 2018. Source apportionment and environmental fate of lead chromates in atmospheric dust in arid environments. Sci. Total Environ. 630, 1596–1607. https://doi.org/10.1016/j.scitotenv.2018.02.285.

Milton, S., Pliakas, T., Hawkesworth, S., Nanchahal, K., Grundy, C., Amuzu, A., Casas, J.-P., Lock, K., 2015. A qualitative geographical information systems approach to explore how older people over 70 years interact with and define their neighbourhood environment. Health Place 36, 127–133. https://doi.org/10.1016/j.healthplace.2015.10.002.

Milton, K., Kelly, M.P., Baker, G., Cleland, C., Cope, A., Craig, N., Foster, C., Hunter, R., Kee, F., Kelly, P., Nightingale, G., Turner, K., Williams, A.J., Woodcock, J., Jepson, R., 2021. Use of natural experimental studies to evaluate 20mph speed limits in two major UK cities. J. Transp. Health 22, 101141. https://doi.org/10.1016/j.jth.2021.101141.

Mindell, J.S., Karlsen, S., 2012. Community severance and health: what do we actually know? J. Urban Health 89, 232–246. https://doi.org/10.1007/s11524-011-9637-7.

Mirzaei Aminiyan, M., Baalousha, M., Mousavi, R., Mirzaei Aminiyan, F., Hosseini, H., Heydariyan, A., 2018. The ecological risk, source identification, and pollution assessment of heavy metals in road dust: a case study in Rafsanjan, SE Iran. Environ. Sci. Pollut. Res. 25, 13382–13395. https://doi.org/10.1007/s11356-017-8539-y.

Monfort, S.S., Mueller, B.C., 2020. Pedestrian injuries from cars and SUVs: updated crash outcomes from the vulnerable road user injury prevention alliance (VIPA). Traffic Inj. Prev. 21, S165–S167. https://doi.org/10.1080/15389588.2020.1829917.

Mora, C., Dousset, B., Caldwell, I.R., Powell, F.E., Geronimo, R.C., Bielecki, C.R., Counsell, C.W.W., Dietrich, B.S., Johnston, E.T., Louis, L.V., Lucas, M.P., McKenzie, M.M., Shea, A.G., Tseng, H., Giambelluca, T.W., Leon, L.R., Hawkins, E., Trauernicht, C., 2017. Global risk of deadly heat. Nat. Clim. Chang. 7, 501–506. https://doi.org/10.1038/nclimate3322.

Morabia, A., Mirer, F.E., Amstislavski, T.M., Eisl, H.M., Werbe-Fuentes, J., Gorczynski, J., Goranson, C., Wolff, M.S., Markowitz, S.B., 2010. Potential health impact of switching from car to public transportation when commuting to work. Am. J. Public Health 100, 2388–2391. https://doi.org/10.2105/AJPH.2009.190132.

Mott, J.A., Wolfe, M.I., Alverson, C.J., Macdonald, S.C., Bailey, C.R., Ball, L.B., Moorman, J.E., Somers, J.H., Mannino, D.M., Redd, S.C., 2002. National vehicle emissions policies and practices and declining US carbon monoxide–related mortality. JAMA 288, 988–995. https://doi.org/10.1001/jama.288.8.988.

Mudway, I.S., Dundas, I., Wood, H.E., Marlin, N., Jamaludin, J.B., Bremner, S.A., Cross, L., Grieve, A., Nanzer, A., Barratt, B.M., Beevers, S., Dajnak, D., Fuller, G.W., Font, A., Colligan, G., Sheikh, A., Walton, R., Grigg, J., Kelly, F.J., Lee, T.H., Griffiths, C.J., 2019. Impact of London's low emission zone on air quality and children's respiratory health: a sequential annual cross-sectional study. Lancet Public Health 4, e28–e40. https://doi.org/10.1016/S2468-2667(18)30202-0.

Muller, C., Sampson, R.J., Winter, A.S., 2018. Environmental inequality: the social causes and consequences of lead exposure. Annu. Rev. Sociol. 44, 263–282. https://doi.org/10.1146/annurev-soc-073117-041222.

Mumford, L., 1964. The Highway and the City, Revised edition. ed. Secker & Warburg, London.

Nader, R., 1965. Unsafe at any Speed: The Designed-in Dangers of the American Automobile. Grossman Publishers, New York, United States.

Nakano, K., Shibahara, N., 2017. Comparative assessment on greenhouse gas emissions of end-of-life vehicles recycling methods. J. Mater. Cycles Waste Manag. 19, 505–515. https://doi.org/10.1007/s10163-015-0454-z.

Nall, C., 2018. The Road to Inequality: How the Federal Highway Program Polarized America and Undermined Cities. Cambridge University Press, Cambridge. https://doi.org/10.1017/9781108277952.

National Highway Traffic Safety Administration, 2021. Traffic Safety Facts Annual Report Tables [WWW Document]. National Highway Traffic Safety Administration. URL. https://cdan.nhtsa.gov/tsftables/tsfar.htm (accessed 3.14.22).

Needleman, H.L., 2000. The removal of Lead from gasoline: historical and personal reflections. Environ. Res. 84, 20–35. https://doi.org/10.1006/enrs.2000.4069.

Newbury, J.B., Arseneault, L., Beevers, S., Kitwiroon, N., Roberts, S., Pariante, C.M., Kelly, F.J., Fisher, H.L., 2019. Association of air pollution exposure with psychotic experiences during adolescence. JAMA Psychiatry 76, 614–623. https://doi.org/10.1001/jamapsychiatry.2019.0056.

Newman, P., Kenworthy, J.R., 1999. Sustainability and Cities: Overcoming Automobile Dependence. Island Press, Washington, D.C.
Nieuwenhuijsen, M.J., Khreis, H., 2016. Car free cities: pathway to healthy urban living. Environ. Int. 94, 251–262. https://doi.org/10.1016/j.envint.2016.05.032.
Norton, P.D., 2008. Fighting Traffic: The Dawn of the Motor Age in the American City, Inside Technology. MIT Press, Cambridge, Mass.
Núñez-Córdoba, J.M., Bes-Rastrollo, M., Pollack, K.M., Seguí-Gómez, M., Beunza, J.J., Sayón-Orea, C., Martínez-González, M.A., 2013. Annual motor vehicle travel distance and incident obesity: a prospective cohort study. Am. J. Prev. Med. 44, 254–259. https://doi.org/10.1016/j.amepre.2012.10.019.
Nussbaum, M.C., 2011. Creating Capabilities. Harvard University Press.
Oda, H., Noguchi, H., Fuse, M., 2022. Review of life cycle assessment for automobiles: a meta-analysis-based approach. Renew. Sust. Energ. Rev. 159, 112214 https://doi.org/10.1016/j.rser.2022.112214.
O'Donovan, S., van den Heuvel, C., Baldock, M., Byard, R.W., 2022. An overview of suicides related to motor vehicles. Med. Sci. Law. https://doi.org/10.1177/00258024221122187, 00258024221122187.
O'Lear, S. (Ed.), 2021. A Research Agenda for Geographies of Slow Violence: Making Social and Environmental Injustice Visible, Elgar Research Agendas. Edward Elgar Publishing, Cheltenham.
Oliver, M., Mavoa, S., Badland, H., Parker, K., Donovan, P., Kearns, R.A., Lin, E.-Y., Witten, K., 2015. Associations between the neighbourhood built environment and out of school physical activity and active travel: an examination from the kids in the City study. Health Place 36, 57–64. https://doi.org/10.1016/j.healthplace.2015.09.005.
Oliver, C.W., Kelly, P., Baker, G., du Feu, D., Davis, A., 2018. There is too much traffic for Alex to walk to school, so we drive: a call to action based on a 42-year trend. Br. J. Sports Med. 53, 323–324. https://doi.org/10.1136/bjsports-2017-098933.
Organisation for Economic Co-operation and Development, 2021. Transport - Road Accidents [WWW Document]. Organisation for Economic Co-operation and Development. URL. http://data.oecd.org/transport/road-accidents.htm (accessed 12.2.21).
Ossiander, E.M., Koepsell, T.D., McKnight, B., 2014. Crash fatality risk and unibody versus body-on-frame structure in SUVs. Accid. Anal. Prev. 70, 267–272. https://doi.org/10.1016/j.aap.2014.03.019.
Oudin, A., Bråbäck, L., Åström, D.O., Strömgren, M., Forsberg, B., 2016. Association between neighbourhood air pollution concentrations and dispensed medication for psychiatric disorders in a large longitudinal cohort of Swedish children and adolescents. BMJ Open 6, e010004. https://doi.org/10.1136/bmjopen-2015-010004.
Ozaki, H., Watanabe, I., Kuno, K., 2004. Investigation of the heavy metal sources in relation to automobiles. Water Air Soil Pollut. 157, 209–223. https://doi.org/10.1023/B:WATE.0000038897.63818.f7.
Paul, K.C., Haan, M., Mayeda, E.R., Ritz, B.R., 2019. Ambient air pollution, noise, and late-life cognitive decline and dementia risk. Annu. Rev. Public Health 40, 203–220. https://doi.org/10.1146/annurev-publhealth-040218-044058.
Pavlovskaya, M., 2006. Theorizing with GIS: a tool for critical geographies? Environ. Plan. A 38, 2003–2020. https://doi.org/10.1068/a37326.
Pereira, R.H.M., Schwanen, T., Banister, D., 2017. Distributive justice and equity in transportation. Transp. Rev. 37, 170–191. https://doi.org/10.1080/01441647.2016.1257660.
Peris, E., Blanes, N., Fons, J., Sainz de la Maza, M., José Ramos, M., Domingues, F., Biala, K., Peterlin, M., Ganzleben, C., Adams, M., 2020. Environmental noise in Europe, 2020. European Environment Agency, Luxembourg.
Philips, I., Anable, J., Chatterton, T., 2022. E-bikes and their capability to reduce car CO2 emissions. Transp. Policy 116, 11–23. https://doi.org/10.1016/j.tranpol.2021.11.019.
Pierson, E., Simoiu, C., Overgoor, J., Corbett-Davies, S., Jenson, D., Shoemaker, A., Ramachandran, V., Barghouty, P., Phillips, C., Shroff, R., Goel, S., 2020. A large-scale analysis of racial disparities in police stops across the United States. Nat. Hum. Behav. 4, 736–745. https://doi.org/10.1038/s41562-020-0858-1.
Ponsavady, S., 2018. Cultural and Literary Representations of the Automobile in French Indochina: A Colonial Roadshow. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-94559-0.
Potts, D., 2020. Broken Cities: Inside the Global Housing Crisis. Bloomsbury Publishing.
Power, A., 2016. Disability, (auto)mobility and austerity: shrinking horizons and spaces of refuge. Disab. Soc. 1–5 https://doi.org/10.1080/09687599.2016.1145385.
Power, M.C., Weisskopf, M.G., Alexeeff, S.E., Coull, B.A., Spiro, A., Schwartz, J., 2011. Traffic-related air pollution and cognitive function in a cohort of older men. Environ. Health Perspect. 119, 682–687. https://doi.org/10.1289/ehp.1002767.
Raz, R., Roberts, A.L., Lyall, K., Hart, J.E., Just, A.C., Laden, F., Weisskopf, M.G., 2015. Autism spectrum disorder and particulate matter air pollution before, during, and after pregnancy: a nested case–control analysis within the Nurses' Health Study II Cohort. Environ. Health Perspect. 123, 264–270. https://doi.org/10.1289/ehp.1408133.
Reis, H., Reis, C., Sharip, A., Reis, W., Zhao, Y., Sinclair, R., Beeson, L., 2018. Diesel exhaust exposure, its multi-system effects, and the effect of new technology diesel exhaust. Environ. Int. 114, 252–265. https://doi.org/10.1016/j.envint.2018.02.042.
Resongles, E., Dietze, V., Green, D.C., Harrison, R.M., Ochoa-Gonzalez, R., Tremper, A. H., Weiss, D.J., 2021. Strong evidence for the continued contribution of lead deposited during the 20th century to the atmospheric environment in London of today. Proc. Natl. Acad. Sci. 118, e2102791118 https://doi.org/10.1073/pnas.2102791118.
Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S.E., Donges, J.F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., Petri, S., Porkka, M., Rahmstorf, S., Schaphoff, S., Thonicke, K., Tobian, A., Virkki, V., Wang-Erlandsson, L., Weber, L., Rockström, J., 2023. Earth beyond six of nine planetary boundaries. Sci. Adv. 9 https://doi.org/10.1126/sciadv.adh2458 eadh2458.
Rivadeneyra, A.T., Shirgaokar, M., Deakin, E., Riggs, W., 2017. Building more parking at major employment centers: can full-cost recovery parking charges fund TDM programs? Case Studi. Transp. Policy 5, 159–167. https://doi.org/10.1016/j.cstp.2016.10.002.
Rocheta, V.L.S., Isidoro, J.M.G.P., de Lima, J.L.M.P., 2017. Infiltration of Portuguese cobblestone pavements – an exploratory assessment using a double-ring infiltrometer. Urban Water J. 14, 291–297. https://doi.org/10.1080/1573062X.2015.1111914.
Santamouris, M., Cartalis, C., Synnefa, A., Kolokotsa, D., 2015. On the impact of urban heat island and global warming on the power demand and electricity consumption of buildings—a review. Energy Build. Renew. Energy Sourc. Healthy Build. 98, 119–124. https://doi.org/10.1016/j.enbuild.2014.09.052.
Santosa, B., Rosidi, A., Anggraini, H., Latrobdiba, Z.M., Damayanti, F.N., Nugroho, H.S. W., 2022. Mask protection against lead exposure and its correlation with erythropoiesis in automotive body painters at Ligu District, Semarang, Indonesia. J. Blood Med. 13, 113–119. https://doi.org/10.2147/JBM.S335557.
Schönmayr, D., 2017. Automotive Recycling, Plastics, and Sustainability. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-57400-4.
Schultze-Kraft, M., 2017. Understanding organised violence and crime in political settlements: oil wars, petro-criminality and amnesty in the Niger Delta. J. Int. Dev. 29, 613–627. https://doi.org/10.1002/jid.3287.
Seiler, A., Helldin, J.-O., 2006. Mortality in wildlife due to transportation. In: Davenport, J., Davenport, J.L. (Eds.), The Ecology of Transportation: Managing Mobility for the Environment, Environmental Pollution. Springer, Netherlands, Dordrecht, pp. 165–189. https://doi.org/10.1007/1-4020-4504-2_8.
Sen, A., 1993. Capability and well-being. In: Nussbaum, M., Sen, A. (Eds.), The Quality of Life. Oxford University Press. https://doi.org/10.1093/0198287976.003.0003.
Seo, S.A., 2019. Policing the Open Road: How Cars Transformed American Freedom. Harvard University Press, Cambridge, Massachusetts.
Sheller, M., 2018. Mobility Justice: The Politics of Movement in the Age of Extremes. Verso, London.
Sheller, M., Urry, J., 2000. The City and the Car. Int. J. Urban Reg. Res. 24, 737–757. https://doi.org/10.1111/1468-2427.00276.
Shoup, D., 2011. The High Cost of Free Parking. Routledge, New York.
Showalter, D.E., Royde-Smith, J.G., 2022. World War I - Causes & Effects. Encyclopædia Britannica.
Slabbekoorn, H., 2019. Noise pollution. Curr. Biol. 29, R957–R960. https://doi.org/10.1016/j.cub.2019.07.018.
Smith, T.W., Axon, C.J., Darton, R.C., 2013. The impact on human health of car-related air pollution in the UK, 1995–2005. Atmos. Environ. 77, 260–266. https://doi.org/10.1016/j.atmosenv.2013.05.016.
Smith, R.B., Fecht, D., Gulliver, J., Beevers, S.D., Dajnak, D., Blangiardo, M., Ghosh, R.E., Hansell, A.L., Kelly, F.J., Anderson, H.R., Toledano, M.B., 2017. Impact of London's road traffic air and noise pollution on birth weight: retrospective population based cohort study. BMJ 359, j5299. https://doi.org/10.1136/bmj.j5299.
Smithers, 2021. Tire industry rebounds to reach $264.0 billion in 2021, and $325.6 billion in 2026 according to latest Smithers research.
Soret, A., Guevara, M., Baldasano, J.M., 2014. The potential impacts of electric vehicles on air quality in the urban areas of Barcelona and Madrid (Spain). Atmos. Environ. 99, 51–63. https://doi.org/10.1016/j.atmosenv.2014.09.048.
Steg, L., 2005. Car use: lust and must. Instrumental, symbolic and affective motives for car use. In: Transportation Research Part A: Policy and Practice, Positive Utility of Travel, 39, pp. 147–162. https://doi.org/10.1016/j.tra.2004.07.001.
Steptoe, A., Shankar, A., Demakakos, P., Wardle, J., 2013. Social isolation, loneliness, and all-cause mortality in older men and women. Proc. Natl. Acad. Sci. USA 110, 5797–5801. https://doi.org/10.1073/pnas.1219686110.
Stoner, D., 1925. The toll of the automobile. Science 61, 56–57. https://doi.org/10.1126/science.61.1568.56.
Subramanian, R., Kagabo, A.S., Baharane, V., Guhirwa, S., Sindayigaya, C., Malings, C., Williams, N.J., Kalisa, E., Li, H., Adams, P., Robinson, A.L., DeWitt, H.L., Gasore, J., Jaramillo, P., 2020. Air pollution in Kigali, Rwanda: spatial and temporal variability, source contributions, and the impact of car-free Sundays. Clean Air J. 30 https://doi.org/10.17159/caj/2020/30/2.8023.
Sullman, M.J.M., Paxion, J., Stephens, A.N., 2017. Gender roles, sex and the expression of driving anger. Accid. Anal. Prev. 106, 23–30. https://doi.org/10.1016/j.aap.2017.05.016.
Sun, S., Ertz, M., 2021. Environmental impact of mutualized mobility: evidence from a life cycle perspective. Sci. Total Environ. 772, 145014 https://doi.org/10.1016/j.scitotenv.2021.145014.
Sun, X., Liu, J., Hong, J., Lu, B., 2016. Life cycle assessment of Chinese radial passenger vehicle tire. Int. J. Life Cycle Assess. 21, 1749–1758. https://doi.org/10.1007/s11367-016-1139-0.
Svennevik, E.M.C., Dijk, M., Arnfalk, P., 2021. How do new mobility practices emerge? A comparative analysis of car-sharing in cities in Norway, Sweden and the Netherlands. Energy Res. Soc. Sci. 82, 102305 https://doi.org/10.1016/j.erss.2021.102305.
Sysalová, J., Sýkorová, I., Havelcová, M., Száková, J., Trejtnarová, H., Kotlík, B., 2012. Toxicologically important trace elements and organic compounds investigated in size-fractionated urban particulate matter collected near the Prague highway. Sci. Total Environ. 437, 127–136. https://doi.org/10.1016/j.scitotenv.2012.07.030.

Te Brömmelstroet, M., 2020. Framing systemic traffic violence: media coverage of Dutch traffic crashes. Transp. Res. Interdiscipl. Perspect. 5, 100109 https://doi.org/10.1016/j.trip.2020.100109.

Tessum, C.W., Apte, J.S., Goodkind, A.L., Muller, N.Z., Mullins, K.A., Paolella, D.A., Polasky, S., Springer, N.P., Thakrar, S.K., Marshall, J.D., Hill, J.D., 2019. Inequity in consumption of goods and services adds to racial–ethnic disparities in air pollution exposure. Proc. Natl. Acad. Sci. 116, 6001–6006. https://doi.org/10.1073/pnas.1818859116.

Tian, Z., Zhao, H., Peter, K.T., Gonzalez, M., Wetzel, J., Wu, C., Hu, X., Prat, J., Mudrock, E., Hettinger, R., Cortina, A.E., Biswas, R.G., Kock, F.V.C., Soong, R., Jenne, A., Du, B., Hou, F., He, H., Lundeen, R., Gilbreath, A., Sutton, R., Scholz, N.L., Davis, J.W., Dodd, M.C., Simpson, A., McIntyre, J.K., Kolodziej, E.P., 2021. A ubiquitous tire rubber–derived chemical induces acute mortality in coho salmon. Science 371, 185–189. https://doi.org/10.1126/science.abd6951.

Trounstine, J., 2020. The geography of inequality: how Land use regulation produces segregation. Am. Polit. Sci. Rev. 114, 443–455. https://doi.org/10.1017/S0003055419000844.

Trowbridge, M.J., Gurka, M.J., O'Connor, R.E., 2009. Urban sprawl and delayed ambulance arrival in the U.S. Am. J. Prev. Med. 37, 428–432. https://doi.org/10.1016/j.amepre.2009.06.016.

Tubelo, R., Rodrigues, L., Gillott, M., 2021. Characterising Brazilian housing through an investigation of policies, architecture, and statistics. J. Archit. 26, 191–211. https://doi.org/10.1080/13602365.2021.1895279.

Turner, A., Filella, M., 2023. Lead and chromium in European road paints. Environ. Pollut. 316, 120492 https://doi.org/10.1016/j.envpol.2022.120492.

UN Environment Programme, 2021. Era of leaded petrol over, eliminating a major threat to human and planetary health [WWW Document]. UN Environment Programme.. URL. http://www.unep.org/news-and-stories/press-release/era-leaded-petrol-over-eliminating-major-threat-human-and-planetary (accessed 11.3.22).

Urry, J., 2006. Inhabiting the Car. In: Against Automobility. Blackwell, Oxford, UK, pp. 17–31.

US Department of Transportation, 2022. Manual on Uniform Traffic Control Devices for Streets and Highways: 2009 Edition including Revision 3 dated July 2022.

van der Kuijp, T.J., Huang, L., Cherry, C.R., 2013. Health hazards of China's lead-acid battery industry: a review of its market drivers, production processes, and health impacts. Environ. Health 12, 61. https://doi.org/10.1186/1476-069X-12-61.

van Kempen, E.E.M.M., Kruize, H., Boshuizen, H.C., Ameling, C.B., Staatsen, B.A.M., de, H.A.E.M, 2002. The association between noise exposure and blood pressure and ischemic heart disease: a meta-analysis. Environ. Health Perspect. 110, 307–317. https://doi.org/10.1289/ehp.02110307.

Vélez, A.M.A., 2023. Economic impacts, carbon footprint and rebound effects of car sharing: scenario analysis assessing business-to-consumer and peer-to-peer car sharing. Sustain. Prod. Consumpt. 35, 238–249. https://doi.org/10.1016/j.spc.2022.11.004.

Verbich, D., El-Geneidy, A., 2016. The pursuit of satisfaction: variation in satisfaction with bus transit service among riders with encumbrances and riders with disabilities using a large-scale survey from London, UK. Transp. Policy 47, 64–71. https://doi.org/10.1016/j.tranpol.2015.12.009.

Verlinghieri, E., Schwanen, T., 2020. Transport and mobility justice: evolving discussions. J. Transp. Geogr. 87, 102798 https://doi.org/10.1016/j.jtrangeo.2020.102798.

Vethaak, A.D., Legler, J., 2021. Microplastics and human health. Science 371, 672–674. https://doi.org/10.1126/science.abe5041.

Wadud, Z., Adeel, M., Anable, J., Lucas, K., 2022. A disaggregate analysis of 'excess' car travel and its role in decarbonisation. Transp. Res. Part D: Transp. Environ. 109, 103377 https://doi.org/10.1016/j.trd.2022.103377.

Waygood, E.O.D., Friman, M., Olsson, L.E., Taniguchi, A., 2017. Transport and child well-being: an integrative review. Travel Behav. Soc. 9, 32–49. https://doi.org/10.1016/j.tbs.2017.04.005.

Whitelegg, J., 1993. Transport for a Sustainable Future: The Case for Europe / John Whitelegg. Belhaven Press, London.

Wilkins, J., Weekes, S., Cameron, C., Sevenel, P., 2017. Transport Statistics Great Britain: 2017. Department for Transport, London.

Willson, R.W., 2013. Parking Reform Made Easy. Island Press, Washington, DC.

Woods, J.B., 2021. Traffic without the police. Stanford Law Rev. 73, 1471–1549.

World Health Organization, 2018. Global Status Report on Road Safety 2018. World Health Organization, Geneva.

World Health Organization, 2021a. Road Traffic Mortality [WWW Document]. World Health Organization: The Global Health Observatory. URL. https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/road-traffic-mortality (accessed 3.11.22).

World Health Organization, 2021b. Ambient (outdoor) Air Pollution [WWW Document]. URL. https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health (accessed 1.28.22).

World Health Organization, 2021c. Road Traffic Injuries [WWW Document]. World Health Organization Newsroom. URL. https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries (accessed 11.24.21).

World Health Organization, 2022. Lead Poisoning [WWW Document]. World Health Organization Newsroom. URL. https://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health (accessed 11.18.22).

Wright, S.L., Kelly, F.J., 2017. Plastic and human health: a Micro issue? Environ. Sci. Technol. 51, 6634–6647. https://doi.org/10.1021/acs.est.7b00423.

Wyly, E., 2014. Automated (post)positivism. Urban Geogr. 35, 669–690. https://doi.org/10.1080/02723638.2014.923143.

Xiong, Y., Partha, D., Prime, N., Smith, S.J., Mariscal, N., Salah, H., Huang, Y., 2022. Long-term trends of impacts of global gasoline and diesel emissions on ambient PM2.5 and O3 pollution and the related health burden for 2000–2015. Environ. Res. Lett. 17, 104042 https://doi.org/10.1088/1748-9326/ac9422.

Zannoni, D., Valotto, G., Visin, F., Rampazzo, G., 2016. Sources and distribution of tracer elements in road dust: the Venice mainland case of study. J. Geochem. Explor. 166, 64–72. https://doi.org/10.1016/j.gexplo.2016.04.007.

Zegeer, C.V., Bushell, M., 2012. Pedestrian crash trends and potential countermeasures from around the world. In: Accident Analysis & Prevention, Safety and Mobility of Vulnerable Road Usears: Pedestrians, Bicyclists, and Motorcyclists, 44, pp. 3–11. https://doi.org/10.1016/j.aap.2010.12.007.

Zhong, C., Wang, R., Morimoto, L.M., Longcore, T., Franklin, M., Rogne, T., Metayer, C., Wiemels, J.L., Ma, X., 2023. Outdoor artificial light at night, air pollution, and risk of childhood acute lymphoblastic leukemia in the California linkage study of early-onset cancers. Sci. Rep. 13, 583. https://doi.org/10.1038/s41598-022-23682-z.

Ziter, C.D., Pedersen, E.J., Kucharik, C.J., Turner, M.G., 2019. Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. Proc. Natl. Acad. Sci. 116, 7575–7580. https://doi.org/10.1073/pnas.1817561116.