Environment International 94 (2016) 251–262

Contents lists available at ScienceDirect

Environment International

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

Review article

Car free cities: Pathway to healthy urban living

Mark J. Nieuwenhuijsen [a,b,c,*], Haneen Khreis [d]

[a] ISGlobal, Centre for Research in Environmental Epidemiology (CREAL), Barcelona, Spain
[b] Universitat Pompeu Fabra (UPF), Spain
[c] CIBER Epidemiologia y Salud Publica (CIBERESP), Spain
[d] Institute for Transport Studies (ITS), University of Leeds, Leeds, United Kingdom

ARTICLE INFO

Article history:
Received 21 March 2016
Received in revised form 25 May 2016
Accepted 30 May 2016
Available online xxxx

ABSTRACT

Background: Many cities across the world are beginning to shift their mobility solution away from the private cars and towards more environmentally friendly and citizen-focused means. Hamburg, Oslo, Helsinki, and Madrid have recently announced their plans to become (partly) private car free cities. Other cities like Paris, Milan, Chengdu, Masdar, Dublin, Brussels, Copenhagen, Bogota, and Hyderabad have measures that aim at reducing motorized traffic including implementing car free days, investing in cycling infrastructure and pedestrianization, restricting parking spaces and considerable increases in public transport provision. Such plans and measures are particularly implemented with the declared aim of reducing greenhouse gas emissions. These reductions are also likely to benefit public health.
Aims: We aimed to describe the plans for private car free cities and its likely effects on public health.
Methods: We reviewed the grey and scientific literature on plans for private car free cities, restricted car use, related exposures and health.
Results: An increasing number of cities are planning to become (partly) private car free. They mainly focus on the reduction of private car use in city centers. The likely effects of such policies are significant reductions in traffic-related air pollution, noise, and temperature in city centers. For example, up to a 40% reduction in NO_2 levels has been reported on car free days. These reductions are likely to lead to a reduction in premature mortality and morbidity. Furthermore the reduction in the number of cars, and therefore a reduction in the need for parking places and road space, provides opportunities to increase green space and green networks in cities, which in turn can lead to many beneficial health effects. All these measures are likely to lead to higher levels of active mobility and physical activity which may improve public health the most and also provide more opportunities for people to interact with each other in public space. Furthermore, such initiatives, if undertaken at a sufficiently large scale can result in positive distal effects and climate change mitigation through CO_2 reductions. The potential negative effects which may arise due to motorized traffic detouring around car free zone into their destinations also need further evaluation and the areas in which car free zones are introduced need to be given sufficient attention so as not to become an additional way to exacerbate socioeconomic divides. The extent and magnitude of all the above effects is still unclear and needs further research, including full chain health impact assessment modeling to quantify the potential health benefits of such schemes, and exposure and epidemiological studies to measure any changes when such interventions take place.
Conclusions: The introduction of private car free cities is likely to have direct and indirect health benefits, but the exact magnitude and potential conflicting effects are as yet unclear. This paper has overviewed the expected health impacts, which can be useful to underpin policies to reduce car use in cities.

Contents

* Corresponding author at: Research Professor in Environmental Epidemiology, Center for Research in Environmental Epidemiology (CREAL), Parc de Recerca Biomèdica de Barcelona - PRBB (office 183.05) C., Doctor Aiguader, 88, 08003 Barcelona, Spain.
E-mail address: mnieuwenhuijsen@creal.cat (M.J. Nieuwenhuijsen).

http://dx.doi.org/10.1016/j.envint.2016.05.032
0160-4120/

1. Introduction

The car is an important part of the transport system that has brought increased mobility and convenience, increased employment, technological advances and economic prosperity. To a large extent, the car defined the past century which some have previously described as the century of the car (Gilroy, 2001).

Although it is hard to imagine a world without cars, many cities are beginning to shift their mobility solutions away from the private car and towards more environmentally friendly and citizen-focused mobility means. Hamburg, Helsinki, Madrid and Oslo have recently announced their plans to become partly private car free cities (Cathkart-Keays, 2015). Other cities like Bogota, Brussels, Chengdu, Copenhagen, Dublin, Hyderabad, Milan and Paris have different measures that aim at reducing motorized traffic including implementing car free days, investing in cycling infrastructure and pedestrianization, restricting parking space and considerable increases in public transport provision (Cathkart-Keays, 2015). Such plans and measures are particularly implemented with the declared aim of reducing greenhouse gas emissions (Cathkart-Keays, 2015). Reductions in motorized road traffic, particularly when complemented by increases in active transport (de Nazelle et al., 2011), are also likely to benefit public health, both in the short and long-term.

Yet despite these emerging initiatives and an ever-growing awareness of the health impacts of traffic-related exposures and practices (Nieuwenhuijsen et al., 2016; Khreis et al., in press), the number of cars (and car mobility) in the world continues to rise. This is particularly true in countries with rapidly growing economies (HEI, 2010); which are following mass motorization trajectories of developed countries (Singh, 2012). By the year 2030, the planet is expected to host 2 billion vehicles (Sperling and Gordon, 2008). These trends are problematic as the predominance of car mobility is associated with numerous adverse health outcomes through pathways of motor vehicle crashes, human physical inactivity and traffic-related environmental exposures including air pollution, noise, green space reduction, and local temperature rises (Khreis et al., in press). Car traffic density also tends to be high in cities as a result of economic and social activities and urban planning patterns, exacerbating the health concerns in urban areas particularly when there is little public or active transport provision. This is challenging as cities, where around 70–80% of people live in Europe, also tend to be the space where people generally congregate.

Cars emit CO_2 and other important greenhouse gases (black carbon for example) and air pollutants such as particulate matter and nitrogen oxides (HEI, 2010). Cars and car-related infrastructure are furthermore related to other deleterious environmental exposures most notably including heat and noise (Nieuwenhuijsen et al., 2016, Khreis et al., in press). Air pollution, noise and heat levels can be particularly high near roadsides (HEI, 2010; Foraster et al., 2011, Bell and Galatioto, 2013; Cyrys et al., 2012; Eeftens et al., 2012b; Petralli et al., 2014). Car use is also a sedentary behavior associated with a reduced level of active transport and physical activity (Mackett and Brown, 2011), and lowers the likelihood of making and interacting with social contacts on regular basis (Besser et al., 2008; Putnam, 2000). Finally, motor vehicle crashes are a direct cause of a large number of global deaths and millions of injuries (Bhalla et al., 2014; WHO, 2015). Air pollution, heat-islands, noise, accidents, and sedentary behavior have all been associated with substantial increases in premature mortality and morbidity (Forouzanfar et al., 2015, Bhalla et al., 2014; WHO, 2015; Mueller et al., 2016), particularly in cities.

Besides the numerous adverse health outcomes, car use is also related to multiple other externalities including inequalities (Lucas, 2004; Markovich and Lucas, 2011; Rachele et al., 2015), road damage, congestion, and oil dependence (Santos et al., 2010). The cost of these externalities to the society is too big to overlook, yet is generally not reflected in the current market prices of the road transport sector (Santos et al., 2010). The total bill for traffic congestion, pollution and accidents for example has been estimated at EUR 502 billion per year across the EU Member States (INFRAS, 2000). Finally, cars, and related roads and parking space, use up a large amount of the already limited space in cities that could arguably be used for other purposes such as trees, parks and other greenness, which are often lacking in cities but are more beneficial to public health and well-being (Nieuwenhuijsen et al., 2014).

In this paper, we aim to describe the plans for private car free cities and its likely effects on public health. We also highlight research gaps and provide suggestions for further work.

2. Methods

To devise our searches and narrative, we were guided by a conceptual framework linking urban and transport planning, environmental exposures, physical activity and health (Fig. 1). In this framework, urban planning and design, including land use, leads to certain behavior including transport mode choice and certain transport planning patterns. Transport mode choice is associated with a range of environmental exposures such as air pollution and noise, which in turn are associated with morbidity and subsequent mortality. In this case, increases in

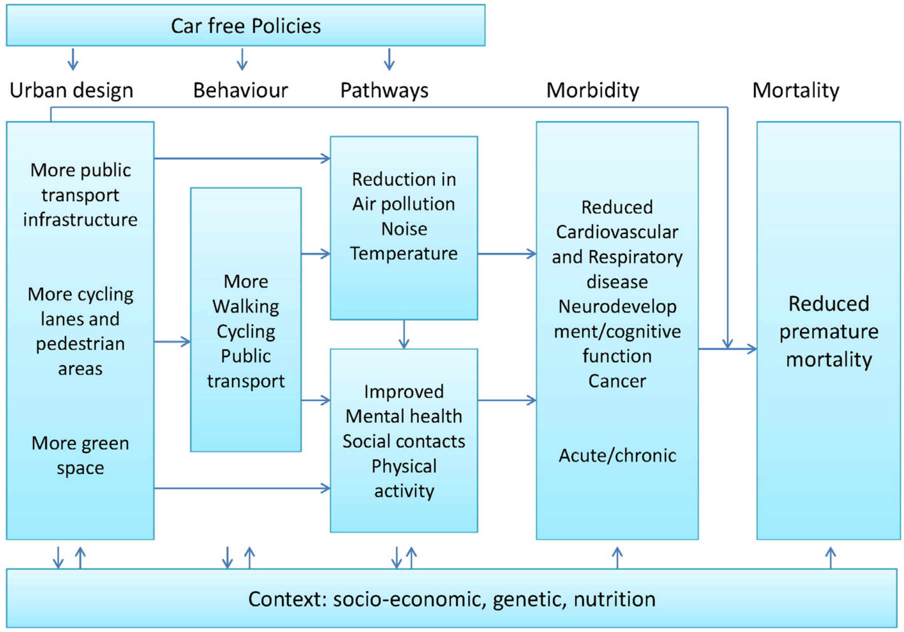

Fig. 1. Linkage between urban and transport planning, environmental exposures, physical activity and health.

public and active transportation may lead to a reduction in environmental exposures and increased physical activity, leading to reduced morbidity and mortality. Finally green space provision may lead to e.g. improved mental health and more physical activity and social contacts and therefore reduce morbidity and mortality. Car free planning policies could be directed towards urban and transport planning, behavior and certain pathways, yet the whole framework is context dependent.

We searched PubMed, Web of Science, Science Direct, and references from relevant articles in English language from Jan. 1, 1980, to Jan. 1, 2016, using the search terms: "city",˝urban˝,˝car free˝ in combination with "traffic", "air pollution", "noise", "temperature", "green space", "heat island", "carbon emissions", "built environment", "walkability", "cycling" and/or "mortality", "respiratory disease", "cardiovascular disease", "hypertension", "blood pressure", "annoyance", "cognitive function", "reproductive outcomes" following an initial rapid review of the literature of the topic area and the authors´ knowledge. We do not systematically report the results, but focus on systematic reviews, meta-analyses and articles published in the past 5 years, giving priority to findings of the former two. We use older articles if they represent seminal research or are necessary to understand more recent findings. We furthermore searched Google for any other material related to ˝car free cities˝.

3. Results

3.1. Plans for reducing or restricting car use in cities

Recently, some cities have been seeking to shift their focus away from cars and towards greener, citizen-focused mobility solutions that may also be healthier. Towards the end of the 20th century, many cities started to pedestrianize streets of their centers as a first step to restrict the use of cars (https://en.wikipedia.org/wiki/Pedestrian_zone). But increasingly cities are becoming more radical in their approach to reduce car use. A theoretical design for a car free city of one million people was first proposed by J.H. Crawford in 1996 and further refined in his books, *Car free Cities* (Crawford, 2000) and *Car free Design Manual* (Crawford, 2009).

In January 2014, Hamburg was the first city to announce that it will be private car free by 2034 (Nuwer, 2014), followed by Oslo who wants a car free center by 2019 (Reuters, 2015). Hamburg plans a car-ban on a number of urban roads which will be transformed into routes for pedestrians and bikes that link parks and open spaces (about 40% of the city). These plans are being implemented accompanied with substantial green infrastructure investments with the aspiration of absorbing CO_2 and bringing the city closer to its goal of an 80% greenhouse gas emissions reduction in the next three decades.

In October 2015, Oslo revealed plans to ban all private vehicles from the center by 2019. Oslo's new Leftist city government declared that banning private cars from the city center by 2019 is part of a plan to 'slash' greenhouse gas emissions (Agence France Presse, 2015). Oslo's plans include implementing a car-free zone within the city's central ring road, alongside other complementary proposals, such as the introduction of substantial new bike lanes, rush-hour congestion charging and restrictions in parking spaces (Cathkart-Keays, 2015).

Similarly, Madrid is focusing on the city at a human level, and has new plans to pedestrianize its urban center pushing out cars by 2020. These plans are already being realized in early 2015, when the city introduced a limit on non-residential vehicles entering an extended pedestrianized area of the center, and launched Europe's first fully electric bike scheme. Others measures that will be implemented as part of this plan are enlarging the city's bus network and providing extra pedestrian infrastructure (Cathkart-Keays, 2015).

Cities from around the world seem to become more willing to try out similar car free initiatives. Helsinki has plans to significantly improve its "mobility on demand" service so that nobody will want to drive a car in the center by 2025, while Paris's car-free days have successfully reduced the notorious high pollution levels in the French capital (Chrisafis, 2015). Other cities including the Great City in China, and Masdar near Abu Dhabi also plan to focus on mass transit or electric cars as alternatives to fuel driven private cars (Cathkart-Keays, 2015).

As it stands, these cars free policy measures appear to mainly target private cars and exclude public cars such as police and hospital vehicles, and also heavy goods vehicles as they are seen as a necessary public need and instrumental for economic activity. Restrictions may be placed on the emissions and frequency of these vehicles to ensure an improvement in air quality and other car-related exposures.

3.2. Policy measures for reducing or restricting car use in cities

For most of these examples, multiple policy packages seem to be key in pushing car-free plans forward. Cities are not only banning or restricting private car use, but importantly providing a reasonable alternative and an appealing counterfactual reality which the public realm can transition to. Ensuring public transport availability, cycling infrastructure, green space and inviting and secure pedestrian areas are policy instruments that are being packaged in the bigger plans for car restrictions. The effectiveness of these policies for encouraging modal alternatives and shifting away from car use varies. There is however (scarce) evidence on the effectiveness of relevant interventions as several reviews aimed to describe the impact of bicycle infrastructure on bicycle use for example (Heinen et al., 2010; Pucher et al., 2010; Scheepers et al., 2014; Scheepers et al., 2015).

Scheepers et al. (2015) systematically reviewed the effectiveness of interventions designed to stimulate a shift from car use to cycling or walking and increase physical activity. Nineteen studies met their inclusion criteria and only two studies evaluated the effectiveness of the introduction of car free zones. One was the study by Topp and Pharoah (1994) who described four cities which have introduced car free city centers. Bologna, Italy, Lubeck, Germany, and Aachen, Germany reported on the effectiveness of car free zones in bringing about a mode shift. In Bologna, passenger cars commuting via the old town were reduced in number by over 60%. In Lubeck there was a reduction of 40–80% of cars (depending on the time of the day) entering the city center. Twelve percent of the respondents switched to public transport, cycling and walking. Nevertheless, 58% of the respondents still used the car to get as near as possible to their destination and 30% used park-and-ride. Generally, these reviews reveal a lack of before and after evaluation to test the impacts of a specific intervention, and poor reporting of intervention characteristics that limits the possibilities to describe a dose-response relationship, which can be of particular importance to support 'evidence-based' policy making.

3.3. Cars owning public space

In the European Union alone there are more than 200 cities with more than 100,000 inhabitants. The European Union is the third top market for vehicles sale after China and the US buying 14 million vehicles in 2011 (ICCT, 2013). The mode share of cars varies substantially between cities with as low as 9% in the city of London, UK, to up to 85% in Swindon, also the UK (http://www.epomm.eu/tems/). Mode shares for walking, cycling and public transport vary from a few percent up to 76%, 44% and 63% respectively, and there is an inverse relationship between the mode share of cars and the mode share of other mobility means.

When car mode share increases in a city, the amount of land used for transportation also increases. For example, when coupled with the extreme amounts of land required for parking, cars consume as much as 70% of downtown land in some American cities (Crawford, 2002). In a study of 12 US cities, a 10 percentage points in the portion of commuters traveling by automobile was associated with an increase of more than 2500 m^2 of parking per 1000 people and a decrease of 1700 people per km^2 (McCahill and Garrick, 2012). In cities with higher rates of automobile use (roughly 30% more driving), about twice as much land is committed to parking for each resident and employee (McCahill and Garrick, 2012). The most demanding mode of transport in terms of space is the private car. For example, a car journey home or to work consumes 90 times more space than if the same journey was taken by bus or tram (INFRAS, 2000). For parking alone a typical parking space is 2.4–3.0 m wide and 5.5–6.0 m deep, totaling 13–19 m^2. Off-street parking typically requires 28–33 m^2 per space, including access lanes and landscaping, allowing 250–370 cars per hectare, depending on design. Up to 20 bikes can usually fit into the total space typically required to park one car (Litman, 2013). A study published by the Transportation Research Board quantified the spatial impact of transit and found that without public transit American cities would take up 37% more space (Gallivan et al., 2015). Galivan et al. modeled not just how many driving miles are directly averted by people riding transit, but importantly how the availability of transit affects the way cities were built.

3.4. Competitiveness with other modes

Although, speed by transport mode differs by city, there is evidence that the average speeds of cars in cities do not differ much from average speeds of public transport modes. In Barcelona for example average speeds for trips by car is 23.5 km/h, by bike 14 km/h, by bus/tram 11.2 km/h and by metro/train 25 km/h (Rojas-Rueda et al., 2012); suggesting a less than two fold differences in speeds between these modes. Cities have the advantage over rural and semi-rural areas that they are denser and easier to connect, easier to get around on public and active transport modes, but generally have problems with incoming traffic from surrounding areas, for example from people living outside the city and working in the city. Of course travel time is not the only consideration, and comfort, convenience, and safety are also important. There is competition for investments and investments in public transport and cycling differ as compared to investment in cars related infrastructure and amenities (infrastructure investment, parking requirements, fees and taxes, traffic management etc), even though the cost benefit analyses for walking and cycling show a large favorable ratio (Davis, 2014), and quality public transport may have many attractive attributes (Redman et al., 2013). Both priority and the largest proportion of the budget are not given to public transport and cycling infrastructure, but car infrastructure. Furthermore, transport funding dedicated to roadways cannot be used for alternative modes or mobility management strategies, even if they are more cost effective and beneficial overall (Litman, 2014).

3.5. Contribution of car traffic to environmental exposures

Car traffic and related infrastructure contributes to three key environmental exposures: air pollution, noise and local temperature rises. Forty one percent of the European (EU 27) urban population lives in areas where the EU air quality 24-hour limit value (LV) for particulate matter (PM10) was exceeded in 2010, while 7% lives in areas where the annual EU LV for nitrogen dioxide (NO_2) was exceeded in the same year (Sundvor et al., 2012). Car traffic contributes to a considerable proportion of ambient air pollution in cities but the extent varies depending on factors such as the car fleet make up, car density, traffic conditions and lay out of the city. The range of the traffic contribution to urban PM concentrations in Europe ranges from 9–53% for PM_{10} and 9–66% for $PM_{2.5}$ with an average of 39% and 43% at traffic sites, respectively and a higher range for NO_2 of over 80% (Sundvor et al., 2012). Traffic indicators such as distance to major roads, surrounding road length, and traffic density explain a large proportion of the variability of air pollution within urban areas (Eeftens et al., 2012a; Beelen et al., 2013). Average concentrations of air pollutants are generally considerably higher at street locations compared to urban backgrounds with average ratios in Europe of 1.63 for NO_2, 1.93 for NO_x (Cyrys et al., 2012), and 1.14, 1.38, 1.23 and 1.42 respectively for $PM_{2.5}$, $PM_{2.5}$ absorbance (soot), PM_{10} and PMcoarse (Eeftens et al., 2012b).

The levels of ambient noise are also associated with the road network, traffic flow, speed and load, junctions, acoustics and meteorological conditions in cities (Foraster et al., 2011; Bell and Galatioto, 2013; Zuo et al., 2014). For example, the L50 noise levels (total data) range from about 54 dBA in acoustic shadows in residential tertiary streets up to 74 dBA on the high traffic roads (Bell and Galatioto, 2013).

The urban heat island effect is often observed where open, wooded or green areas have been replaced by concrete and asphalt for roads. Determinants of the heat islands are population density, (lack of) green vegetation, urban design, road network and albedo effects (Zhang et al., 2013; Gago et al., 2013; Petralli et al., 2014). Other than traffic-related infrastructure, motor vehicles traffic also release anthropogenic heat by way of tailpipe emissions (black carbon, carbon dioxide, methane, nitrous oxide) that together with re-radiation effects of dense urban structures and long term climate change have the potential to amplify urban summer temperatures and contribute to the urban heat island effect (Rizwan et al., 2008). Petralli et al. (2014) found that intra-urban variability of summer values was up to 3 °C both in minimum and maximum air temperature. The annual mean air temperature of a city with 1 million people or more can be 1.0–3.0 °C warmer than its surroundings. In the evening, the difference can be as high as 12 °C. (United States Environmental Protection Agency, 2015).

3.6. Effects of car free days on air pollution and noise

There are no data yet available on changes in levels of environmental exposures due to car free cities, because there are no cities yet that have gone car free. However there are a number of interventions such as car free days or restricting traffic in a specific area which provide insight to what these changes may be, but the number of studies is limited.

Airparif, which measures city pollution levels, showed that levels of nitrogen dioxide dropped by up to 40% in parts of the city on Sunday 27 September 2015, when cars were banned (Willsher, 2015). When the Tour de France cycling event came to Leeds, NO_2 levels dropped by 20% on the day of the Grand Départ when cars were banned from the center and cyclists took over (http://airquality.thecitytalking.com). Masiol et al. (2014) examined 13 years of air pollution data in the city of Mestre in the Po Valley and tried to assess the effect of motorized traffic free Sundays. They found no statistically significant impact of traffic free Sundays on air quality. They found that weather had a larger influence on air quality and noted that traffic free Sundays often diverts the traffic to the suburbs of the city, the ring road is never included in the actions and the surroundings towns are commonly not involved in motorized traffic restrictions. It is therefore reasonable to state that the traffic is moved, rather than decreased.

An example of motorized traffic restriction is the London congestion zone, which resulted in a sustained reduction in vehicle numbers and increased vehicle speed. According to air dispersion modeling conducted prior to the intervention the London congestion charging scheme was expected to result in a 12% reduction in PM_{10} and NO_x emissions within the zone (Tonne et al., 2008). Measurements however showed no impact on PM_{10} levels, a reduction of NO levels and an increase in NO_2 levels (Atkinson et al., 2009). Possible reasons behind these counterintuitive findings is that PM_{10} is primarily a non-exhaust pollutant and has other important local (traffic and non-traffic) and regional sources that are not affected by the intervention, that the existing fleet was replaced by a more polluting fleet as newer diesel passenger cars turn out to be of higher primary NO_2 emissions when compared to older generations (Carslaw et al., 2011), and that the area of the intervention was limited/small (Atkinson et al., 2009).

There is also the example of the Milan congestion charging zone referred to as the Ecopass. The scheme was initially expected to reduce PM_{10} levels emissions produced within the area by 15%. However post studies found that although there was no significant difference in PM levels between Ecopass area and outside (Ruprecht and Invernizzi, 2008); a black carbon (BC) monitoring project launched in 2010 found a 28%–40% reduction in BC in the charging area (as compared to outside). Likewise, car free Sundays implemented within the city also showed a 75%–78% reduction in BC. The authors argued that black carbon, a pollutant primarily emitted by traffic sources, could be a PM metric more suitable to demonstrate pollutant reductions of such an intervention (Invernizzi et al., 2011).

Barrett (2013) reviewed a number of studies on low emission zones (LEZ), which may also restrict motorized traffic coming into a zone. He suggested that LEZ only affect traffic exhaust components, whereas traffic reduction measures affect all traffic related air pollution. He also showed that air pollution modeling exercises suggested greater benefits compared to actual measurements, partly because of the uncertainties and unknowns in the modeling.

There are significantly fewer studies on noise and no studies on urban temperature changes due to car free interventions. Brussels Environment (2015) found a greater than 10 dB reduction in noise levels on car free Sundays.

3.7. Car related impacts on health

3.7.1. Accidents

Car traffic causes around 1.3 million global deaths, and some 78 million injuries (Bhalla et al., 2014). In 2011, more than 30,000 people died on the roads of the European Union, i.e. the equivalent of a medium town. For every death on Europe's roads there are an estimated 4 permanently disabling injuries such as damage to the brain or spinal cord, 8 serious injuries and 50 minor injuries (European Commission, 2016). Road traffic injuries rank as the eighth leading cause of death, and are furthermore not equally distributed. Low-income and middle-income countries, where investments in road safety campaigns, safe infrastructure and technologies are generally less, account for over 90% of the world's fatalities on the roads despite having only 48% of the world's registered vehicles (WHO, 2009; WHO, 2015). Furthermore, vulnerable road users are most adversely affected. Although there is a high variability between the different regions, the highest accident rates in cities are generally for motorbike commuters, followed by active transport modes commuters (pedestrians and cyclists), then public transport commuters and finally car commuters (Rojas-Rueda et al., 2012). Studies have shown that accident rates for active transport depend on the number of cyclists resulting in a rapid decline in accidents when the numbers of cyclists increase; the so called safety in numbers effects (Jacobsen, 2003).

A reduction in motorized traffic is expected to lead to a reduction in accidents. For example, Green et al. (2014) examined monthly traffic accident counts, based on counts reported to the police in central London before and after the congestion charge compared to several suitable controls and found a substantial and robust decline in accidents associated with the advent of the congestion charge in London. The effect of congestion charging was in the order of a reduction of 34 accidents per month when compared to other cities.

3.8. Cars-related environmental exposure and health

Ambient particulate air pollution was twelfth in the ranking of the Global Burden of Disease estimates in 2010 (Forouzanfar et al., 2015); contributing to an estimated 3–4 million premature deaths and an average 9 months life expectancy reduction in Europe (WHO, 2015). Bhalla et al. (2014) estimated that air pollution from motor vehicles is the cause of 184,000 deaths globally, including 91,000 deaths from ischemic heart disease, 59,000 deaths from stroke, and 34,000 deaths from lower respiratory infections, chronic obstructive pulmonary disease, and lung cancer. Lelieveld et al. (2015), using more sophisticated source models, estimated that traffic emissions are responsible for about one-fifth of mortality by ambient $PM_{2.5}$ and O_3 in Germany, the UK and the USA, while they globally account for about 5% of the 3.3 million annual premature deaths due to outdoor air pollution. Adding the health impacts of NO_x, as was recently done in London, doubles these numbers (Walton et al., 2015). Of course, deaths are only the top of the pyramid and there is an extensive range of other health effects of traffic-related air pollution (Héroux et al., 2015).

A number of studies have shown that a reduction in air pollution can lead to a reduction in mortality and morbidity (Pope et al., 2009, Giles et al., 2011), but the numbers of studies are small and there are no studies on car free cities. However there are many studies showing the effect of the exposure to mainly traffic related air pollution on mortality (Beelen et al., 2014), lung cancer (Raaschou-Nielsen et al., 2013), cardiovascular disease incidence (Cesaroni et al., 2014), decreased lung function in children (Gehring et al., 2013; Eeftens et al., 2014), reduced cognitive function in children (Sunyer et al., 2015), respiratory infections during early childhood (MacIntyre et al., 2014), and low birth weight (Pedersen et al., 2013). Furthermore evidence is emerging for a role of traffic-related air pollution in other prevalent disease such as diabetes (Krämer et al., 2010; Coogan et al., 2012; Eze et al., 2015), and obesity (Jerrett et al., 2014).These studies suggest that reductions in traffic-related air pollution can be expected to lead to reductions in these diseases.

No studies have evaluated the effects of a reduction of traffic noise on health. However, the health effects of noise are increasingly being recognized and can contribute to a large burden of disease that may be comparable to that of air pollution (Hänninen et al., 2014). Ambient noise has been associated with a range of different auditory and non-auditory outcomes including cardio-vascular mortality and morbidity (Ndrepepa and Twardella, 2011; Babisch et al., 2014; Münzel et al., 2014; Basner et al., 2014), annoyance and sleep disturbances (Omlin et al., 2011; Laszlo et al., 2012; Basner et al., 2014), high blood pressure in children (Paunović et al., 2011), cognitive effects in children (Stansfeld et al., 2005; Van Kempen and Babisch, 2012; Basner et al., 2014), and adverse reproductive outcomes (Ristovska et al., 2014). Cardiovascular effects by ambient noise have also been shown to be independent of air pollution exposures (Van Kempen and Babisch, 2012; Sørensen et al., 2012; Foraster et al., 2014; Liu et al., 2014).

Likewise, no studies have evaluated the effects of a reduction of heat increases on health. However, high and low ambient temperatures have been associated with mortality (Ma et al., 2014; Guo et al., 2014), cardiorespiratory morbidity (Turner et al., 2012; Ye et al., 2012; Cheng et al., 2014), hospital admissions (Hondula and Barnett, 2014), and children's mortality and hospitalization (Xu et al., 2012). Specifically, the urban heat island effect contributed significantly to health impacts of the 2003 heat wave in Paris (Laaidi et al., 2012).

Few studies have evaluated the effects of an increase of green space on health. However, green space has been associated a number of beneficial health effects (Lee and Maheswaran, 2010; Hartig et al., 2014) including decreased mortality and longevity (Mitchell and Popham, 2008; Gascon et al., 2016), decreased cardiovascular disease (Pereira et al., 2012; Tamosiunas et al., 2014), improved people's self-reported general health (Maas et al., 2006; de Vries et al., 2013) and mental health (Gascon et al., 2015), reduced behavioral problems (Amoly et al., 2014) and increased cognitive function (Dadvand et al. 2015)in children, better sleep patterns (Astell-Burt et al., 2013), recovery from illness (Ulrich, 1984), social contacts (Maas et al., 2009; de Vries et al., 2013), the microbiome (Hanski et al., 2012) and improved birth outcomes (Dzhambov et al., 2014). Increased physical activity and social contacts, psychological restoration/stress reduction, and a reduction in environmental exposure such as noise and air pollution and temperature have been proposed as possible mechanisms for the health benefits of green space (Lee and Maheswaran, 2010; Hartig et al., 2014; de Vries et al., 2013).

3.8.1. Physical activity

Approximately 2.1 million deaths each year are attributable to insufficient physical activity (Forouzanfar et al., 2015). People who are insufficiently physically active have a 20% to 30% increased risk of all-cause mortality compared to those who engage in at least 30 min of moderate intensity physical activity most days of the week (Woodcock et al., 2011). In different regions around the world between 20 to 50% of the population do not meet the WHO physical activity guidelines (WHO, 2015). Recent health impact assessments have shown great potential health benefits of switching to active transportation through increased physical activity and minor risks through air pollution and accidents (Mueller et al., 2015). Increased physical activity has been associated with a reduction in a number of diseases including cardiovascular diseases, dementia, type 2 diabetes, breast cancer or colon cancer (Rojas-Rueda et al., 2013). The greatest benefits are obtained when people switch from being non-active to doing some physical activity because the dose response relationship is steeper in low levels reaching a plateau at the highest levels of physical activity.

Also it has been suggested that moderate-intensity physical activity may reduce stress and anxiety on a daily basis while improving self-perception and mood (Fox, 1999; Peluso and de Andrade, 2005). Some literature recognizes commuting as a potential source of stress (Koslowsky, 1997), but recent qualitative research suggests that commuting is often perceived as a relaxing or transitional time between home and work life, which can also be about enjoying pleasant landscape, nature and wildlife (Guell and Ogilvie, 2013). Active commuters have shown higher levels of satisfaction, less stress, more relaxation and a sense of freedom than car drivers (St-Louis et al., 2014; Lajeunesse and Rodríguez, 2012; Anable and Gatersleben, 2005).

3.9. Social contacts and cohesion, and equity

Pedestrianization of the public realm and increased green space offer more opportunities for social interaction (Nieuwenhuijsen et al., 2014). Markovich and Lucas (2011) synthesised and critically evaluated the literatures pertaining to the social impacts and equity of transport, transport disadvantage as it pertains to different social groups, and the wider interactions between transport poverty and social exclusion. They found a range of issues suggesting that the social and distributional impacts of transport have historically been underestimated. Schwanen et al. (2015) provided a critical review of the progress in understanding the linkages between transport disadvantage and social exclusion. It follows earlier work in proposing social capital as a concept that mediates those linkages, and they suggested that there are various fairly complex pathways. Lucas (2012) contends that transport disadvantage results in inaccessibility of goods, services, decision-making, life chances, social network and social capital, which then leads to social exclusion. More specifically, Putnam (2000) argues that the increase over time in solo driving in the USA is one of the processes that has contributed to the diminishing of the country's social capital in the period 1945–2000; Urry (2007) considers active mobility the glue that holds together social networks; Currie and Stanley (2008) hold that public transport use can strengthen social capital by providing a safety net of transport options for (economically) disadvantaged groups, encouraging high-density living and enabling social interaction with fellow users during trips. People living on streets with high traffic volume have on average less than one quarter the number of friends and social interactions than people living on streets with low traffic volumes (Appleyard, 1982; Hart and Parkhurst, 2011).

3.9.1. Greenhouse gas emissions

Car free initiatives, if undertaken at a sufficiently large scale can result in positive distal effects and climate change mitigation through CO_2 and other greenhouse gas reductions such as black carbon (Woodcock et al., 2009). Acting to reduce greenhouse gas emissions evidently protects human health from the direct and indirect impacts of climate change. However, it also benefits human health through mechanisms quite independent of those relating to modifying climate risk: so-called health co-benefits of mitigation (Watts et al., 2015). In 2014, WHO estimated an additional 250,000 potential deaths annually between 2030 and 2050 for well understood impacts of climate change. WHO suggest their estimates represent lower bound figures because they omit important causal pathways. The effects of economic damage, major heat wave events, river flooding, water scarcity, or the impacts of climate change on human security and conflict for example, are not accounted for in their global burden estimates (Hales et al., 2014).

3.9.2. Health impact assessment studies

The extent and magnitude of reduced car use on health is to a large extent still unknown, and there are few if any epidemiological studies exploring this question. However, a number of studies have attempted to estimate the possible effects of relevant interventions. A review of 28 HIA studies around the theme of reduced car use and increased active transportation showed that great benefits may be obtained for health, particularly through physical activity and that they outweigh the risk of air pollution and accidents (Mueller et al., 2015) (Table 1). The introduction of a bike sharing system was estimated to lead to the reduction of premature mortality in users of the system in Barcelona (Rojas-Rueda et al., 2012). Two HIA studies that modeled the impact of a shift of 20% and 40% of private car journeys being replaced by public or active transportation showed great health benefits for those who shifted transport mode, particularly because of increased physical activity, but found only small health benefits from air pollution reduction in the general population. The reduction of air pollution even when a reduction in 40% private car was modeled was partly due to the fact that they do not contribute greatly to the air pollution levels, and that trucks and motors would be still on the road (Rojas-Rueda et al., 2012, 2013). Yet there are many uncertainties related to the modeling of air pollution and effects may be bigger with different emissions/pollution estimation models and in different populations.

Woodcock et al. (2013a, b) modeled three scenarios with increased walking and cycling and lower car use generated based on the Visions 2030 Walking and Cycling project in England and Wales. They found considerable reductions in disease burden under all three scenarios (vision 3 < 5% private car use), with the largest health benefits attributed to reductions in ischemic heart disease. The pathways that produced the largest benefits were, in order, physical activity, road traffic injuries, and air pollution.

The implementation of the congestion charging scheme in London was estimated to lead to a very modest decrease of 0.73 μg/m^3 in the annual average nitrogen dioxide concentration in the congestion charging zone; however, this decrease was still associated with an increase of 183 years of life gained per 100,000 populations within the zone (Tonne et al., 2008).

A recent health impact analysis of urban and transport planning related exposures showed that contemporary physical inactivity and increased exposure to air pollution, noise, heat and a lack of green spaces in a Southern European city were responsible for around 20% of all-cause mortality. Physical inactivity made the largest contribution (Mueller et al., 2016).

There are yet no HIA studies that have modeled the impacts of car free cities on health.

4. Discussion

An increasing number of cities are planning to become partly private car free. They mainly focus on the reduction of private car use in city centers. The likely effects of such policies are reductions in traffic-related air pollution, noise, and temperature in city centers, and potential increases in active transport, but the extent will depend on various factors that determine the contribution of traffic to pollutants such as the traffic fleet mix, traffic density, conditions and layout of the cities and active transport provision. These changes are likely to lead to a reduction in premature mortality and morbidity. Furthermore the reduction in the number of cars and therefore a reduction in the need for parking places and road space provide opportunities to increase green space and green networks in cities, which in turn can lead to many beneficial health effects. Higher levels of active travel from car free measures may have the largest positive impact on public health and provide more opportunities for people to interact with each other in public space. Car free initiatives, if undertaken at a sufficiently large scale can result in positive distal effects and climate change mitigation through greenhouse gas reductions. The extent and magnitude of all the above effects is still unclear and needs further research, including the evaluation of any intervention on exposure and health and full chain health impact assessment modeling to quantify the potential health benefits of such schemes.

Table 1
Health effects for people changing from car to active transportation and the general population.

	Person changing	General population
Physical activity	Substantial benefits	NA
Air pollution	Small increase risk	Small benefits
Accidents	Small increase risk	NA
Noise	Small increased risk	Small benefits
Green space	Small benefits	Small benefits

NA = not applicable.

4.1. Moves towards public and active transportation

Present cities in many regions are too car dominated and transport planning and policy making seem to cater too much for the motorized private travel and too little for public and active transport modes that could benefit public health and mitigate the effects of traffic-related environmental exposures. Decades of planning and investments in car infrastructure attracted cars to the cities and it will take decades to overturn this. These large infrastructures for cars are in place and are still underway with relatively small proportions of the budget allocated to and little work done for quality active transport provision across most regions. There is an urgent need to rebalance and provide better and safer infrastructures and policy support for active and public transport modes, building a new culture for it on the long term.

The move towards public and active transport in this must be understood as crucial, as physical activity is one of the main drivers for health and lack of time has been repeatedly listed as a detriment of physical activity (Wilcox et al., 2000; Brownson et al., 2001). Public and active transport could provide means to build physical activity patterns into daily routines, which may provide the largest gains for health in relation to car free initiatives. Coupled with urban and planning practices such as providing mixed land-use (e.g. green spaces and gym), street furniture, safe urban environments and pedestrian and cyclist-friendly amenities could all promote positive physical activity patterns and build them into daily routines (Scheepers et al., 2014; Heinen et al., 2010).

Beyond the health benefits of physical activity related to active transport (Hamer and Chida, 2008; Bauman et al., 2012; Reiner et al., 2013); active transport transitions could reduce the carbon impact and local air pollution contribution of individuals and can go some way to resolving some of these issues (Poudenx, 2008; Woodcock et al., 2009; Pratt et al., 2012). Already almost half of car journeys are less than 5 km (Xia et al., 2013), and these could be feasibly substituted by active transport modes, which are both healthier and environmentally more friendly.

Public and active transport can also reduce other detrimental impacts of transportation including accidents and congestion. However, active transport to key destinations will only be possible when cities are made more compact and where urban infrastructure supports cyclists and pedestrians. This highlights the importance of city leaders and planners working across sectors and the fact that the transport system cannot be made sustainable in its own right, without considering actions of the other complementing sectors (Hall et al., 2014). A car free city would provide a catalyst for better town planning by removing the need to facilitate car mobility and ensuring that urban areas are planned around people, functionality and better built environments instead.

At times, technological advancements such as electric cars and autonomous cars have been suggested as the solution to current issues, but the former only reduces tailpipe emissions and some noise levels and does not address physical activity issues and the latter has not yet a solid business case and may not greatly reduce the number of cars on the road. Importantly, both are unlikely to change physical activity patterns, congestion and problems with space. In this paper we are not arguing against the car per sé and we acknowledge that the car is likely to be an essential mobility mean outside cites for years to come as the conditions outside cities are quite different; particularly due the longer distances and lack of good alternatives. In that case, electric cars and autonomous cars may be a better alternative to the conventional car.

4.2. Alternative use of space

Freeing cities from cars is likely to free up space. This road space need to be filled up with attractive and physiologically and socially healthy alternatives such as green space, public squares, markets, shops or other facilities to make the change more feasible, more attractive and importantly more acceptable by the public. In the past shortening journey travel by car ended up driving people to live further away from e.g. their work or shopping further away from their home. Car free cities need everyday facilities and shops nearby within travel distance of citizens. This highlights the importance of integrating car free cites transport plans with land use planning and policy instruments, and integrating these plans may also attract citizens to live closer to or in the city, which may require more housing and facilities and hence unlock economic development and growth. Car free cities are likely to be more livable and attractive than the current car dominated cities, and provide a competitive advantage in attracting certain population groups such as highly educated professionals who consider lifestyle factors in their decision of where to live.

In particular, replacing roads and parking with green environments can be one way forward to change an environment from detrimental to beneficial. It provides opportunities for physical activity and active transport mode shifts (Wahlgren and Schantz, 2014) while mitigating air pollution, heat and noise levels. Such provisions need to be carefully planned considering where they are situated so that urban sprawl is not reinforced and cities are not fragmented further. In its own right, providing 'access' to green space is not enough and 'surrounding greenness' in term of street trees, sidewalk vegetation and building envelope greening, has been proposed as more important for providing health benefits (Gascon et al., 2015). Providing surrounding greenness can potentially be a cost-effective policy that can be implemented in a wider range of areas within cities (KPMG, 2012). Car-free cities also offer complementing opportunities for getting rid of car parks, and perhaps car infrastructure, freeing up considerable public space that can be used for vegetation and open spaces with recreational or retail purposes.

4.3. Success stories and concerns

Notable success stories come from the hailed Dutch and Danish cycling utopias, where investment into cycling is highest. But even they've had their share of problems. During the urban modernization of cities after the second world war, cars became a dominating force on the streets of Copenhagen, and modal share of bicycles fell to as low as 10% before the city sought to tackle the problem through a combination of car free days, the removal of parking spaces and making areas for pedestrian use. However the process took many decades to implement and needed long term planning and commitment, with small incremental changes being implemented continuously.

There are however concerns regarding going car-free within cities. A concern for reducing car traffic in cities is the reduction in retail sales. However, Lawlor (2014) reviewed the effect of the reduction of cars on impact on existing business performance (footfall and retail); urban regeneration (new business, rental income, employment, social exclusion etc.); improved consumer and business perceptions, and business diversity. They found that case study evidence suggests that well-planned improvements to these public spaces can boost footfall and trading by up to 40% and that investing in better streets and spaces for walking can provide a competitive return compared to other transport projects; walking and cycling projects can increase retails sales by 30%. Put another way, people who walk to the shops spend up to six times more than people who arrive by car. They suggested also that better streets and places may create a virtuous circle by raising self-esteem for residents and promoting investor confidence in an area. Studies have linked the quality of public spaces to people's perceptions of attractiveness of an area, contributing towards their quality of life and influencing where they shop. However further research is needed as the evidence is still scarce and not available for full car free cities.

Other concerns are related to important issues around inequalities. Car-free cities might mean increased difficulties of accessing vibrant centers by the proportion of the population who do not live in the vicinity of these centers and who has relied on their private cars to access goods, services or opportunities to participate in the society. It is important that this proportion of the population are given sufficient consideration as not to deter their opportunities and access any further and exacerbate currently existing inequalities transport poses on the society. Ideally, development and opportunities should not be restricted to certain centers of agglomeration and part of development budgets should be put into ensuring that other towns and centers have their needs and opportunities accessible too.

The potential negative effects which may arise due to traffic detouring around car free zone into their destinations also need further evaluation and the areas in which car free zones are introduced need to be given attention so as not to become an additional way to exacerbate socioeconomic divides and distributional effects of traffic-related environmental exposures (Markovich and Lucas, 2011; Schwanen et al., 2015). Equity should be one of the objectives of any transport plan as evidence continues to show that there is great potential for inequalities in transport planning at the various levels.

There are further strong political and economic forces such as the motor lobby that may hinder the realization of car free cities, but which can also be tackled. The motor lobby in particular is a powerful and diffuse force (Irwin, 1987; Douglas et al., 2011), and has previously successfully opposed traffic restriction measures from restriction in parking space (Higginson, 2013) to scrutinizing and opposition of proposals for car free zones in some German cities (Hajdu, 1988) leading municipal authorities to delay plans or scrap them altogether. It has also opposed other health benefiting interventions related to improving traffic safety (Sfetcu, 2014) and successfully weakened and delayed car emissions regulations in Europe (The Greens, European Free Alliance Group, 2015; Neslen, 2015). Yet '*the interest of the consumers of transport must not be compromised by the interests of those who produce means of transport*' (Irwin, 1987 page 103) and modern transport policy is supposedly oriented around sustainability (see for example recent European Commission plans on mobility and transport) and thus should not only be decorative thus obscuring `*the extent to which governments sustain unsustainable economic institutions* […] *and the extent to which they have a hand in structuring options and possibilities*.` (Shove, 2010). We acknowledge that there has been enormous benefits that global economies have been harvesting from car manufacturing and car mobility and that these will continue, but there are also enormous costs that the society and governments are paying in terms of for example increasing inequalities, premature mortality and increased morbidity which also takes its toll on the workforce, productivity and health services. The notion of car free cities as we discuss it in this paper excludes public vehicles and truck driving out and between cities could potentially remain as usual.

4.4. The need for systemic approaches and modeling, political commitment and public participation

Healthy and environmentally friendly journeys should now become the core goal of cities, making public health its priority. To enable this it is important that we have a more systemic approach to our cities, bringing together urban and transport planners, with environmentalist and public health professionals (Nieuwenhuijsen, 2016). Modeling potential future scenarios, taking into account different policy measures and estimating the impact on health is now possible and should become routine when planning new urban and transport schemes (Mueller et al., 2015;

Perez et al., 2015). This could provide better insights into the various aspects being considered and provide policy makers with better data to guide their decision making process.

The planning of car free cities requires long term political commitment at the highest level and public acceptance. Political stability and cross party commitment is essential. This can only be achieved if the benefits of car free cities largely outweigh these benefits and if these factors are transparent and can be discussed in larger fora. When considering the wider range of the potential health benefits and even business and innovation benefits which car free initiatives can bring along, these may outweigh these benefits or losses from banning cars in cities, yet more quantification work is needed in this regard.

Citizen and business participation is essential to obtain commitment for the proposed changes and vision. Citizens' needs and convenience are tightly linked to public acceptability, calling for more public participation in the planning and policy-making process, which needs to become more transparent to those affected first-hand. Public acceptability and citizens' movements are core to successful implementation and radical change (Banister, 2008). The process may not be straight forward and linear and it may contain a multitude of policy measures to achieve the overarching goal. The implementation of the plans could be incremental with car free zones for part of the city first, as is already being done in many cities (through e.g. pedestrianization), and the introduction of car free days for part or most of the city throughout the year, with events being organized to increase the appeal and awareness of such measures and show examples of what could be done with the available space. Furthermore, public and active transport can be put at the top of the hierarchy when it comes to, for example, road allocation and traffic signaling systems rather than at the bottom where it is often now.

There are yet many uncertainties e.g. in terms of acceptability and changes in behaviors of people when introducing the car free city and also what the likely changes are in terms of air pollution, noise, temperature, social cohesion and physical activity. Further research and research synthesis are needed to build a good evidence base. It is also vital to better understand how mobility patterns change with the introduction of car free measures, evaluations of health impacts of (planned) interventions in cities, assessing people's perceptions, attitudes and acceptability and HIA modeling of future scenarios.

4.4.1. "It always seems impossible until it's done" (Nelson Mandela (1918–2013))

Douglas et al. (2011) argue that the car lobby resists measures that would restrict car use, using tactics similar to the tobacco industry, and that it may take a long time to implement the aspired solutions to current public health challenges (Douglas et al., 2011). However, until fairly recently smoking in public places bars and restaurants was acceptable, but the smoking ban was widely and readily accepted and led to a reduction in exposure and improvement in health. Perhaps the same may apply to banning cars from the city, which although may seem as a radical solution, could be also embraced and have significant benefits on the public's health.

Acknowledgement

The review was conducted without any specific funding source.

References

Agence France Presse, 2015. http://www.theguardian.com/environment/2015/oct/19/oslo-moves-to-ban-cars-from-city-centre-within-four-years.

Amoly, E., Dadvand, P., Forns, J., López-Vicente, M., Basagaña, X., Julvez, J., Alvarez-Pedrerol, M., Nieuwenhuijsen, M.J., Sunyer, J., 2014. Green and blue spaces and behavioral development in Barcelona schoolchildren: the breathe project. Environ. Health Perspect. 122 (12), 1351–1358.

Anable, J., Gatersleben, B., 2005. All work and no play? The role of instrumental and affective factors in work and leisure journeys by different travel modes. Transp Res Part A Policy Pract 39 (2–3), 163–181.

Appleyard, D., 1982. Livable Streets. University of California Press.

Astell-Burt, T., Feng, X., Kolt, G.S., 2013. Does access to neighbourhood green space promote a healthy duration of sleep? Novel findings from a cross-sectional study of 259 319 Australians. BMJ Open 3 (8), e003094.

Atkinson, R.W., Barratt, B., Armstrong, B., Anderson, H.R., Beevers, S.D., Mudway, I.S., Green, D., Derwent, R.G., Wilkinson, P., Tonne, C., Kelly, F.J., 2009. The impact of the congestion charging scheme on ambient air pollution concentrations in London. Atmos. Environ. 43, 5493–5500.

Babisch, W., Wolf, K., Petz, M., Heinrich, J., Cyrys, J., Peters, A., 2014. Associations between traffic noise, particulate air pollution, hypertension, and isolated systolic hypertension in adults: the KORA study. Environ. Health Perspect. 122 (5), 492–498.

Banister, D., 2008. The sustainable mobility paradigm. Transp. Policy 15 (2), 73–80.

Barrett, B., 2013. http://www.healtheffects.org/Slides/AnnConf2013/Barratt-MonPM.pdf Accessed 30/01/2016.

Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., Stansfeld, S., 2014. Auditory and non-auditory effects of noise on health. Lancet 383 (9925), 1325–1332.

Bauman, A.E., Reis, R.S., Sallis, J.F., Wells, J.C., Loos, R.J., Martin, B.W., Lancet Physical Activity Series Working Group, 2012. Correlates of physical activity: why are some people physically active and others not? Lancet 380 (9838), 258–271.

Beelen, R., Hoek, G., Vienneau, D., Eeftens, M., Dimakopoulou, K., Pedeli, X., Tsai, M.Y., Künzli, N., Schikowski, T., Marco, A., Eriksen, K., Raaschou-Nielsen, O., Stephanou, E., Patelarou, E., Lanki, T., Yli-Tuomi, T., Declerq, C., Grégoire, F., Stempfelet, M., Birk, M., Cyrys, J., Nádor, G., Varró, M., Dėdelė, A., Gražulevičienė, R., Mölter, A., Lindley, S., Madsen, C., Cesaroni, G., Ranzi, A., Badaloni, C., Hoffmann, B., Nonnemacher, M., Krämer, U., Kuhlbusch, T., Cirach, M., De Nazelle, A., Nieuwenhuijsen, M., Bellander, T., Korek, M., Olsson, D., Strömgren, M., Dons, E., Jerrett, M., Brunekreef, B., de Hoogh, K., 2013. Development of NO_2 and NO_x land use regression models for estimating air pollution exposure in 36 study areas in Europe – the ESCAPE project. Atmos. Environ. 72, 10–23.

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

Bell, M.C., Galatioto, F., 2013. Novel wireless pervasive sensor network to improve the understanding of noise in street canyons. Appl. Acoust. 74, 169–180.

Besser, L.M., Marcus, M., Frumkin, H., 2008. Commute time and social capital in the U.S. Am. J. Prev. Med. 34, 207–211.

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. World Bank Group, Washington, DChttp://documents.worldbank.org/curated/en/2014/01/19308007/transport-health-global-burden-disease-motorized-road-transport.

Brownson, R.C., Baker, E.A., Housemann, R.A., Brennan, L.K., Bacak, S.J., 2001. Environmental and policy determinants of physical activity in the United States. Am. J. Public Health 91 (12), 1995–2003.

Brussels Environment, 2015. http://www.environment.brussels/state-environment/summary-report-2011-2012/noise/focus-acoustic-evaluation-car-free-sunday-action.

Carslaw, D., Beevers, S., Westmoreland, E., Williams, M., Tate, J., Murrells, T., et al., 2011. Trends in NO_x and NO_2 Emissions and Ambient Measurements in the UK. Defra, London.

Cathkart-Keays, A., 2015. http://www.theguardian.com/cities/2015/dec/09/car-free-city-oslo-helsinki-copenhagen.

Cesaroni, G., Forastiere, F., Stafoggia, M., Andersen, Z.J., Badaloni, C., Beelen, R., Caracciolo, B., de Faire, U., Erbel, R., Eriksen, K.T., Fratiglioni, L., Galassi, C., Hampel, R., Heier, M., Hennig, F., Hilding, A., Hoffmann, B., Houthuijs, D., Jöckel, K.H., Korek, M., Lanki, T., Leander, K., Magnusson, P.K., Migliore, E., Ostenson, C.G., Overvad, K., Pedersen, N.L., Penell, J., Pershagen, G., Pyko, A., Raaschou-Nielsen, O., Ranzi, A., Ricceri, F., Sacerdote, C., Salomaa, V., Swart, W., Turunen, A.W., Vineis, P., Weinmayr, G., Wolf, K., de Hoogh, K., Hoek, G., Brunekreef, B., Peters, A., 2014. Long term exposure to ambient air pollution and incidence of acute coronary events: prospective cohort study and meta-analysis in 11 European cohorts from the ESCAPE Project. BMJ 348, f7412.

Cheng, J., Xu, Z., Zhu, R., Wang, X., Jin, L., Song, J., Su, H., 2014. Impact of diurnal temperature range on human health: a systematic review. Int. J. Biometeorol. 58 (9), 2011–2024.

Chrisafis, A., 2015. http://www.theguardian.com/cities/2015/sep/27/all-blue-skies-in-paris-as-city-centre-goes-car-free-for-first-time accessed 2/3/2016.

Coogan, P.F., White, L.F., Jerrett, M., Brook, R.D., Su, J.G., Seto, E., Burnett, R., Palmer, J.R., Rosenberg, L., 2012. Air pollution and incidence of hypertension and diabetes mellitus in black women living in Los Angeles. Circulation 125 (6), 767–772.

Crawford, J.H., 2000. Carefree cities. International Books ISBN 978-90-5727-037-6.

Crawford, J.H., 2002. https://www.opendemocracy.net/ecology-climate_change_debate/article_480.jsp.

Crawford, J.H., 2009. Carefree design manual. International Books ISBN 978-90-5727-060-4.

Currie, G., Stanley, J., 2008. Investigating links between social capital and public transport. Transp. Rev. 28 (4), 529–547.

Cyrys, J., Eeftens, M., Heinrich, J., Ampe, C., Armengaud, A., Beelen, R., Bellander, T., Beregszaszi, T., Birk, M., Cesaroni, G., Cirach, M., de Hoogh, K., De Nazelle, A., de Vocht, F., Declercq, C., Dėdelė, A., Dimakopoulou, K.D., Eriksen, K., Galassi, C., Gražulevičienė, R., Grivas, G., Gruzieva, O., Hagenbjörk Gustafsson, A., Hoffmann, B., Ineichen, A., Krämer, U., Lanki, T., Lozano, P., Madsen, C., Meliefste, K., Minas, I., Modig, L., Mölter, A., Mosler, G., Nieuwenhuijsen, M., Nonnemac, M., Oldenwening, M., Pontet, S., Quass, U., Raaschou-Nielsen, O., Peters, A., Ranzi, A., Sugiri, D., Taimisto, P., Tsai, M., Tziaras, T., Vasskövi, E., Villani, S., Wang, M., Brunekreef, B., Hoek, G., 2012. Variation of NO_2 and NO_x concentrations between and within 36 European study areas. Atmos. Environ. 62, 374–390.
Dadvand, P., Nieuwenhuijsen, M.J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., Rivas, I., López-Vicente, M., De Castro Pascual, M., Su, J., Jerrett, M., Querol, X., Sunyer, J., 2015. Green spaces and cognitive development in primary schoolchildren. Proc. Natl. Acad. Sci. 112 (26), 7937–7942.
Davis, A., 2014. Claiming the Health Dividend: A Summary and Discussion of Value for Money Estimates From Studies of Investment in Walking and Cycling. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/371096/claiming_the_health_dividend.pdf (Department of Transport, UK).
de Nazelle, A., Nieuwenhuijsen, M.J., Anto, J.M., Brauer, M., Briggs, D., Braun-Fahrlander, C., Cavill, N., Cooper, A.R., Desqueyroux, H., Fruin, S., Hoek, G., Int Panis, L., Janssen, N., Jerrett, M., Joffe, M., Jovanovic Andersen, Z., Kempen, E., Kingham, S., Kubesch, N., Leyden, K., Marshall, J.D., Matamala, J., Mellios, G., Mendez, M., Nassif, H., Ogilvie, D., Peiro, R., Pérez, K., Rabl, A., Ragettl, M., Rodríguez, D., Rojas, D., Ruiz, P., Sallis, J.F., Terwoert, J., Toussaint, J.F., Tuomisto, J., Zuurbier, M., Lebret, E., 2011. Improving health through policies that to promote active travel: a review of evidence to support integrated health impact assessment. Environ. Int. 37, 766–777.
de Vries, S., van Dillen, S.M., Groenewegen, P.P., Spreeuwenberg, P., 2013. Streetscape greenery and health: stress, social cohesion and physical activity as mediators. Soc. Sci. Med. 94, 26–33.
Douglas, M.J., Watkins, S.J., Gorman, D.R., Higgins, M., 2011. Are cars the new tobacco? Journal of Public Health 33 (2), 160–169.
Dzhambov, A.M., Dimitrova, D.D., Dimitrakova, E.D., 2014. Association between residential greenness and birth weight: systematic review and meta-analysis. Urban For. Urban Green. 13 (4), 621–629.
Eeftens, M., Beelen, R., Bellander, T., Cesaroni, G., Cirach, M., Declerq, C., Dėdelė, A., Dons, E., de Hoogh, K., De Nazelle, A., Dimakopoulou, K., Eriksen, K., Falq, G., Galassi, C., Gražulevičienė, R., Heinrich, J., Hoffmann, B., Jerrett, M., Keidel, D., Korek, M., Lanki, T., Lindley, S., Madsen, C., Mölter, A., Nádor, G., Nieuwenhuijsen, M., Nonnemacher, M., Pedeli, X., Raaschou-Nielsen, O., Patelarou, E., Quass, U., Ranzi, A., Schindler, C., Stempfelet, M., Stephanou, E., Sugiri, D., Tsai, M.Y., Yli-Tuomi, T., Varró, M., Vienneau, D., von Klot, S., Brunekreef, B., Hoek, G., 2012a. Development of land use regression models for $PM_{2.5}$, $PM_{2.5}$ absorbance, PM_{10} 1 and PM coarse in 20 European study areas; results of the ESCAPE project. Environ. Sci. Technol. 46 (20), 11195–11205.
Eeftens, M., Tsai, M.Y., Ampe, C., Anwander, B., Beelen, R., Bellander, T., Cesaroni, G., Cirach, M., Cyrys, J., de Hoogh, K., De Nazelle, A., de Vocht, F., Declercq, C., Dėdelė, A., Eriksen, K., Galassi, C., Gražulevičienė, R., Grivas, G., Heinrich, J., Hoffmann, B., Iakovides, M., Ineichen, A., Katsouyanni, K., Korek, M., Krämer, U., Kuhlbusch, T., Lanki, T., Madsen, C., Meliefste, K., Mölter, A., Mosler, G., Nieuwenhuijsen, M., Oldenwening, M., Pennanen, A., Probst-Hensch, N., Quass, U., Raaschou-Nielsen, O., Ranzi, A., Stephanou, E., Sugiri, D., Udvardy, O., Vaskövi, E., Weinmayr, G., Brunekreef, B., Hoek, G., 2012b. Variation of $PM_{2.5}$, PM_{10}, $PM_{2.5}$ absorbance and PM coarse concentrations between and within 20 European study areas - results of the ESCAPE project. Atmos. Environ. 62, 303–317.
Eeftens, M., Hoek, G., Gruzieva, O., Mölter, A., Agius, R., Beelen, R., Brunekreef, B., Custovic, A., Cyrys, J., Fuertes, E., Heinrich, J., Hoffmann, B., de Hoogh, K., Jedynska, A., Keuken, M., Klümper, C., Kooter, I., Krämer, U., Korek, M., Koppelman, G.H., Kuhlbusch, T.A., Simpson, A., Smit, H.A., Tsai, M.Y., Wang, M., Wolf, K., Pershagen, G., Gehring, U., 2014. Elemental composition of particulate matter and the association with lung function. Epidemiology 25 (5), 648–657.
European Commission, 2016. http://ec.europa.eu/transport/road_safety/specialist/statistics/index_en.htm Accessed 2/3/2016.
Eze, I.C., Hemkens, L.G., Bucher, H.C., Hoffmann, B., Schindler, C., Künzli, N., Schikowski, T., Probst-Hensch, N.M., 2015. Association between ambient air pollution and diabetes mellitus in Europe and North America: systematic review and meta-analysis. Environ. Health Perspect. 123 (5), 381–389.
Foraster, M., Deltell, A., Basagaña, X., Medina-Ramón, M., Aguilera, I., Bouso, L., Grau, M., Phuleria, H.C., Rivera, M., Slama, R., Sunyer, J., Targa, J., Künzli, N., 2011. Local determinants of road traffic noise levels versus determinants of air pollution levels in a Mediterranean city. Environ. Res. 111 (1), 177–183.
Foraster, M., Künzli, N., Aguilera, I., Rivera, M., Agis, D., Vila, J., Bouso, L., Deltell, A., Marrugat, J., Ramos, R., Sunyer, J., Elosua, R., Basagaña, X., 2014. High blood pressure and long-term exposure to indoor noise and air pollution from road traffic. Environ. Health Perspect. 122 (11), 1193–1200.
Forouzanfar, M.H., Alexander, L., Anderson, H.R., Bachman, V.F., Biryukov, S., Brauer, M., Burnett, R., Casey, D., Coates, M.M., Cohen, A., Delwiche, K., Estep, K., Frostad, J.J., Kc, A., Kyu, H.H., Moradi-Lakeh, M., Ng, M., Slepak, E.L., Thomas, B.A., Wagner, J., Aasvang, G.M., Abbafati, C., Ozgoren, A.A., Abd-Allah, F., Abera, S.F., Aboyans, V., Abraham, B., Abraham, J.P., Abubakar, I., Abu-Rmeileh, N.M., Aburto, T.C., Achoki, T., Adelekan, A., Adofo, K., Adou, A.K., Nieuwenhuijsen, M.J., Weintraub, R.G., Werdecker, A., Wessells, K.R., Westerman, R., Whiteford, H.A., Wilkinson, J.D., Williams, H.C., Williams, T.N., Woldeyohannes, S.M., Wolfe, C.D., Wong, J.Q., Woolf, A.D., Wright, J.L., Wurtz, B., Xu, G., Yan, L.L., Yang, G., Yano, Y., Ye, P., Yenesew, M., Yentür, G.K., Yip, P., Yonemoto, N., Yoon, S.J., Younis, M.Z., Younoussi, Z., Yu, C., Zaki, M.E., Zhao, Y., Zheng, Y., Zhou, M., Zhu, J., Zhu, S., Zou, X., Zunt, J.R., Lopez, A.D., Vos, T., Murray, C.J., 2015. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the Global Burden of disease study 2013. Lancet S0140–6736 (15), 00128.
Fox, K.R., 1999. The influence of physical activity on mental well-being. Public Health Nutr. 2 (3A), 411–418.
Gago, E.J., Roldan, J.J., Pacheco-Torres, R., Ordóñez, J., 2013. The city and urban heat islands: a review of strategies to mitigate adverse effects. Renew. Sust. Energ. Rev. 25, 749–758.
Gallivan, F., Rose, E., Reid, E., Hamidi, C.A., Brown, S., Nelson, T., 2015. Quantifying transit's impact on GHG emissions and energy use— the land use component. Transit Cooperative Research Program Report. 176 http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_176.pdf.
Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Forns, J., Plasència, A., Nieuwenhuijsen, M.J., 2015. Mental health benefits of long-term exposure to residential green and blue spaces: a systematic review. Int. J. Environ. Res. Public Health 12, 4354–4379.
Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Forns, J., Plasència, A., Nieuwenhuijsen, M.J., 2016. Green space and mortality: a systematic review and meta-analysis. Environ. Int. 2 (86), 60–67.
Gehring, U., Gruzieva, O., Agius, R.M., Beelen, R., Custovic, A., Cyrys, J., Eeftens, M., Flexeder, C., Fuertes, E., Heinrich, J., Hoffmann, B., de Jongste, J.C., Kerkhof, M., Klümper, C., Korek, M., Mölter, A., Schultz, E.S., Simpson, A., Sugiri, D., Svartengren, M., von Berg, A., Wijga, A.H., Pershagen, G., Brunekreef, B., 2013. Air pollution exposure and lung function in children: the ESCAPE project. Environ. Health Perspect. 121 (11−12), 1357–1364.
Giles, L.V., Barn, P., Künzli, N., Romieu, I., Mittleman, M.A., van Eeden, S., Allen, R., Carlsten, C., Stieb, D., Noonan, C., Smargiassi, A., Kaufman, J.D., Hajat, S., Kosatsky, T., Brauer, M., 2011. From good intentions to proven interventions: effectiveness of actions to reduce the health impacts of air pollution. Environ. Health Perspect. 119 (1), 29–36.
Gilroy, P., 2000. Driving while black'. In: Miller, D. (Ed.), Car Cultures. Berg Publishers.
Green, C.P., Heywood, J.S., Navarro, M., 2014. Traffic Accidents and the London Congestion Charge Economics Working Paper Series Lancaster University.
Guell, C., Ogilvie, D. 2013. Picturing commuting: photovoice and seeking wellbeing in everyday travel. Qual. Res. http://qrj.sagepub.com/cgi/doi/http://dx.doi.org/10.1177/1468794112468472
Guo, Y., Gasparrini, A., Armstrong, B., Li, S., Tawatsupa, B., Tobias, A., Lavigne, E., de Sousa, Z., Stagliorio Coelho, M., Leone, M., Pan, X., Tong, S., Tian, L., Kim, H., Hashizume, M., Honda, Y., Guo, Y.L., Wu, C.F., Punnasiri, K., Yi, S.M., Michelozzi, P., Saldiva, P.H., Williams, G., 2014. Global variation in the effects of ambient temperature on mortality: a systematic evaluation. Epidemiology 25 (6), 781–789.
Hajdu, J.C., 1988. Pedestrian malls in West Germany: perceptions of their role and stages in their development. J. Am. Plan. Assoc. 54 (3), 325–335.
Hales, S., Kovats, S., Lloyd, S., Campbell-Lendrum, D., 2014. Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. World Health Organization, Geneva.
Hall, R.P., Gudmundsson, H., Marsden, G., Zietsman, J., 2014. Sustainable Transportation. Sage Publications Incorporated.
Hamer, M., Chida, Y., 2008. Active commuting and cardiovascular risk: a meta-analytic review. Prev. Med. 46 (1), 9–13.
Hänninen, O., Knol, A.B., Jantunen, M., Lim, T.A., Conrad, A., Rappolder, M., Carrer, P., Fanetti, A.C., Kim, R., Buekers, J., Torfs, R., Iavarone, I., Classen, T., Hornberg, C., Mekel, O.C.L., The EBoDE Working Group, 2014. Environmental burden of disease in Europe: assessing nine risk factors in six countries. Environ. Health Perspect. 122, 439–446.
Hanski, I., von Hertzen, L., Fyhrquist, N., Koskinen, K., Torppa, K., Laatikainen, T., Karisola, P., Auvinen, P., Paulin, L., Mäkelä, M.J., Vartiainen, E., Kosunen, T.U., Alenius, H., Haahtela, T., 2012. Environmental biodiversity, human microbiota, and allergy are interrelated. Proc. Natl. Acad. Sci. U. S. A. 109 (21), 8334–8339.
Hart, J., Parkhurst, G., 2011. Driven to excess: impacts of motor vehicles on the quality of life of residents of three streets in Bristol UK. World Transport Policy & Practice 17 (2), 12–30.
Hartig, T., Mitchell, R., de Vries, S., Frumkin, H., 2014. Nature and health. Annu. Rev. Public Health 35, 207–228.
HEI, 2010. Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects Special report p. 17http://pubs.healtheffects.org/getfile.php?u=553.
Heinen, E., van Wee, B., Maat, K., 2010. Commuting by bicycle: an overview of the literature. Transp. Rev. 30, 59–96.
Héroux, M.E., Anderson, H.R., Atkinson, R., Brunekreef, B., Cohen, A., Forastiere, F., Hurley, F., Katsouyanni, K., Krewski, D., Krzyzanowski, M., Künzli, N., Mills, I., Querol, X., Ostro, B., Walton, H., 2015. Quantifying the health impacts of ambient air pollutants: recommendations of a WHO/Europe project. Int J Public Health 60 (5), 619–627.
Higginson, M., 2013. Workplace parking levies as an instrument of transport policy. Public Transport International 62 (3).
Hondula, D.M., Barnett, A.G., 2014. Heat-related morbidity in Brisbane, Australia: spatial variation and area-level predictors. Environ. Health Perspect. 122 (8), 831–836.
ICCT, 2013. European Vehicle Market Statistics. http://www.theicct.org/sites/default/files/publications/EU_vehiclemarket_pocketbook_2013_Web.pdf accessed 2/3/2016.
INFRAS Traffic congestion, pollution and accidents result in significant direct and indirect costs. The total bill has been estimated at EUR 502 billion per year across the EU member states. 2000. INFRAS Consulting Group for Policy Analysis and Implementation (www.INFRAS.ch) and IWW, Universitaet Karlsruhe, Germany (www.iww.uni-karlsruhe.de)
Invernizzi, G., Ruprecht, A., Mazza, R., De Marco, C., Mocnik, G., Sioutas, C., et al., 2011. Measurement of black carbon concentration as an indicator of air quality benefits of traffic restriction policies within the ecopass zone in Milan, Italy. Atmos. Environ. 45, 3522–3527.

Irwin, A., 1987. Risk and the Control of Technology: Public Policies for Road Traffic Safety in Britain and the United States. Manchester University Press.
Jacobsen, P.L., 2003. Safety in numbers: more walkers and bicyclists, safer walking and bicycling. Inj Prev 9 (3), 205–209.
Jerrett, M., McConnell, R., Wolch, J., Chang, R., Lam, C., Dunton, G., Gilliland, F., Lurmann, F., Islam, T., Berhane, K., 2014. Traffic-related air pollution and obesity formation in children: a longitudinal, multilevel analysis. Environ. Health 13, 49.
Khreis, H., Warsow, K.M., Verlinghieri, E., Guzman, A., Pellecuer, L., Ferreira, A., Jones, I., Heinen, E., Rojas-Rojas, D., Mueller, N., Schepers, P., Nieuwenhuijsen, M., 2016. Urban transport and health: Understanding Real Impacts and co-Producing Future Directions.
Koslowsky, M., 1997. Commuting stress: problems of definition and variable identification. Appl Psychol An Int Rev 46 (2), 153–173.
KPMG, 2012. Green, healthy and productive, the economics of ecosystems and biodiversity (TEEB NL), green space and health. Ministry of Economic Affairs, Agriculture and Innovation, The Netherlands.
Krämer, U., Herder, C., Sugiri, D., Strassburger, K., Schikowski, T., Ranft, U., Rathmann, W., 2010. Traffic-related air pollution and incident type 2 diabetes: results from the SALIA cohort study. Environ. Health Perspect. 118 (9), 1273–1279.
Laaidi, K., Zeghnoun, A., Dousset, B., Bretin, P., Vandentorren, S., Giraudet, E., Beaudeau, P., 2012. The impact of heat islands on mortality in Paris during the August 2003 heat wave. Environ. Health Perspect. 120 (2), 254–259.
Lajeunesse, S., Rodríguez, D.A., 2012. Mindfulness, time affluence, and journey-based affect: exploring relationships. Transp Res Part F Traffic Psychol Behav 15 (2), 96–205.
Laszlo, H.E., McRobie, E.S., Stansfeld, S.A., Hansell, A.L., 2012. Annoyance and other reaction measures to changes in noise exposure - a review. Sci. Total Environ. 435–436, 551–562.
Lawlor, E., 2014. The pedestrian pound. The Business Case for Better Streets and Places http://www.livingstreets.org.uk/sites/default/files/content/library/Reports/PedestrianPound_fullreport_web.pdf.
Lee, A.C.K., Maheswaran, R., 2010. The health benefits of urban green spaces: a review of the evidence. J Public Health 33, 212–222.
Lelieveld, J., Evans, J.S., Fnai, M., Giannadaki, D., Pozzer, A., 2015. The contribution of outdoor air pollution sources to premature mortality on a global scale. Nature 525, 367–371.
Litman, T., 2013. http://www.planetizen.com/node/66021 accessed 2/3/2016.
Litman, T., 2014. http://www.vtpi.org/wwclimate.pdf accessed 2/3/2016.
Liu, C., Fuertes, E., Tiesler, C.M., Birk, M., Babisch, W., Bauer, C.P., Koletzko, S., von Berg, A., Hoffmann, B., Heinrich, J., 2014. GINIplus and LISAplus Study Groups. The associations between traffic-related air pollution and noise with blood pressure in children: results from the GINIplus and LISAplus studies. Int. J. Hyg. Environ. Health 217 (4–5), 499–505.
Lucas, K., 2004. Running on Empty: Transport, Social Exclusion and Environmental Justice. The Policy Press.
Lucas, K., 2012. Transport and social exclusion: where are we now? Transp. Policy 20, 105–113.
Ma, W., Chen, R., Kan, H., 2014. Temperature-related mortality in 17 large Chinese cities: how heat and cold affect mortality in China. Environ. Res. 134, 127–133.
Maas, J., Verheij, R.A., Groenewegen, P.P., de Vries, S., Spreeuwenberg, P., 2006. Green space, urbanity and health: how strong is the relation? J. Epidemiol. Community Health 60, 587–592.
Maas, J., van Dillen, S.M., Verheij, R.A., Groenewegen, P.P., 2009. Social contacts as a possible mechanism behind the relation between green space and health. Health Place 15 (2), 586–595.
MacIntyre, E.A., Gehring, U., Mölter, A., Fuertes, E., Klümper, C., Krämer, U., Quass, U., Hoffmann, B., Gascon, M., Brunekreef, B., Koppelman, G.H., Beelen, R., Hoek, G., Birk, M., de Jongste, J.C., Smit, H.A., Cyrys, J., Gruzieva, O., Korek, M., Bergström, A., Agius, R.M., de Vocht, F., Simpson, A., Porta, D., Forastiere, F., Badaloni, C., Cesaroni, G., Esplugues, A., Fernández-Somoano, A., Lerxundi, A., Sunyer, J., Cirach, M., Nieuwenhuijsen, M.J., Pershagen, G., Heinrich, J., 2014. Air pollution and respiratory infections during early childhood: an analysis of 10 European birth cohorts within the ESCAPE Project. Environ. Health Perspect. 122 (1), 107–113.
Mackett, R.L., Brown, B., 2011. Transport, physical activity and health: present knowledge and the way ahead. Scanning Study Commissioned by the Department for Transport, London, Great Britain https://www.ucl.ac.uk/news/pdf/transportactivityhealth.pdf.
Markovich, J., Lucas, K., 2011. The social and distributional impacts of transport: a literature review Working Paper No 1055 Transport Studies Unit School of Geography and the Environment http://www.tsu.ox.ac.uk Oxford.
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.
McCahill, C., Garrick, N., 2012. Automobile Use and Land Consumption: Empirical Evidence From 12 Cities Urban Design International. 17 pp. 221–227.
Mitchell, R., Popham, F., 2008. Effect of exposure to natural environment on health inequalities: an observational population study. Lancet 372 (9650), 1655–1660.
Mueller, N., Rojas-Rueda, D., Cole-Hunter, T., de Nazelle, A., Dons, E., Gerike, R., Götschi, T., Panis, L.I., Kahlmeier, S., Nieuwenhuijsen, M., 2015. Health impact assessment of active transportation: a systematic review. Prev. Med. 76, 103–114.
Mueller, N., Rojas-Rueda, D., Basagaña, X., Cirach, M., Cole-Hunter, T., Dadvand, P., Donaire-Gonzalez, D., Foraster, M., Gascon, M., Martinez, D., Tonne, C., Triguero-Mas, M., Valentín, A., Nieuwenhuijsen, M., 2016. Urban and transport planning related exposures and mortality: a health impact assessment for cities. Environ. Health Perspect. in print.
Münzel, T., Gori, T., Babisch, W., Basner, M., 2014. Cardiovascular effects of environmental noise exposure. Eur. Heart J. 35 (13), 829–836.
Ndrepepa, A., Twardella, D., 2011. Relationship between noise annoyance from road traffic noise and cardiovascular diseases: a meta-analysis. Noise Health 13 (52), 251–259.
Neslen, Arthur 2015: EU Caves in to Auto Industry Pressure for Weak Emissions Limits.The Guardian available from: http://www.theguardian.com/environment/2015/oct/28/eu-emissions-limits-nox-car-manufacturers.
Nieuwenhuijsen, M. 2016. Urban and Transport Planning, Environmental Exposures and Health-New Concepts, Methods and Tools to Improve Health in Cities. http://ehjournal.biomedcentral.com/articles/supplements/volume-15-supplement-1
Nieuwenhuijsen, M.J., Kruize, H., Gidlow, C., Andrusaityte, S., Antó, J.M., Basagaña, X., Cirach, M., Dadvand, P., Danileviciute, A., Donaire-Gonzalez, D., Garcia, J., Jerrett, M., Jones, M., Julvez, J., van Kempen, E., van Kamp, I., Maas, J., Seto, E., Smith, G., Triguero, M., Wendel-Vos, W., Wright, J., Zufferey, J., van den Hazel, P.J., Lawrence, R., Grazuleviciene, R., 2014. Positive health effects of the natural outdoor environment in typical populations in different regions in Europe (PHENOTYPE): a study programme protocol. BMJ Open 4 (4), e004951.
Nieuwenhuijsen, M.J., Khreis, H., Verlinghier, E., Rojas-Rueda, D., 2016. Transport and health: a marriage of convenience or an absolute necessity. Environ. Int. 88, 150–152.
Nuwer, 2014. http://www.smithsonianmag.com/ist/?next=/smart-news/hamburg-plans-become-car-free-2034-180949780 Accessed 27/10/2015.
Omlin, S., Bauer, G.F., Brink, M., 2011. Effects of noise from non-traffic-related ambient sources on sleep: review of the literature of 1990–2010. Noise Health 13 (53), 299–309.
Paunović, K., Stansfeld, S., Clark, C., Belojević, G., 2011. Epidemiological studies on noise and blood pressure in children: observations and suggestions. Environ. Int. 37 (5), 1030–1041.
Pedersen, M., Giorgis-Allemand, L., Bernard, C., Aguilera, I., Nybo Andersen, A.M., Ballester, F., Beelen, R.M.J., Chatzi, L., Cirach, M., Danileviciute, A., Dedele, A., van Eijsden, M., Estarlich, M., Fernández-Somoano, A., Fernández, M.F., Forastiere, F., Gehring, U., Grazuleviciene, R., Gruzieva, O., Heude, B., Hoek, G., de Hoogh, K., van den Hooven, E.H., Håberg, S.E., Jaddoe, V., Klümper, C., Korek, M., Krämer, U., Lerchundi, A., Lepeule, J., Nafstad, P., Nystad, W., Patelarou, E., Porta, D., Postma, D., Raaschou-Nielsen, O., Rudnai, P., Sunyer, J., Stephanou, E., Sørensen, M., Thiering, E., Tuffnell, D., Varró, M.J., Vrijkotte, T.J.M., Wijga, A., Wilhelm, M., Wright, J., Nieuwenhuijsen, M.J., Pershagen, G., Brunekreef, B., Kogevinas, M., Slama, R., 2013. Ambient air pollution and low birth weight: a European cohort study (ESCAPE). Lancet Respir Med 1 (9), 695–704.
Peluso, M.A.M., de Andrade, L.H.S.G., 2005. Physical activity and mental health: the association between exercise and mood. Clinics (Sao Paolo) 60 (1), 61–70.
Pereira, G., Foster, S., Martin, K., Christian, H., Boruff, B.J., Knuiman, M., Giles-Corti, B., 2012. The association between neighborhood greenness and cardiovascular disease: an observational study. BMC Public Health 12, 466.
Perez, L., Trüeb, S., Cowie, H., Keuken, M.P., Mudu, P., Ragettli, M.S., Sarigiannis, D.A., Tobollik, M., Tuomisto, J., Vienneau, D., Sabel, C., Künzli, N., 2015. Transport-related measures to mitigate climate change in Basel, Switzerland: a health-effectiveness comparison study. Environ. Int. 85, 111–119.
Petralli, M., Massetti, L., Brandani, G., Orlandini, D., 2014. Urban planning indicators: useful tools to measure the effect of urbanization and vegetation on summer air temperatures. Int. J. Climatol. 34 (4), 1236–1244.
Pope, C.A., Ezzati, M., Dockery, D.W., 2009. Fine-particulate air pollution and life expectancy in the United States. New Eng J Med 360, 376–386.
Poudenx, P., 2008. The effect of transportation policies on energy consumption and greenhouse gas emission from urban passenger transportation. Transp Res Part A: Policy Pract 42 (6), 901–909.
Pratt, M., Sarmiento, O.L., Montes, F., Ogilvie, D., Marcus, B.H., Perez, L.G., Brownson, R.C., Lancet Physical Activity Series Working Group, 2012. The implications of megatrends in information and communication technology and transportation for changes in global physical activity. Lancet 380 (9838), 282–293.
Pucher, J., Dill, J., Handy, S., 2010. Infrastructure programs and policies to increase bicycling: an international review. Prev. Med. 50, S106–S125.
Putnam, R.D., 2000. Bowling Alone: The Collapse and Revival of American Community. Simon & Schuster, New York.
Raaschou-Nielsen, O., Andersen, Z.J., Beelen, R., Samoli, E., Stafoggia, M., Weinmayr, G., Hoffmann, B., Fischer, P., Nieuwenhuijsen, M.J., Brunekreef, B., Xun, W.W., Katsouyanni, K., Dimakopoulou, K., Sommar, J., Forsberg, B., Modig, L., Oudin, A., Oftedal, B., Schwarze, P.E., Nafstad, P., De Faire, U., Pedersen, N.L., Ostenson, C.G., Fratiglioni, L., Penell, J., Korek, M., Pershagen, G., Eriksen, K.T., Sørensen, M., Tjønneland, A., Ellermann, T., Eeftens, M., Peeters, P.H., Meliefste, K., Wang, M., Bueno-de-Mesquita, B., Key, T.J., de Hoogh, K., Concin, H., Nagel, G., Vilier, A., Grioni, S., Krogh, V., Tsai, M.Y., Ricceri, F., Sacerdote, C., Galassi, C., Migliore, E., Ranzi, A., Cesaroni, G., Badaloni, C., Forastiere, F., Tamayo, I., Amiano, P., Dorronsoro, M., Trichopoulou, A., Bamia, C., Vineis, P., Hoek, G., 2013. Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the European study of cohorts for Air Pollution Effects (ESCAPE). Lancet Oncol. 14 (9), 813–822.
Rachele, J.N., Kavanagh, A.M., Badland, H., Giles-Corti, B., Washington, S., Turrell, G., 2015. Associations between individual socioeconomic position, neighbourhood disadvantage and transport mode: baseline results from the HABITAT multilevel study. J. Epidemiol. Community Health 69 (12), 1217–1223.
Redman, L., Friman, M., Gärling, T., Hartig, T., 2013. Quality attributes of public transport that attract car users: a research review. Transp. Policy 25, 119–127.
Reiner, M., Niermann, C., Jekauc, D., Woll, A., 2013. Long-term health benefits of physical activity–a systematic review of longitudinal studies. BMC Public Health 13 (1), 813.
Reuters, 2015. http://www.reuters.com/article/2015/10/19/us-norway-environment-oslo-idUSKCN0SD1GI20151019#4MvYsc2VgV8PYozO.97 accessed 11 Nov 2015.
Ristovska, G., Laszlo, H.E., Hansell, A.L., 2014. Reproductive outcomes associated with noise exposure — a systematic review of the literature. Int. J. Environ. Res. Public Health 11, 7931–7952.
Rizwan, A.M., Dennis, L.Y., Chunho, L., 2008. A review on the generation, determination and mitigation of Urban Heat Island. J. Environ. Sci. 20 (1), 120–128.

Rojas-Rueda, D., de Nazelle, A., Teixidó, O., Nieuwenhuijsen, M.J., 2012. Replacing car trips by increasing bike and public transport in the greater Barcelona metropolitan area: a health impact assessment study. Environ. Int. 49, 100–109.

Rojas-Rueda, D., de Nazelle, A., Teixidó, O., Nieuwenhuijsen, M., 2013. Health impact assessment of increasing public transport and cycling use in Barcelona: a morbidity and burden of disease approach. Prev. Med. 57 (5), 573–579.

Ruprecht, A., Invernizzi, G., 2008. Impact of the Milan traffic charging scheme on particulate matter pollution. Epidemiology 19 (6).

Santos, G., Behrendt, H., Maconi, L., Shirvani, T., Teytelboym, A., 2010. Part I: externalities and economic policies in road transport. Res. Transp. Econ. 28 (1), 2–45.

Scheepers, C.E., Wendel-Vos, G.C.W., den Broeder, J.M., van Kempen, E.E.M.M., van Wesemael, P.J.V., Schuit, A.J., 2014. Shifting from car to active transport: a systematic review of the effectiveness of interventions. Transport Res Part A 70, 264–280.

Scheepers, P., Fishman, E., Beelen, R., Heinen, E., Wijnen, W., Parkin, 2015. The mortality impact of bicycle paths and lanes related to physical activity, air pollution exposure and road safety. J Transport Health http://dx.doi.org/10.1016/j.jth.2015.09.004i.

Schwanen, T., Lucas, K., Akyelken, N., Solsona, D.C., Carrasco, J.A., Neutens, T., 2015. Rethinking the links between social exclusion and transport disadvantage through the lens of social capital. Transport Res Part A: Policy Practice 74, 123–135.

Sfetcu, N., 2014. The Car Show. available from https://books.google.co.uk/books?id=ZyluAwAAQBAJ&pg=PT516&lpg=PT516&dq=car+manufacturer+oppose+traffic+restrictions&source=bl&ots=8RiZzrT1mb&sig=xra7J2gF0d75oAXGHLW8wMJfeIg&hl=en&sa=X&ved=0ahUKEwi16fXi5PLMAhUDJMAKHbpaBogQ6AEIMzAE#v=onepage&q=car%20manufacturer%20oppose%20traffic%20restrictions&f=false.

Shove, E., 2010. Beyond the ABC: climate change policy and theories of social change. Environ. Plan. A 42, 1273.

Singh, S.K., 2012. Urban transport in India: issues, challenges, and the way forward. European Transport 52, 5.

Sørensen, M., Hoffmann, B., Hvidberg, M., Ketzel, M., Jensen, S.S., Andersen, Z.J., Tjønneland, A., Overvad, K., Raaschou-Nielsen, O., 2012. Long-term exposure to traffic-related air pollution associated with blood pressure and self-reported hypertension in a Danish cohort. Environ. Health Perspect. 120 (3), 418–424.

Sperling, D., Gordon, D., 2008. Two billion cars; transforming a culture. TRNEWS http://onlinepubs.trb.org/onlinepubs/trnews/trnews259billioncars.pdf.

Stansfeld, S.A., Berglund, B., Clark, C., Lopez-Barrio, I., Fischer, P., Ohrström, E., Haines, M.M., Head, J., Hygge, S., van Kamp, I., Berry, B.F., RANCH study team, 2005. Aircraft and road traffic noise and children's cognition and health: a cross-national study. Lancet 365 (9475), 1942–1949.

St-Louis, E., Manaugh, K., van Lierop, D., El-Geneidy, A., 2014. The happy commuter: a comparison of commuter satisfaction across modes. Transp Res Part F Traffic Psychol Behav 26, 160–170.

Sundvor, I., Castell Balaguer, N., Viana, M., Querol, X., Reche, C., Amato, F., Mellios, G., Guerreiro, C., 2012. Road traffic's contribution to air quality in European cities. ETC/ACM technical paper 2012/14 November 2012. The European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM) (a Consortium of European Institutes under Contract of the European Environment Agency).

Sunyer, J., Esnaola, M., Alvarez-Pedrerol, M., Forns, J., Rivas, I., López-Vicente, M., Suades-González, E., Foraster, M., Garcia-Esteban, R., Basagaña, X., Viana, M., Cirach, M., Moreno, T., Alastuey, A., Sebastian-Galles, N., Nieuwenhuijsen, M., Querol, X., 2015. Association between traffic-related air pollution in schools and cognitive development in primary school children: a prospective cohort study. PLoS Med. 12 (3), e1001792.

Tamosiunas, A., Grazuleviciene, R., Luksiene, D., Dedele, A., Reklaitiene, R., Baceviciene, M., Vencloviene, J., Bernotiene, G., Radisauskas, R., Malinauskiene, V., Milinaviciene, E., Bobak, M., Peasey, A., Nieuwenhuijsen, M.J., 2014. Accessibility and use of urban green spaces, and cardiovascular health: findings from a Kaunas cohort study. Environ. Health 13 (1), 20.

The Greens, European Free Alliance Group, 2015. InfluenceMap EU NO_x emissions: how the automotive industry shaped policy. A Report Prepared for the European Parliament Greens/EFA Group available from http://www.sven-giegold.de/wp-content/uploads/2016/01/Greens_EP_Automotive_Jan-2016_report.pdf December 2015.

Tonne, C., Beevers, S., Armstrong, B., Kelly, F., Wilkinson, P., 2008. Air pollution and mortality benefits of the London congestion charge: spatial and socioeconomic inequalities. Occup. Environ. Med. 65 (9), 620–627.

Topp, H., Pharoah, T., 1994. Car-free city centres. Transportation 21, 231–247.

Turner, L.R., Barnett, A.G., Connell, D., Tong, S., 2012. Ambient temperature and cardiorespiratory morbidity: a systematic review and meta-analysis. Epidemiology 23, 594–606.

Ulrich, R.S., 1984. Views through a windows may influence recovery from surgery. Science 224 (4647), 420–421.

United States Environmental Protection Agency. Heat Island Effect. By EPA N.P., 29 August 2013 2015. http://www.epa.gov/heatisld/about/index.htm

Urry, J., 2007. Mobilities, Polity Cambridge.

Van Kempen, E., Babisch, W., 2012. The quantitative relationship between road traffic noise and hypertension: a meta-analysis. J. Hypertens. 30, 1075–1086.

Wahlgren, L., Schantz, P., 2014. Exploring bike ability in a suburban metropolitan are using the active commuting route environment scale (ACRES). Int. J. Environ. Res. Public Health 11 (8), 8276–8300.

Walton, H., Dajnak, D., Beevers, S., Williams, M., Watkiss, P., Hunt, A., 2015. https://www.london.gov.uk/sites/default/files/HIAinLondon_KingsReport_14072015_final_0.pdf Accessed 27/10/2015.

Watts, N., Adger, W.N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., Chaytor, S., Colbourn, T., Collins, M., Cooper, A., Cox, P.M., Depledge, J., Drummond, P., Ekins, P., Galaz, V., Grace, D., Graham, H., Grubb, M., Haines, A., Hamilton, I., Hunter, A., Jiang, X., Li, M., Kelman, I., Liang, L., Lott, M., Lowe, R., Luo, Y., Mace, G., Maslin, M., Nilsson, M., Oreszczyn, T., Pye, S., Quinn, T., Svensdotter, M., Venevsky, S., Warner, K., Xu, B., Yang, J., Yin, Y., Yu, C., Zhang, Q., Gong, P., Montgomery, H., Costello, A., 2015. Health and climate change: policy responses to protect public health. Lancet 386 (10006), 1861–1914.

WHO, 2009. http://www.un.org/ar/roadsafety/pdf/roadsafetyreport.pdf.

WHO, 2015. Global health Observatory. http://www.who.int/gho/road_safety/mortality/en/ accessed 26/10/2015.

Wilcox, S., Castro, C., King, A.C., Housemann, R., Brownson, R.C., 2000. Determinants of leisure time physical activity in rural compared with urban older and ethnically diverse women in the United States. J. Epidemiol. Community Health 54 (9), 667–672.

Willsher, K., 2015. http://www.theguardian.com/world/2015/oct/03/pariss-first-attempt-at-car-free-day-brings-big-drop-in-air-and-noise-pollution.

Woodcock, J., Edwards, P., Tonne, C., Armstrong, B.G., Ashiru, O., Banister, D., Beevers, S., Chalabi, Z., Chowdhury, Z., Cohen, A., Franco, O.H., Haines, A., Hickman, R., Lindsay, G., Mittal, I., Mohan, D., Tiwari, G., Woodward, A., Roberts, I., 2009. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. Lancet 374 (9705), 1930–1943.

Woodcock, J., Franco, O.H., Orsini, N., Roberts, I., 2011. Non-vigorous physical activity and all-cause mortality: systematic review and meta-analysis of cohort studies. Int. J. Epidemiol. 40 (1), 121–138.

Woodcock, J., Givoni, M., Morgan, A.S., 2013a. Health impact modelling of active travel visions for England and Wales using an integrated transport and health impact modelling tool (ITHIM). PLoS One 8 (1), e51462.

Woodcock, J., Givoni, M., Morgan, A.S., 2013b. Health impact modelling of active travel visions for England and Wales using an integrated transport and health impact modelling tool (ITHIM). PLoS One 8 (1), e51462.

Xia, T., Zhang, Y., Crabb, S., Shah, P., 2013. Cobenefits of replacing car trips with alternative transportation: a review of evidence and methodological issues. J Environ Public Health 2013, 1–14.

Xu, Z., Etzel, R.A., Su, H., Huang, C., Guo, Y., Tong, S., 2012. Impact of ambient temperature on children's health: a systematic review. Environ. Res. 117, 120–131.

Ye, X., Wolff, R., Yu, W., Vaneckova, P., Pan, X., Tong, S., 2012. Ambient temperature and morbidity: a review of epidemiological evidence. Environ. Health Perspect. 120 (1), 19–28.

Zhang, H., Qi, Z.F., Ye, X.Y., Cai, Y.B., Ma, W.C., Chen, M.N., 2013. Analysis of land use/land cover change, population shift, and their effects on spatiotemporal patterns of urban heat islands in metropolitan Shanghai, China. Appl. Geogr. 44, 121–133.

Zuo, F., Li, Y., Johnson, S., Johnson, J., Varughese, S., Copes, R., Liu, F., Wu, H.J., Hou, R., Chen, H., 2014. Temporal and spatial variability of traffic-related noise in the City of Toronto, Canada. Sci. Total Environ. 472, 1100–1107.