HHS Public Access
Author manuscript
Lancet. Author manuscript; available in PMC 2017 November 28.

Published in final edited form as:
Lancet. 2017 October 14; 390(10104): 1781–1791. doi:10.1016/S0140-6736(17)31958-X.

Transport and public health in China: the road to a healthy future

Prof Baoguo Jiang, MD[1], **Song Liang, PhD**[2], **Prof Zhong-Ren Peng, PhD**[3], **Haozhe Cong, PhD**[4], **Morgan Levy, PhD**[5], **Qu Cheng, PhD**[6], **Prof Tianbing Wang, MD**[1], and **Prof Justin Remais, PhD**[5,*]

[1]Department of Traumatology and Orthopedics, Peking University People's Hospital, and Peking University Trauma Medicine Center, Beijing, China

[2]Department of Environmental and Global Health, College of Public Health and Health Professions, and Emerging Pathogens Institute, University of Florida, Gainesville, Florida

[3]Department of Urban and Regional Planning, University of Florida, Gainesville, Florida

[4]Road Traffic Safety Research Center of the Ministry of Public Security, Beijing, China

[5]Environmental Health Sciences, University of California, Berkeley, Berkeley, California

[6]Department of Earth System Science, Tsinghua University, Beijing, China

Abstract

Transportation-related risk factors are a major source of morbidity and mortality in China, where expansion of road networks and surges in personal vehicle ownership are having profound effects on public health. Road traffic injuries and fatalities have increased alongside motorized transport in China, and accident injury risk is aggravated by inadequate emergency response systems and trauma care. National air quality standards and emission control technologies are having a positive effect, yet persistent air pollution is increasingly attributable to a growing and outdated vehicle fleet, and famously congested roads. Urban design favors motorized transport, and physical activity and its associated health benefits are hindered by poor urban infrastructure. Transport emissions of greenhouse gases contribute substantially to regional and global climate change, which compound public health risks from multiple factors. Despite these complex challenges, technological advances and innovations in planning and policy stand to make China a leader in sustainable, healthy transportation.

1. Introduction

The health of China's populations—from cities to townships to villages—will be shaped in part by the investments, innovations and policy actions that governments, institutions and private organizations make in the transport sector in the coming years and decades. There

*correspondence to Prof. Justin Remais jvr@berkeley.edu; +1 510 643 8900 (tel).

Conflicts of interest
We declare that that we have no conflicts of interest.

Author roles
JVR conceived and led the preparation of the report. All authors participated in data analysis, interpretation, discussion, and writing of the report.

are exciting developments in transportation infrastructure in China, including massive investments in high-speed rail, subway systems, and traffic management technologies. Meanwhile, an upwelling of entrepreneurial transportation activity is changing the lives of urban and rural citizens across the country. Take for instance the innovations in public and private bike sharing technologies, which rolled out 1.9 million bicycles in urban centers as of 2016[1] using innovative pricing schemes, hailing via social media, and 'dockless' rental designs that maximize accessibility and bicycle use. At the same time, other transportation innovations, such as app-based taxi hailing services, are creating new challenges for traffic management, passenger safety, and licensing schemes.[2]

As transportation transforms in the country, so too does the health of China's population. Transport choices, technologies and policies determine exposure to certain environmental pollutants; the frequency and severity of traffic-related accidents and injuries; the strain placed on emergency rescue systems; the level and types of population physical activity; exposures to noise and associated disruption of sleep and hearing; and many other determinants of population health.[3–8] These impacts will extend far beyond China's borders, as health- and climate-damaging air pollutants sourced from the country's transportation sector are dispersed internationally and intercontinentally.[9, 10] China's transport choices are set to be even more important given the tremendous expansion of the country's transportation network.

China is a country on the move: the nation has built the world's largest high-speed rail network,[10] constructed more than 4 million kilometers of highways,[11] and has achieved a massive rollout of electric, zero-tailpipe emission, two-wheeled vehicles.[12] At the same time, private motor vehicle ownership is skyrocketing, numbering 123.4 million,[13] while active modes of transport, including walking and cycling, have fallen precipitously.[14–16] The rapidly increasing number of vehicles has led to substantial ill-health associated with transportation combustion emissions, while the growing number of new, inexperienced drivers, low seat belt use, and poor road design with inadequate separation between pedestrians, cyclists, and motor vehicles have led to large numbers of accidents and injuries.[17, 18] These realities are joined, and in part driven, by a rising dominance of car culture in China's cities and rural villages alike: pedestrians and cyclists are intimidated by aggressive driving; right-of-way rules are poorly codified and enforced; and the future of health in China is at risk from attitudes and policies that allow transportation hazards such as air pollution, noise and dangerous road conditions to persist and grow even as many other public health improvements sweep the country.

The recent growth of China's transportation system is striking, with massive increases in automobile registrations and length of highways (appendix). These trends raise social equity concerns, as major transportation investments have focused on accommodating rapidly increasing numbers of motor vehicles, with less attention paid to public transport and non-motorized modes of transport on which the poor depend. Here, we analyze the public health consequences of China's transportation decisions, technologies and infrastructure; examine the transport trends that will define the health of China's population; and review the policy and technology options that are available to protect health while stimulating a more mobile and connected China in the decades to come.

2. Health consequences of transport associated with accidents and injuries

2.a. Road accidents and injuries

Road traffic injuries and deaths take a major toll on China's population health, and their burden is high relative to other countries (Figure 1). Traffic-related fatalities account for 80% of accidental deaths in China,[19] and the country's reported rate of road traffic injuries and fatalities increased significantly with rapid motorization beginning in the late 1980s (see appendix; Figure 2). The increases continued until approximately 2003, when the country adopted and began enforcing its first major transportation and traffic law—the Road Traffic Safety Law of China. The result was a reported reduction in both injuries and fatalities associated with road accidents (Figure 2), both in absolute number and on a population basis.[20] This is despite the fact that road transport distance traveled per capita has increased sharply in the country, from 51.4 km·person^{-1} in 2001 to 66.4 km·person^{-1} in 2015.[13] China's population is increasingly mobile, and at the same time road injuries and fatalities are on the decline.

Though police-reported road injury data comprise the official road accident and injury dataset in the country, and is the only dataset that tabulates number of accidents and economic losses,[21, 22] its reliability has been questioned because of reporting challenges.[23] When adjusted to account for underreporting, fatalities as estimated by China's cause of death reporting system exceed the police-reported data by a factor of two (Figure 2).[24] Possible explanations include different definitions of road traffic deaths, different data collection methods, and under-reporting by traffic officers because of conflicts of interest, although the reporting rate has been rising.[21, 24]

In 2015, 87 percent of road fatalities were caused by motor vehicles,[26] and sharp disparities are evident in the burden of road accidents both regionally (Figure 3)[27] and with respect to the affected population (appendix). It is important to note that the road injury mortality rate is higher in China's rural areas when compared to urban areas (Figure 4). In 2014, around 55 percent of deaths happened in rural areas, but these areas comprise only 45 percent of the population. These areas have unique circumstances that confer road traffic accident and injury risks, including more heavy vehicles, e.g., tractors and trailers; high vehicle speeds, e.g., due to weaker traffic law enforcement; isolation from emergency rescue response; older cars with poor safety equipment; poorer road lighting conditions; and more unlicensed drivers.[22, 28, 29]

2.b. Pedestrian, cyclist and motorcyclist injuries and accidents

China has witnessed a dramatic shift away from active cycling and walking transport. As recently as 1995, more than 540 million bicycles dominated China's streets in urban and rural areas alike, and pedestrian travel was common. These transport modes have been dramatically reduced, and yet with the growth in vehicle traffic, road traffic injuries and fatalities among pedestrians and cyclists have soared (appendix). Because of their vulnerability to vehicular collision, pedestrians, cyclists, e-bike riders, and motorcyclists contribute substantially to roadway injuries and deaths, accounting for 25.5, 11.9, 4.2 and 25.5 percent of all road traffic deaths, respectively, from 2001 to 2015. Over this period, traffic fatalities decreased among pedestrians and cyclists, increased among e-bike riders, and peaked and then declined among motorcyclists (Figure 5). The recent rapid growth in dockless private and public bike sharing programs may yield an increase in the number of cyclist injuries; however, there is some evidence that the number of accidents per kilometer decreases with rising bicycle usage, per the so-called 'safety-in-numbers effect' that has been observed elsewhere.[34]

Because of their convenience and low cost, electric bicycle, or 'e-bike', sales have increased from a few thousand in 1998 to an estimated 37 million in 2015, accounting for 92 percent of global sales.[12, 35] Unlike Europe, North America and Australia, scooter-style e-bikes (SSEBs), which are heavier and have higher maximum attainable speeds, are more popular than bicycle-style e-bikes (BSEBs) in China.[12] The boom in e-bikes poses major concerns regarding the safety of riders and other road users. E-bike traffic shares crowded lanes with traditional bicycles, yet e-bikes achieve relatively high average speeds and riders generally have neither licenses nor helmet requirements. Though e-bike related fatalities are on par with those of traditional bicycles—and about half of motorcycle-related accident fatalities—they have risen approximately 6-fold from 2004 to 2015, even as overall traffic fatalities, and those related to traditional bicycle riding, have decreased over the same period (Figure 5). The soaring number of SSEBs is a phenomenon somewhat unique to China, and the country has an opportunity to lead the development of e-bike safety features, rider education, and road infrastructure interventions to mitigate this rising public health concern.

2.c. Emergency rescue system for transportation injuries and trauma

Transportation injuries and trauma can clinically manifest in many forms, from mild to severe. In China, the most common serious transportation injuries include injuries to the head, limbs, craniocerebral injury and thoracic trauma.[36, 37] The mortality rate from these and other traffic injuries is extremely high in the county, amounting to more than 6 deaths per 10,000 vehicles, in comparison with an average 1–2 deaths per 10,000 vehicles in advanced economies.[36, 37] There are a number of reasons for this, largely reflecting weaknesses in the country's traffic injury rescue system. The emergency rescue system in China is primarily structured around local emergency centers or individual hospitals, consisting of pre-hospital emergency workers, and specialized departments within the hospital that coordinate care. Trauma specialization is rare across China's medical system, and this is true even in advanced, comprehensive hospitals.[38] What is more, emergency medical service workers are often poorly trained, and care received at the site of accidents is often substandard, resulting in a low rate of successful pre-hospital resuscitation.[39] Standardized procedures for emergency rescue are lacking, yielding incorrect therapy and poor success at stabilization of patients before hospital admission (appendix).[39, 40]

A multi-city and -region study across China found that more than 80% of general hospitals have emergency rooms with limited trauma care infrastructure, and identified a major shortage in comprehensive, well-equipped rescue medical centers with well-trained processionals—in particular pre-hospital workers.[41, 42] Gaps in information exchange between pre-hospital first aid and in-hospital emergency services, and weak communication between in-hospital emergency services and specialists, hindered emergency care for traffic-related trauma.[41, 42] Additionally, the consultation call time associated with emergency response in a study of 12 general hospitals in China ranged from 17 minutes to 54 minutes, representing substantial delays in the response of pre-hospital emergency systems.[41, 42] The lack of specialized professionals in trauma, and poor coordination and communication between specific departments within hospitals, all contributed to delays in diagnosis and treatment of traffic accident injuries.[41, 42] These problems are compounded by long emergency rescue transport times that stem from inconsiderate road users, heavy traffic, and low service levels in isolated areas, which severely limit access to trauma care (appendix).

3. Health consequences of transport associated with physical activity and pollution

3.a. Physical inactivity and chronic disease

Transportation has strong linkages to physical activity (PA), and thus has consequences for the prevention of chronic diseases that are associated with inactivity. Transportation infrastructure, degree of access to public transportation, and the design and layout of cities and towns can either promote or hamper active modes of travel, which include walking and cycling, but also include active segments of public transport use, such as walking to bus stops or train stations.[43, 44] Active travel is also directly affected by the presence of traffic-related air pollution, as commuters avoid active transport options on poor air quality days.[43]

Some connections between PA and transportation are self-evident, such as when the central government promoted the use of motor vehicles in the mid-1990s, leading to the conversion of marked bicycle lanes in Beijing into temporary car parking lots, sharply diminishing cycling in the city.[43] Other connections are indirect. For example, it has been established that PA—expressed and measured multiple ways—increases when public transport use increases, and of course, much larger increases in PA are observed when active transport modes are adopted, such as walking or cycling.[3]

These findings have important consequences for public health in China (appendix). Physical inactivity and low PA were responsible for an estimated 0.25 million deaths in the country in 2015 (contributing 2.66 percent of total deaths), and the health-related economic burden of physical inactivity amounted to an estimated 6.7 billion USD in 2007 through its association with coronary heart disease, stroke, hypertension, cancer, and type 2 diabetes.[45, 46] Even when taking into account the adverse health risks of active transportation (e.g., road injuries, exposure to air pollutants), net health benefits have been demonstrated (appendix). Yet despite the clear benefits of PA, and the strong association between transport and PA, increasing car ownership in China has sharply reduced travel PA (appendix). Interventions that aim to increase PA through increased access or ease of active transport are known to be effective, and pose unique opportunities to reverse these downward PA trends (appendix).

3.b. Air pollution attributable to transport

A critical linkage between transport and ill-health in China stems from the substantial burden of disease associated with ambient air pollution in the country. Adverse health effects from transportation-sourced air pollutants in China are chiefly from exposure to particulate matter (PM), ozone (O_3), nitrogen oxides (NO_x), and their combination.[47] On-road vehicle emissions dominate the emission of air pollutants from the transportation sector, especially those from the combustion of diesel fuels.[48] These include health-damaging emissions of: (i) PM, and specifically "fine" PM of less than 2.5 microns in diameter (PM2.5) that accounts for 90% of PM from on-road vehicles in China; and (ii) smog "precursors", such as NO_x, carbon monoxide (CO), and volatile organic compounds (VOCs) including hydrocarbons (HC), which contribute to the secondary formation of PM and O_3.[47, 49, 50] Overall, transportation is an important source of emissions of health-damaging air pollutants (appendix).

Even while Chinese ambient air quality standards are being strengthened, such as through the rollout of China's National Ambient Air Quality Standards in 2012 that helped reduce primary pollutants in the past decade from sources such as coal-burning, secondary pollutants emitted by transportation sources are a growing problem.[52] Between 1980 and 2005, total vehicle emissions of transportation air pollutants (PM, NO_x, CO, and VOCs) increased rapidly, after which emissions evened out or declined on average for all major transportation air pollutants except NO_x (see appendix; Figure 6).[51, 52]

Short- and long-term exposure to air pollution, including PM, NO_2, O_3, and CO from transportation, are associated with substantial morbidity and mortality.[53, 54] Air pollutants have been positively and significantly associated with increased total, cardiovascular, and respiratory mortality across urban centers in China.[54, 55] Infants and children, adolescents, and the elderly, are more susceptible than the general population to the damaging effects of these pollutants,[55, 56] and ambient air pollution in China (especially PM) is associated with adverse pregnancy outcomes including lower birth weights, pre-term birth, and congenital anomaly, especially cardiovascular defects.[57] Epidemiological studies that assess exposure to air pollutants in relation to population proximity to roads shed some light on the unique role of transportation emissions in contributing to poor health (appendix).

3.c. Climate change dimensions of transport

While direct emissions of health-damaging air pollutants from the transportation sector pose immediate public health threats, the emissions of greenhouse gases (GHG) from transportation also drive climate change[58, 59], with important long-term consequences for public health in China. Transportation fossil fuel consumption is responsible for a substantial proportion of China's GHG emissions (appendix),[60] and increased global temperatures have been, and will continue to be, attributable to increases in GHGs globally and in China.[59, 61] While certain transportation-associated GHGs (e.g., CO_2) contribute to warming, others (e.g., NO_x) have a net cooling effect,[59, 60] although these should not detract from efforts to reduce GHG emissions in the transportation sector (appendix).[58] Certain transportation pollutants, such as black carbon, affect *regional* climate (appendix), and global climate change and weather will also in turn directly affect local air pollution in complex ways (appendix).[49]

Importantly, transportation infrastructure itself creates vulnerability to climate change impacts. First, the presence of urban heat islands, or urban areas with higher land surface and air temperatures than less urban surroundings, is partly a function of heat storage by roads and buildings in heavily built-up cities, particularly in Northern China.[62] Urban warming is further intensified by transportation-sourced urban haze[63], and urban heat islands exacerbate heat waves, increasing vulnerability to heat-related mortality.[64] Expansion of impervious surfaces (concrete and pavement) used to construct roads and accompanying urban development also put cities at greater risk of flooding[65], which can result in direct injuries and fatalities, and increased incidence of waterborne and water-related diseases.[66]

4. Future of healthy transportation in China

4.a. Policy options to protect public health and improve transport safety

It is urgent that transport authorities take concrete steps to manage transportation demand, reduce road traffic accidents, develop safety-enhancing infrastructure, and improve regulation. High priority actions include expanding and separating lanes for pedestrians, motorcyclists and cyclists (many of which have been removed to alleviate congested roads); improving road conditions, lighting, and signage; implementing measures that prevent pedestrians from violating traffic rules; requiring vehicle safety inspections and safety training sessions for truck drivers; rolling out road safety information campaigns in rural areas and for children and teens; and strengthening penalties for drunk driving, speeding, and driving without a license.[17, 18, 67] Evidence suggests that a multi-faceted approach that includes infrastructure improvements, legal mandates and their enforcement, and public information campaigns is required in urban and rural China alike (appendix).

Speeding, which increases the likelihood and injury severity of traffic accidents, especially for non-drivers,[68] is a challenge that requires such a multi-faceted approach. In developing country environments, establishing speed limits with respect to the function of each road, enforcing those speed limits, and raising awareness about the dangers of speeding through public education campaigns can reduce speeding related accident and injury (appendix).[69] Drunk driving is another example. While strict criminalization of drunk driving in China has been effective in some settings (appendix), drunk driving behavior persists—especially among men[70, 71]—indicating that regulation should be supplemented by increasing the number of traffic police officers such that routine enforcement, and awareness of enforcement, is improved;[72] conducting police enforcement at night and in low-visibility areas specifically;[73] and educating the public about the dangers of drunk driving.[72]

Given their dominant role in China’s urban transportation, safety of e-bike transport should be urgently addressed by introducing modified (2-step) left-turning at intersections; e-bike speed reduction and licensing requirements; amending and enforcing drunk driving and child passenger regulations for e-bikes specifically; developing group-specific licensing connected to training (i.e., for the elderly and those with less driver education); and launching e-bike awareness campaigns targeted at both e-bike and automobile drivers (appendix).[35, 74, 75] E-bikes should require registration, clear rules for their use should be adopted, and manufacturing of e-bike equipment that meets national standards should be pursued (appendix).

While education programs for drivers and cyclists have been developed,[18] research on their effectiveness is limited, and training and education efforts in China—especially for children—may be most effective alongside or following other interventions, such as substantial road infrastructure improvement, especially in rural areas (appendix). While driver training and education programs are recommended as part of almost all traffic safety recommendations, internationally and in China, there is a dearth of evidence supporting their impact in China. Cost-effective ways of reducing persistent, dangerous road conditions—for drivers, cyclists, and pedestrians alike—should receive urgent priority if education programs are to ever have an impact on road safety.

4.b. Initiatives to encourage safe active transport

To increase the use of active and public transportation in China, targeted policies are needed that mitigate traffic congestion in big cities, improve pedestrian and cyclist safety, and increase public transportation coverage, accessibility and pass subsidies; doing so would boost the physical activity associated with active transport modes.[44, 76] For example, because bikesharing programs can help solve the 'last mile problem' of public transportation, a study of car owners in Hangzhou found that 78 and 63 percent have turned to public bicycle sharing programs to substitute for private car and taxi trips, respectively.[77] Programs that restrict car license plate issuance through lotteries and limit private vehicle usage based on the last digit of license plates continue to make important contributions in many Chinese cities, but critical infrastructure improvements are also needed, including construction and enhancement of safe sidewalks and bicycle lanes.

Assuring appropriate space for pedestrians along roadways—through unobstructed sidewalks, safety islands and pedestrian signaling, for instance—is urgent in many of China's cities, as is the enforcement of strict consequences for illegal parking or driving in pedestrian lanes. Similar improvements are needed in bicycle lanes, including ensuring appropriate width of bicycle lanes, and installing barriers between motor vehicle and bicycle lanes. China has made progress in several of these areas, yet without other essential measures, such as community-based or mass media health campaigns and programs that encourage behavior change, the great strides in physical infrastructure will not be sufficient for encouraging active transportation and increasing physical activity (appendix).

4.c. Vehicle safety equipment and new technologies to reduce injuries and fatalities

China has a range of available policy options to reduce vehicular injuries through improvements in, or mandates of, vehicle and personal safety equipment. There is a large evidence base—some drawn from experience in China—substantiating the linkage between such equipment and reductions in transportation related injuries and death.[17, 23, 78] Protective technologies and associated policies for specific transport modes in China include enforced use of seatbelts and child restraints in vehicles; helmet wearing for e-bike riders; helmet wearing, protective clothing, advanced breaking systems, daytime running lights, and better guardrails for motorcycle riders; automatic emergency braking (AEB) systems for passenger and cargo vehicles; alcohol locks; and improved truck safety equipment focused on the safety of other vehicles, including blind spot detection technology, underride protection on truck sides and rear, and energy-absorbing fronts.[18, 79]

A number of these recommendations are viable only for newer vehicles, yet enforcement of use for even simple protective equipment is very low in China (seat belts, car seats, helmets), and thus supportive policies could generate cost-effective safety gains quickly (appendix).[17, 80] At the same time, leading-edge transport technologies may offer China opportunities to make long-term investments in safety. Autonomous driving technologies (i.e., AEB, and potentially including autonomous steering, acceleration, and deceleration) and connected vehicle technologies (e.g. dynamic routing systems) have the capacity to improve road safety and traffic flow,[18, 81] although there are potential adverse consequences of these technologies to consider (appendix).

4.d. Emerging emissions controls for motorized transport in China

Because both primary and secondary pollutants are an important driver of total pollution levels,[49] and presence of multiple pollutants is thought to heighten morbidity and mortality, traffic emissions controls that address emissions of *all* transportation sourced air pollutants combined would best address the public health burden of transport-sourced air pollution.[82] Some of the most promising opportunities to strengthen emission controls across China's transportation sector have been partially implemented at the municipal or national level, including stricter emission standards for new vehicles, improved fuel quality, license controls, driving restrictions, parking and congestion fees, and phasing out older vehicles.[48, 83]

Still greater progress could be made in reducing health-damaging emissions from vehicles in China by implementing policies that target trucks (appendix), promoting alternative fuel vehicles and buses (battery electric and natural gas), and enforcing scrappage and retrofit programs for older heavy-duty diesel vehicles (HDDV).[48, 83] Traffic restrictions implemented to improve air quality during the Beijing 2008 Olympics provide an example of one of the most dramatic air pollution interventions ever documented through municipal traffic control measures, with major benefits accruing to public health (appendix).[84]

4.e. Demand management, planning and urban design solutions

Demand management will be essential to reducing the public health burden associated with transportation in China. With reduced need to travel as distant and as frequently will come reduced motor vehicle use, fewer emissions of health-damaging pollutants, reduced traffic congestion, lower population exposure to road hazards, and reduced GHG emissions.[85] Urban planning offers a range of policies that can improve public health while moderating demand and ensuring safe, efficient, and convenient transport. Many widely-adopted urban planning strategies, such as the compact urban development model that promotes high urban density, are applicable to Chinese cities (appendix).[86–88] These involve mixed land uses, balancing jobs and housing development to reduce commute distances and times, establishing walkable neighborhoods, and diverting traffic away from pedestrian and cyclist routes. Such compact city planning principles should be pursued alongside active transport subsidies, demand management, and driving disincentives—such as parking charges—that encourage non-automobile commuting in these areas.[89, 90]

Land use zoning and land use plans should separate areas near transportation emissions (i.e., noise and air pollution) from residential areas,[91] and larger buffers should be implemented downwind of diesel railway corridors and large highways (appendix). Low impact development practices (green roofs and urban green space, porous pavement) have the capacity to reduce urban heat island effects[92] and urban flooding,[93] which would moderate the public health impacts of transportation infrastructure and could be pursued in both old city centers and new towns and suburbs. Key to implementing such urban design policy recommendations will be to have a close institutional coordination among government agencies (appendix).[94]

4.f. Improvements to emergency response system for traffic accidents

China must overcome major issues facing comprehensive emergency rescue for traffic-related injuries, central to which is the lack of integrated and comprehensive treatment of trauma. There is an urgent need to develop a comprehensive trauma specialization in hospitals, particularly large general hospitals, and to adapt medical school curriculum and training accordingly. In doing so, it will be critical to take advantage of China's existing infrastructure and healthcare resources to establish more effective regional rescue and treatment systems. Although there are no trauma rescue and treatment centers in large urban hospitals at present, these hospitals maintain professionals of all specializations, and are relatively well-equipped and well-resourced. One path forward would be to establish trauma rescue and treatment networks, each network comprising one trauma center in a qualified general hospital, and 4–6 trauma rescue and treatment stations in nearby secondary hospitals in specific areas, configured based on their locations, population distribution and density, and local demand for first response and rescue.[38, 39] The Peking University Trauma Medicine Center has developed highly successful demonstration networks using such a models (appendix),[39, 95] and these efforts will need to be supported by programs to train a robust pool of qualified first responders and health professionals (appendix).

Finally, any improvements to emergency response systems for traffic accidents must include reductions in pre-hospital response times. This will require more precise communication of the location of accidents and stricter enforcement of the right-of-way for privileged vehicles. For example, patients in Wuhan use mobile apps to send their GPS coordinates while calling for help;[96] and ambulances in Shenzhen are equipped with cameras that can be used as evidence for fining drivers who fail to yield for emergency vehicles.[97]

4.g. China as a healthy transport leader

China is a country wherein public sector initiatives and technological innovation in urban transportation systems are moving quickly—outpacing those of many developed, industrialized nations through a combination of novel bike sharing programs; supplementation of higher-emission motorized transport (personal vehicles, motorcycles) with lower-emission e-bikes; development of partial and fully autonomous driving systems; and construction and expansion of subway systems and high-speed rail. Nevertheless, critical infrastructure development and maintenance, road-safety awareness, compliance with traffic law, emergency response system function and capacity, and achievement of transportation air pollution targets remain major challenges at scales akin to many developing countries. In addressing the unique challenge that exceptionally large-scale and rapid economic growth, urban expansion, and rural-urban connectivity bring to transportation, China stands to become a world leader in the use of forward-looking technological innovation, proactive government action, and local-level advocacy and public awareness raising.

Yet paving a way for healthy transportation in the 21st century will require substantial change to the status quo in China. Namely, the current coupling of dense urban growth, diversification in modes of transport, and outdated road infrastructure increases the odds that pedestrians, cyclists, and drivers are brought into close contact, increasing risk for all. Safety risk is compounded by insufficiently comprehensive traffic laws, lack of awareness and enforcement of road safety laws that do exist, and inadequate emergency response. Because traffic accidents are responsible for such a large number of injuries and fatalities, first order efforts should target improvements to legal requirements (e.g., road type-specific speed limits, improved seat belt and helmet requirements and their enforcement, and enforcement and awareness-raising of existing laws such as for drunk driving) and associated infrastructure (e.g., signage, lighting, road surface improvement, pedestrian and cyclist paths and barriers). Second order efforts should address the need to rapidly curb emissions of air pollution—increasingly from the transportation sector—to protect public health and limit changes to the global climate system. High priority air pollution controls should include demand management, licensing restrictions, parking and congestion fees, phasing in alternative fuel buses (e.g., battery electric and natural gas), and enforcing scrappage and retrofit programs for older vehicles, especially heavy-duty diesel vehicles.

A chief feature of the Chinese transportation-health interface is interdependence of transportation-health pathways that are commonly understood in isolation. For example, the benefits of improved active transport (walking, cycling) are clear, but the capacity to realize those benefits is limited by transportation infrastructure and air pollution. Pedestrians and cyclists, while they may benefit from increased levels of exercise, are put at substantial risk in urban and rural roadway environments due to lacking infrastructure; outdoor air pollution; poor road-safety awareness; inadequate incentives to obey traffic law; and in the case of an accident—an emergency medical service sector with insufficient training and inefficient triage systems. Improvements must be made on multiple fronts—infrastructure, emergency response, regulation, and public awareness—for health gains to be realized.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the paper. No payment was received by any of the co-authors for the preparation of this report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

References

1. The Bike-sharing Blog. The Bike-sharing World at the End of 2016. [2017-03-16]. 2017. http://bike-sharing.blogspot.com/2017/01/the-bike-sharing-world-at-end-of-2016.html
2. Wang J. Regulatory Quandary and its Solutions of Internet Chauffeured Carin China. Administrative Law Review. 2016
3. Sahlqvist S, Song Y, Ogilvie D. Is active travel associated with greater physical activity? The contribution of commuting and non-commuting active travel to total physical activity in adults. Preventive medicine. 2012; 55(3):206–11. [PubMed: 22796629]
4. China Centers for Disease Prevention and Control. Report on Injury Prevention in China. Beijing: People's Medical Publishing House; 2007.
5. Huang J, Deng F, Wu S, Guo X. Comparisons of personal exposure to PM 2.5 and CO by different commuting modes in Beijing, China. Science of the Total Environment. 2012; 425:52–9. [PubMed: 22472140]
6. Zuurbier M, Hoek G, Oldenwening M, et al. Commuters' exposure to particulate matter air pollution is affected by mode of transport, fuel type, and route. Environ Health Perspect. 2010; 118(6):783. [PubMed: 20185385]
7. Pucher J, Peng ZR, Mittal N, Zhu Y, Korattyswaroopam N. Urban transport trends and policies in China and India: Impacts of rapid economic growth. Transport Rev. 2007; 27(4):379–410. English.
8. Gong P, Liang S, Carlton EJ, et al. Urbanisation and health in China. Lancet. 2012; 379(9818):843–52. eng. [PubMed: 22386037]
9. Air pollution–crossing borders. Lancet. 2016; 388(10040):103. [PubMed: 27411862]
10. Zhang J, Mauzerall DL, Zhu T, Liang S, Ezzati M, Remais JV. Environmental health in China: progress towards clean air and safe water. Lancet. 2010; 375(9720):1110–9. English. [PubMed: 20346817]
11. Mikesell JL, Wang JQ, Zhao ZJ, He Y. Impact of Transportation Investment on Economic Growth in China. Transport Res Rec. 2015; (2531):9–16. English.
12. Fishman E, Cherry C. E-bikes in the Mainstream: Reviewing a Decade of Research. Transport Rev. 2015; 36(1):72–91.
13. National Bureau of Statistics of China. China Statistical Yearbook. Beijing: State Council of the People's Republic of China; 1996–2015.
14. Beijing Transport Institute. Beijing transportation development report 2005. Beijing: Beijing Transport Institute; 2005.
15. Beijing Transport Institute. Beijing transportation development report 2016. Beijing: Beijing Transport Institute; 2016.
16. Cui Z, Bauman A, Dibley MJ. Temporal trends and correlates of passive commuting to and from school in children from 9 provinces in China. Preventive medicine. 2011; 52(6):423–7. [PubMed: 21524662]
17. Wang SY, Li YH, Chi GB, et al. Injury-related fatalities in China: an under-recognised public-health problem. The Lancet. 2008; 372(9651):1765–73.
18. Wismans J, Skogsmo I, Nilsson-Ehle A, Lie A, Thynell M, Lindberg G. Commentary: Status of road safety in Asia. Traffic injury prevention. 2016; 17(3):217–25. [PubMed: 26148214]
19. State Administration of Work Safety. National work safety in 2011. 2012. http://www.chinasafety.gov.cn/newpage/Contents/Channel_4181/2012/0114/167212/content_167212.htm
20. State Department of China. , editor. State Department of China. Road Traffic Safety of China. Beijing: 2003.
21. Alcorn T. Uncertainty clouds China's road-traffic fatality data. The Lancet. 2011; 378(9788):305–6.
22. Ma S, Li Q, Zhou M, Duan L, Bishai D. Road traffic injury in China: a review of national data sources. Traffic injury prevention. 2012; 13(sup1):57–63. [PubMed: 22414129]
23. World Health Organization. Global status report on road safety 2015. Geneva: World Health Organization; 2015.

24. Hu G, Baker T, Baker SP. Comparing road traffic mortality rates from police-reported data and death registration data in China. Bulletin of the World Health Organization. 2011; 89(1):41–5. [PubMed: 21346889]
25. Institute for Health Metrics and Evaluation (IHME). GBD Compare Data Visualization. 2017. http://vizhub.healthdata.org/gbd-compare (accessed March 10, 2017)
26. Bureau of Transportation Management. Yearbook of traffic accidents. China: Beijing Ministry of Public Safety; 2015.
27. Zhang X, Xiang H, Jing R, Tu Z. Road traffic injuries in the People's Republic of China, 1951–2008. Traffic injury prevention. 2011; 12(6):614–20. [PubMed: 22133338]
28. Loo BP, Cheung W, Yao S. The rural-urban divide in road safety: the case of China. The Open Transportation Journal. 2011
29. Wang S, Li Y, Chi G, et al. Injury-related fatalities in China: an under-recognised public-health problem. The Lancet. 2008; 372(9651):1765–73.
30. Traffic Management Bureau of the Public Security Ministry PRC. Yearbook of China Road Traffic Accidents Statistics 2015. Wuxi: Traffic Management Research Institute of the Ministry of Public Security; 2015.
31. National Health and Family Planning Commission of the People's Republic of China. China Health and Family Planning Yearbook, 2003–2015. Beijing: Pecking Union Medical College Press; 2003–2015.
32. Traffic Management Bureau of the Public Security Ministry PRC. Yearbook of China Road Traffic Accidents Statistics 2005. Wuxi: Traffic Management Research Institute of the Ministry of Public Security; 2005.
33. Traffic Management Bureau of the Public Security Ministry PRC. Yearbook of China Road Traffic Accidents Statistics 2010. Wuxi: Traffic Management Research Institute of the Ministry of Public Security; 2010.
34. Elvik R, Bjørnskau T. Safety-in-numbers: A systematic review and meta-analysis of evidence. Safety Science. 2015; 92:274–82.
35. Yao L, Wu C. Traffic safety for electric bike riders in China: attitudes, risk perception, and aberrant riding behaviors. Transportation Research Record: Journal of the Transportation Research Board. 2012; (2314):49–56.
36. Tan ZK, Chen ZH, Zheng YM. Characteristics, prevention, and rescue measures of transportation injuries. South China National Defense Medicine. 1994; (1):1–3.
37. Wang, ZG. Modern Transporation Medicine. Chongqing: Chongqing Press; 2011.
38. Jiang BG. Challenges facing road traffic injury rescue in China. Chinese Surgical Journal. 2015; 53(6):401–4.
39. Wang T, Yin X, Zhang P, Kou Y, Jiang B. Road traffic injury and rescue system in China. Lancet. 2015; 385(9978):1622.
40. Gui L, Gu S, Lu F, Zhou B, Zhang L. Prehospital Emergency Care in Shanghai: Present and Future. J Emerg Med. 2012; 43(6):1132–7. English. [PubMed: 23047196]
41. Jiang BG. Status of road traffic injury rescue and current work in China. Chinese medical journal. 2011; 124(23):3850–1. [PubMed: 22340308]
42. Jiang BG. Current status of trauma treatment and estalishment of rescue and treatment standards in China. Chinese Surgical Journal. 2012; 50(7):577–8.
43. Yang M, Zacharias J. Potential for revival of the bicycle in Beijing. International journal of sustainable transportation. 2016; 10(6):517–27.
44. Kerr J, Emond JA, Badland H, et al. Perceived neighborhood environmental attributes associated with walking and cycling for transport among adult residents of 17 cities in 12 countries: the IPEN study. Environmental Health Perspectives (Online). 2016; 124(3):290.
45. Zhang J, Chaaban J. The economic cost of physical inactivity in China. Preventive medicine. 2013; 56(1):75–8. [PubMed: 23200874]
46. Forouzanfar MH, Afshin A, Alexander LT, et al. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of

risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. The Lancet. 2015; 388(10053):1659–724.

47. World Health Organization. Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide:Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide. Europe, CH: World Health Organization Regional Office for Europe; 2006. Air Quality Guidelines : Global Update 2005.
48. Wu X, Wu Y, Zhang S, Liu H, Fu L, Hao J. Assessment of vehicle emission programs in China during 1998–2013: Achievement, challenges and implications. Environmental Pollution. 2016; 214:556–67. [PubMed: 27131815]
49. Guo S, Hu M, Zamora ML, et al. Elucidating severe urban haze formation in China. PNAS. 2014; 111(49):17373–8. en. [PubMed: 25422462]
50. Lei Y, Zhang Q, He KB, Streets DG. Primary anthropogenic aerosol emission trends for China, 1990–2005. Atmos Chem Phys. 2011; 11(3):931–54.
51. Chinese Ministry of Environmental Protection. China Vehicle Emission Control Annual Reports 2010–2015. Department of Pollution Prevention and Control, Chinese Ministry of Environmental Protection of the People’s Republic of China; 2010.
52. Huo H, Zheng B, Wang M, Zhang Q, He K-B. Vehicular air pollutant emissions in China: evaluation of past control policies and future perspectives. Mitigation and Adaptation Strategies for Global Change. 2015; 20(5):719–33.
53. Guan W-J, Zheng X-Y, Chung KF, Zhong N-S. Impact of air pollution on the burden of chronic respiratory diseases in China: time for urgent action. The Lancet. 2016; 388(10054):1939–51.
54. Shang Y, Sun Z, Cao J, et al. Systematic review of Chinese studies of short-term exposure to air pollution and daily mortality. Environment international. 2013; 54:100–11. [PubMed: 23434817]
55. Xing Y-F, Xu Y-H, Shi M-H, Lian Y-X. The impact of PM2.5 on the human respiratory system. Journal of Thoracic Disease. 2016; 8(1):E69–E74. [PubMed: 26904255]
56. Kan H, Chen R, Tong S. Ambient air pollution, climate change, and population health in China. Environment international. 2012; 42:10–9. [PubMed: 21440303]
57. Jacobs M, Zhang G, Chen S, et al. The association between ambient air pollution and selected adverse pregnancy outcomes in China: A systematic review. Science of The Total Environment. 2017; 579:1179–92. [PubMed: 27913015]
58. Creutzig F, Jochem P, Edelenbosch OY, et al. Transport: A roadblock to climate change mitigation? Science. 2015; 350(6263):911–2. en. [PubMed: 26586747]
59. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC; 2014. Intergovernmental Panel on Climate Change Climate Change 2014: Synthesis Report.
60. Li B, Gasser T, Ciais P, et al. The contribution of China’s emissions to global climate forcing. Nature. 2016; 531(7594):357–61. en. [PubMed: 26983540]
61. Ward DS, Mahowald NM. Contributions of developed and developing countries to global climate forcing and surface temperature change. Environmental Research Letters. 2014; 9(7):074008. en.
62. Zhou D, Zhao S, Zhang L, Sun G, Liu Y. The footprint of urban heat island effect in China. Scientific Reports. 2015; 5:11160. en. [PubMed: 26060039]
63. Cao C, Lee X, Liu S, et al. Urban heat islands in China enhanced by haze pollution. Nature Communications. 2016; 7:12509. en.
64. Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. Nature. 2005; 438(7066):310–7. en. [PubMed: 16292302]
65. Huang Q, Wang J, Li M, Fei M, Dong J. Modeling the influence of urbanization on urban pluvial flooding: a scenario-based case study in Shanghai, China. Natural Hazards. 2017; 87(2):1035–55. en.
66. Li X, Song J, Lin T, Dixon J, Zhang G, Ye H. Urbanization and health in China, thinking at the national, local and individual levels. Environmental Health. 2016; 15(1):S32.
67. The World Bank. China - Road traffic safety: the achievements, the challenges, and the way ahead. Washington, DC: The World Bank; 2008. en

68. Zhou, J., Qiu, J. Current Developments on Traffic Medicine. In: Fu, X., Liu, L., editors. Advanced Trauma and Surgery. Springer; Singapore: 2017. p. 59-77.
69. World Health Organization. Managing speed. Geneva, Switzerland: World Health Organization (WHO); 2017.
70. Wang Z, Zhang Y, Zhou P, et al. The Underestimated Drink Driving Situation and the Effects of Zero Tolerance Laws in China. Traffic Injury Prevention. 2015; 16(5):429–34. [PubMed: 25629625]
71. Zhao A, Chen R, Qi Y, et al. Evaluating the Impact of Criminalizing Drunk Driving on Road-Traffic Injuries in Guangzhou, China: A Time-Series Study. J Epidemiol. 2016; 26(8):433–9. [PubMed: 26947952]
72. Jia, K., Fleiter, JJ., King, MJ., Sheehan, M., Dunne, M., Ma, W. Reducing alcohol-related driving on china's roads : Traffic police officers' perceptions and practice. Guangdong Institute of Public Health; 2013. 2013 2013
73. Zhang G, Yau KKW, Gong X. Traffic violations in Guangdong Province of China: Speeding and drunk driving. Accident Analysis & Prevention. 2014; 64:30–40. [PubMed: 24316505]
74. Du W, Yang J, Powis B, et al. Understanding on-road practices of electric bike riders: An observational study in a developed city of China. Accident Analysis & Prevention. 2013; 59:319–26. [PubMed: 23877004]
75. Yang J, Hu Y, Du W, et al. Unsafe riding practice among electric bikers in Suzhou, China: an observational study. BMJ Open. 2014; 4(1)
76. Zhang Y, Li Y, Liu Q, Li C. The built environment and walking activity of the elderly: an empirical analysis in the Zhongshan metropolitan area, China. Sustainability. 2014; 6(2):1076–92.
77. Shaheen S, Zhang H, Martin E, Guzman S. China's Hangzhou public bicycle: understanding early adoption and behavioral response to bikesharing. Transportation Research Record: Journal of the Transportation Research Board. 2011; (2247):33–41.
78. Peden, M., Scurfield, R., Sleet, D., et al. World report on road traffic injury prevention. Geneva, Switzerland: World Health Organization (WHO); 2004.
79. Sui, B., Ding, C., Fredriksson, R., Zhou, S., Zhao, X. Vehicle-to-Vehicle Rear Crashes in China - A Study of Accident Characteristics to Provide Input to Active Safety System Design; 2016 Eighth International Conference on Measuring Technology and Mechatronics Automation (ICMTMA); 2016 2016/03//; 2016. p. 889-96.
80. Zhang W, Tsimhoni O, Sivak M, Flannagan MJ. Road safety in China: Analysis of current challenges. Journal of Safety Research. 2010; 41(1):25–30. [PubMed: 20226947]
81. Lin, P-S., Wang, Z., Guo, R. Impact of Connected Vehicles and Autonomous Vehicles on Future Transportation. In: Shon, JZ.Tseng, P-Y.Chen, C-H., Lo, S-C., editors. Bridging the East and West: Theories and Practices of Transportation in the Asia Pacific. Hsinchu, Taiwan: 2016.
82. Lu X, Yao T, Fung JCH, Lin C. Estimation of health and economic costs of air pollution over the Pearl River Delta region in China. Science of The Total Environment. 2016; 566–567:134–43.
83. Wu Y, Zhang S, Hao J, et al. On-road vehicle emissions and their control in China: A review and outlook. Science of The Total Environment. 2017; 574:332–49. [PubMed: 27639470]
84. Wang S, Zhao M, Xing J, et al. Quantifying the Air Pollutants Emission Reduction during the 2008 Olympic Games in Beijing. Environmental Science & Technology. 2010; 44(7):2490–6. [PubMed: 20222727]
85. Davies GR, Roberts I. Is road safety being driven in the wrong direction? Int J Epidemiol. 2014; 43(5):1615–23. [PubMed: 24808047]
86. Giles-Corti B, Vernez-Moudon A, Reis R, et al. City planning and population health: a global challenge. Lancet. 2016; 388(10062):2912–24. [PubMed: 27671668]
87. Sallis JF, Bull F, Burdett R, et al. Use of science to guide city planning policy and practice: how to achieve healthy and sustainable future cities. Lancet. 2016; 388(10062):2936–47. English. [PubMed: 27671670]
88. Stevenson M, Thompson J, de Sa TH, et al. Land use, transport, and population health: estimating the health benefits of compact cities. Lancet. 2016; 388(10062):2925–35. English. [PubMed: 27671671]
89. Campoli J. Made for walking: Density and neighborhood form. 2012

90. Ewing R, Cervero R. Travel and the Built Environment. Journal of the American Planning Association. 2010; 76(3):265–94.
91. Bertazzon S, Johnson M, Eccles K, Kaplan GG. Accounting for spatial effects in land use regression for urban air pollution modeling. Spatial and Spatio-temporal Epidemiology. 2015; 14–15:9–21.
92. Zhan W, Chui TFM. Evaluating the life cycle net benefit of low impact development in a city. Urban Forestry & Urban Greening. 2016; 20:295–304.
93. Hu M, Sayama T, Zhang X, Tanaka K, Takara K, Yang H. Evaluation of low impact development approach for mitigating flood inundation at a watershed scale in China. Journal of environmental management. 2017; 193:430–8. [PubMed: 28237222]
94. Feiock RC. Metropolitan Governance and Institutional Collective Action. Urban Aff Rev. 2009; 44(3):356–77. English.
95. Yin XF, Wang TB, Zhang PX, et al. Evaluation of the effects of standard rescue procedure on severe trauma treatment in china. Chinese medical journal. 2015; 128(10):1301–5. [PubMed: 25963348]
96. Hubei Daily. Emergency app online for Wuhan. Sep 12. 2015 http://news.cnhubei.com/xw/wuhan/201509/t3383238.shtml (accessed May-13 2017)
97. Wang X. Ambulances in Shenzhen will be equipped with cameras. Shenzhen Evening News. 2014 Jan 21. Sect. 10.

Key Messages

- Public sector transportation initiatives and technological innovation in urban transportation systems are advancing very rapidly in China, with major consequences for public health.
- There are critical challenges facing the country's transport sector, including road-safety awareness, demand management, compliance with traffic law, emergency response system function and capacity, and achievement of transportation air pollution targets.
- China stands to become a world leader in the use of forward-looking technological innovation, proactive government action, and local-level advocacy and public awareness raising in order to achieve healthy, 21st century transportation systems.
- Because traffic accidents are responsible for such a large number of injuries and fatalities, immediate improvements are needed to legal requirements (e.g., road type-specific speed limits, improved seat belt and helmet requirements and their enforcement) and associated infrastructure (e.g., signage, lighting, road surface improvement, pedestrian and cyclist paths and barriers).
- Further efforts should address the need to manage transportation demand through innovative planning, and to rapidly curb emissions of air pollution to protect public health and limit changes to the global climate system.
- Improvements are needed on multiple fronts—in emergency response and trauma care, regulation, public awareness, and infrastructure—for health gains to be realized.

Search strategy and selection criteria

We searched China National Knowledge Infrastructure and Wanfang for Chinese language papers and PubMed for English language papers, using the medical subject heading terms “transportation”, “urbanization”, and “motor vehicles”, and the search terms “health”, “healthcare”, “injuries”, “accident”, “traffic”, “road”, “highway”, “safety”, “air pollution” and specific transport air pollutant names (e.g. “PM2.5”), “physical activity”, “chronic diseases”, “public transportation”, “cycling”, “commute”, “driver”, “passenger”, “rail”, and “climate change”. We also searched for geographical terms such as “China” and province and municipality names. Searches included appropriate wild cards and truncation, and we reviewed the references cited in relevant papers. We selected publications from the past 20 years and manually reviewed Chinese health, demography, infrastructure and transportation statistical yearbooks published over the past 20 years, and government reports published over the past 15 years.

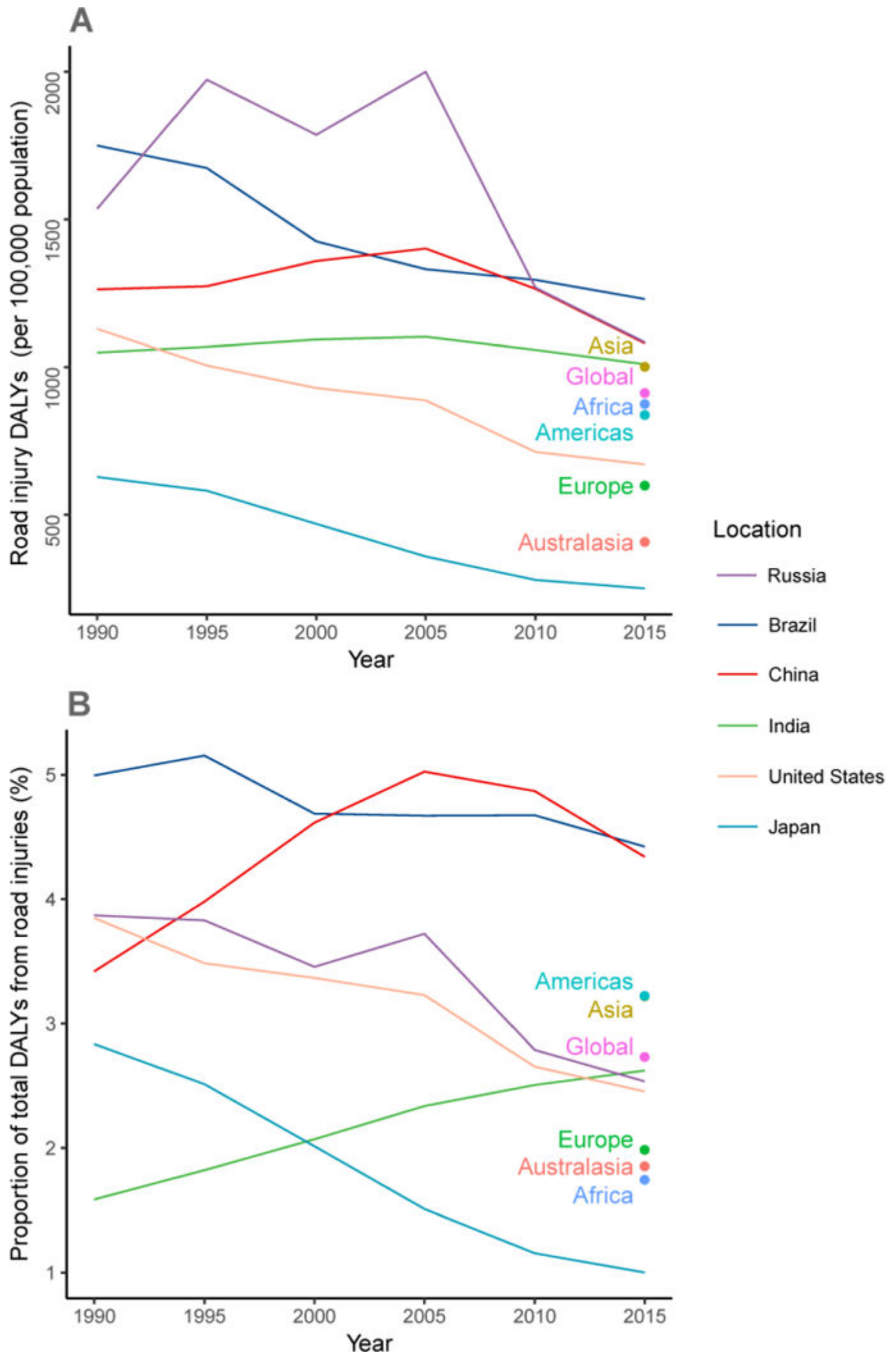

Figure 1.

Disease burden of road injuries for several countries, 1990–2015 as (A) DALYs per 100,000, and (B) proportion of total DALYs.[25]

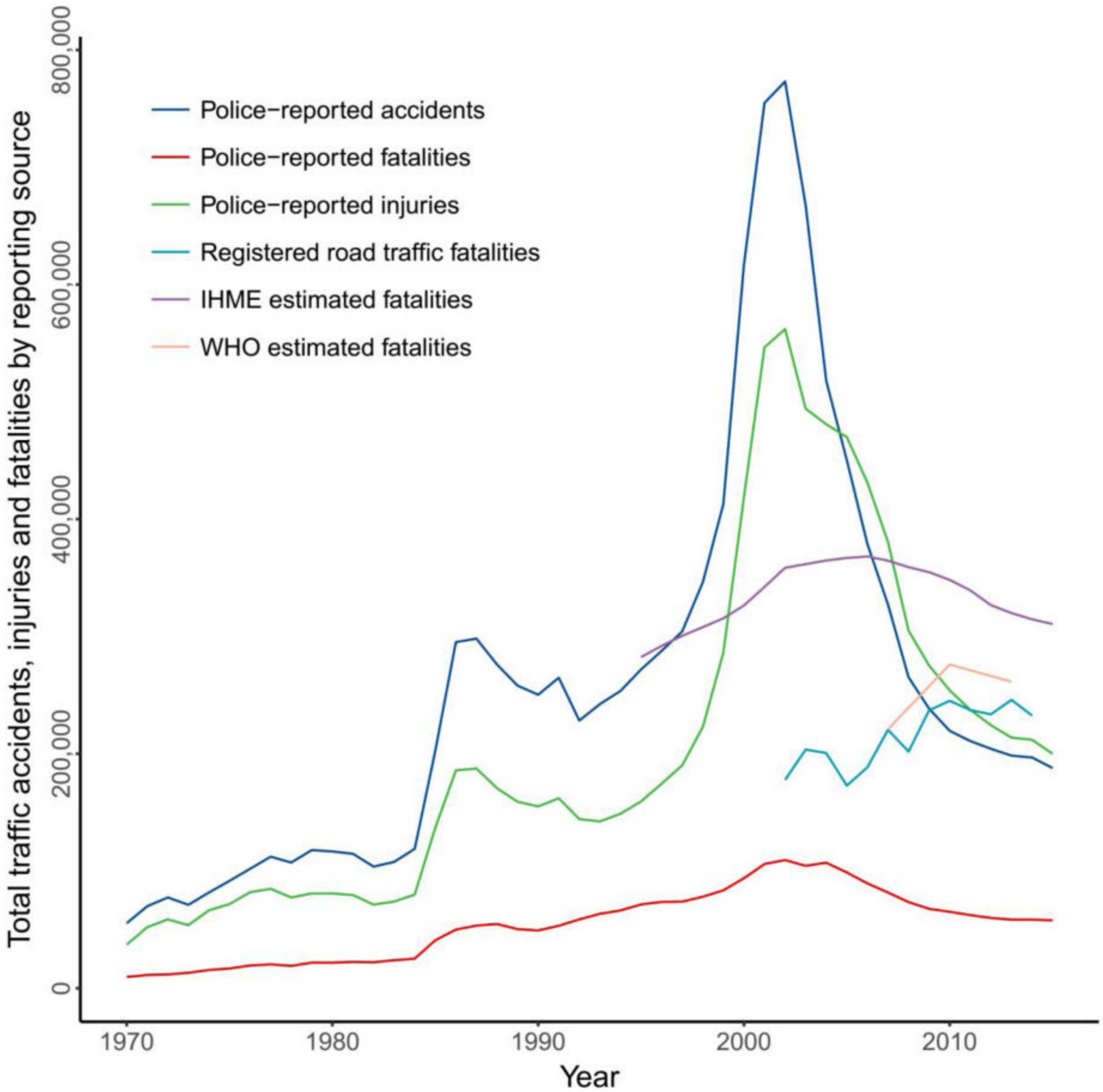

Figure 2.

Traffic accidents, injuries and fatalities in China, 1970–2015.[23, 25, 30, 31]

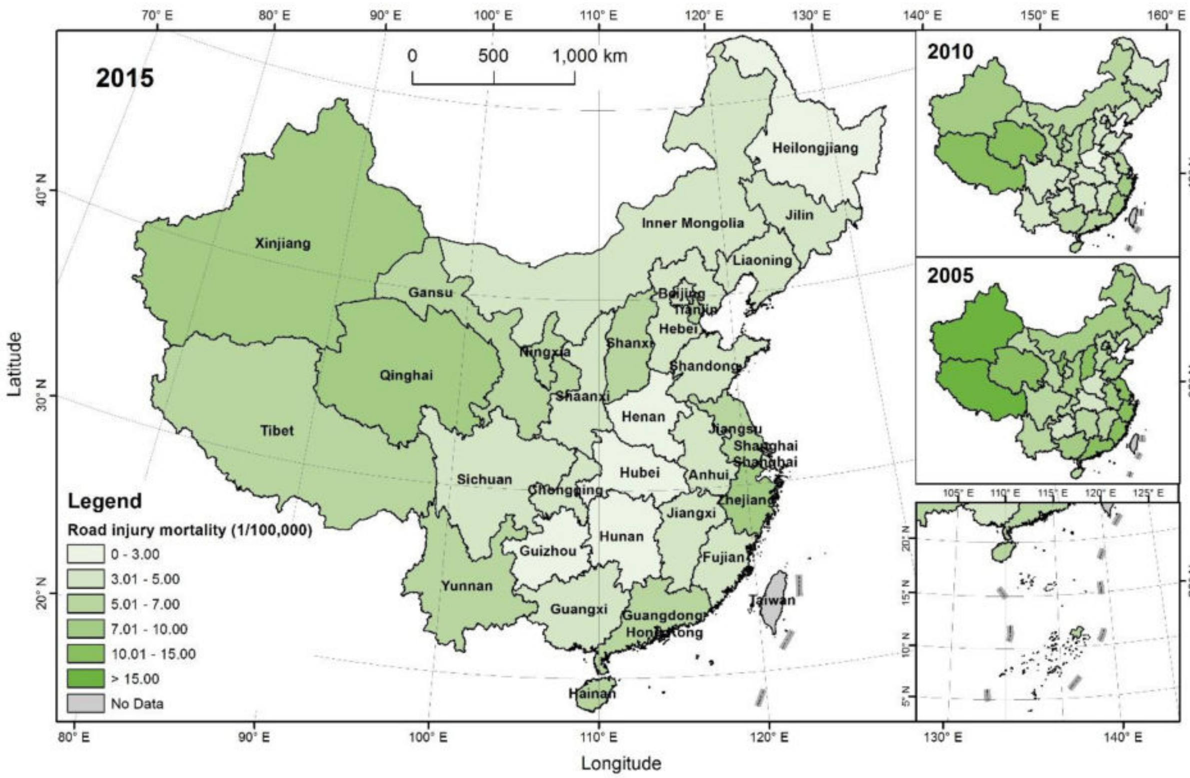

Figure 3.

Road injury mortality rate by province in 2005, 2010 and 2015.[30, 32, 33]

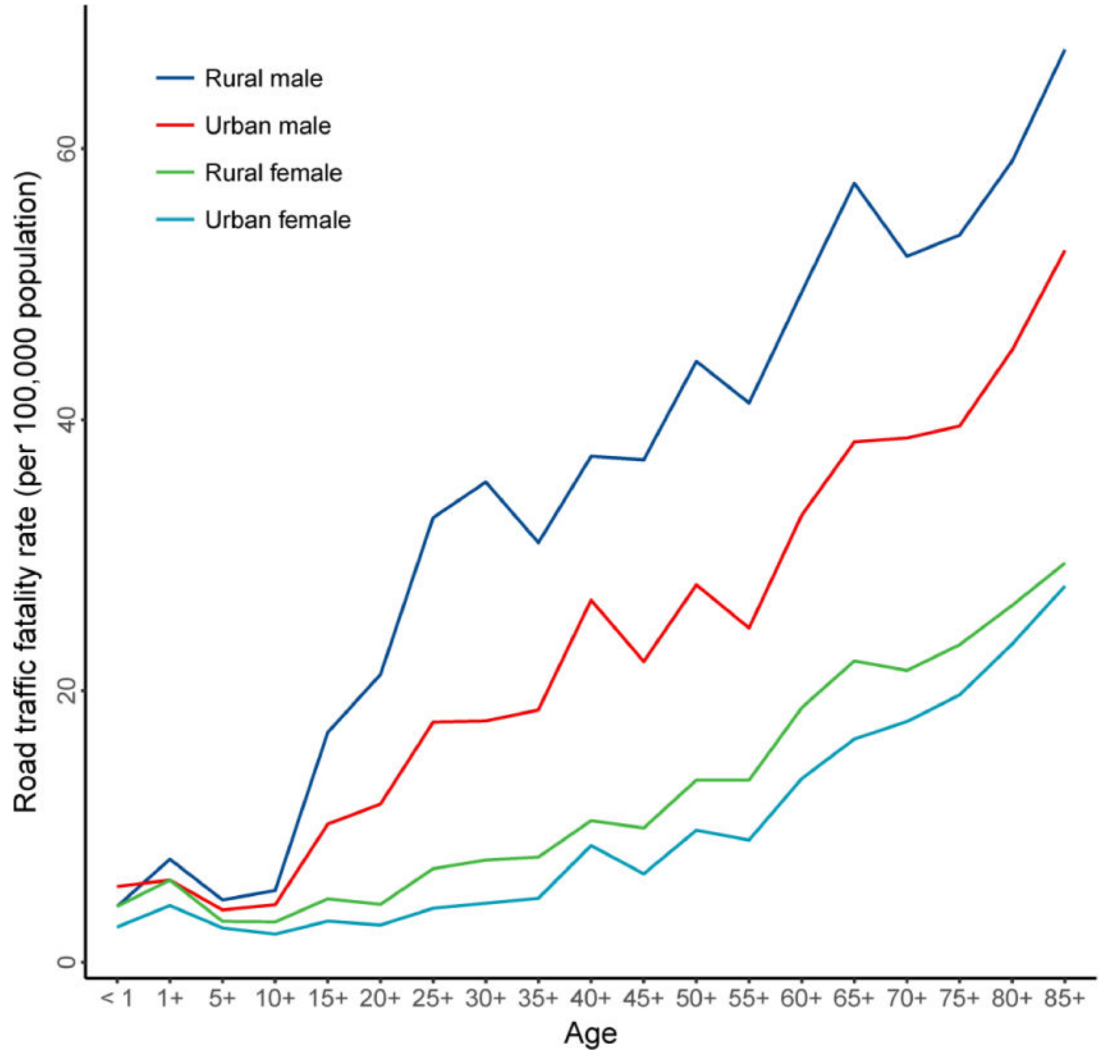

Figure 4.

Age-specific road injury mortality from death registration data for rural female, rural male, urban female and urban male, 2014.[31]

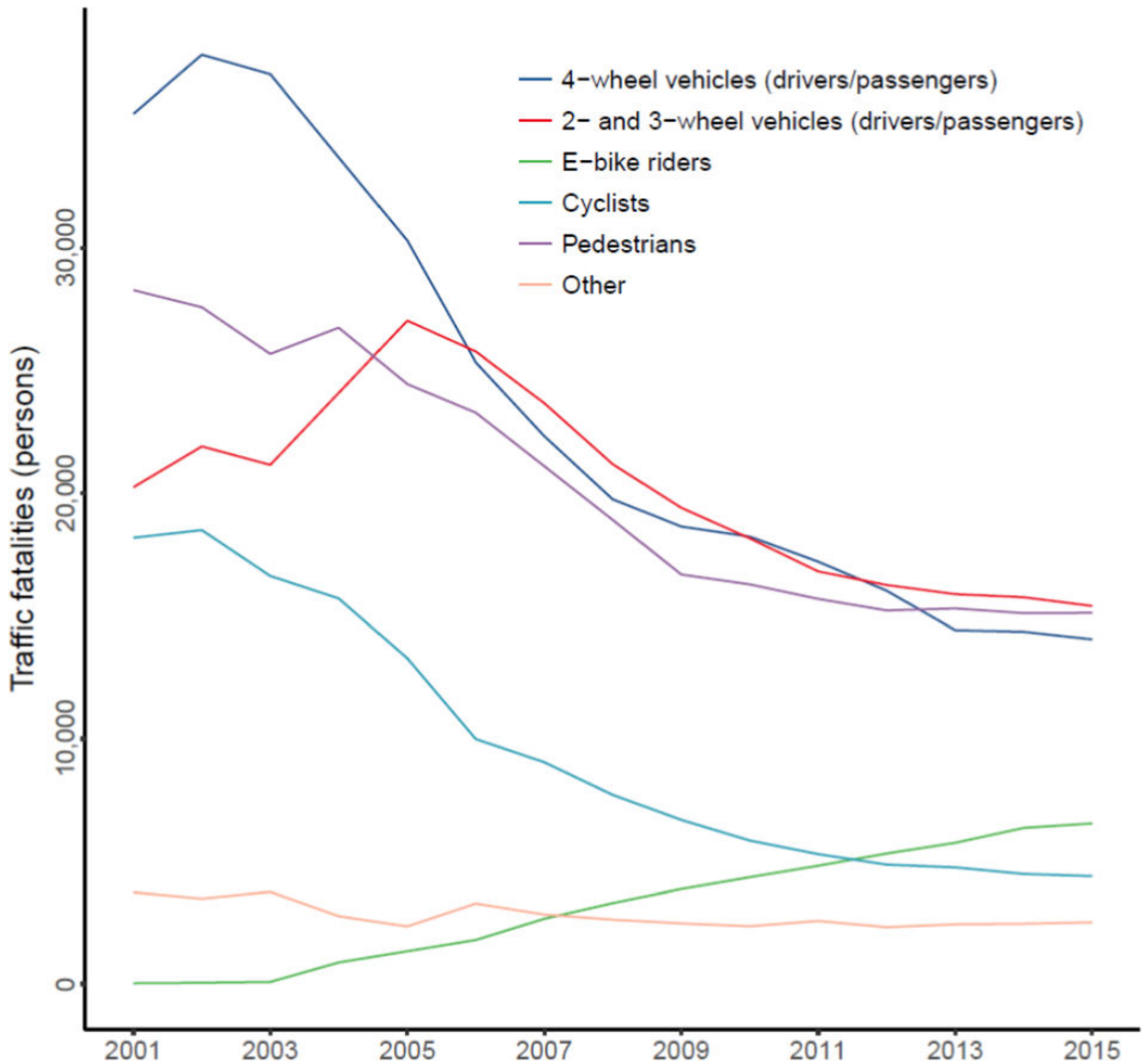

Figure 5.

Police-reported traffic fatalities by road use type from 2001 to 2015. 'Other' refers to other motorized and non-motorized vehicles (e.g., animal-drawn; farm vehicles; etc.).[30]

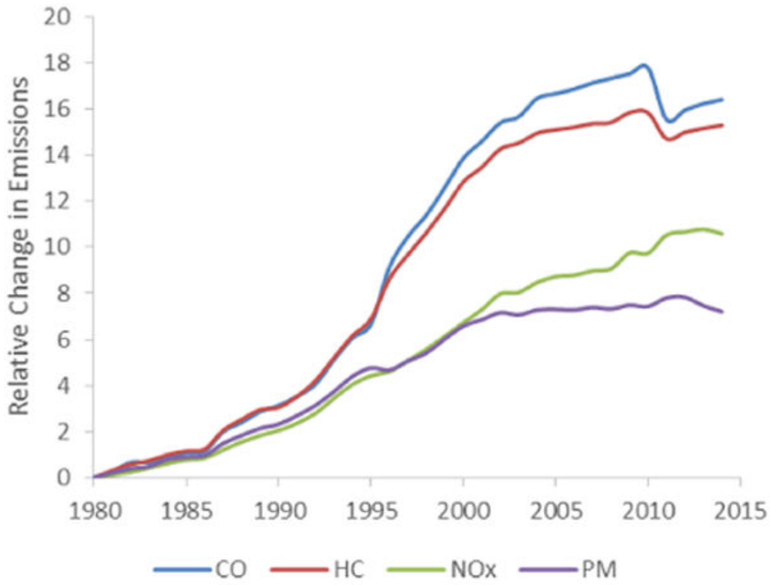

Figure 6.

Relative change in transportation air pollutant emissions from passenger cars and trucks between 1980 and 2014. The relative change is the annual change in million tons (Mt) emitted by passenger vehicles and trucks combined as a fraction of baseline 1980 emissions for CO, HC (VOC), NO_x, and PM, which were 1.7, 0.2, 0.5, and 0.1 Mt, respectively.[51]