World Health Organization
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Walking and cycling: latest evidence to support policy-making and practice

THE PEP
Transport, Health and Environment Pan-European Programme

UNECE

World Health Organization
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Abstract

Active travel modes, especially walking and cycling, are now recognized by many as modes that are fully equal to other urban transport modes, integrated in planning frameworks, and adopted as part of the mainstream – not just in trailblazer countries, but worldwide. An ever-growing body of science underpins the gains society can reap from active travel in terms of transport, health and environmental benefits. Planning practice has accumulated a rich portfolio of measures ready to be considered for inspiration, adaptation and possible application in every city. This publication presents a comprehensive case for why and how to promote walking and cycling, based on the latest evidence from scientific research and planning practice.

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Foreword

In a region where the impact of the major noncommunicable diseases, such as diabetes, cardiovascular diseases, cancer, chronic respiratory diseases and mental disorders, account for an estimated 86% of deaths and 77% of the disease burden, transport and urban policies can play a key role in shaping health – for better or for worse.

Walking and cycling can reduce physical inactivity, responsible for approximately one million deaths per year in the WHO European Region. Walking and cycling can also help reduce air pollution, which alone claims more than half a million deaths every year in the Region, as well as emissions of greenhouse gases, thereby significantly contributing to decarbonizing transport. Investments in policy actions that promote walking and cycling can contribute directly to achieving many of the Sustainable Development Goals.

The 2020s promise to be pivotal for urban mobility. While electric car models compete for the limelight in television commercials, active travel modes, such as walking and cycling, more quietly contribute their part to the transport revolution.

The COVID-19 pandemic has been a powerful catalyst of change by allowing millions of people around the globe to experience different transport options – given changed schedules, mobility needs, and traffic conditions – characterized by less traffic, less noise and pollution, more dedicated space for pedestrians and cyclists, and streets as outdoor liveable spaces. This has created an unprecedented window of opportunity for changes to be supported and sustained in the longer term, transforming the quality of urban life for the better and increasing societal resilience.

The pandemic aside, a steadier but equally dramatic reality is sinking in. Climate change is now a reality rather than a mere prediction, affecting many aspects of our lives. Policies to mitigate climate change need to take top priority, and the transport sector, lagging behind others, must assume its responsibilities. Shifting short car trips to active travel modes will be one part of the climate solution.

We are happy to present this booklet developed under the Transport, Health and Environment Pan-European Programme (THE PEP) – a joint programme between WHO and the United

Nations Economic Commission for Europe (UNECE), with the aim of providing policy-makers with the latest scientific evidence behind the rationale to promote walking and cycling, and numerous examples from urban and transport planning practice on how to successfully do so.

This is at the core of the WHO European Programme of Work, *United Action for Better Health in Europe*, which supports the aspiration of people to be able to thrive in healthy communities, where public health action and appropriate public policies secure a better life in an economy of well-being. This booklet also continues the work of UNECE on recovering better from the COVID-19 pandemic.

We believe that this publication provides governments and practitioners; professionals in public health, transport, planning and urban development; and civil society actors with timely information as they prepare, are already implementing or advocating recovery packages to reopen their economies. In particular, we hope that this publication will support the commitments taken by Member States through the Vienna Declaration on *Building forward better by transforming to new, clean, safe, healthy and inclusive mobility and transport* adopted in 2021 – aimed at steering the process in directions that will deliver better health, a better environment, reduced inequalities and the increased resilience of our societies and communities.

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List of abbreviations

DALYs	Disability-adjusted life years
ECEH	WHO European Centre for Environment and Health
EU	European Union
FLOW	Furthering Less congestion by creating Opportunities for more Walking and cycling
HEAT	Health Economic Assessment Tool for walking and cycling
MET	Metabolic equivalent of task
$PM_{2.5}$	Fine particulate matter of median diameter of 2.5µm
QALYs	Quality-adjusted life years
SCC	Social Costs of Carbon
SDGs	Sustainable Development Goals
THE PEP	Transport, Health and Environment Pan-European Programme
UN	United Nations
UNECE	United Nations Economic Commission for Europe
VSL	Value of Statistical Life

Executive summary

Active travel modes, especially walking and cycling, are now recognized by many as modes that are fully equal to other urban transport modes, integrated in planning frameworks, and adopted as part of the mainstream – not just in trailblazer countries, but worldwide.

An ever-growing body of science underpins the gains society can reap from active travel in terms of transport, health and environmental benefits. Planning practice has accumulated a rich portfolio of measures ready to be considered for inspiration, adaptation and possible application in every city.

This publication presents a comprehensive case for why and how to promote walking and cycling, based on the latest evidence from scientific research and planning practice. It is addressed to a broad spectrum of readers with the aim to provide pointers and highlights that will help create greater awareness, commitment and capacities to effectively govern sustainable transport developments, so that their benefits can be maximized, and any risks understood and properly managed.

This booklet is organized into four main chapters. The first chapter introduces the latest trends and policies around urban mobility and transport, and the prospects for an increasing role of walking and cycling. It highlights the Transport Health and Environment Pan-European Programme (THE PEP) and the recently adopted first Pan-European Master Plan for Cycling Promotion. The second chapter explores changes in transport policy and planning practice and argues for a modern, evidence-based approach to promoting walking and cycling. The third chapter provides compelling scientific evidence explaining why walking and cycling should be promoted, covering a wide range of benefits, including for health, the climate, environment, mobility and well-being. The last chapter presents an overview of measures and policies for the promotion of walking and cycling.

Reinventing urban transport: why the 2020s will be all about walking and cycling

Walking and cycling had already been recognized for their favourable features many years ago. They are healthy, clean, quiet and cheap, and check off many boxes among the requirements for modern, sustainable means of transport. Despite these obvious advantages, for too long and in most countries worldwide, walking and cycling have been marginalized and lacked recognition in official policy, planning practice and governmental funding. But this is no longer the case. An impressive and growing number of cities around the globe have turned sporadic local efforts into a global trend, rethinking the role of walking and cycling in urban transport. In many places, this has gone hand-in-hand with a significant rethinking of urban spaces and functions and striving to facilitate equitable and sustainable access to services, goods and amenities within neighbourhoods. Urbanists are referring to so-called cities of proximity or 15-minute cities, as well as high-density and mixed land use, where residential, commercial and leisure spaces are highly interspersed, travel distances become walkable and bikeable, and travel is affordable. As a result, a substantial body of experience and evidence has accumulated, which makes a stronger case for investments in walking and cycling than ever before.

Our cities face countless challenges related to demographic changes, financial constraints and technical progress. Congestion remains an apparently inherent side-effect of driving. Calls for decarbonizing transport grow louder with every climate record-breaking year. More than 40 years after the invention of the catalytic converter, urban air pollution is still a ubiquitous problem, as is noise pollution. At the same time, more people than ever live in cities. Transport and urban planning policies are at a crucial crossroad as urban travel patterns undergo fundamental changes.

The electrification of cars certainly helps resolve the issue of tail pipe emissions and noise, and in the not so far future, autonomous vehicles may optimize some aspects of driving even further, such as safety for drivers and other road users. However, by no means will the technical advancements of cars be the instant, single-handed solution to urban transport problems: the conversion of the current vehicle stock to a completely electrified fleet is estimated to take some 15–20 years, and in any case will not address the problem of congestion or use of public space (Brand et al., 2021b), or air pollution related to tire and brake wear (Lewis, Moller and Carslaw, 2019). More likely, it is reasonable to assume that electrification and autonomous driving will introduce several new challenges, such as the sustainable production and handling of batteries, or curb side congestion.

Ride-hailing-services can decrease the need to own a car, and as such may lead to an increase in the use of public transport and other travel modes. In several societies, there is also a fundamental change in personal aspirations. Younger generations in particular are open to consider the possibility of using car-sharing schemes when needed, or switching to alternative modes of transport entirely, rather than allocating personal income to private car ownership (Kuhnimhof et al., 2012). Car ownership also appears to be losing grounds as a symbol of social status, albeit not in all societies (Pojani, Van Acker and Pojani, 2018).

With the appearance of bike sharing systems, new forms of micro-mobility (e.g. e-scooters, e-bikes, electric skateboards), ride-hailing services and the anticipated emergence of autonomous vehicles, the longstanding simplification of categorizing transport as either private cars, public transport or so-called other modes is falling short. The contemporary urban dweller is first a pedestrian, and then also a multi-modal traveller assisted by the latest inventions that emerge from digitalization. In this new urban mobility mix, walking and cycling have emerged as central ingredients and positive enablers. The allocation of street space and transport funds will have to evolve accordingly.

Bike sharing schemes have made bicycles widely accessible and widened the appeal of cycling to urbanites who did not put up with the hassle of secure bike storage and parking (Fishman, 2016). Furthermore, electric-assist technology of e-bikes boosts the range and appeal of cycling, making it feasible for longer trips, in hillier terrains, and for less fit and elderly people (Bourne et al., 2020).

On-demand mobility services and the emergence of highly integrated mobility-as-a-service solutions – enabling users to plan, book and pay for multiple types of mobility services – may impress as the latest cutting-edge technologies. But at the same time, they potentially offer a boost for the most basic transport mode of all – walking. Navigating cities by walking has become more convenient, efficient and reliable with the omnipresence of a back-up option during the occasional downpour or for the missed bus.

As a result of these developments, it is more feasible than ever to shift a substantial fraction of urban car trips to cycling, e-biking, e-scooters and, often, walking. But the appeal of walking and cycling is not limited to how they address transport issues. Many cities invest in alternatives to motorized transportation because they realize that a good combination of policies, which rebalance modal shares and reallocate public space – placing humans, rather than cars, at the centre – can change the transport narrative to a more positive one. Highlighting the breadth of health, environmental, economic and societal benefits is a strong selling point for new urban transport policies. Significant shifts towards walking and cycling are important to address the multiple problems resulting from current transport patterns, including emissions of air pollution, greenhouse gases and noise; traffic safety; and limited opportunities for physical activity. Several of these effects contribute to the global epidemic of noncommunicable diseases; a leading cause of premature death in the WHO European Region. Moreover, health research calls for the promotion of active lifestyles, yet one out of every four European adults are insufficiently active (Guthold et al., 2018). Promoting active travel for day-to-day needs is a promising strategy to battle inactivity.

Closely linked to the health aspects, assuring equity of urban transport systems remains a major challenge. Who gets to reap the benefits and opportunities, and who has to bear the burden imposed by various technologies and infrastructures, must be constantly questioned (Davis and Obree, 2020; Goodman and Cheshire, 2014; Lee, Sener and Jones, 2017). The distribution of benefits to users, or conversely the adverse impacts of transport policies, are often distributed unevenly. Such inequalities can materialize in the location of new infrastructures (beneficial or harmful) and the economic ability to relocate, the affordability of new technologies (vehicle safety features, digital information and payment, etc.), and the differential effects on users of different transport modes (inside vs. outside of vehicles, private vs. public transport, etc).

The call to promote walking and cycling has regained a new urgency as we transition to a new post-pandemic reality. The COVID-19 pandemic has caused tremendous harm and challenged our public health systems and more. Through its disruptive nature, however, the pandemic is also a catalyst for change.

We have seen massive impacts on urban travel patterns (Buehler and Pucher, 2021b; Combs and Pardo, 2021; Molloy et al., 2021a; Venter et al., 2021). Lockdowns have brought to light the face of cities without ubiquitous congestion, the pleasure of noise-free nights, the joy of car-free walking zones, and pollution-free skies. Urban cycling has seen a tremendous rise in popularity in many places (Buehler and Pucher, 2021b), and proved to be an important backbone of resilience when public transport was not a feasible option. Working from home, and in general a more flexible take on work hours, will have a lasting effect on the commuting habits of office workers, and as a result, on peak hour and overall traffic. On the flip side, public transport systems have faced drops in ridership, which may take years to fully bounce back, and vehicle speeding increased, as fewer vehicles clogged the roads. Changes in travel patterns also revealed a concerning degree of inequity, as lesser-paid front-line workers could not benefit from a home office or afford to avoid public transport, and lower income groups were less likely to substitute utilitarian walking (e.g. commuting to work or to run errands) with leisure walking (e.g. for exercise) (Hunter et al., 2021).

The COVID-19 pandemic has also raised a new awareness for public health and the fact that health policies do make a difference, and that changes can indeed happen at a scale and pace that were once unthinkable (Box 1). Ad hoc bicycle infrastructure, such as temporary, low-cost installations, is a good example (Kraus and Koch, 2021). Many people have also flocked to walking and cycling as a physically distanced form of exercise and because other forms of physical activity had become temporarily unavailable, such as fitness centres and sport activities. Finally, the susceptibility of subjects with underlying conditions to COVID-19 has added yet another argument to the importance of preventing chronic diseases. While many of these changes may reverse on their own, some may be here to stay. Either way, they provide ample opportunities to shape the new normal of healthier, sustainable and resilient urban transport systems (International Energy Agency, 2021; THE PEP, 2021b).

Box 1
COVID-19 pandemic: rethinking the allocation of urban space to promote active mobility

The restrictive measures implemented in response to the COVID-19 pandemic have triggered significant shifts towards active mobility modes. Despite the technical, financial, legal and administrative challenges required for improving the conditions for cyclists and pedestrians, during the pandemic national and local authorities from all around the world implemented unprecedented measures almost overnight. Pop-up bicycle infrastructure has been coined as a term for cities' swift response to this increase in demand (Combs and Pardo, 2021), and research has already been able to show that these efforts were worthwhile (Buehler and Pucher, 2021b; Kraus and Koch, 2021). Cities that provided temporary infrastructure, such as reallocating travel lanes to cycling, saw a much greater increase in cycling than those which did not. The European Commission guidelines on restoring transport post-lockdown include considerations for active travel. In relation to space reallocation, the guidelines specify that urban areas could consider temporary enlargements of pavements and increased space for active mobility options. The guidelines also recommend reducing speed limits of vehicles in increased active mobility areas.

COVID-19 measures in Geneva, Switzerland. In favour of cycling as a mode of transport, a specifically designed lane for bicycle travel. ©Rue de l'Avenir

Box 1 (contd)

Examples illustrating the pandemic-induced surge in active travel include:

- ☑ Bike sales have experienced a boom almost everywhere: in the United Kingdom of Great Britain and Northern Ireland, year-on-year sales increased +677% (Lozzi et al., 2020).
- ☑ Many countries, such as Denmark and Germany, put forward public recommendations to avoid private car use in favour of cycling or walking. Italy offered a 60% cash-back of up to €500 for a bicycle or e-bike purchase to incentivize this shift, while in France the government allocated an individual €50 incentive to repair bicycles (Lozzi et al., 2020).
- ☑ In Amsterdam, the Netherlands, the municipality provided 1600 bikes to students to ensure safe travel. Lisbon, Portugal, allocated funds for creating additional bike lanes, and a new mobility fund will allow citizens to apply for financial assistance to buy bikes, with up to €100 available for students to buy regular bicycles and up to €350 for e-bikes and €500 for cargo bikes available for all citizens. In Italy, the city of Bologna accelerated works for an additional 348 km of cycle paths (Lozzi et al., 2020).
- ☑ In Hungary, the city of Budapest started building 26 km of new bicycle lanes, completing the pre-existing bike lane network. Additionally, several travel lanes were reallocated to cycling and, after significantly reducing the price of shared bikes, the usage of shared bikes increased by 20%. Communication campaigns – through both social media and the city's transport operator app – is heavily promoting active mobility (Euro cities, 2020).
- ☑ Vienna and other cities in Austria started converting more streets to shared spaces, with the streets having a speed limit of 20 km/h – while a recent change in the federal law allowed complete closure to car traffic on streets with narrow sidewalks of less than two metres width, so that people can walk on the street and adhere to physical distancing (Euro cities, 2020).

Box 1 (contd)

- ☑ Milan, Italy, launched an ambitious scheme to reduce car usage after lockdown. Called strade aperte [open streets], the plan aims at reallocating 35 km of street space from cars to cycling and walking (Euro cities, 2020). Within the entire inner-city area of Brussels, Belgium, priority will be given to pedestrians and cyclists and vehicles will have to respect a 20 km/h speed limit (Lozzi et al., 2020).

"Cycling has come out a big winner," said Jill Warren, chief executive officer, of the European Cycling Federation in 2020. It remains to be seen which cities will seize on the opportunity to make these changes permanent.

Walking and cycling have enjoyed increasing attention in recent years, reflected in a rapidly growing number of scientific and other publications. This booklet aims to provide an easily accessible scoping review of some of the latest scientific literature and examples from urban and transport planning practice. Specifically, it aims to highlight evidence from research and practice related to:

- ☑ why walking and cycling should be promoted to tackle challenges related to transport, the environment, health and beyond; and
- ☑ how walking and cycling can be promoted with the most pertinent measures and policies.

Policy-makers, planners, advocates and other stakeholders are invited to gain an up-to-date overview of the key topics of relevance for decisions pertaining to investments in and facilitations for walking and cycling. Advancing active transport is a broad endeavour, which requires collaborative efforts and knowledge transfer across various sectors, including transport, environment, inclusive societies for all and health.

This publication centres around a European perspective, however, its core conclusions can be generalized globally. By and large, the reasons for why walking and cycling should be promoted, and the ways to do so, apply to countries and cities around the world within, of course, a wide range of local variation. This is also reflected in the reviewed evidence from research and practice, which is increasingly of a global nature.

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The Region is looked up to by many as a leader at the forefront of sustainable mobility. Most major cities in the Region provide highly efficient and popular public transport systems. With two out of three Europeans living in cities with one million inhabitants or less, travel distances for many trips are compatible with active travel (United Nations, 2018). Restrictions for car use, in the form of pay-to-park schemes, congestion charges, low speed limits, and regulations on air pollution or noise, are common tools available to planners. Historic city layouts and traditionally mixed land use favour pedestrian-friendly city centres and neighbourhoods. The Netherlands and Denmark are world renowned for their gold standard bicycle infrastructure.

Nonetheless, planning for active transportation remains a fragmented patchwork across cities in the Region and beyond, where innovative leaders remain outnumbered by places stuck in old structures dominated by a car-focused approach to transport. Some aiming to break with old patterns seem forced to reinvent the wheel – to plan for walking and cycling – over and over again; and yet others seem to have found comfort in a well-established integration of active modes in their planning processes, only to see progress slowed down to a crawling pace.

In the pan-European region – which consists of the United Nations Economic Commission for Europe (UNECE) countries, namely countries in the WHO European Region plus Canada, Lichtenstein and the United States of America – the Transport, Health and Environment Pan-European Programme (THE PEP) is a policy framework that brings 56 countries together and supports joint efforts across sectors with the aim of promoting active mobility (Box 2) (THE PEP, 2022). Equally important is bolstering the exchange between national and local authorities.

Box 2
Transport, Health and Environment Pan-European Programme (THE PEP)

Transport, Health and Environment Pan-European Programme (THE PEP) is a unique intergovernmental, cross-sectoral, tripartite policy platform for policy-makers and stakeholders of the countries of the pan-European region for achieving healthy and sustainable transport and mobility.

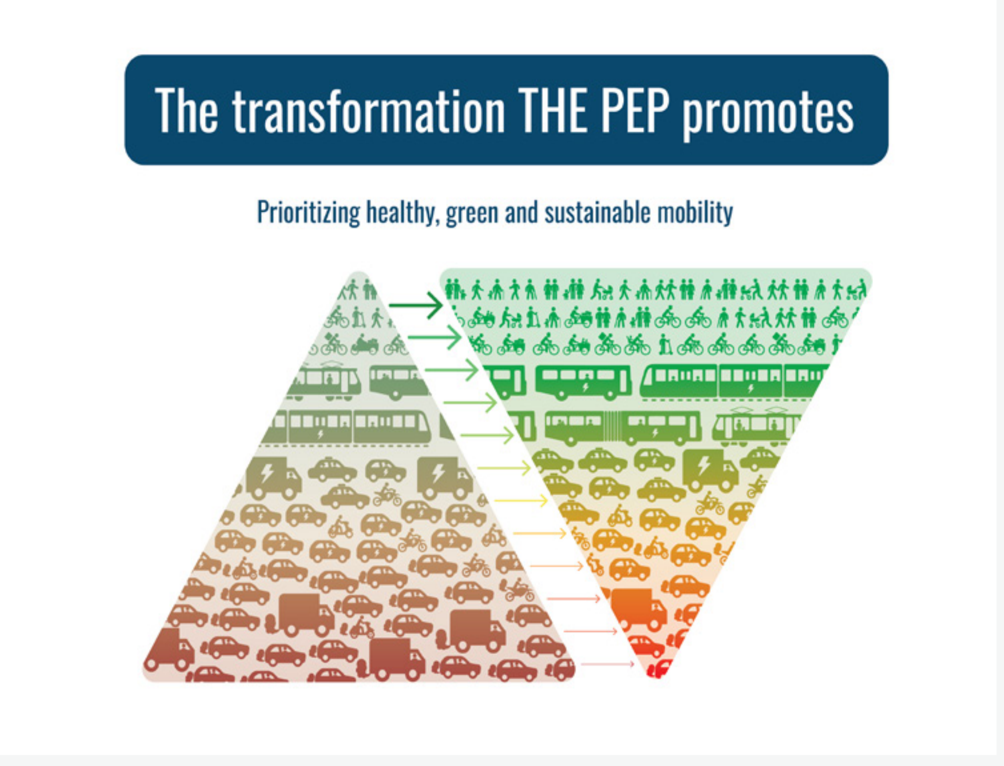
Established in 2002 and serviced jointly by the UNECE and WHO Regional Office for Europe, THE PEP is driven by the political commitments of the Member States through a series of High-level Meetings on Transport, Health and Environment, which convenes every five to six years. The Fifth High-level Meeting on Transport, Health and Environment, held in Vienna in May 2021, was hosted by the Austrian government. It brought together 46 ministers and state secretaries, and more than 850 participants from 42 Member States.

Member States adopted the Vienna Declaration, Building forward better by transforming to new, clean, safe, healthy and inclusive mobility and transport (United Nations Economic Commission for Europe, 2021), and the first Pan-European Master Plan for Cycling Promotion (THE PEP, 2021).

Box 2 (contd)

Working together for the implementation of THE PEP Workplan 2021–2025, Member States have been advancing the implementation of the 2030 Agenda for Sustainable Development on several fronts and across numerous goals and targets, including those related to health, energy efficiency, the protection of climate and the environment, the quality of urban life, and transport and health equity.

More information about THE PEP can be found on the Programme's website (THE PEP, 2022).



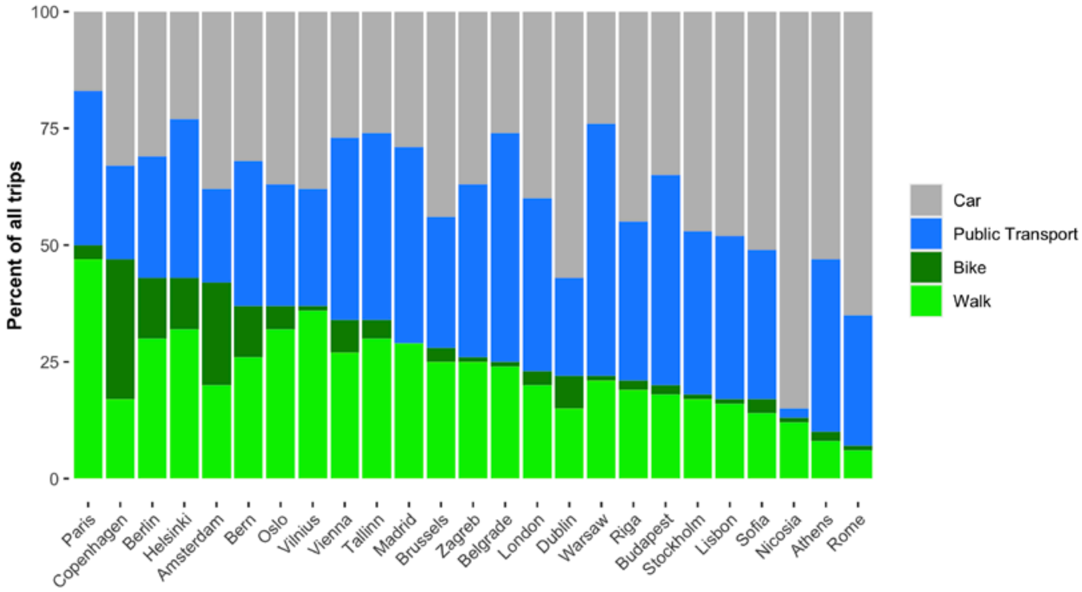
Short car trips may be the most striking indicator of the fact that the potential for active modes is far from having been exhausted. A substantial proportion of urban car trips remain very short; a fact that seems to apply ubiquitously across countries. In England, more than half of all trips between two and three kilometres long are made by car (House of Commons Transport Committee, 2019). In Austria, over 40% of car trips are shorter than five kilometres (Katsis, Papageorgiou and Ntziachristos, 2014). In Germany, the average car trip is less than 17 kilometres (Bundesministerium für Verkehr und digitale Infrastruktur, 2017). In Switzerland, more than 60% of commuter distances are shorter than 10 kilometres (Bundesamt für Statistik, 2012). Moreover, a Spanish study estimated that 30% to 40% of all car trips in a medium-sized city could be replaced by active modes (Delso, Martín and Ortega, 2018).

There is no question that urban and transport planning is an inherently local issue and there is no one-size-fits-all solution to boost active transportation (United Nations Economic Commission for Europe, 2020). Nevertheless, the continuously growing recognition of active transport modes as crucial elements of urban mobility – in places such as the Netherlands as early as after the 1970s oil crisis – has led to an accumulation of experience, testing, piloting and evaluation, which now renders obsolete the notion that every city needs to start from scratch or needs to come up with their own best approach. The first Pan-European Master Plan for Cycling Promotion developed within THE PEP Partnership for Cycling (Box 3), and adopted in May 2021 under the auspices of THE PEP framework, is the first strategic plan at the pan-European level to promote the development of cycling policies at the pan-European, national and local level (THE PEP, 2021). The European Union (EU) guidelines for Sustainable Urban Mobility are another instrument that supports local efforts with approaches proven to be effective (Rupprecht et al., 2019).

European readers are reminded that they do not have to look far to find walking and cycling success stories (Fig. 1). But at the same time, unexpected places around the world are challenging Europe's legacy as the leader in the field of sustainable transportation. To the readers beyond Europe and around the globe, we hope this booklet provides insights that inspire you to match and go beyond what several European countries have achieved for active transportation to date.

As we work towards resolving the challenges of urban mobility, the oldest and most sustainable travel modes – namely, walking and cycling and their latest technological offspring, such as e-bikes and other forms of micro-mobility – will play an increasingly important role. This requires the development of greater awareness and capacities to effectively govern these developments, so that their benefits can be maximized, and any risks understood and properly managed. An ever-growing body of science underpins the gains society can reap in terms of transport, health and environmental benefits, and planning practice has accumulated a rich portfolio of measures ready to be reapplied in every city.

Fig. 1. Distribution of travel modes across European capital cities



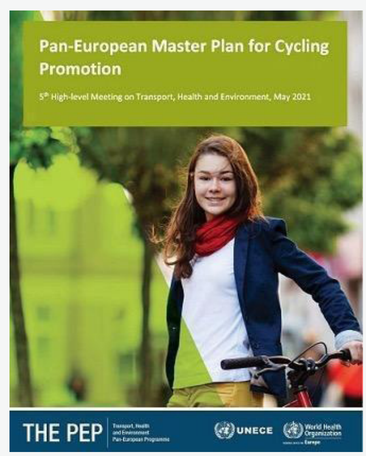
Mode shares based on main transport mode used for the most frequent trip. Ranked by share of active modes.

Source: Fiorello et al., 2016.

Box 3
The Pan-European Master Plan for Cycling Promotion

On 18 May 2021, in the context of the Fifth High-level Ministerial Meeting on Transport, Health and Environment hosted by Austria, the countries of the pan-European region adopted the Vienna Declaration and the first ever Pan-European Master Plan for Cycling Promotion (THE PEP, 2021), calling for countries to acknowledge cycling as an equal mode of transport and double cycling in the region by 2030.

The Master Plan was developed by THE PEP partnership on Cycling, actively involving 28 Member States, UNECE, WHO, the European Cyclists Federation, the Confederation of the European Bicycle Industry, as well as external experts and several civil society organizations. It is designed to help national and local stakeholders streamline efforts to promote cycling. It contains seven key objectives to be implemented by 2030:



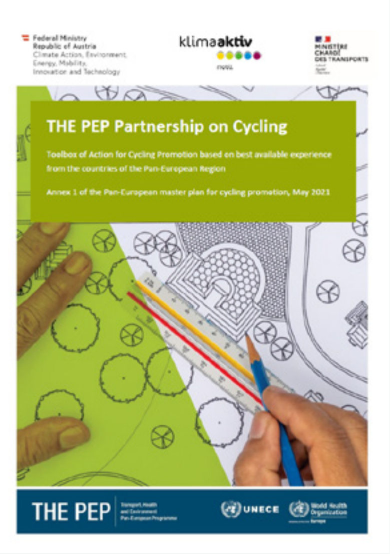
- ☑ significantly increase cycling in every country;
- ☑ develop and implement national cycling policies, plans, strategies and programmes;
- ☑ provide appropriate space in favour of active mobility;

Box 3 (contd)

- ☑ extend and improve cycling infrastructure;
- ☑ significantly increase cyclists' safety and reduce the number of fatalities and serious injuries;
- ☑ integrate cycling into health policies; and
- ☑ integrate cycling and cycling infrastructure into land use and urban, regional and transport infrastructure planning.

To help countries achieve these objectives, the Master Plan includes 33 recommendations for a broad promotion of cycling grouped under 11 policy areas.

The Master Plan is complemented by a Toolbox of Action for Cycling Promotion (THE PEP, 2021a). This is a collection of good practices on the implementation of the recommendations identified in the Master Plan, compiled and based on experiences from the countries of the Pan-European Region.



A decision was also made at the High-level meeting to expand this work through the development of a pan-European master plan on walking, which would include guidelines and tools, and establish a pan-European competence centre on active mobility to support capacity building, the sharing of good practices and implementation initiatives.

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2 Establishing walking and cycling in evidence-based planning practice

Transport planning is very much about allocating space and financial resources to various modes of transport, which makes it inherently contentious. In many cities, the historic prioritization of private motorized traffic and public transport has led to a marginalization of walking and cycling, which many cities struggle to overcome to this day. Efforts to realign priorities in transport planning in favour of active transport modes often still face stiff resistance. A car-centric paradigm, which questions walking and cycling as viable modes of transport, often categorically rejects impediments on driving (and sometimes public transport). Examples include the removal of vehicle travel lanes and parking spots, or speed reductions. Consequently, in some places, progress for cycling has been driven almost entirely by grassroots advocacy – often quite successfully, but sometimes perhaps overly confrontational.

This compilation of evidence and practice-proven policies and measures shows that simplistic arguments, such as categorically questioning the feasibility of cycling or walking, or refuting the regulation of transport as an infringement on consumers' free choice, on the one side, or portraying car-free cities as the only possible future, on the other side, belong to the past. Modern planning requires a much more pragmatic and matter-of-fact approach, where the uni-modal silos of the past are exchanged for collaborative efforts rooted in evidence-based practice to achieve policy goals. Policy goals, of course, are subject to societal negotiation. Commonly accepted policy goals centre around the need for the reduction of carbon emissions; the importance of health and quality of life; the value of an efficient urban transport mix; or the prospect that cars will play a role in the future in some shape or form. Arguably, many would also agree that the car-centric planning of the past is not sustainable environmentally or financially, nor with regards to its use of precious urban space.

Nonetheless, there is still widespread reluctance to push for more walking or cycling. Some argue consumers should be free to make their own choices. This overlooks the fact that, for many people, current travel behaviour is not a free choice without constraints and is therefore not an optimized state of a free market of transport options. Current transport patterns reflect

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how consumers weigh the advantages and disadvantages of their current transport options, which they get to choose from day by day, based on current conditions, habits and beliefs (Götschi et al., 2017). For one trip, the private car may be better suited, while for another trip, walking may be preferable. This is most obvious for the use of public transport, where, if there is a lack of access, this poses an insurmountable constraint preventing people from using it. For walking and cycling, such constraints are more subtle, for example in the form of insufficient safety and the lack of good infrastructure, many of which are related to how cities historically prioritized motorized transport.

Transport policy should therefore create conditions, parameters and circumstances that allow people to make good, optimal travel choices, resulting in a transport mix that is aligned with societal goals (Box 4). Research has produced a rich body of evidence that makes a strong case for why the promotion of walking and cycling aligns with key policy goals, namely in the areas of urban transport, environmental impacts, public health and overall prosperity, and why promoting these modes improves consumers' choices and is economically desirable. These are reviewed in section 3.

Several key factors of travel behaviour, such as availability, access, cost, social norms, convenience, attractiveness and safety, lay within the realm of urban and transport planning, and related policy areas. Promotion of walking and cycling in its broadest sense therefore means shifting these factors in favour of walking and cycling. As a result, short-term results may often appear modest. It is not possible to make walking or cycling feasible everywhere overnight, or the perfect option for every transport need. Instead, successful and sustainable promotion is the sum of many, often small improvements, each of which makes walking and cycling a bit more appealing to some people, for some trips, in some situations, on some days. The degree of success of walking and cycling promotion must be measured by the cumulative result of such efforts. Thinking of the promotion of walking and cycling as a continuous endeavour, rather than a radical change, leaves plenty of space for ambition. Broader policies, more projects, and better integration will result in faster progress. Research and practice have identified several effective targets for such improvements. This publication aims to facilitate the transfer of such evidence into the urban and transport planning practice. In section 4, we take a systematic look at some of the most promising approaches across a wide spectrum, from street design to national policies.

Box 4
Linking transport, health and environmental goals to consistent planning practice and design in Copenhagen, Denmark

Copenhagen, Denmark, has built a coherent network of over 386 kilometres of cycle tracks, and 64 kilometres of green cycle routes that have been placed in natural surroundings and far from car traffic. Cycling is an important element in the declared goal of making Copenhagen carbon-neutral by 2025, and almost half of all daily trips to work or school in Copenhagen are done by bike.

On a strategic level, cycling in Copenhagen is supported through several strategic policy papers. First and foremost is the Municipal Plan, which states that the bicycle is the preferred mode of transport for Copenhageners. The specific goals and measurables related to bringing cycling in the city to the next level are contained in the city of Copenhagen's Bicycle Strategy 2011–2025, Good, better, best. The strategy functions as a visionary policy document that links the underlying reasons behind promoting cycling – such as economic, health, environmental and quality of life – with concrete decision-making, such as for street design, street cleaning and maintenance, car parking provisions, public transport planning, parks and open space, and neighbourhood renewal. Significant care and attention are given to street design, using both vertical and

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Box 4 (contd)

horizontal cues and devices to support active travel. Interventions are chosen from a mix of validated and constantly developing designs.

The secret of cycling in Copenhagen lies in its convenience. Cycling in Copenhagen is comfortable, fast and safe, and when asked why they cycle, more than half of Copenhageners say it is because it is the fastest method of transportation. Cycle tracks, the main staple in Copenhagen's cycle infrastructure, have emerged to a gold standard for cycle route design. Found alongside many main roads, they are tarmac paths segregated vertically, by low curbs, from both cars on the roadway and pedestrians on the pavement. Vertical cues are also used at side road junctions, maintaining a continuity of level and priority for the cyclist; cars that are entering or exiting the side road must cross the raised cycle path. This junction design often also involves reducing road space for parked cars and increasing pedestrian quality with seating and trees or shrubs. At major intersections, a diverse portfolio of other measures is used to improve cyclist safety, including forward stop lines for cyclists, blue lanes highlighted across intersections for cyclists, and advanced green light phases for cyclists.

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Why walking and cycling should be promoted

This section summarizes some of the most compelling scientific support to promote walking and cycling, while distinguishing impacts on transport, the environment and health (Fig. 2).

3.1. Mobility: optimizing urban transport

Walking and cycling are space-efficient travel modes – an aspect that is ever more important as urban populations keep growing and transport competes for increasingly scarce space. How much space the individual traveller requires translates sooner or later into how much space needs to be allocated for roads and parking (Fig. 3). Some studies have estimated that European cities allocate one-fifth of their space to transport and about half of that to cars (Gössling et al., 2016; TransportShaker, 2018). Various publications contrast the space requirements by mode, clearly showing that cars require the most space and pedestrians require the least, with public transport similarly as efficient as walking. Findings for cyclists are somewhat mixed, probably because the density and speed of bicycle traffic, as well as cycling infrastructure, vary across cities. For example, while the Bicycle Plan for Amsterdam (City of Amsterdam, 2017) estimates bicycle traffic to be about 30 times more space-efficient than driving, a micro-simulation based on values from Copenhagen has bicycle space requirements at a little more than half of those for driving (PTV Group Traffic, 2016).

The extent to which a mode shift from car to more space-efficient walking, biking and e-biking leads to congestion relief is not well understood. While in some cases there may be some merit to concerns that allocating road space to bicycle infrastructure may worsen car congestion in the short-term, it is important to keep in mind the long-term increase in transport utility from allocating road space to

Fig. 2. Mapping out the benefits of walking and cycling

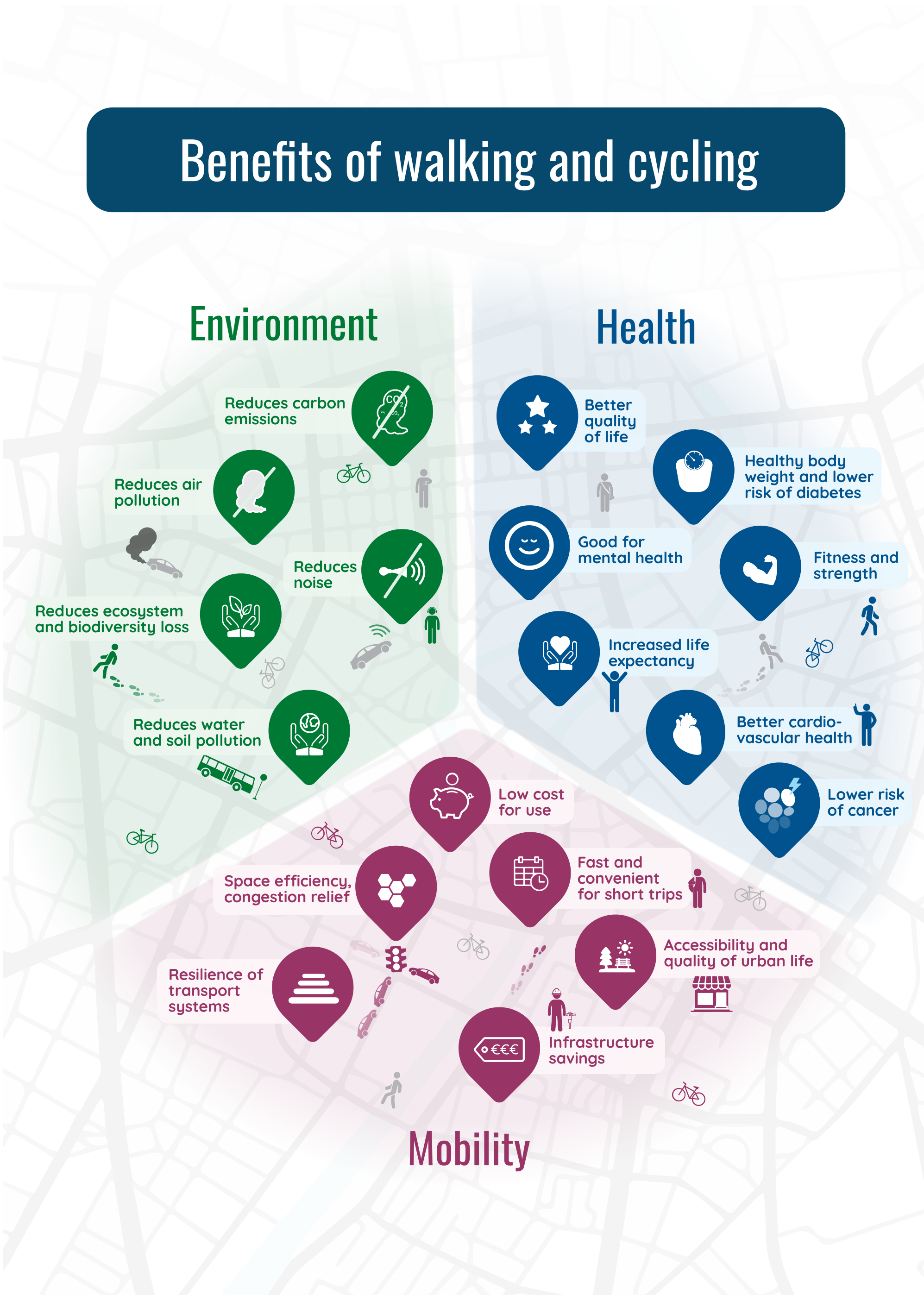
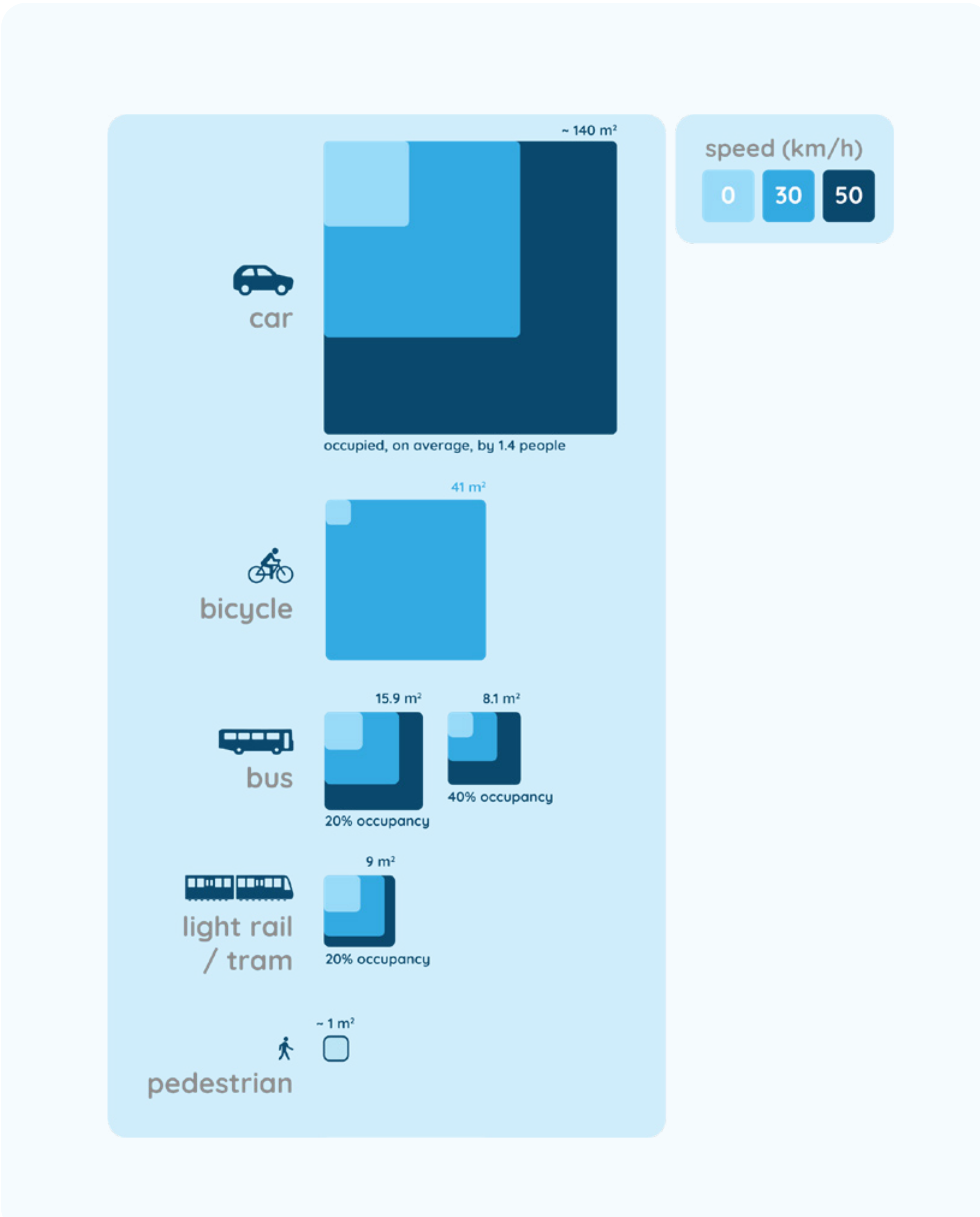


Fig. 3. Space requirements by travel mode, as presented in Amsterdam's bicycle plan



Source: Department of traffic and public space of the city of Amsterdam, 2017.

the most efficient modes. The European FLOW project (Furthering Less congestion by creating Opportunities for more Walking and cycling) investigated 20 case studies of pedestrian and cycling measures and found that congestion was reduced in ten cases, no effect in eight cases, and a slight increase in congestion in only two situations (FLOW Project, 2016).

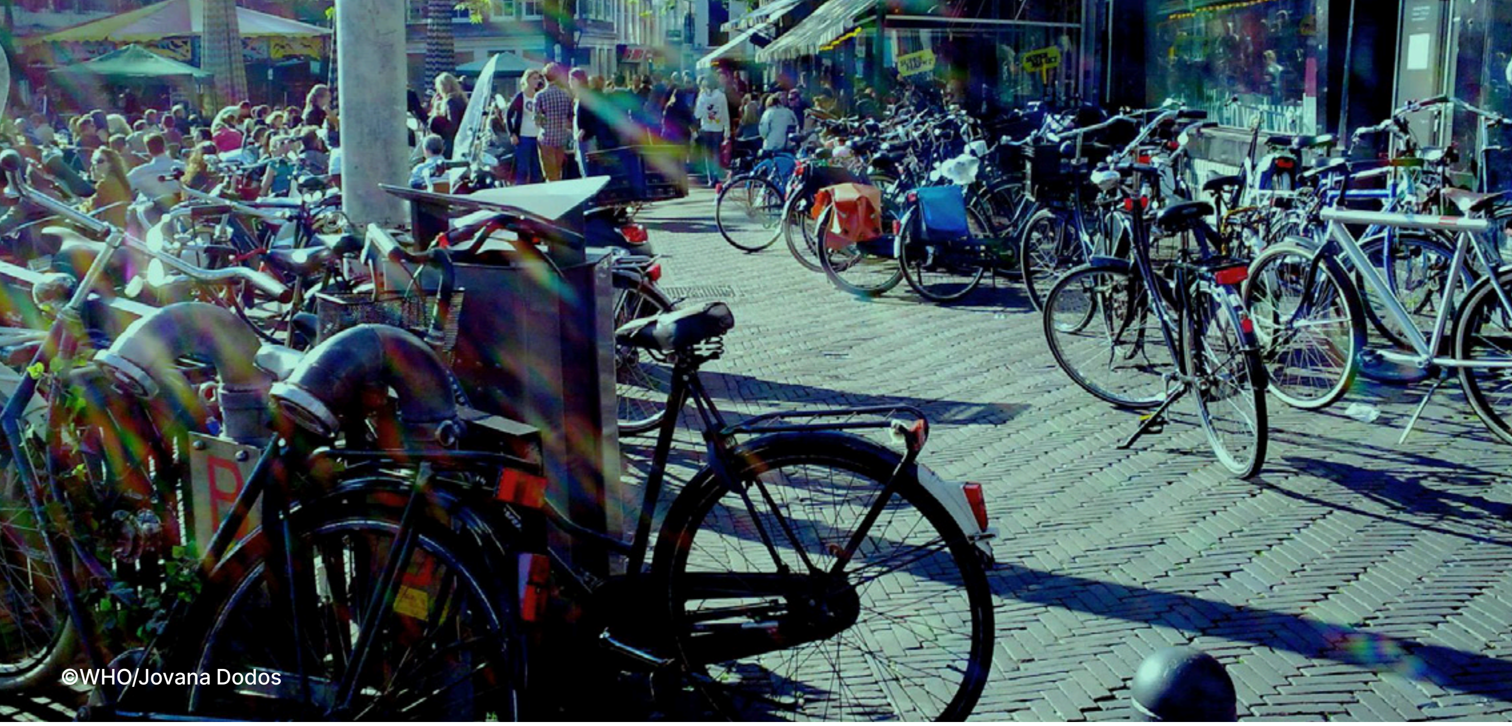
Similar considerations apply to parking space, and in particular curb side space, which may be on track to become the scarcest resource in cities. As streets become more walkable, inviting spaces, restaurants and cafes are eager to offer outdoor, roadside dining. Ride-hail services are becoming ever more popular, and steadily increasing online trade translates to increased deliveries. The parking-to-car ratio of European cities may not be as excessive as in some American cities (Scharnhorst, 2018), nonetheless the European Parking Association estimated in 2013 that there were 40 million regulated parking spots, 15 million of which were on streets, plus close to two hundred million unregulated spots, compared to about 250 million registered vehicles. Parking space requirements for a single car, which carries on average 1.3 passengers, are at least 10 times higher than for a bicycle. Accommodating bicycle access and parking, and providing attractive pedestrian facilities, are successful strategies to alleviate parking pressure in areas with scarce parking supplies, such as shopping districts, event venues and other locations that attract large crowds, and are equally so across residential neighbourhoods.

Road infrastructure costs by travel mode are notoriously difficult to quantify, since road-using modes are often lumped together (Schroten et al., 2019a). But it is clear that lesser space requirements and the low weights of active travel modes eventually translate into cheaper infrastructure, which does not need to be built as sturdily and suffers less from wear and tear than that for motorized modes. Cost savings can further be attributed to infrastructure that can be built faster, delivering its benefits in a shorter period of time and reducing the extensive inconvenience created by major road or public transport infrastructure projects, which can take several years to complete.

Active modes are often considered slow. While this certainly applies to walking, cycling in contrast is highly time-competitive for a large fraction of urban travel needs, in particular when door-to-door time is considered, and in very congested cities, where the average speed of trips undertaken by car may be well below the average of 12–15 km/h for cycling at a relaxed pace. This is even more the case for e-biking (Box 5).

For some of what active modes lack in travel speed, they can make up in travel time reliability, which is a key indicator in congestion management (Batley et al., 2019). It considers travellers needing to factor in possible delays (e.g. due to congestion) when determining their departure time for trips that require timely arrival (e.g. to work). If travel time is not reliable, gains from shorter travel time are lost because they do not translate into later departure times. Because walking and cycling are not affected by congestion or similar variables, cyclists and pedestrians do not need to factor in extra time due to travel time variability.

Traffic safety is an important issue for walking and cycling. The health risks for pedestrians and cyclists resulting from crashes are discussed further below. However, an indirect effect of promoting walking and cycling is worth mentioning here. Research has shown that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transport systems that are safer for active travel modes are safer for all transport users, presumably because walking- and cycling-friendly street designs result in reduced driving speeds (Marshall and Ferenchak, 2019).

Walking, and increasingly cycling, create key synergies with efficient public transport systems (Buehler et al., 2017; Tønnesen et al., 2020). How attractive the access paths to public transport are, how convenient the storing of bicycles is at public transport stations, and whether there are good possibilities to carry bicycles on public transport (e.g. metro and urban/regional rail) are important determinants of the overall appeal of public transport. Conversely, it is important for pedestrians, and to a lesser degree, cyclists, to be able to rely on public transport for trips that do not favour active travel, or during adverse weather conditions.

Walking- and cycling-friendly transport systems also lessen the pressure for urban residents to own their own car, a trend that is being enforced by the rise of car-sharing and ride-hailing systems, and particularly noticeable among younger city dwellers (Nicola and Behrmann, 2018).

Finally, cycling in particular has been shown to provide a resilient alternative for times when other modes fail to reliably perform, be it because of congestion due to road closures, public transport reaching its capacity, or during more extraordinary times of crises, as for example during the COVID-19 pandemic, when riding in public transport was not considered safe.

However, urban transport is more than just transport. While transport has always been recognized as a means of access to necessities and opportunities, and hence essential for economic prosperity, for too long its environmental and health impacts remained secondary thoughts. As a more holistic take on sustainable urban living takes hold, the emission-free and health-promoting nature of active travel modes provides a tremendous boost to their benefit-cost balance.

Box 5
E-bikes: an emerging healthy and sustainable mode of transport

Electrically assisted bicycles (e-bikes, or pedelecs) have become increasingly popular in the past decade. In many European countries, e-bikes represent one of the fastest growing transportation industries, with sales in Germany in 2018 accounting for 23.5% of all bikes sold, while more than half of the adult bikes sold in the Netherlands in 2018 were electric (Cooper, Page and Bourne, 2020).

In addition to increased popularity, the evidence suggests that the personal use of e-bikes is associated with a reduction in motorized vehicle use, favouring both health and the environment, by increasing levels of physical activity and decreasing traffic noise, greenhouse gas emissions and urban air pollution (Bourne et al., 2020).

In 17 studies assessing the health benefits associated with e-biking, it was found that the use of e-bikes can contribute to meeting physical activity recommendations and increasing physical fitness (Bourne et al., 2018). For those with health conditions, such as obesity or orthopaedic diseases, who may particularly benefit from physical activity but often find it difficult, e-biking may be an important way to become more regularly active (Cooper et al., 2018;

Basel, Switzerland. E-bikes offer advantages in terms of speed and carrying capacity, while maintaining the requirement to pedal.
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Box 5 (contd)

Cooper, Page and Bourne, 2020). E-bikes also have the potential to re-engage older adults with cycling and provide an opportunity to increase physical activity and engagement with the outdoor environment, which can have a positive impact on their well-being (Leyland et al., 2019).

In addition, e-bikes have proved to be an attractive and acceptable option for people living in hilly places, having a long commute and/or not feeling fit enough to cycle very far or at all because they make cycling easier, requiring less effort to ride. The use of e-bikes could, therefore, address commonly reported barriers to active travel, such as the distance people must travel, lack of time, hilly terrain, and the undesirability of being out of breath or sweaty when arriving at a destination (de Geus et al., 2008).

Examining the impact of e-bike use on other travel modes, it has been found that the uptake of e-cycling substitutes not only for conventional cycling, but also quite substantially for private car and public transport journeys; the proportion of car journeys substituted after people bought e-bikes ranged from 20% to as high as 86% (Bourne et al., 2020), potentially reducing both motor vehicle congestion and air pollution. Life cycle analyses demonstrate that e-bikes are more energy efficient and less polluting than conventionally powered motor vehicles and public transport systems (Weiss et al., 2015).

The impact of the e-bike on travel behaviour is largely influenced by the primary mode of travel prior to the introduction of the e-bike. Specifically, in Antwerp e-bikes primarily substituted for conventional bike journeys (34%) and private car journeys (38%), while in Zurich the e-bike primarily substituted for public transport journeys (22%) (Castro et al., 2019).

The large-scale adoption of e-bikes can therefore decrease urban air pollution when substituting for conventionally powered cars and demand for infrastructure when substituting for passenger cars.

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Box 5 (contd)

While physical activity benefits could be reduced if e-bikes substitute for conventional bicycle use (Weiss et al., 2015), evidence suggests that e-cyclists compensate the ease from electric-assist by riding further and more often (Castro et al., 2019).

The particular appeal of e-bikes to elderly riders highlights the importance of safety considerations. Crash risks can be higher for e-bikes than conventional bikes, although the exact magnitude and reasons for this are not sufficiently understood. Swiss data suggests a doubling of risk in older age groups, whereas the risk in younger adults is comparable to cycling (Fig. 4) (Uhr and Hertach, 2017). Safety factors of relevance are the higher speeds and greater weight of e-bikes, while demographic factors such as age, risk-taking behaviour, and fragility make comparisons difficult. Safety policies should be of high priority in light of the popularity of these new modes; examples include the provision of adequate cycling infrastructure; introduction of 30 km/h speed limits on streets and enforcement of traffic laws. These should be complemented with encouraging helmet wearing and requiring them for fast e-bikes that can reach speeds of up to 45 km/h, similar to requirements for motorbikes.

3.2. Environment: zero emissions for real

Transport-related carbon emissions per person in Europe are about twice the global average, and despite increased reduction efforts, transport emissions on average have basically remained the same for the past decade from 2010–2019 (SLOCAT Partnership, 2021).

In contrast to electric cars, which remain to a large extent powered by energy from fossil fuels, active transportation modes are basically carbon neutral (Brand et al., 2021a; Neves and Brand, 2019) (Box 6).

When comparing the life cycle emissions of carbon dioxide of each travel mode, taking into account the carbon generated by making the vehicle, fuelling it and disposing of it, empirical research suggests that emissions per kilometre are at least 30 times lower for cycling than driving a fossil fuel car, and about ten times lower than driving an electric one (Brand et al., 2021b).

Cars are responsible for approximately 12% of Europe's greenhouse gas emissions (Haas and Sander, 2020). In contrast to other sectors, transport emissions have been increasing until recently (European Commission, 2016), as car manufacturers have been sluggish in increasing fuel efficiency and adopting new technologies, and the limited gains in fuel efficiency have been compensated by increased travel and vehicle weight with the growth in ownership of Sports Utility Vehicles.

To achieve ambitious greenhouse gas reduction goals (European Commission, 2019), a broad set of transport policies will be required, including shifting some travel to active modes. Particularly promising in this regard is the rise in e-bikes, which thanks to their increased range bare the potential to substitute for a sizable fraction of urban car trips (Bigazzi and Wong, 2020). Walking and cycling do not cause any tailpipe emissions, sparing people from exposure to harmful air pollutants (Castro, Künzli and Götschi, 2017). The same is true for traffic noise, which has also been linked to health (Babisch, 2014).

Box 6
Active travel can contribute to tackling the climate emergency

Globally only one in every 50 new cars (International Energy Agency, 2020) were fully electric in 2020, while in the United Kingdom, it was one in 14; increasing to 1 in 6 by 2022 (Lilly, 2021). However, even if all new cars were electric from now on, it would still take 15 to 20 years (Keith, Houston and Naumov, 2019) to replace the world's fossil fuel car fleet. As such, the emission savings from replacing all those internal combustion engines with zero-carbon alternatives will not feed in fast enough (Creutzig et al., 2018) to make the necessary difference in the time we can spare, which is the next five years (Forster, 2020). Tackling the climate and air pollution crises requires curbing all motorized transport, particularly private cars, as quickly as possible. Focusing solely on electric vehicles is actually slowing down the race to zero emissions (United Nations Framework Convention on Climate Change, 2021).

This is partly because electric cars are not truly zero-carbon (EEA, 2020) and will not solve all the problems associated with car-dependent lifestyles (International Transport Forum, Organisation for Economic Co-operation and Development, 2021), such as social inequity, traffic congestion, road deaths and some aspects of local air pollution. One way to reduce transport emissions relatively quickly, and potentially globally (Cuenot, Fulton and Staub, 2012), is therefore to swap car journeys for cycling, e-biking and walking.

But how much carbon can active travel save daily? And what is its role in reducing emissions from transport overall?

Addressing the first question, it has been shown time and again that people who walk or cycle have lower carbon footprints from all daily travel,

Box 6 (contd)

which may include car trips to the supermarket or rail trips to work, including in cities where many people are already doing this. Even though some walking and cycling happens on top of motorized journeys instead of replacing them, more people switching to active travel would equate to lower carbon emissions from transport on a daily and trip-by-trip basis.

Over a two-year period, empirical research conducted with thousands of urban dwellers in seven European cities revealed that people who cycled daily had 84% lower carbon emissions from all their daily travel than those who did not. The research also found that the average person who shifted from using a car to a bike, for just one day a week, cut their carbon footprint by 3.2 kg of carbon dioxide. This is equivalent to the emissions from driving a car for 10 km, eating a serving of lamb or chocolate (Stylianou, Guibourg and Briggs, 2019), or sending 800 emails (Griffiths, 2020).

With regards to the second question, it has been shown (Brand et al., 2021a) in longitudinal studies that urban residents who switched from driving to cycling for just one trip per day reduced their carbon footprint by about half a tonne of carbon dioxide over the course of a year and saved the equivalent emissions of a one-way flight (EEA, 2020) from London to New York. If just one in five urban residents permanently changed their travel behaviour in this way over the next few years, it would cut emissions from all car travel in Europe by about 8% (Brand et al., 2021a).

A mode shift from car to active travel is possible for trips up to 16 km in length. Such trips are responsible for 40% of carbon emissions from cars. So, even if not all car trips could be substituted by active travel, the potential for decreasing emissions is considerable.

3.3. Health: major benefits, and some risks

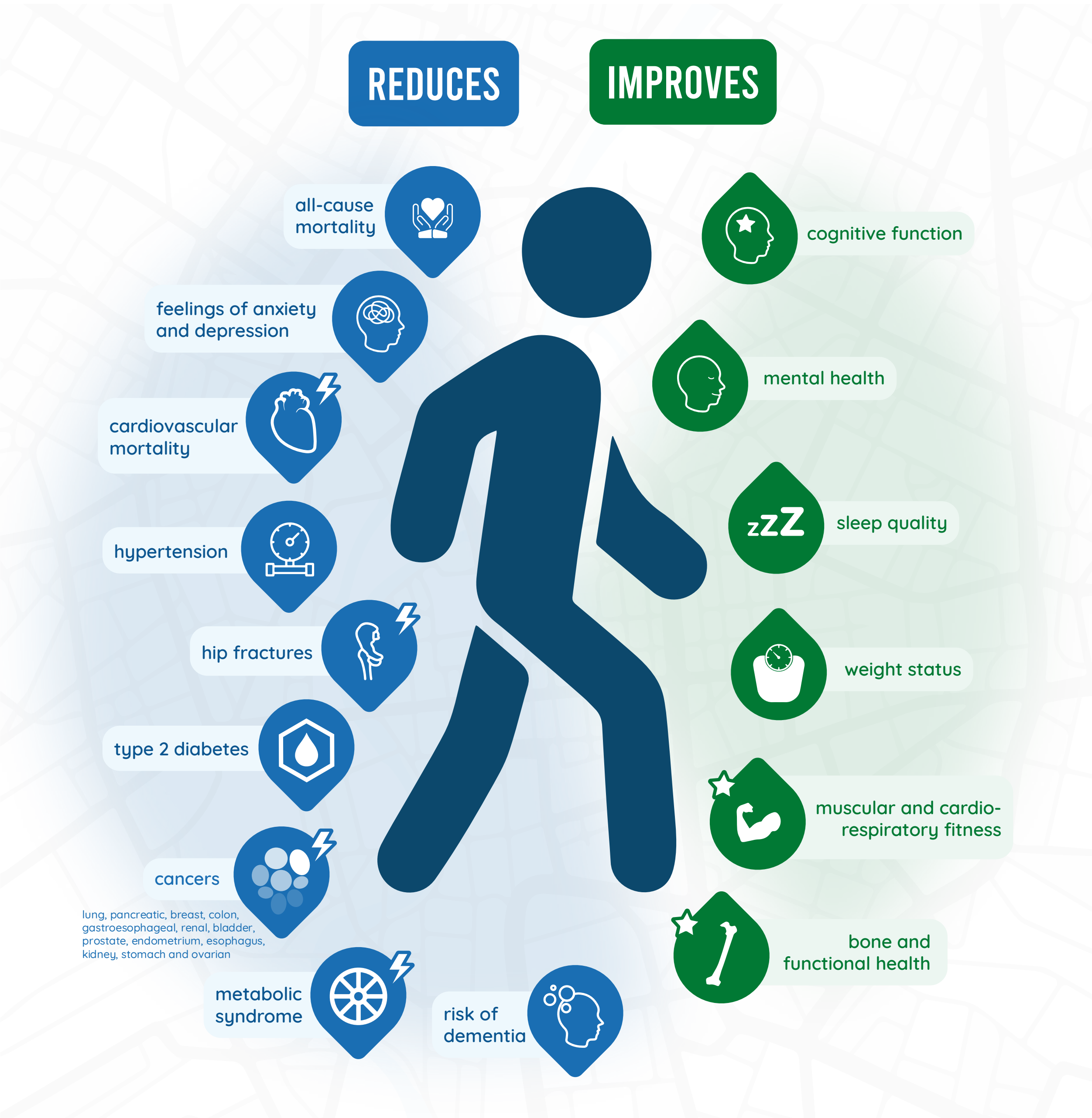
For decades, transport-related health considerations mainly focussed on the adverse effects of road safety, air pollution and noise (Davis, 2005; Litman, 2013). With the re-emergence of active travel modes as serious proponents in the transport discourse, the transport and health paradigm had to be expanded to include benefits from physical exercise (Dora, 1999; Dora, Phillips and WHO Regional Office for Europe, 2000; Litman, 2013). In the following sections, the health impacts of walking and cycling are reviewed along the most important impact pathways (Fig. 4). Box 7 presents a glossary of public health terminology used throughout this section.

Physical activity

WHO recommends at least 150 minutes of moderate-intensity physical activity per week for adults, and children should be active on average for at least one hour per day (World Health Organization, 2020a). In Europe, almost one out of four European adults, and four out of five school-going adolescents, are not sufficiently active (Guthold et al., 2018, 2020). The annual number of deaths caused by insufficient physical activity globally has been estimated anywhere between one to six million (Lee et al., 2012; Lim et al., 2012; Lancet GBD, 2020), and the annual number of premature deaths prevented by sufficient physical activity globally was estimated at four million (Strain et al., 2020). WHO estimates that physical inactivity causes about one million deaths each year in the WHO European Region alone (World Health Organization, 2009).

Physical activity is an important determinant of health. Physiologists distinguish between moderate-intensity physical activity – between three and less than six METs, which includes activities such as gardening, dancing or brisk walking – and vigorous-intensity physical activity, with 6 or more METs, which includes activities such as fast swimming or running. A vast body of epidemiologic literature has associated moderate-intensity physical activity with risk reduction for a large number of health outcomes including all-cause mortality, cardiovascular disease, several types of cancer, type 2 diabetes, dementia, depression, and others (2018 Physical Activity Guidelines Advisory Committee, 2018). The beneficial effect of physical activity on mortality risk has been recognized for a long time and it may be the most studied and best understood health outcome associated with physical activity. But in its relevance for public health, it should be thought of as the tip of a spear. Similar mechanisms that lead to extended duration of life due to regular, long-term physical activity also reduce the risks for getting diseases earlier in life. The benefits of physical activity therefore equally manifest in longer life and improved quality of life, a concept captured in the measures of disability-adjusted life years (DALYs) and quality-adjusted life years (QALYs), both of which are considered to be more comprehensive for quantifying health benefits than just mortality.

Fig. 4. Health benefits of walking and cycling



Box 7
Glossary of public health terminology

To grasp the relationship between transport and health, it is helpful to introduce a few key concepts and terms from health science, which includes public health and epidemiology.

- Public health is concerned with health at the **population level**, in contrast to a doctor, who is concerned with the health of **individual** patients. While individual health varies dramatically from person to person, there are nonetheless many factors that can be generalized and that will hold true at the population level, which is what the discipline of epidemiology is concerned with.
- To judge the public health relevance of a **risk factor**, one needs to consider **how healthy** or unhealthy it is, and **how many people** are affected by it, for example through exposure to a source of pollution or a certain behaviour. Epidemiologists will distinguish generalizable **health effects** of a **risk factor** and specific **health impacts**, or the **burden** that a risk factor causes in a specific population. These can be either beneficial or detrimental.
- Health effects are sometimes referred to as health outcomes or health responses. They can be harmful or beneficial.
- Health effects depend on the **dose**, or amount of **exposure** to a risk factor. A higher dose leads to a stronger effect. But a **dose-response relationship** does not always have to be linear. In other words, the same increase in dose or exposure may result in a different effect size, depending on the starting level, or baseline.
- **Pathways** refer to how health effects in the human body come to be, such as along which exposure, physiological or impact pathways.
- **Metabolic equivalent of task (MET)** is a measure for the intensity of physical activity.

Other beneficial effects predominantly affect overall quality of life, such as reduced risk of excessive weight gain, feelings of anxiety and depression, and improved sleep (2018 Physical Activity Guidelines Advisory Committee, 2018). And beyond direct disease prevention, physical activity has been linked to bone strength, improved cognitive and physical function, and reduced risk of injury associated with falls among the elderly. More recent research suggests that physical activity may be beneficial for school-age academic achievement (Barbosa et al., 2020), which provides further grounds to invest in safe routes to walk and bike to school. Research related to commuters suggests that active commuting has a positive effect on work performance and sick leave (Ma and Ye, 2019; Hendriksen et al., 2010; Mytton, Panter and Ogilvie, 2015). More recently, research has also confirmed benefits of even only light intensity activity, and independent harms related to excessive sitting time (2018 Physical Activity Guidelines Advisory Committee, 2018).

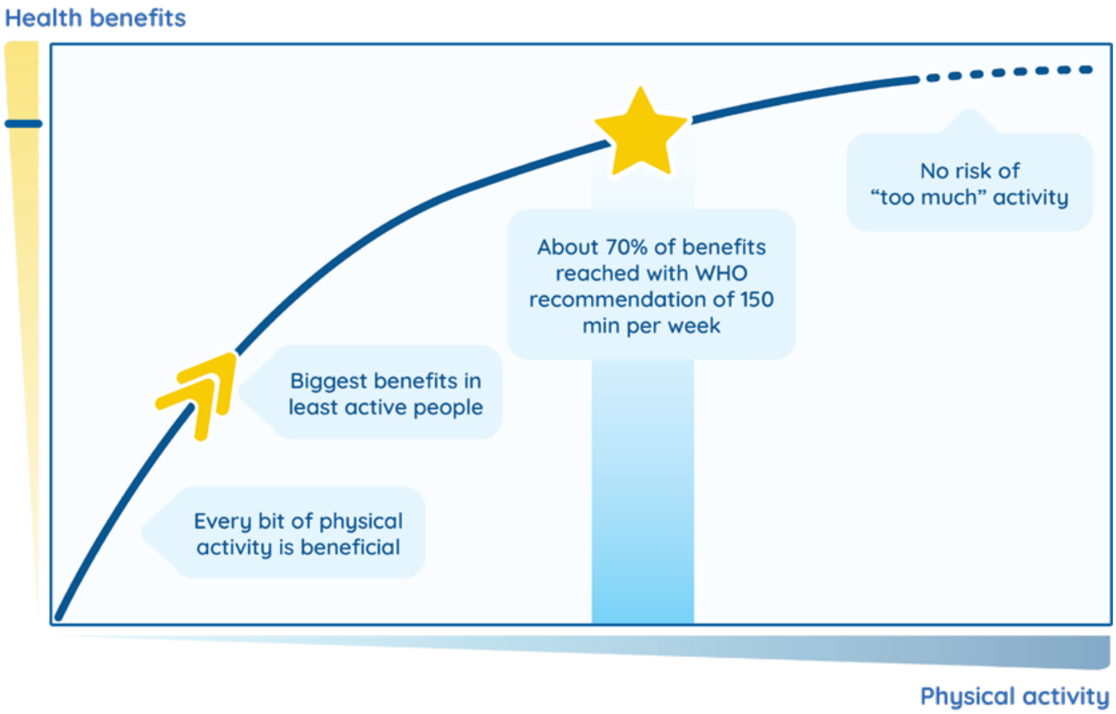
To achieve such benefits, physical activity does not necessarily have to be high-intensity, as would typically be the case with sports and some modes of exercise. Moderate-intensity activity, such as from walking or cycling, is sufficient. Walking is typically less intense, at 4 METs, than cycling, at 6.8 METs; and e-biking is somewhere in-between, at roughly around 5 METs (Castro et al., 2019). More importantly, the activity must occur somewhat regularly and over the long-term. The benefits of physical activity follow a non-linear dose-response curve (Fig. 5). As levels of physical activity increase (horizontal axis) the resulting health benefits increase (vertical axis). The strongest benefits occur in inactive, or barely active people that manage to add some activity to their daily routines. With higher activity levels, benefits still increase, but less strongly. People who achieve the minimum level of WHO's recommendation of 150 minutes of moderate-intensity physical activity per week attain at least 70% of potential benefits, but there is no harm from being even more active. Equally, there is no minimum threshold that needs to be reached before physical activity becomes beneficial, which practically means that every amount of activity counts and is better than nothing (2018 Physical Activity Guidelines Advisory Committee, 2018).

It is exactly these characteristics of the health-enhancing nature of physical activity – the requirement of having only moderate intensity, the need for regular activity, and the benefits already had at low levels of activity – which make active travel, such as walking and cycling, perfectly suited as a source of physical activity. Numerous studies show that active travel translates into higher overall levels of physical activity. Thus, walking and cycling do not merely substitute for other forms of exercise, but rather, at least in part, replace passive forms of transport (Aldred, Woodcock and Goodman, 2021; Buehler, Pucher and Bauman, 2020; Goodman, Sahlqvist and Ogilvie, 2014; Götschi and Hadden Loh, 2017; Mäki-Opas et al., 2016; Raser et al., 2018; Sahlqvist et al., 2013). The same appears to be true for e-biking (Castro et al., 2019).

There are also a sizable number of studies that specifically investigated the effects of walking and cycling directly on health, rather than studying physical activity in general (Dinu et al., 2019; Kelly et al., 2014; Zhao et al., 2021). Walking 30 minutes or cycling 20 minutes on most days reduces mortality risk by at least 10% (Kelly et al., 2014) and possibly even more for cycling (Dinu et al., 2019; Zhao et al., 2021). Active commuting is associated with about a 10% decrease in risk for cardiovascular disease (Dinu et al., 2019;

Fig. 5. Key facts about the dose-response relationship between physical activity and health benefits

Health benefits (vertical axis) increase as physical activity (horizontal axis) increases.



Source: adapted from 2018 Physical Activity Guidelines Advisory Committee, 2018.

Hamer and Chida, 2008) and a 30% decrease in type 2 diabetes risk (Dinu et al., 2019). Cancer-related mortality is 30% lower among bike commuters (Dinu et al., 2019).

Counter to the general notion, the evidence for weight loss from physical activity is scarce. However, there is substantial evidence that shows physical activity, including from active travel, prevents excessive weight gain, supports maintenance of healthy weight, and prevents obesity (2018 Physical Activity Guidelines Advisory Committee, 2018; Brown et al., 2017; Dons et al., 2018; Wanner et al., 2012). Obesity, on the other hand, has been identified as a barrier to cycling (Kroesen and De Vos, 2020) although this hurdle is being substantially attenuated with the ascent of electric-assist bikes (Rérat, 2021).

Injury risk from falls and collisions

Injury risk is the biggest and quite possibly the only real concern for active travel, and in particular, for cycling. The likelihood of getting injured while walking or cycling is very small, but crashes (i.e. collisions and falls) can cause great harm, and

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unsafe traffic conditions are intimidating. Traffic safety therefore plays a key role in the promotion of active travel. This section provides an overview of what is known about risks of crashes for active travel and puts some of the data in perspective. Many safety-relevant aspects are further addressed in the section on how to promote walking and cycling (Section 4). Box 8 presents a glossary on traffic safety related terminology used throughout this section.

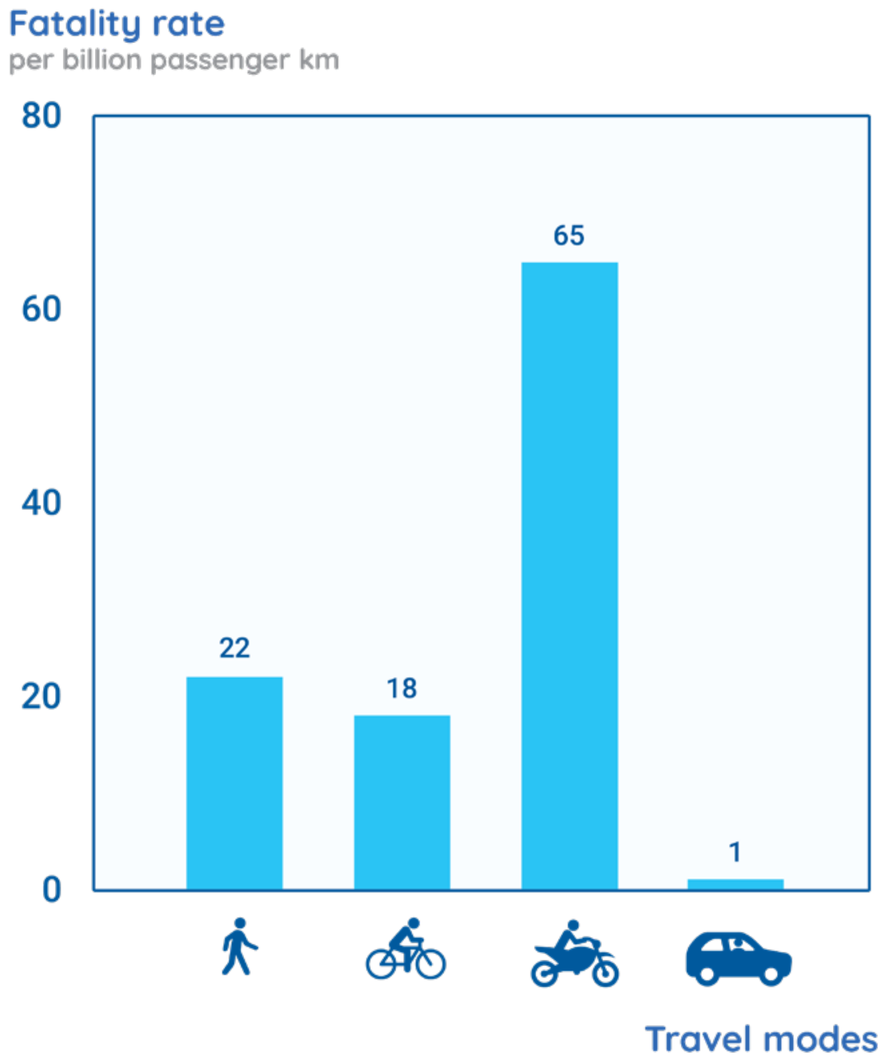
Health impact assessments show that the societal impacts of traffic crashes involving cyclists and pedestrians are typically outweighed by the benefits from physical activity (Doorley, Pakrashi and Ghosh, 2015; Mueller et al., 2015), but they can cause tremendous suffering to the individuals hurt, or worse, fatality. Worldwide, around 270 000 pedestrians and 40 000 cyclists die in traffic every year. Injury data are less reliable but estimates for pedestrians are in the range of 12 million (World Health Organization, 2018), whereas for cyclists there are no consistent estimates available (World Health Organization, 2020b). In the WHO European Region, 84 000 people die from road injuries annually, including over 20 000 pedestrians and over 3000 cyclists (WHO Regional Office for Europe, 2015, 2016). While traffic fatalities have declined steadily over the past decade, fatalities of pedestrians and cyclists have stagnated in recent years. Pedestrians and cyclists are vulnerable road users. Consistently, pedestrians and cyclists make up a disproportionate share of road victims compared to their share of distance travelled. Crash risks *per distance travelled* can be 10 to 20 times higher for pedestrians and cyclists than for driving or public transport (Fig. 6) (Department for Transport, 2019; Feleke et al., 2018), whereas the discrepancy is reduced to about two to three times higher when the rates are expressed *per time travelled* (Feleke et al., 2018). Perceived lack of safety also poses a serious hurdle for more people to take up active travel, especially for cycling, which causes indirect harm through self-imposed inactivity (Porter et al., 2020).

Box 8
Glossary of traffic safety terminology

To grasp the safety risk associated with active travel modes, it is helpful to introduce some key concepts from safety research.

- **Crash types** may be distinguished by various categories, such as: collision type (e.g. falls, or collisions with objects (e.g. single vehicle crash), between vehicles, or between vehicles and pedestrians); severity of the resulting injury (e.g. slight, moderate, severe, fatal); and by who is at fault of causing the crash.
- Absolute **numbers of crashes** provide insight on the overall magnitude of a safety problem (e.g. number of cyclists injured at a specific intersection in the past 5 years), whereas crash rates provide a relative estimate for how dangerous or risky an activity or location is.
- **Crash rates** relate the number of incidents (i.e. crashes) to a corresponding exposure (i.e. the volume of traffic that led to the incidents). Understanding the corresponding exposure is key to understanding the meaning of a crash rate (Götschi, Garrard and Giles-Corti, 2015).
- **Data on the road safety of active travel modes** are limited. Commonly available statistics relate crashes to the population size of a country or region, while more informative rates, which relate the number of crashes to the actually travelled distance by walking or cycling (i.e. **exposure-adjusted crash rates**), are only rarely available (Castro, Kahlmeier and Götschi, 2018).

Fig. 6. Fatality rates for vulnerable road users in the United Kingdom, 2019



While the odds of dying in traffic are generally small, at approximately 1 pedestrian death per 45 million km of walking in the United Kingdom, crash risks are substantially higher for vulnerable road users – approximately 20 times higher for active travel, compared to driving.

Source: Department for Transport, 2019.

The magnitude of crash rates for walking and cycling are not inherently linked to these modes, but depend heavily on local circumstances, such as traffic conditions and quality of infrastructure, as comparisons across countries show. Although such comparisons are challenging due to data comparability, a number of studies show variations of rates that are several times lower between the safest and the least safe locations. In a comparison between European countries (Castro, Kahlmeier and Götschi, 2018), rates for fatal cycling crashes were lowest for the Netherlands, Denmark and Norway – rates that were less than half of those in countries such as France, Austria and Belgium, and five times lower than in Italy. For walking, fatal crash rates were lowest in Norway, the Netherlands and Switzerland, while rates four to five times higher than these were observed in France, Austria and Italy (see Fig. 7). For many countries with less reliable data, rates appeared to be dramatically higher.

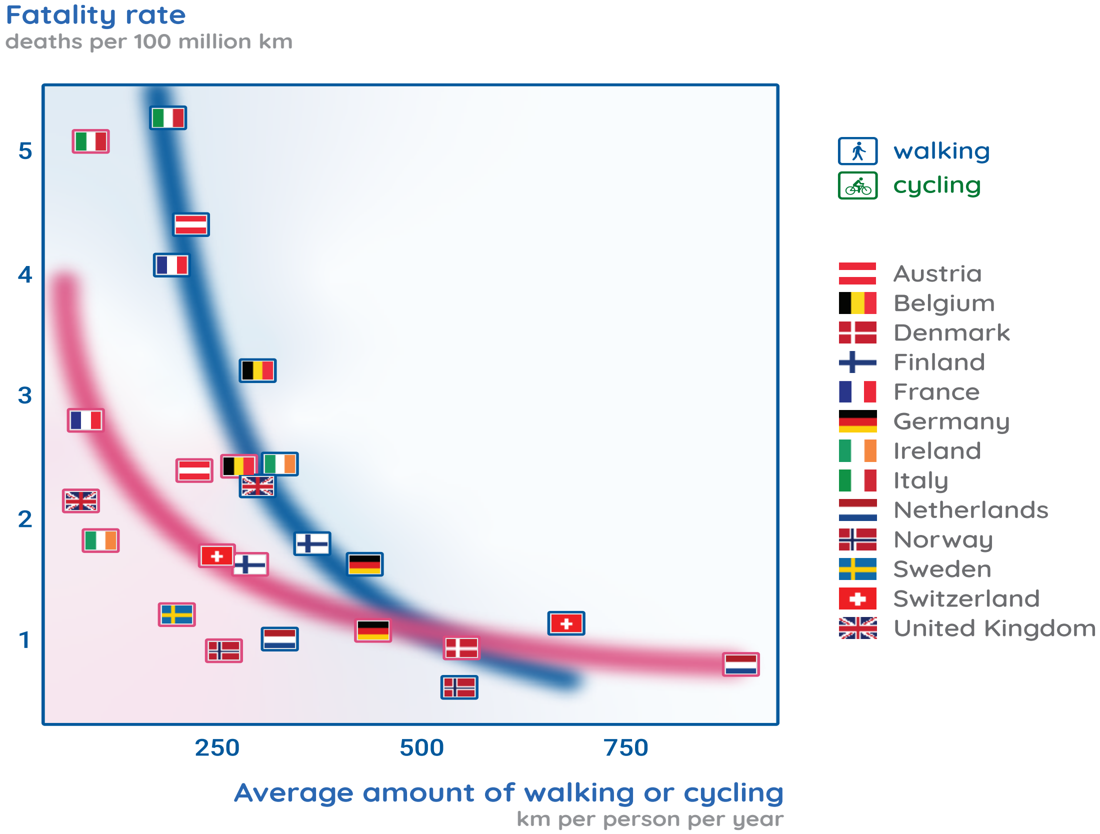
The variance across countries clearly demonstrates that traffic safety is a result of how countries choose to design their transport networks, regulate traffic and protect vulnerable road users. Comparing crash rates to levels of active travel also clearly demonstrates the strong relation between safety and higher levels of walking and cycling (Fig. 7). This has been observed consistently and is often referred to somewhat misleadingly as safety in numbers (Bhatia and Wier, 2011; Carlson et al., 2019; Elvik, 2009; Fyhri et al., 2017; Gotschi, 2011; Götschi, Garrard and Giles-Corti, 2015; Jacobsen, 2003; Yao and Loo, 2016). While some have attributed this pattern to factors such as safer interactions between drivers and vulnerable road users, due to a familiarity with and expectation to encounter pedestrians and cyclists, among other behavioural factors, others have emphasized the importance of improving traffic safety in the first place, typically through regulation and infrastructure measures, to achieve higher numbers of active transport use (Bhatia and Wier, 2011; Götschi, Garrard and Giles-Corti, 2015).

Injury risks are considerably more difficult to compare because reporting is less standardized and underreporting is a concern, especially for light injuries. According to various sources, for every cyclist death there are around 30–50 severe cyclist injuries and 100 to 300 light injuries (ASTRA, 2021; Buehler and Pucher, 2017; Pucher and Buehler, 2012). Walking tends to skew a bit less towards light injuries, because falls are less frequent and less impactful than for bikes (ASTRA, 2021; Buehler and Pucher, 2017).

Aside from these relative comparisons, it is important to recognize that all in all, walking and cycling crashes are rare. In Europe it takes anywhere between 20 to over 100 million kilometres of cycling for a fatal crash to occur (Castro, Kahlmeier and Götschi, 2018). A study across seven European cities estimated cycling crashes (incl. those without injury) to occur every 725 hours of cycling, with the highest rates in London (1 crash per 450 hours) and the lowest in the small Swedish city of Örebro (1 crash every 3000 hours) (Branion-Calles et al., 2020).

The crash risks of e-bikes remain an understudied topic. Greater speeds and vehicle weight and the popularity of e-bikes among older people raise concerns about crash severity. However, the older age of riders associated with more prudent riding styles may counteract some of these effects. E-bike crashes have seen dramatic increases in the past years, but so have e-bike sales. To assess crash rates reliably, data on both incidents and the underlying volume of riding need to be collected

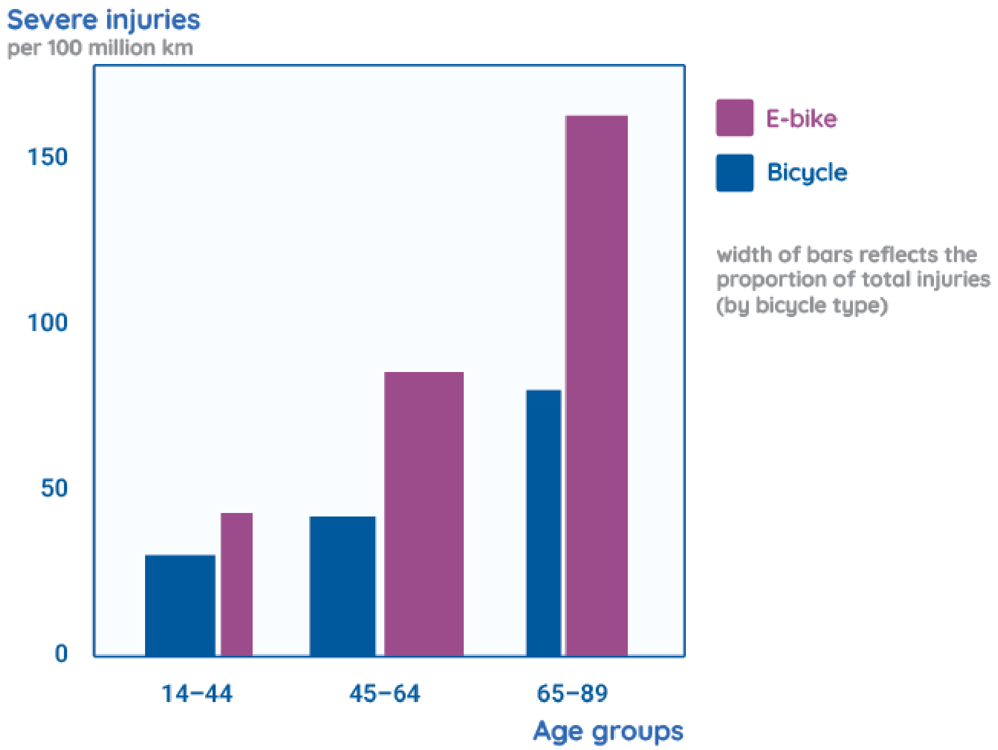
Fig. 7. Rates of fatal cycling and walking crashes (per 100 million km) across selected European countries



Source: Castro, Kahlmeier and Götschi, 2018.

separately, which is not done routinely in most countries. Switzerland introduced the separate collection of e-bike usage data in their travel survey in 2015. Combined with crash statistics, the data suggest that the risk with an e-bike compared to a conventional bicycle is seven times higher for a fatal crash and two times higher for severe and light injuries (calculations based on: Bundesamt für Statistik, 2015, 2017). Some of this difference may be attributable to lower fitness or the increased vulnerability of elderly e-bike users (Schepers et al., 2020). The data also clearly shows the greater popularity of e-bikes among older age groups as compared to conventional cycling (Fig. 8). This highlights the need to encompass safety, age-friendliness and user-friendliness as criteria into the promotion of walking and cycling for diverse groups.

Fig. 8. Relative risks of severe injuries from e-bikes and bicycles in Switzerland



Swiss data combining road crash registry and travel survey data illustrates increased risks of e-biking compared to cycling, and increased injury risk with age. Compared to cycling, e-bike injuries are much more common in older age groups.

Source: adapted from Uhr and Hertach, 2017.

Research has identified numerous factors that affect the crash risks of cyclists and pedestrians, including traffic volume and speed, and the presence of heavy-duty vehicles; road user behaviours, such as distracted driving, alcohol consumption and disobeying traffic laws; weather and light conditions; and infrastructure designs that invite or prevent conflicts (Schepers et al., 2014). The risk for injury severity increases with the age of victims, speed of vehicles involved, and cyclists not wearing helmets (Zahabi et al., 2011). As such, safety improvement measures should target multiple structural levels, from individual education to infrastructure design and traffic regulation (see section 4).

Air pollution

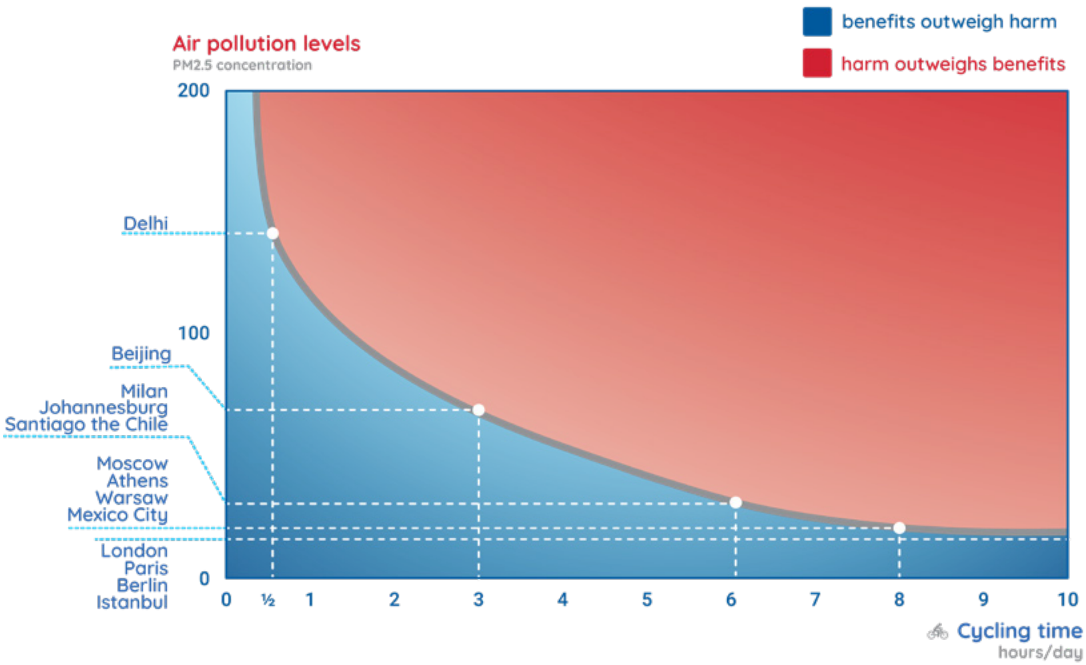
Two aspects of exposure to air pollution are of interest in the context of active travel. First are concerns that pedestrians and cyclists are exposed to air pollution on their routes. Second, shifting urban travel to walking and cycling can reduce air pollution emissions and result in reduced health risks for urban populations.

The concerns about air pollution for walking and cycling are rooted in two factors. First, increased ventilation rates due to the physical effort that comes with active travel lead to higher pollution intake. Second, compared to staying at home or using another mode of transport, walking and cycling may occur in areas of higher pollution, which is of particular concern as traffic-related air pollution is considered potentially more harmful than pollution from other sources (Matz et al., 2019).

Under normal conditions, compared to when they are at rest, pedestrians inhale about twice as much pollution and cyclists about four times as much; under extreme conditions, during peak effort, ventilation rates may be raised dramatically (Johnson, 2002). Air pollution concentrations are higher in traffic compared to, for example, at home or background levels. Drivers tend to be exposed to the highest concentrations, at around 2.5 times that of background concentrations, while cyclists face two times and pedestrians face about 1.5 times higher levels, large local variations notwithstanding (Götschi et al., 2020; Kahlmeier, Castro and Brand, 2017; de Nazelle, Bode and Orjuela, 2017; WHO Regional Office for Europe, 2020).

Health impact assessments comparing long-term harms from air pollution to long-term benefits from physical activity suggest that benefits outweigh harms even under extreme conditions, such as pollution levels over 100 µg $PM_{2.5}$ (Fine particulate matter of median diameter of 2.5µm) or several hours of daily cycling (Mueller et al., 2015; Tainio et al., 2016) (Fig. 9). However, the same may not be true for short-term effects, such as the exacerbation of asthma and other respiratory symptoms. It is therefore prudent for active travellers to avoid high pollution areas as much as possible, and for planners to design pedestrian and cycling networks separated from heavy traffic (World Health Organization, 2020c). High air pollution levels also deter people from being physically active (Giallouros et al., 2020; Tainio et al., 2021).

Fig. 9. Comparing physical activity benefits against harms from air pollution exposure while cycling



Plotting air pollution concentration (vertical axis) against average daily cycling time (horizontal axis), one can compare physical activity benefits against harms from air pollution exposure while cycling. Air pollution/cycling time combinations which fall below the line yield net benefits in terms of mortality risk, while for combinations above the line, such as high levels of pollution and/or high levels of cycling, the harms from air pollution outweigh physical activity benefits. In 99% of major cities worldwide, an average of 100 minutes of daily cycling is beneficial for health. In most cities, one could ride more than 5 hours per day without having air pollution negate the benefits from physical activity.

Source: Tainio et al., 2016.

There is no research directly linking shifts to walking or cycling to reduced air pollution levels and the resulting health effects in the general population. Such studies are challenging because the effects of active transport policies are often too small, or accompanied by other measures (Castro, Künzli and Götschi, 2017), to be reliably identified, and health effects take time to manifest. Instead, indirect scenario calculations combine observed or anticipated emission reductions scenarios with atmospheric science (Pisoni, Thunis and Clappier, 2019) and epidemiologic findings (World Health Organization, 2014) to calculate expected impacts. Most studies have shown small impacts on general population health (Mueller et al., 2015), although more ambitious mode shift scenarios indicate that gains in population level health through air quality improvements could be substantial (Grabow et al., 2011; de Hartog et al., 2010; Johansson et al., 2017).

Other health impacts

Other impacts fall into the domains of quality of life and well-being, and other health benefits that are more difficult to quantify. A number of studies have reported that active commuters have higher mental well-being scores (Avila-Palencia et al., 2017) and lower absence from work due to sickness (Box 9), but traffic safety can add stress for cyclists (Ma and Ye, 2019; Mytton et al., 2015; Singleton, 2019). Walking to school has been associated with positive cognitive development in school children (Ruiz-Hermosa et al, 2019). However, in countries with low walking and cycling levels, pedestrians and cyclists can be at higher risk of becoming victims of crimes (Appleyard and Ferrel, 2017).

Box 9
Active commuting: a strategy to enhance work performance and productivity

Active commuting, namely travel to work by walking or cycling, has been recommended as a practical way of incorporating more physical activity into daily life (Audrey, Procter and Cooper, 2014; Petrunoff, Rissel and Wen, 2016), especially for people who find prioritizing exercise difficult. There is a strong association between cycling to work and health outcomes. The evidence shows that cycle commuters have considerably lower health risks (Dinu et al. 2019). A major cohort study found as much as a 40% lower risk of dying from cancer and a 52% lower risk of dying from heart disease compared to those commuting by car or public transport (Celis-Morales et al., 2017). They also have a 46% lower risk of developing heart disease and a 45% lower risk of developing cancer at all (Celis-Morales et al., 2017).

In addition to well-documented benefits for the physical health of employees, active commuting, and in particular cycling, may also enhance job performance, contributing to economic benefits to employers and society (Ma and Ye, 2019). Recent evidence suggests that those who walk or cycle to work have better self-reported work performance than public transport and car commuters (Ma and Ye, 2019). This can be explained by the proven positive effects of physical activity on brain function and cognition, which are closely related to performance (Hillman, Erickson and Kramer, 2008). Low physical activity, on the other hand, can lead to obesity and related chronic diseases, significantly reducing workforce participation and increasing

Box 9 (contd)

absenteeism. Mental stress associated with commuting may further affect work performance (Ma and Ye, 2021).

A study involving over 1000 Dutch employees examined the association between commuter cycling and all-cause sickness absence. It demonstrated that regular cyclists had significantly lower rates of absenteeism due to sickness than non-cyclists. The more often employees cycled to work and the longer the distance travelled, the less they reported being sick (Hendriksen et al., 2010).

Given the significant benefits of walking and cycling to work, employers should consider promoting active commuting as part of their overall strategies for improving job performance. This can be done, for example, by providing safe bike parking and showers at work (Ma and Ye, 2021), providing financial incentives to give up car parking spaces, or by subsidizing the purchase of bicycles or e-bikes (Melendez, 2021). Policy implications include specific budget allocations to implement cycling policies and more investments in transport infrastructure that supports active travel to work.

Bike commuters in Ghent, Belgium.
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3.4. Liveability and economic vitality

Several impacts from walking and cycling are less tangible than those on transport and health. Economic aspects include attractive business districts and shopping areas, increases in real estate value, or a city's ability to attract a young, well-educated workforce and therefore prospering businesses (Badawi, Maclean and Mason, 2018).

Pedestrians and cyclists appear to be better customers for small businesses, presumably because it's easier for them to spontaneously make additional stops than for drivers. Studies have shown that they spend more money on average than drivers (Badger, 2012; Reid, 2018; Transport for London, 2018). Although often confronted with initial opposition, the removal of parking spaces and banning of cars to create pedestrian zones have beneficial impacts on the sales figures of restaurants and businesses (Jaffe, 2015; New York City Department of Transportation, 2013; Sustrans, 2020; Szarata et al., 2017).

Real estate in the vicinity of good walking and cycling infrastructure increases in value (Choi, Park and Dewald, 2021; Conrow, Mooney and Wentz, 2021; Li, Joh and Board, 2016; Lieske et al., 2021). This has raised concerns of gentrification and inequity, which should be addressed early in the planning process (Flanagan, Lachapelle and El-Geneidy, 2016; McNeil et al., 2018; Torres-Barragan, Cottrill and Beecroft, 2020). Tourism in cities and beyond benefits from pedestrian- and cycling-friendly environments. Bikeshare schemes and bike rentals have gained tremendous popularity among tourists as a convenient means to explore cities, and likewise, cities have recognized the potential of bikeshare schemes to accommodate sightseeing-related traffic sustainably (Bardi et al., 2019; Buning and Lulla, 2021; Chen and Huang, 2021; Nilsson, 2019).

Walking and cycling are also highly affordable and are hence an equitable means of transport, providing access for the vast majority of the population, especially when supported by safe and comfortable infrastructure (Gössling and Choi, 2015; Lee, Sener and Jones, 2017; Smith et al., 2017). A pedestrian- and cyclist-friendly public realm provides a low-stress environment which bolsters social cohesion. Furthermore, bicycle- and pedestrian-friendly cities are more resilient to catastrophic disruptions to their motorized transport systems, offering their citizens viable alternatives when coping with the travel impediments posed by pandemics, natural disasters or security threats.

3.5. Putting impacts into perspective

The diverse spectrum of beneficial impacts from walking and cycling, as well as some risks associated with walking and cycling in unhealthy and unsafe conditions, call for attempts to draw a comprehensive bottom line. From the previous sections it is obvious that there are substantial benefits from active travel modes, but what is their magnitude, do they make a difference, are they worth the investments, and do they outweigh the risks?

These and similar questions are addressed by impact assessments, comparative risk assessments, transport appraisals, cost-benefit studies, similar efforts (Brown et al., 2016; Götschi et al., 2020; Krizek, 2018; Mueller et al., 2015; Mulley et al., 2013; Ruffino and Jarre, 2021; van Wee and Börjesson, 2015). While fully comprehensive assessments remain elusive for several reasons, research has made substantial strides in quantifying the impacts of the promotion of active travel, providing decision-makers with tools to put benefits, risks, and investment cost into perspective. In contrast to studies that look at the effects of walking and cycling among individuals, risk assessments calculate what these mean for an entire population, in a certain area, over a specified time period. As such, one can assess what, for example, a 10% increase in walking or cycling translates into, in a certain city, in terms of annual benefits. Among the many impacts of transport on health (van Schalkwyk and Mindell, 2018), health impact assessments of active travel are typically concerned with health benefits resulting from physical activity and air pollution reduction for the general population, as well as risks associated with increased exposure to air pollution and traffic injuries for active travellers (Doorley, Pakrashi and Ghosh, 2015; Mueller et al., 2015).

Some impacts, such as those on mortality, are directly comparable. For example, many studies show that the reduction in mortality through physical activity from walking and cycling by far outweighs the increased mortality risk from exposure to air pollution or fatal traffic crashes (Mueller et al., 2015; de Hartog et al., 2010). Caveats may apply to young populations, however, where the relatively smaller effects of physical activity on mortality may not necessarily outweigh the risks from dangerous traffic environments (Woodcock et al., 2014); and in general, for areas with high traffic injury risks and high air pollution levels (Garcia et al., 2021; de Sá et al., 2017). Such comparisons are somewhat more challenging when the effects on diseases and injuries are considered in addition to effects on mortality. To compare the benefits of disease reduction to the burden from injuries, studies estimate durations of hospital stays and related treatment costs, losses in productivity due to absence from work, and related measures. In a study of increasing active travel in England and Wales, Jarrett and colleagues predicted savings to the National Health Service of billions of pounds (Jarrett et al., 2012), as did a study from New Zealand (Mizdrak et al., 2019).

A sign of caution is raised by an assessment of transport-related costs by the Swiss government, where external costs associated with cycling crashes outweigh the external benefits associated with physical activity (INFRAS and Ecoplan, 2018). The study includes minor injuries from falls, namely crashes without the involvement of others, and relies on a number of assumptions. As such, it is probable that minor benefits of physical activity are not equally meticulously reflected in the findings, tilting the benefits to risks ratio unfavourably.

Many health impact assessments also integrate environmental concerns, namely the reductions in carbon and other emissions, such as air pollution or noise, from mode shifts towards walking and cycling (Maizlish, Linesch and Woodcock, 2017; Mizdrak et al., 2019). Diverse impact indicators require monetization to make them comparable. While this results in impacts expressed in the same monetary unit, the resulting values strongly depend on the applied monetization methods, which can be controversial (Cameron, 2010; Colmer, 2020). Nonetheless, such comparisons can be insightful to compare impacts that are of an entirely different nature, such as health and environmental impacts.

To assess the transport benefits that active travellers gain from walking or cycling, as compared to using other modes of transport, more inclusive measures of benefits, such as the logsum method (measures that include things other than just cost and time), rather than a narrow focus on travel cost or time, have been proposed (Standen et al., 2019).

Currently, there are several tools available to facilitate such assessments, catering to users with different backgrounds and skill sets (see Annex I). Several agencies have also adopted impact assessments or similar tools into their regulatory frameworks for new transport policies or projects.

Numerous studies have calculated the impacts of active travel measures and policies, and an unknown number of undocumented assessments inform the work of planners and advocates alike. A few example studies are highlighted below, and an example calculation is provided in Box 10 .

- A study of 12 large European bike sharing systems estimated that, due to their replacement of car trips, these systems prevent five premature deaths annually, translating to an economic value of 18 million euros (Otero, Nieuwenhuijsen and Rojas-Rueda, 2018). Under more ambitious assumptions for car trip substitutions, economic benefits could be over 100 million annually. Additionally, the benefits from physical activity outweighed the risks from crashes and air pollution by approximately 20 times.
- An analysis of Scottish travel survey data, using the Health Economic Assessment Tool for walking and cycling (HEAT) (see Box 10), concluded that active commuting, such as on foot or by bike, prevents 200 premature deaths annually, equivalent to economic benefits of close to one billion euros annually (Baker, 2020).
- A scenario analysis using the Propensity to Cycle Tool, comparing levels of cycling to school in England to levels observed in the Netherlands, estimated that achieving Dutch levels would result in carbon emission reductions of 80 kilotonnes per year (Goodman et al., 2019).
- A study comparing cycling levels and cycling network expansion across 167 European cities found a strong relationship: the greater the cycling network, the higher the cycling levels, with levels up to approximately one out of

every four trips being undertaken by bicycle (Fig. 13) (Mueller et al., 2018). If all examined cities were to achieve cycling levels of such magnitude, approximately 10 000 premature deaths would be prevented annually.

- A study in Stockholm, Sweden, assessed the cost-effectiveness of investments into cycling infrastructure to facilitate shifts in commute trips from car to bicycle (Kriit et al., 2019). Impacts were monetized using health-care cost savings, and investments were concluded to be cost-effective, with net benefits amounting to several percent of the local health-care budget.
- In a study of Porto, Portugal, various mode shift scenarios were demonstrated to result in substantial benefits to travellers shifting to active modes related to several morbidities, as well as work absenteeism (Rodrigues et al., 2020). The assessment quantified gains in DALYs, as well as air pollution and carbon emission reductions.
- A Norwegian evaluation concluded that cycling network expansions are highly cost-effective. This study modelled increases in cycling based on a large data set of European cycling network data and quantified benefits in terms of QALYs gained from increased cycling (Lamu et al., 2020).

Box 10
Health Economic Assessment Tool (HEAT) for walking and cycling

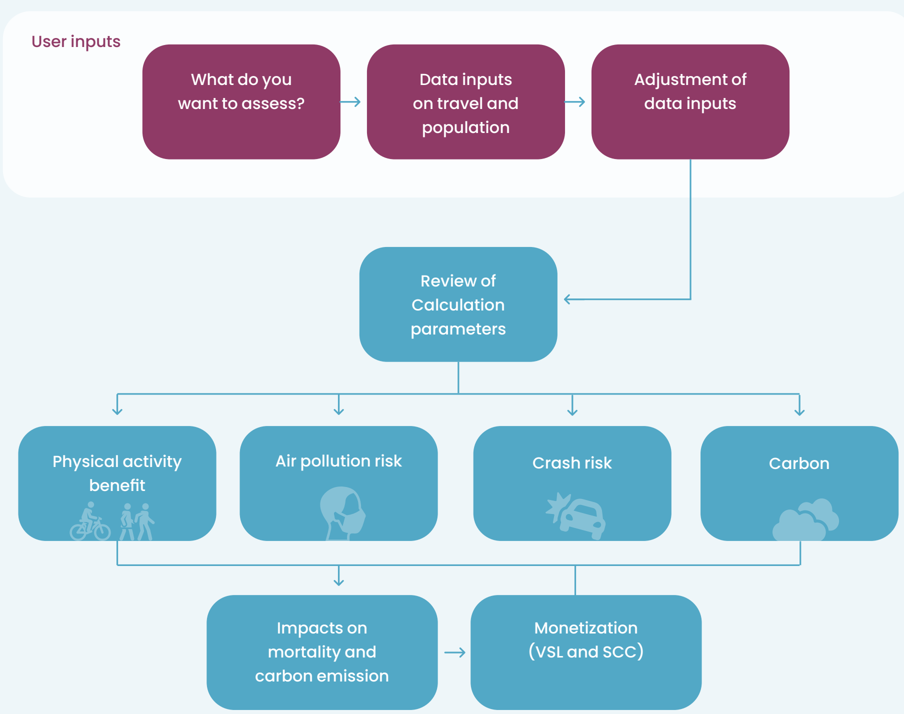
WHO recognized the importance of integrating health and economic considerations into transport appraisals early on, and in 2007 launched the first version of the Health Economic Assessment Tool (HEAT) for walking and cycling (HEAT v5.0, 2022). The HEAT tool for walking and cycling is a user-friendly online calculator to assess active travel policies in terms of premature deaths avoided and the corresponding economic value based on Value of Statistical Life (VSL). It calculates the health impacts of walking and cycling on premature mortality through the pathways of increased physical activity,

Box 10 (contd)

exposure to air pollution while walking or biking, and the risk of fatal crashes in traffic. In addition, it calculates impacts on carbon emissions due to shifts between active and motorized travel modes, which are monetized using Social Costs of Carbon (SCC).

The HEAT is based on the latest scientific evidence and experts' consensus (Götschi et al., 2020). The tool is available online at www.heatwalkingcycling.org.

Workflow of the Health Economic Assessment Tool for walking and cycling



Box 10 (contd)

For an example calculation with the HEAT, mode share data (% of all trips) for 25 European capital cities was used (see Fig. 1). A hypothetical scenario where these cities manage to increase walking by 20% and cycling by 50% was calculated. For example, in Berlin, Germany, the share of walking trips would increase from 30% to 36%, and in Paris, France, cycling trips would increase from 3% to 4.5%. This translates to an average increase of just a bit more than five minutes of active travel per day for the roughly 40 million people living in these cities.

The calculation requires some assumptions in addition to default parameters and data provided by the tool. For example, it assumes that people take three trips per day. The overall assessment is calculated for a period of 10 years.

The assumed increases in active travel, over the period of 10 years, are estimated to result in the prevention of 8670 premature deaths and a reduction of carbon emissions of 40 million tonnes. The monetary value, based on country-specific estimates for the VSL and SSC, amounts to approximately 35 billion dollars, adjusted for purchasing power parity and discounted to 2021.

How walking and cycling can be promoted

Urban and transport planning and related sectors have amassed a wealth of measures and policies to promote walking and cycling (Winters, Buehler and Götschi, 2017). Many of these are supported by or based on a rapidly growing body of research (Box 11). This booklet cannot provide a comprehensive compendium of all such measures, but instead aims to provide an overview and highlight some particularly promising or innovative approaches. The promotion of active travel can involve a wide range of actors, including engineers, planners, actors in the environmental and health sectors, and policy-makers at various levels of government. Equally, active travel measures aim at a wide range of targets, from local infrastructure to national policies. The following section provides an overview of selected measures starting from smaller and moving to larger socio-spatial scales (Götschi et al., 2017). In other words, it begins with infrastructure measures at the street level and ends with an overview of high-level policies at national or even international scale.

4.1. Infrastructure, infrastructure, infrastructure

Streets and intersections, travel speeds and mode separation

Road and intersection design has an extraordinary impact on how safe, comfortable, and attractive it is to travel by foot and bike, and therefore play a central role in the promotion of active travel. Recognizing the special needs of pedestrians and cyclists, engineers have come up with a rich portfolio of tweaks to roads and intersections which originally were designed to accommodate cars, first and foremost.

In a stereotypical old school way of planning, the allocation of road space followed a clear hierarchy where cars and public transport were accommodated first, and pedestrians, and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where feasible, cyclists, received what was left. As a result, sidewalk widths were often minimal, and bike lanes, if marked at all, were often too narrow, inconsistent, and in the worst case, put cyclists into dangerous so-called door zones of parked cars. Limited road space was typically declared the culprit, while traffic flow and parking space were treated sacrosanct, either because planners were ignorant of the situation, or they were aware but alarmed to have no choice because the space was needed for cars. So-called complete streets represent a counter-concept to such a hierarchical accommodation of travel modes. This planning principle, coined in North America but inspired by European examples, prioritizes safe and convenient road use by all users, independent of their travel mode (Abel et al., 2019; U.S. Department of Transportation, 2021). As the needs of active travellers, and their vulnerability and higher safety requirements, are being recognized more consistently, there have been some significant shifts to the paradigms of road space allocation.

It is now recognized practice that, as the discrepancies between travellers' speeds increase, the physical separation of different modes becomes more important (Fig. 10). The reason for this is rooted to equal degrees in the need to provide both objective and perceived safety. This is reflected in so-called cycle tracks, such as physically separated bike lanes, a practice successfully deployed for decades in the Netherlands and Denmark and now adopted around the world. Cycle tracks are much safer than a typical road (Lusk et al., 2011; Teschke et al., 2012). Consequently, cycle tracks provide a heightened sense of safety, in particular for more vulnerable and safety-concerned cyclists, such as children, the elderly and women (Garrard, Handy and Dill, 2012; Garrard, Rose and Lo, 2008) who would otherwise not dare to ride in heavy traffic. Where space is limited for such accommodations, so-called road diets, such as the removal of travel lanes, centre turning lanes, or parking lanes for cars, can be a remedy (Dill, Smith and Howe, 2017; Gudz, Fang and Handy, 2016; Wikipedia, 2021a). Even more attractive travel environments are provided by routes that have no motorized traffic at all, such as cycle highways, trails, or mixed-use paths.

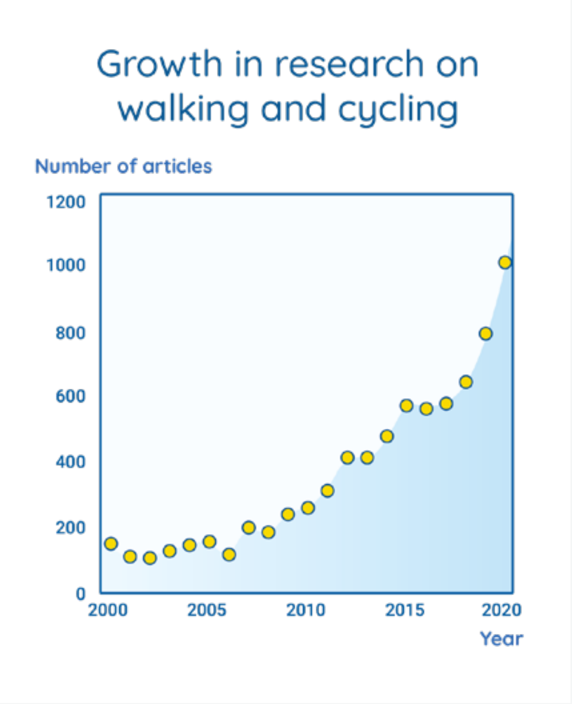
Box 11
The role of research in the promotion of active travel

A rapidly growing body of research (see figure below) is contributing to our understanding of the effectiveness of measures and policies to promote active travel. This is a challenging task for several reasons.

- Implementation of measures with long-lasting effects, such as infrastructure improvements, is slow and therefore difficult to study.
- Effects of more short-term measures, such as targeted campaigns, are easier to study, but may have smaller effects than longer term efforts.
- Reliably assessing travel behaviour requires substantial data collection efforts, however many active travel promotion efforts are run on small budgets, lacking funds for robust evaluation. In many countries, the routine collection of walking and cycling data is still rudimentary.
- Promotional efforts are often part of a diverse package of measures. While there is ample evidence that such packages work, it is challenging to separate the effectiveness of each individual measure.

Walking and cycling research has seen a steady increase over the past couple of decades. It provides an important avenue to present and share success stories. Communities can contribute to the common understanding of successful strategies to promote walking and cycling by investing in data collection efforts, such as automated counters and travel surveys, evaluating their campaigns and infrastructure projects, and supporting dedicated research efforts.

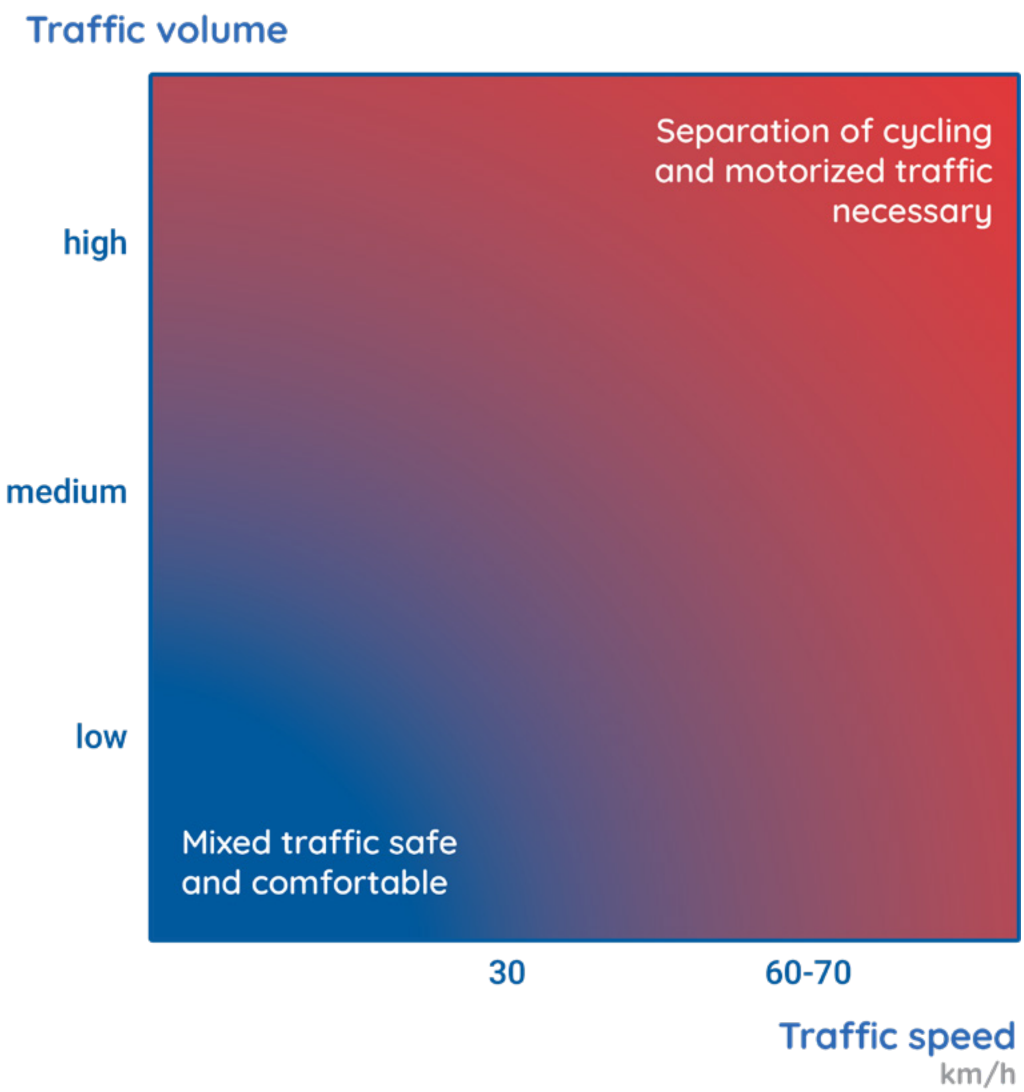
Box 11 (contd)



Web of Science search hits* for "walking" and "cycling" since 2000. (*search terms based on Götschi et al., 2017, and restricted to journals in the fields of engineering, transport planning, environmental sciences, and public health)

Where physical separation of modes is not possible due to space restrictions, reducing the speed of cars, or of faster travellers in general, provides an equally effective way to increase the comfort of slower travellers and reduce road injuries (Bornioli et al., 2020). A broadly applied success story is the implementation of traffic calming measures and speed limits of 30 km/h or less, typically on but not limited to residential streets or zones (Box 12). The key is that speed limits are accompanied by physical changes to the streetscape that are uninviting to speeding, while ideally imposing as little disturbance for cyclists as possible. Such measures can include speed bumps or cushions, curb bulb-outs, raised crosswalks, rearrangements of parking patterns and various others, all with the purpose to disrupt a streamlined, straight line of driving. Traffic-calmed zones are safer (Bunn et al., 2003; Cairns et al., 2015; Elvik, 2001; Welle, Li and Adriazola-Steil, 2016) and less noisy (Krauß, Ruhl and Richter, 2016) and have, contrary to general belief, only moderate impacts on road capacity (Chimba and Mbuya, 2019).

Fig. 10. Visualization of the relation between traffic volume and speed, and the need to physically separate or mix different travel modes



Source: adapted from (CHIPS project, 2022).

Box 12
Streets for life campaign: A global call for 30 km/h urban streets

The United Nations (UN) General Assembly mandated WHO and the UN regional commissions to plan and host periodic UN Global Road Safety Weeks. Held since 2007, the #Love30 campaign of the 6th UN Global Road Safety Week advocates for Streets for Life by making 30 km/h (20 mph) speed limits the norm for cities worldwide in places where people mix with traffic.

Safety Week 2021 garnered policy commitments at national and local levels to deliver 30 km/h speed limits in urban areas; generate local support for such low-speed measures in order to create safe, healthy, green and livable cities; and officially launch the Decade of Action for Road Safety 2021–2030 and its Global Plan. Safety Week 2021 also highlighted the links between 30 km/h speed limits and the attainment of several Sustainable Development Goals, including those on health, education, infrastructure, sustainable cities, climate action and partnerships. More information can be found on the UN website devoted to Road Safety week (United Nations, 2022).

Cycling in an urban 30-km zone in Ghent, Belgium.
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Cycle streets, or boulevards, combine traffic calming with a reduction in motorized traffic and the prioritization of cyclists (Directorate-General for Mobility and Transport, 2021a). For example, by installing semi-permeable chicanes, which provide a horizontal diversion of traffic, in intersections, car through-traffic is eliminated while cyclists can still pass. Rearranging stop signs and rights-of-way can substantially increase comfort and the average travel speed of cyclists. When implemented as a coherent network, such routes can provide a highly efficient, safe and comfortable solution to accommodate cycling in a space- and cost-effective way.

An equally successful and broadly adopted measure is to reduce travel speeds even further to a walking pace, to create living streets, invented in the Netherlands as early as the 1970s under the Dutch term *woonerf* (Wikipedia, 2021b). In these street designs, there is typically no distinct allocation of sidewalks and road space. Instead, all road users share the same space, and signalization indicates to drivers that they do not have priority over other road users (Fig. 11). A similar logic applies to mixed-use zones in areas such as public squares and shopping districts (Directorate-General for Mobility and Transport, 2021b), where various modes can get by with surprisingly little regulation as long as speed is kept close to a walking pace.

Fig. 11. A "living street" in Berlin

"Begegnungszone" is the German term for "living street", Berlin, Germany.

The efforts to calm traffic and make road space more liveable described above do not necessarily have to be exclusively pursued through the slow-moving process of rebuilding traditional, long-lasting road infrastructure. Tactical urbanism (Street Plans Collaborative, 2016) uses a broad range of temporary and typically cheap ad-hoc measures, including repainting road markings, rearranging and/or repurposing parking spaces, and using planters and all sorts of objects to reshape the road space to achieve traffic calming effects more quickly (Fig. 12). Many cities have discovered such approaches as adequate temporary installations to yield immediate results while bridging the time span until more permanent solutions can be implemented. These approaches also allow for testing and experimenting with new measures and designs and adjusting them before fully investing into their implementation, and in turn maximizing acceptance and understanding.

Fig. 12. Example of a tactical urbanism measure

Milan, Italy.
©Rue de l'Avenir

More and more cities are also overcoming the paradigm that every location needs to be reachable by private car, instead recognizing the fundamental shifts in urban quality that come with entirely car-free zones, while permitting taxis and delivery and emergency service vehicles (Box 13). Such oases within the urban traffic grid are equally appreciated by tourists, locals, shoppers, commuters, residents and, typically after an initial phase of resistance, businesses and restaurants that benefit from increased pedestrian traffic.

Box 13
Superblocks in Barcelona

Barcelona, Spain, is demonstrating what reclaiming street space for people on a large scale can look like. Taking advantage of the city's grid structure, a strikingly simple formula scales back the street grid for motorized traffic and creates highly liveable, car-free oases for pedestrians, cyclists and residents engaging in all sorts of outdoor activities. Instead of granting cars a free pass on every street, so-called superblocks – areas of three-by-three street blocks – limit car traffic to their circumference while reserving their inner grids to active travel and minimally necessary car access.

Superblocks model

Source: Nanda, 2020.

The city originally had plans for hundreds more, but so far, only six superblocks have been implemented. A study assessing the potential health benefits from reduced air pollution, increases in physical activity, and other factors from this ambitious scenario found the number of premature deaths that could be prevented annually to be in the hundreds (Mueller et al., 2020).

Box 13 (contd)

The city is currently working on implementing more superblocks, but there is significant deviation from the original model. Despite the change in scope of the ambitions, the objectives stay the same, which are to:

- reclaim space for people
- reduce motorized transport
- promote sustainable mobility and active lifestyles
- provide urban greening and mitigate the effects of climate change.

An evaluation study by the Barcelona Public Health Agency of the implemented superblocks is available in Spanish or Catalan on *L'Agència de Salut Pública de Barcelona's* [The Barcelona Public Health Agency's] website (L'Agència de Salut Pública de Barcelona, 2022)

Intersections or junctions are often the most challenging parts of a journey and are prone to conflicts as the paths of different travel modes cross. Countless agencies have issued guidelines on how to improve intersections for pedestrians and cyclists (CROW, 2021; Directorate-General for Mobility and Transport, 2021c; National Association of City Transportation Officials, 2019; Sustrans, 2014). Goals include reducing travel speeds, improving sightlines and visibility, reducing complexity regarding the decisions that road users need to make or elements they need to react to, increasing reaction times, and reducing wait times for active travel modes. Many of these improvements follow the simple principle of accommodating pedestrians and cyclists first, rather than prioritizing motorized traffic. Some examples include:

- alterations to the geometry of intersections and regulations of rights-of-way;
- keeping sidewalks at grade level, with cars having to cross sidewalks to enter residential areas, so that pedestrians do not have to step into the street to cross a side street but cars must cross the sidewalk to enter the side street;
- curb extensions (which extend the sidewalk or curb line out into the parking lane to reduce the effective street width), and corner cushions and bulb-outs, which extend sidewalk space at four-way intersections;

- ☑ diagonal crossings for pedestrians and cyclists;
- ☑ automatic recognition of cyclists;
- ☑ right-turn on red access for cyclists;
- ☑ bicycle boxes, such as street markings which designate areas for cyclists to stop in front of cars at red lights; and
- ☑ advanced green light phases for cyclists.

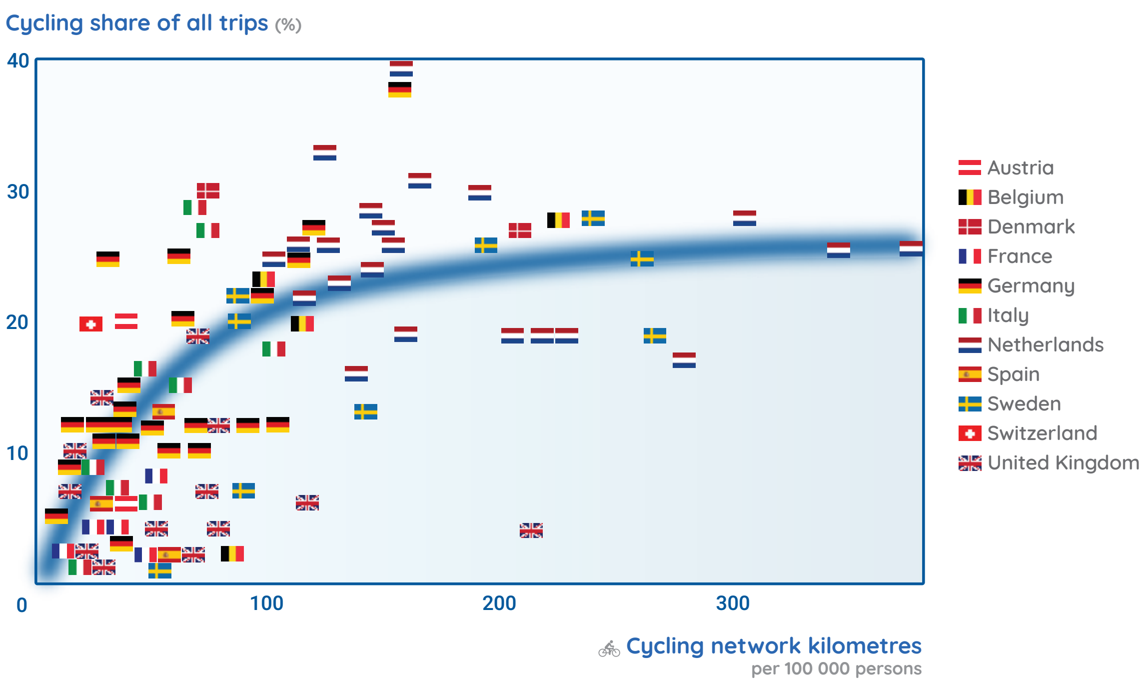
Connectivity and other network qualities

While the design of road segments and intersections can be rated in terms of safety, comfort and attractiveness, it is the coherence and directness of the network which ultimately define the quality of the walking and cycling experience.

Overall, cycling network distance or density is strongly linked to cycling levels (Lamu et al., 2020; Mueller et al., 2018) (See Fig. 13). However, cycling infrastructure is notoriously known to be implemented in opportunistic ways – where there is excess space, bike lanes are marked, only to end abruptly as soon as the roadway narrows. Such piecemeal efforts may eventually lead to the goal of a better cycling environment, but they can be counter-productive, as people may perceive them as taxpayer money wasted on infrastructure that nobody uses. While the issue is less severe for pedestrian infrastructure, sidewalk networks are not immune to this problem.

Modern cycling promotion puts significant focus on building highly connected cycling infrastructure networks (Box 14). To obtain optimal results, the quantitative aspects of connectivity (i.e. minimal gaps, maximum coverage) and directness (i.e. minimal need of detours) should be combined with quality indicators, such as safety and comfort – a concept known as low stress connectivity (i.e. connectivity when applying a certain minimum comfort threshold) (Arellana et al., 2020; Cabral et al., 2019; Furth, Mekuria and Nixon, 2016; Gehrke et al., 2020; Huertas et al., 2020; Lowry, Furth and Hadden-Loh, 2016; Lowry and Loh, 2017; Putta and Furth, 2019; Zuo and Wei, 2019). This approach emphasizes the fact that the weakest links in the network, such as those with the greatest safety issues or lowest comfort level, ultimately determine the quality of a walking or cycling experience, and therefore the suitability of walking or cycling as transport modes. Network analysis can help identify the most pressing gaps, such as a street segment with insufficient cycling infrastructure, and calculate network connectivity gains resulting from gap closures (Boisjoly, Lachapelle and El-Geneidy, 2020; Doorley et al., 2020; Nabavi Niaki, Saunier and Miranda-Moreno 2016; Orozco et al., 2019). Further taking into account the quality of network segments, such as level of service, stress level or similar concepts (Pritchard, Frøyen and Snizek, 2019; Kazemzadeh et al., 2020), such assessments allow for a clear, evidence-based prioritization of network improvement projects (Lowry and Loh, 2017; Lowry, Furth and Hadden-Loh, 2016). For cycling, it is reasonable to consider different types of cyclists (Dill and McNeil, 2013) who have different preferences and requirements with regards to directness, safety and comfort. To achieve maximum levels of cycling, it is crucial to accommodate the most vulnerable cyclists, such as the elderly and children as well. For pedestrians, the directness of routes is relatively more important than for cyclists, as few will go out of their way for increased comfort, unless walking for leisure purposes. In the same regard, pedestrian networks should consistently be built to be suitable for persons with disabilities.

Fig. 13. Association of density of cycling infrastructure with higher levels of cycling across European cities



Source: adapted from Mueller et al., 2018 by permission of Elsevier

Box 14
Plan de la bicicleta de Sevilla [Cycling Plan of Seville], a protected bike lane network for the city's 700 000 inhabitants

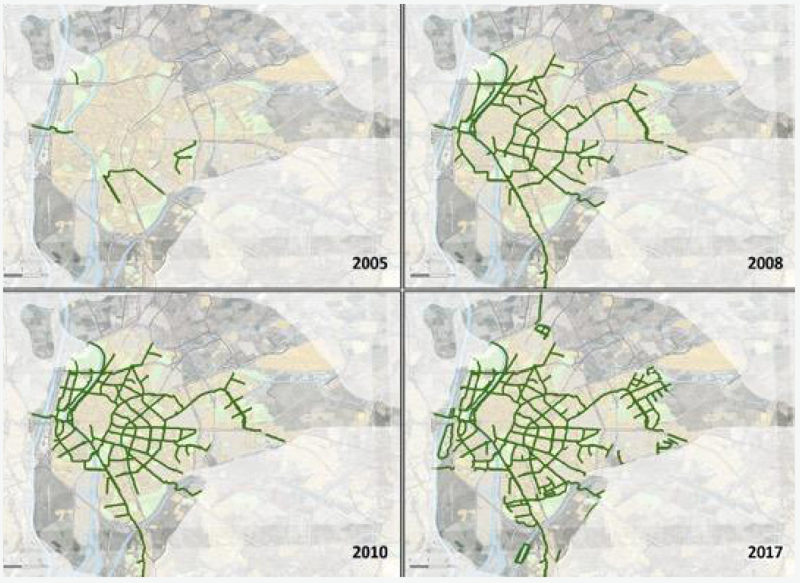
In the 1990s, cycling played a negligible role in urban mobility in Seville, Spain, similar to many other Mediterranean cities. This was changed dramatically with the implementation of a bicycle master plan in 2007, which called for a state-of-the art cycling network adhering to the following principles:

1) segregation: all bike paths are physically segregated from motorized traffic;
2) connectivity: the network connects the main residential areas with the main destination areas
3) continuity: all bike paths are integrated in a continuous network without gaps;
4) homogeneity: all bike paths have a recognizable pavement design;
5) bi-directionality – bike paths accommodate traffic in both directions where possible.

Seville's cycling network was built as a single project. It cost 5000 parking spaces, €32 million and transformed the city. The two-way system was built along main avenues and streets, mostly at pavement level, but on space previously occupied by cars. Public input was considered throughout the procedure, resulting in some modifications to the original plans.

Box 14 (contd)

Growth of Seville's network of segregated cycling paths from 2005 to 2017

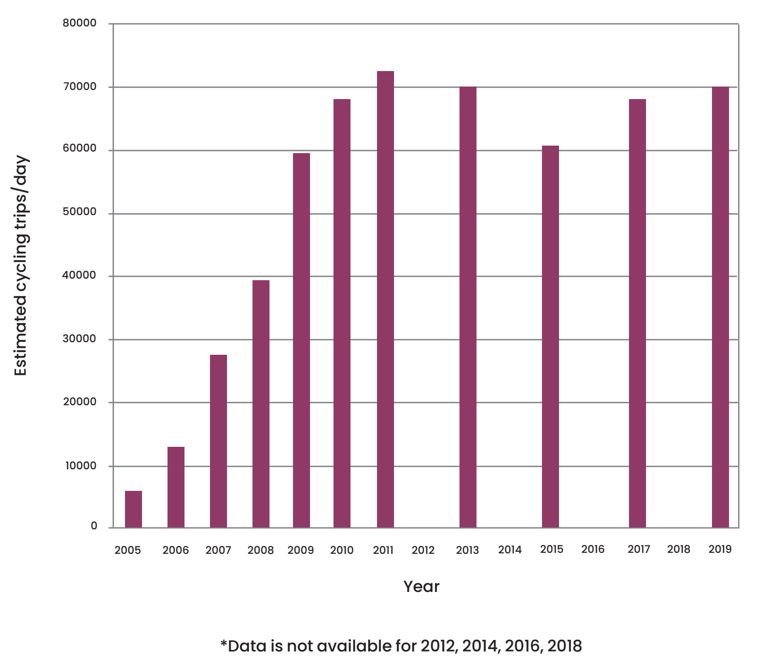


Seville's success story is proof that focused, well-reasoned investments in cycling infrastructure can yield a quick and substantial impact. Seville's cycling mode share was less than 1% of all trips in the 1990s, but by 2011, only five years after construction of the cycling network had begun, it had risen to 5.6%. The network also resulted in substantial safety improvements – cycling in Seville is now twice as safe than before the construction of the cycling network.

The original 80 km network has grown to 180 km and is still being expanded. A new master plan approved in 2017 aims to improve inter-modality, safe parking options and the quality, but not necessarily the extent, of the network. The aim is to increase the cycling mode share among mechanized trips, excluding walking trips, from the current 9%, or 67 000 trips a day, to 15%, or 115 000 daily trips.

Box 14 (contd)

Increase in cycling in Seville from 2005 to 2019



Source: Calvo and Marqués, 2020; Marqués and Hernández-Herrador, 2017.

The shift to cycling, made possible by the cycling network, was further aided by the installation of a public bike share system along the bike network, and a more comprehensive move toward sustainable mobility in the city, including the pedestrianization of important areas and restrictions of car traffic.

Trip-end facilities and other infrastructure

Pedestrian, and in particular cycling, infrastructure is not limited to road segments and intersections. Trip-end facilities, such as safe parking for bikes, or facilities for changing clothes and showering at workplaces, can be important considerations when deciding whether to bike or not. Excellent public transport not only depends on walking and cycling as feeder modes, but also provides a crucial back-up option for active travellers, especially on rainy days and during winters. Bike sharing systems remove the cost of purchasing a bike, and the burden to own and store it (Eren and Uz, 2020; Fishman, Washington and Haworth, 2013). As a result, these schemes represent useful ways to reach occasional cyclists and provide people with the opportunity to try cycling, sometimes for the very first time, resulting in substantial health benefits, among others (Otero, Nieuwenhuijsen and Rojas-Rueda, 2018). As popular as these schemes are with cities, they have also revealed considerable deficits in equity considerations (Goodman and Cheshire, 2014; Howland et al., 2018) – a concern which, of course, can also apply to active transport planning in general (Smith et al., 2017; Tucker and Manaugh, 2018; Winters et al., 2018; Wu, Rowangould and London, 2018).

Green spaces, parks and trails, as well as forms of urban revitalization (e.g. promoting shops, restaurants and businesses in former industrial zones in a way that makes them easily accessible by bike and foot), are further options to indirectly promote walking and cycling. In fact, there is growing evidence that the presence of green spaces may not only promote physical activity, but also, for example, help to reduce exposure to heat or air pollution, and beneficially affect mental health (World Health Organization, 2021b). There is consistent evidence that higher levels of greenness are associated with higher levels of physical activity (Sugiyama et al., 2018). Green spaces are often easier to modify than the built environment; can be the subject of interventions at the community level to help residents become more physically active; and are generally appreciated by residents (Sugiyama et al., 2018).

Another dimension of infrastructure that focuses primarily on walking pertains to the challenges and opportunities for people with reduced mobility to walk and/or bike (i.e. the elderly and persons with disabilities) (World Health Organization, 2018a, 2021a).

4.2. Educate, encourage, empower

It can be helpful to complement sufficient investments in bicycle- and pedestrian-friendly infrastructure with what is sometimes referred to as soft measures, such as the promotion or marketing of active travel, education and training, as well as information campaigns. While infrastructure and traffic conditions determine the safety and practicality of active travel, there are a number of psychological factors, such as habits and attitudes, which ultimately influence the decision for which mode of travel to take (Götschi et al., 2017). Soft measures can increase an individual's inclination to walk or bike by addressing these factors (Cairns et al., 2008; Kelly et al., 2020). Such efforts are often referred to as mobility management (THE PEP, 2020).

In this regard, habits form early in life. Schools should therefore be safely reachable by walking and biking, as advocated for by the Safe Routes to School programme (National Center for Safe Routes to School, 2022), an approach that promotes walking and bicycling to school through infrastructure improvements, enforcement, tools, safety education, and incentives to encourage walking and bicycling to school. A walking school bus is a programme involving a group of children walking to school together with an adult leader, using the routes that are created between students' homes and the school, can provide parental supervision for children too young to walk on their own (Carlson et al., 2020). Schools also provide excellent settings to teach children how to ride a bike and the fundamental rules of traffic and traffic safety. Children should be taught early on about the importance of regular exercise and the environmental impacts of traffic. At higher levels of education, active travel modes should be represented as equivalent modes in transport studies, and planners should obtain a sufficiently inter-disciplinary education to grasp environmental, epidemiological, and other relevant concepts (Box 17). Training courses and other forms of cyclist education can effectively increase safe cycling skills among participants and particularly popular among older cyclists and e-bike users.

Information or social marketing campaigns can be helpful to educate the public about the benefits of active travel, in particular about the magnitude of health benefits, which tend to be underestimated. They can also help promote safe traffic habits, including the wearing of reflective gear and helmets. Additionally, individualized marketing provides personal consultations to optimize individuals' travel patterns – a service sometimes offered by cities or nongovermental organizations to, for example, people who recently moved to a city.

Promotional events can take a range of forms, promoting active travel as healthy, fun or even fashionable. *Ciclovias*, a car-free event originating in Sao Paulo, Brazil, with the largest global network in Bogota, Colombia, is increasingly popular worldwide – and is also known under various other names, such as slow-ups, Sunday streets and Open Streets. The event entails a community temporarily closing expanded stretches of roadways for cars, and the newly traffic-free environments draw large crowds and allow inexperienced or first-time riders to gather a positive experience riding a bike. Organized group rides can have a similar effect, while bike-to-work is a global movement that encourages commuting by bike.

4.3. Incentives and restrictions

Transport policies, such as city-wide or broader norms and laws, have a substantial influence on walking and cycling, even though these modes may often be perceived as unregulated compared to driving. For example, in most countries there is no requirement to register a bicycle or pass any test to ride one. Nonetheless, even though most traffic regulations and transport policies are concerned with motorized modes, they do affect active modes as well, and as a result, could in many cases be optimized in favour of walking and cycling.

Incentivize and subsidize sustainable travel choices

Financial considerations play an important role in travel mode choice, which is an important aspect of travel behaviour. All countries have some sort of transport-related tax provision, including fuel taxes, road tolls, vehicle taxes, or commuter tax credits, among others (Schroten et al., 2019b), which can have a disincentivizing effect on driving (Buehler et al., 2017). Several countries, such as Belgium, the Netherlands, Luxembourg, France, Germany and Switzerland, expand tax credits to cycling commuters (Flemming S, 2019). In a number of countries, employees can purchase a bicycle tax-free through employer programmes (European Cyclists' Federation, 2014; Synek and Koenigstorfer, 2018). Other employer-based mobility management programmes may allow employees to trade in a guaranteed parking spot for a bicycle, or to earn a per-kilometre allowance when using a bike for business travel. Employers may also strategically select office locations to boost commuting by foot or bike (Pritchard and Frøyen, 2019). Also, quite common and popular are subsidies for the purchase of e-bikes (European Cyclists' Federation, 2016a and 2016b).

Disincentivize driving

Instead of, or in addition to, incentivizing active travel, disincentivizing driving can be effective in achieving sustainable transport goals and leading to more walking and cycling. Restricting free car parking may be among the most effective measures to make active travel or travel by public transport more competitive, compared to driving (de Groote, van Ommeren and Koster, 2019; Shoup, 2018). Mobility pricing, also known under different names, such as congestion pricing, is an effective measure to reduce driving (Hosford et al., 2021). Although mobility pricing is to date only implemented in a handful of cities (i.e. London, Stockholm, Milan, Singapore), it offers a promising policy option to implement the user pays principle in urban transport, relieve congestion, and induce shifts to more sustainable travel modes, including walking and cycling. In an elaborate, recent experiment with mobility pricing in Switzerland, study participants were charged the so-called true costs of driving, such as those from congestion, or from the environmental and health effects that impact others (i.e. external costs). As a result, drivers shifted significant amounts of their driving to public transport and cycling (Molloy et al., 2021b).

Traffic laws and regulations

Traffic laws in most countries have been set up with motorized traffic in mind. Reviewing and possibly revising existing regulations with cyclists, e-cyclists and pedestrians in mind is therefore overdue. For example, some cities have opened one-way streets to bicycle traffic flowing in the opposite direction, allowing cyclists to turn right at red lights and to treat stop signs as yield signs As cycling matures into a fully accepted transport mode, safety requirements, such as proper lights, should be required. Mandatory helmet use, on the other hand, is highly controversial among cycling advocates and imposed only in countries that fail to provide safe cycling environments (Buehler and Pucher, 2021a). Opponents point out that it would pose an unnecessary obstacle for people to use bikes casually and spontaneously, for example as part of bike sharing schemes. Also, countries with the highest cycling safety rates, such as the Netherlands and Denmark, have very low helmet wearing prevalence (DEKRA, 2019).

A similarly controversial topic is allowing cyclists to use sidewalks, a practice that is common in low-cycling countries, but one that is sometimes also intended by design in places with designated programmes for cyclists and pedestrians. However, sidewalks are not considered very safe for cycling, and the practice clearly puts pedestrians at risk. In the long-term, cities should strive to provide infrastructure that avoids the mixing of pedestrians and cyclists, and even more so e-bikers, as these modes are not compatible under normal circumstances due to their vastly different speeds. Any notion to lump the two together should be treated as a historical relic from when active modes were marginalized as inferior to driving. Similar concerns apply to scooters and e-scooters. Under current conditions, however, riding on the sidewalk may be the safest place to ride in many cities, in particular for children. Regardless of which regulation may be more appropriate given the state of cycling infrastructure in a city, it is crucial that all traffic participants understand the rules. Misperceptions, such as that cyclists do not belong on the road, or that cycling at maximum speed on a sidewalk is acceptable, need to be countered with educational campaigns. Pedestrians should have the right-of-way at marked crosswalks, and such rules should be enforced sufficiently to change driver behaviour and pedestrian confidence. Overpasses and underpasses for pedestrians to cross major roads should be avoided, while pedestrian-friendly at-grade crossings should be provided instead. Speed regulations should be set low enough to enable pedestrian- and cycling-friendly environments (e.g. speed limits to 20 km/h in shared space zones), rather than putting the sole priority on maximizing motorized traffic flows. For example, Austria is actively considering introducing the concept of school streets to the road traffic regulation, on which driving is banned during the beginning and end of school, when students enter or exit school. The road traffic regulation works as the legal framework, while the implementation of the school streets concept takes place at a local or regional level (Mobilitätsagentur Wien GmbH, 2022)

Driver education should address safe driving with cyclists, including issues such as proper turning behaviour, adequate passing distance, and the prevention of so-called dooring (i.e. checking for cyclists before opening car doors). By any account, cyclists and pedestrians are not any better at obeying traffic rules than drivers. However, as vulnerable road users they bear a disproportionate amount of consequences in cases with collisions with cars, and their faulty behaviour rarely results in severe harm. One way to reflect this disparity is to put the burden of liability on drivers, or their insurance coverage, as is the case with strict liability in the Netherlands (Bicycle Dutch, 2013).

4.4. Safe Systems and Vision Zero

The term Safe System represents the current consensus of what constitutes best practice strategic thinking in road safety (Organisation for Economic Co-operation and Development, 2016). It builds on Sweden's Vision Zero and the Dutch principles of sustainable safety (Johansson, 2009; Wegman, Aarts and Bax, 2008). These policies assume an underlying ethical platform in which human life is sacrosanct, and road victims must not be weighed against the costs of preventing crashes. The key to Safe Systems is human vulnerability and the fact that people make errors. The goal of Safe Systems is to eliminate deaths and serious injuries by designing systems in a way that human error will not lead to catastrophic outcomes. An important aspect of the Safe Systems approach are quantitative goals, such as the elimination of deaths and severe traffic injuries. While many countries have managed to substantially reduce road fatalities from driving, reductions in fatality rates for active travel have lagged behind (Buehler and Pucher, 2017; Ferenchak and Marshall, 2018).

4.5. National walking and cycling policies

In some countries, cycling and walking are not fully incorporated into national policies on transport, health and environment, nor, in many cases, are they included in curricula for future urban planners.

An effective way of addressing this issue and increasing the importance and political visibility of these previously neglected transport modes, is through the development of national cycling and/or walking plans. These are strategically important policy documents that in recent years have been developed by an increasing number of countries. They provide a framework for expanding cycling and walking at various policy levels and supporting regional and local authorities' efforts through, for example, clarifying lines of responsibility and including provisions for the financing of cycling and walking projects. These plans and their objectives and recommendations should reflect the country's characteristics and include cycling and walking policies and strategies. National authorities should coordinate, monitor and update implementation of the plans and ensure the involvement of all relevant stakeholders at the regional and local levels.

Box 15 and Box 16 present two case studies of national policies, while Box 18 provides an overview of international policies in support of walking and cycling.

Box 15
National policies and laws to promote walking and cycling in Switzerland

Switzerland has a unique political mechanism where a popular vote on a *popular initiative* can be used to amend the constitution. In response to a popular initiative for the promotion of cycling, the Swiss Federal Council (the federal government) developed a so-called *counter-proposal* in August 2017 to modify the federal constitution in order to declare principles for cycling within the competence of the federal government, and instruments for implementation of these principles by the cantons (i.e. the sub-national level of government). A similar provision is already in place for walking and hiking (Swiss Federal Council, 2018a). The counter-proposal was a compromise, which led to the withdrawal of the original popular initiative.

After endorsement by the parliament in March 2018, the proposal was submitted to a popular vote and accepted by a 73.6% yes vote. The resulting constitutional amendment empowered the federal government to define principles for cycle networks and coordinate measures conducted by its cantons to plan and build such networks, accommodate everyday biking needs, as well as those of bicycle tourism.

In May 2021, to execute these principles, the Swiss Federal Council proposed a federal law regulating cycling networks, which would mandate cantons to plan and implement cycling routes and provide cohesive and safe cycling networks. The related parliamentary deliberations started in 2021, while differences between the two parliamentary chambers need to be deliberated in 2022.

Box 15 (contd)

There is a YouTube clip that explains the Swiss Cycling amendment (Swiss Federal Council, 2018b) Note: use the auto-translate option to translate subtitles).

Source: (Departement für Umwelt, Verkehr, Energie und Kommunikation, 2018)

4.6. Long-term urban planning

In terms of broader policies that fall within the scope of urban planning, promoting density and mixed land use has been identified as a key factor to determine the pedestrian and bicycle friendliness of cities because they reduce the travel distances to common destinations (Guerra et al., 2020; Saelens and Handy, 2008; United Nations Economic Commission for Europe, 2020). Density may thereby refer to several dimensions, including housing, job opportunities, destinations, or street network/intersections, among others (Voulgaris et al., 2017). While in the short- to medium-term the density of an urban development is difficult to change, it is important to factor it into long-term planning decisions (e.g. zoning codes).

4.7. Integrated policies and supporting efforts

Several policy efforts can be classified as intersectoral, or in other words, they neither solely nor primarily pursue transport objectives, nor are they rooted within the transport sector, but nonetheless play an important role in the promotion of walking and cycling. The promotion of active travel modes has been recognized as a promising strategy – in public health promotion, to increase levels of physical activity, and as part of climate mitigation efforts, to shift short car trips to walking and cycling. Efforts to integrate transport, health and environmental activities should be strengthened at all administrative levels (Box 17).

The quantification of impacts, for example by using HEAT (HEAT v5.0, 2022) (Box 10), can be a helpful tool for cross-sectoral education, as transport planners are often unaware of the magnitude of health benefits resulting from active travel. Health professionals and physicians, on the other hand, may underestimate the magnitude of physical activity individuals could accrue from daily travel. Such efforts should be integrated systematically in transport planning and project assessments, as called for by WHO's Health in all Policies approach (Kahlmeier et al., 2010; World Health Organization, 2013), or the United Kingdom's transport project appraisal guidance (Department for Transport, 2018).

An important aspect of bolstering efforts to promote active travel is to invest in data collection efforts, which then allow for the evaluation of measures and assessments of future needs. Automated bicycle and pedestrian counters provide cheap and reliable means to track trends over time (Buehler and Pucher, 2021b; Kraus and Koch, 2021; Le, Buehler and Hankey, 2019). Household travel surveys (Goel et al., 2021; Wittwer et al., 2018), on the other hand, are best for tracking mode share, or the total contribution of active travel modes to overall mobility, which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among other uses is crucial to assess pedestrian and cyclist safety (Buehler and Pucher, 2017; Castro, Kahlmeier and Götschi, 2018). Similarly, crash registries should be kept up-to-date with regards to collected information, which should be expanded, as needed, to include active modes, separating walking, cycling and e-biking; capture crash location, injuries, even if minor; and other variables of relevance. Exposure-adjusted crash rates should be calculated and published as part of routine safety monitoring efforts (Buehler and Pucher, 2017; Castro, Kahlmeier and Götschi, 2018). Specialized research surveys allow for more in-depth analysis of issues related to active travel (Brand et al., 2021a; Gascon et al., 2019; Panik et al., 2019; Raser et al., 2018). To reflect active modes accurately, walking and cycling, and increasingly e-biking, need to be treated as separate modes, and special attention needs to be paid to capturing short trips and seasonality. Increasingly, smartphone apps are becoming a convenient way to survey travel behaviour (Molloy et al., 2021b).

Policies to promote walking and cycling do not need to be re-invented from scratch. As there are wide discrepancies in how advanced the promotion of active travel is between cities in Europe and around the world, proactively engaging in policy transfer, such as learning and adopting from others' success stories, is a highly promising strategy to make swift progress (Marsden et al., 2011).

Planning standards, norms and official guidance documents play an important role in the daily work of planners and engineers. The development of such regulatory frameworks is typically slow, and outdated rules can have a paralyzing effect on innovative road treatments. Regulatory agencies at all levels of government should systematically review their regulatory documents with regards to the accommodation of active travel modes and update these as needed. In particular, in jurisdictions that are new to the promotion of walking and cycling, it is crucial to provide options that facilitate the introduction of experimental solutions, which may not have been tested locally, but have been successfully implemented elsewhere. Equally, standard setting needs to keep up with the ascent of new vehicle types, including e-bikes and scooters.

Ultimately, funding mechanisms play a crucial role in how effectively active travel can be promoted. What is considered to be a sufficient allocation of general and transportation funds to finance the various measures described above is ultimately a political decision. To inform such decision processes, a holistic view on costs and benefits should be applied, including environmental and health aspects. External costs, such as those borne by society, should whenever possible be internalized, such as through charging them to the causing party (i.e. polluter pays principle). In most cases, such paradigm shifts would improve financial decisions in favour of active modes, compared to the prevailing status quo. It has been estimated that in the EU, driving causes approximately 500 billion euros in external costs, whereas walking and bicycling yield 66 and 24 billion euros, respectively, in external benefits (Gössling et al., 2019).

In many ways, the future of urban transportation lays within the hands of those who plan and shape it in their daily work. Capacity building and sensitization related to active travel topics, among current and future transport planners and engineers as well as other relevant professions, therefore plays a critical role in laying the groundwork for future progress. Investments in education and research – such as through German Cycling Professorships, professional networks and competence centres, among others, are therefore an important component to achieve long-term and sustainable change.

Aside from all the utility-focused consideration regarding active urban transport, there is also an important leisure side to these travel modes. Urban planners and decision-makers have important roles to play in the areas of recreational walking and cycling for exercise or pleasure, as well as in the realm of tourism. Urban green spaces, for example, provide important infrastructure at the fringe of transport and recreation, and long-distance cycling networks, often overlapping with urban cycling infrastructure, are becoming an increasingly popular magnet for tourism.

Digitalization has introduced a myriad of useful tools into our lives, several of which can contribute to making walking and cycling easier, safer and more convenient. Major online mapping services, and in some cases individual cities, have invested in wayfinding maps with specific algorithms for pedestrians and cyclists. Bike sharing systems rely heavily on smartphone apps. Several organizations are using crowd-sourcing approaches to address traffic safety, infrastructure improvements and theft prevention, among others. Moreover, smartphone tracking apps can provide city planners with insightful usage data with regards to route preferences and network improvement needs.

Box 16
Austrian Masterplans for cycling and walking and the national *klimaaktiv* mobil programme to promote walking and cycling

In 2015, Austria has developed an innovative approach to the promotion of cycling and walking, through their integration into its National Energy and Climate Programme.

The Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology, developed a national strategy to promote walking: the Walking Masterplan Austria. The aim of this plan was to raise the profile of walking and consider pedestrian needs in decision-making at the federal, regional and local level, as well as to improve framework conditions to promote walking as a mode of transport. The Walking Masterplan contains 10 fields of action with 26 concrete measures to create a pedestrian-friendly environment. This was a major step forward to promote active mobility and put walking at the forefront of transport policies.

The first national Cycling Masterplan had already been established in 2006 and included the objective of doubling the share of cycling. As a result, the modal share of cycling increased to 7% at the national level. The second national cycling plan covers the period 2015–2025 with the overall objective of almost doubling cycling yet again, to 13%.

Consequently, the Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology established a federal coordination

Box 16 (contd)

mechanism for cycling and walking policies, involving all federal states and their capital cities, and established *klimaaktiv mobil*, a special federal funding portfolio to promote cycling and walking. From 2020 to 2021, the budget increased tenfold: from 4 to 40 million e uros, and further to 60 million e uros for 2022. Through *klimaaktiv mobil*, the federal government is co-financing cycling and walking infrastructure, such as cycling paths, cycling highways, bicycle parking, bicycle-sharing systems including e-bikes and cargo bikes, pedestrian zones, and shared space zones. To receive funding, the establishment of a regional or local cycling or walking strategy or masterplan is required. Furthermore, *klimaaktiv mobil*, supports non-infrastructure programmes on active mobility, such as mobility management in cities, municipalities, companies, tourism and schools, and awareness raising campaigns.

Austrian Master Plans for Walking and Cycling

Sources: Thaler and Eder, 2007, 2015a and 2015b.

Box 17
Healthy Streets Approach to change planning practice

Greater London, United Kingdom, adopted the Healthy Streets Approach and, despite falling budgets, has made huge strides in improving streets for people walking, cycling, standing and sitting. Measures include the widespread roll-out of 20 miles per hour (mph) limits, reallocation of road space from cars to cycles, and greater priority at junctions for people walking and cycling. This has been done at scale across the Greater London region of 10 million people through systematically prioritizing 10 Healthy Streets Indicators in leadership, communications, policy development and project design. It costs little – relative to transport infrastructure budgets – to change priorities and governance processes, and this delivers huge differences in outcomes for citizens. The change was achieved through training transport and planning professionals and applying Healthy Streets tools at each stage of decision-making processes. This successful combination of training and tools is now being rolled out across the United Kingdom and Australia, delivering a sustained shift in the dominant discourse of urban transport from cars first to people's needs first.

The 10 Healthy Streets Indicators

Source: (Saunders, 2021)

Box 18
International policies and programmes in support of walking and cycling promotion

The value of walking and cycling as important pillars in future sustainable transport systems has been recognized in several global and regional policies and processes. These high-level endorsements – as part of climate change mitigation, health promotion, environmental protection and other efforts – provide a further basis and guidance in support of efforts to promote walking and cycling.

The 2030 Agenda for Sustainable Development highlights the importance of the shift towards more sustainable and healthy means of transport, including active travel, for achieving the Sustainable Development Goals (SDGs). For example, investing in efforts to get more people cycling, more often could unleash the potential of cycling for achieving 11 out of 17 SDGs, in particular the collective aspirations for road safety, reducing greenhouse gas emissions from transport and urban air pollution, climate action and energy efficiency (European Cyclists' Federation, 2016b; United Nations in Western Europe, 2022).

WHO recognizes walking and cycling as effective strategies to promote physical activity, a key factor in the prevention of noncommunicable diseases. The WHO Regional Office for Europe's mandate on transport and health is promoted through the WHO European Environment and Health Process (EHP) and THE PEP. Both are rich in the number of ministerial declarations and

Box 18 (contd)

high-level commitments that identify walking and cycling promotion as a regional priority and call for accelerated action towards ensuring healthy and sustainable mobility, including the:

- ☑ 2017 Ostrava Declaration, a high-level commitment by environment and health ministers to low-emission and energy-efficient transport and mobility integrated with urban and spatial planning, including the promotion of walking and cycling (WHO Regional Office for Europe, 2017); and
- ☑ 2021 Vienna Declaration, Building forward better by transforming to new, clean, safe, healthy and inclusive mobility and transport, and especially its Annex III the first ever pan-European Master Plan for Cycling Promotion, focusing on the implementation of environmentally friendly, economically viable, and socially fair and healthy mobility in the pan-European region (United Nations Economic Commission for Europe, 2021).

Other international commitments supportive of walking and cycling promotion include:

- ☑ WHO Global Strategy on Diet, Physical Activity and Health, which encourages environmental planning that allows for increased walking, cycling and other physical activities (World Health Organization, 2004);
- ☑ Physical Activity Strategy for the WHO European Region 2016–2025, which, among other activities, promotes physical activity for all adults as part of daily life, including during transport (WHO European Office for Europe, 2016a);
- ☑ WHO Global Action Plan for the Prevention and Control of Noncommunicable Diseases (2013–2020) (World Health Organization, 2013a);

Box 18 (contd)

- ☑ WHO Global action plan on physical activity 2018–2030: more active people for a healthier world (World Health Organization, 2018b);
- ☑ WHO guidelines on physical activity and sedentary behaviour, which promote walking and cycling as a means of physical activity (World Health Organization, 2020d);
- ☑ Paris Climate Change Agreement, which puts transport and mobility at the centre of the climate change agenda and calls for carbon-free mobility and investing more in walking and cycling infrastructure (United Nations, 2015);
- ☑ Habitat III Conference, held in October 2016, and its outcome, which was the adoption of a New Urban Agenda (United Nations, 2016);
- ☑ Luxembourg Declaration of the Informal meeting of EU ministers for Transport, held in Luxembourg in October 2015 (The Government of the Grand Duchy of Luxembourg, 2015);
- ☑ Graz Declaration of the Informal Meeting of EU Environment and Transport Ministers, Graz, Austria, in October 2018, inviting the European Commission to develop and deliver the comprehensive strategy for sustainable, clean, safe, affordable and inclusive mobility in Europe (Federal Ministry Republic of Austria, 2018);
- ☑ WHO Manifesto for a healthy recovery from COVID-19 (World Health Organization, 2020e).

5 Concluding remarks

A rich body of evidence supports the claim that walking and cycling are beneficial for urban transport, and well beyond. The health benefits from active travel are substantial and their potential to help move towards carbon-free mobility is increasingly recognized.

Research and practice have amassed a rich portfolio of measures to promote walking and cycling, including actionable options for any city around the globe. Increasing safety for pedestrians and cyclists must be a key goal for the vast majority of cities, but the required measures go together with improvements in comfort and convenience for active travellers. Increasing levels of walking and cycling and increasing traffic safety are therefore often one and the same. Central to such efforts is providing coherent networks of consistent quality. Physically separated infrastructure is equally as important as traffic calming, as is consideration of the needs of the most vulnerable travellers, such as children and elderly.

To provide such efforts with sufficient support, current planning practice needs to realign the prioritization of travel modes regarding funds and space and recognize active travel as an intersectoral issue of relevance to a broad set of policy goals, namely those including health and sustainability. Such structural realignments should manifest at all administrative levels, from small project evaluations to high-level departmental strategies, and should routinely be reflected in decision-making.

Policy commitments, such as those taken through the Vienna Declaration and Pan-European Masterplan for Cycling Promotion, can be powerful catalysts for change, helping countries to acknowledge walking and cycling as important modes of transport for attaining greater urban resilience and quality of urban life. With a post-pandemic return to a new normal in sight, this is the right time to realign urban transport priorities with broader goals for public health and sustainability.

References[1]

2018 Physical Activity Guidelines Advisory Committee (2018). 2018 Physical Activity Guidelines Advisory Committee Scientific Report. Washington D.C.: U.S. Department of Health and Human Services (https://health.gov/our-work/nutrition-physical-activity/physical-activity-guidelines/current-guidelines/scientific-report).

Abel S, Hanzlik M, Kraft K, Heidi S, Cass I, Mennesson M (2019). Walking and Biking Perspectives on Active and Sustainable Transportation: National Complete Streets Coalition, Safe Routes to School, and America Walks. ITE J 89(5): 29–34.

Aldred R, Woodcock J, Goodman A (2021). Major investment in active travel in Outer London: Impacts on travel behaviour, physical activity, and health. J Transp Health. 20:100958. doi:10.1016/j.jth.2020.100958.

Appleyard BS, Ferrell CE (2017). The Influence of Crime on Active and Sustainable Travel: New Geo-Statistical Methods and Theories for Understanding Crime and Mode Choice. J Transp Health. 6:516–529. doi:10.1016/j.jth.2017.04.002.

Arellana J, Saltarín M, Larrañaga AM, González VI, Henao CA (2020). Developing an urban bikeability index for different types of cyclists as a tool to prioritise bicycle infrastructure investments. Transp. Res. A: Policy Pract. 139:310–334. doi:10.1016/j.tra.2020.07.010.

ASTRA (2021). Kennzahlen Unfalldaten der Schweiz [Crash Statistics Switzerland] [website]. (https://www.astra.admin.ch/astra/de/home/dokumentation/daten-informationsprodukte/unfalldaten/statistische-auswertungen/kennzahlen.html).

Audrey S, Procter S, Cooper AR (2014). The contribution of walking to work to adult physical activity levels: a cross sectional study. Int J Behav Nutr Phys Act. Mar 11;11(1):37. doi:10.1186/1479-5868-11-37.

Avila-Palencia I, de Nazelle A, Cole-Hunter T, Donaire-Gonzalez D, Jerret M, Rodrigues AD et al. (2017). The relationship between bicycle commuting and perceived stress: a cross-sectional study. BMJ Open. 7(8):e013542. doi:10.1136/bmjopen-2016-013542.

1 All weblinks accessed 20 April 2022.

Babisch W (2014). Updated exposure-response relationship between road traffic noise and coronary heart diseases: A meta-analysis. Noise and Health. 16(68):1–9. doi:10.4103/1463-1741.127847.

Badawi Y, Maclean F, Mason B (2018). The economic case for investment in walking. Melbourne; Victoria Walks Inc (https://www.victoriawalks.org.au/Assets/Files/The-Economic-Case-for-Investment-in-Walking-FINAL.pdf).

Badger (2012). Cyclists and Pedestrians Can End Up Spending More Each Month Than Drivers [website]. New York: Bloomberg (https://www.bloomberg.com/news/articles/2012-12-05/cyclists-and-pedestrians-can-end-up-spending-more-each-month-than-drivers).

Baker G (2020). The health and economic benefits of active commuting in Scotland. SCADR. doi:10.7488/era/727.

Barbosa A, Whithing S, Simmonds P, Scotini Moreno R, Mendes R and Breda J (2020). Physical Activity and Academic Achievement: An Umbrella Review. Int J Env Res and Public Health. 17(16):5972. doi:10.3390%2Fijerph17165972.

Bardi A et al. (2019). Flexible Mobile Hub for E-Bike Sharing and Cruise Tourism: A Case Study. Sustainability. 11(19):5462. doi:10.3390/su11195462.

Batley R, Bates J, Bliemer M, Börjesson M, Bourdon J, Ojeda Cabral M et al. (2019). New appraisal values of travel time saving and reliability in Great Britain. Transportation. 46(3):583–621. doi:10.1007/s11116-017-9798-7.

Bhatia R, Wier M (2011). "Safety in numbers" re-examined: Can we make valid or practical inferences from available evidence? Accid Anal Prev. 43(1):235–240. doi:10.1016/j.aap.2010.08.015.

Bicycle Dutch (2013). Strict liability in the Netherlands [website]. The Netherlands: Bicycle Dutch (https://bicycledutch.wordpress.com/2013/02/21/strict-liability-in-the-netherlands/).

Bigazzi A, Wong K (2020). Electric bicycle mode substitution for driving, public transit, conventional cycling, and walking. Transp Res D Transp Environ. 85:102412. doi:10.1016/j.trd.2020.102412.

Boisjoly G, Lachapelle U, El-Geneidy A (2020). Bicycle network performance: Assessing the directness of bicycle facilities through connectivity measures, a Montreal, Canada case study. Int J Sustain Transp. 14(8):620–634. doi:10.1080/15568318.2019.1595791.

Bornioli A, Bray I, Pilkington P, Parkin J (2020). Effects of city-wide 20 mph (30km/hour) speed limits on road injuries in Bristol, UK. Inj Prev. 26(1):85–88. doi:10.1136/injuryprev-2019-043305.

Bourne JE, Sauchelli S, Perry R, Page A, Leary S, England C, et al (2018). Health benefits of electrically-assisted cycling: a systematic review. Int JBehav Nutr Phys Act, 15(1):116. doi:10.1186/s12966-018-0751-8.

Bourne JE, Cooper AR, Kelly P, Kinnear FJ, England C, Leary S, et al. (2020). The impact of e-cycling on travel behaviour: A scoping review. J Transp Health. 19:100910. doi:10.1016/j.jth.2020.100910.

Brand C, Götschi T, Dons E, Gerike R, Anaya-Boig E, Avila-Palencia, et al. (2021a). The climate change mitigation impacts of active travel: Evidence from a longitudinal panel study in seven European cities. Glob Env Change. 67:102224. doi:10.1016/j.gloenvcha.2021.102224.

Brand C, Dons E, Anaya-Boig E, Avila-Palencia I, Clark A, de Nazelle A, et al (2021b). The climate change mitigation effects of daily active travel in cities. Transp Res D Transp Environ. 93:102764. doi:10.1016/j.trd.2021.102764.

Branion-Calles M, Götschi T, Nelson T, Anaya Boig E, Avila-Palencia I, Castro A, et al (2020). Cyclist Crash Rates and Risk Factors in a Prospective Cohort in Seven European Cities. Accid Anal Prev. 141:105540. doi:10.1016/j.aap.2020.105540.

Brown V, Zapata Diomendi B, Moodie M, Veerman JL, Carter R (2016). A systematic review of economic analyses of active transport interventions that include physical activity benefits. Transp Policy. 45:190–208. doi:10.1016/j.tranpol.2015.10.003.

Brown V, Moodie M, Mantilla Herrera AM, Veerman JL, Carter R (2017). Active Transport and Obesity Prevention - A Transportation Sector Obesity Impact Scoping Review and Assessment for Melbourne, Australia. Prev Med. 96:49-66. doi:10.1016/j.ypmed.2016.12.020.

Buehler R, Pucher J, Gerike R, Götschi T. (2017). Reducing car dependence in the heart of Europe: lessons from Germany, Austria, and Switzerland. Transp Rev. 37(1):4–28. doi:10.1080/01441647.2016.1177799.

Buehler R, Pucher J (2017). Trends in walking and cycling safety: Recent evidence from high-income countries, with a focus on the United States and Germany. Am J Public Health. 107(2):281–287. dx.doi:10.2105%2FAJPH.2016.303546.

Buehler R, Pucher J, editors (2021a). Cycling for sustainable cities. Cambridge, Massachusetts: MIT Press (mitpress.mit.edu/books/cycling-sustainable-cities).

Buehler R, Pucher J (2021b). COVID-19 Impacts on Cycling, 2019–2020. Transp Rev. 4:1–8. doi:10.1080/01441647.2021.1914900.

Buehler R, Pucher J, Bauman A (2020). Physical Activity from Walking and Cycling for Daily Travel in the United States, 2001–2017: Demographic, Socioeconomic, and Geographic Variation. J Transp Health. 16:100811. doi:10.1016/j.jth.2019.100811.

Bundesministeriums für Verkehr und digitale Infrastruktur [German Federal Ministry of Transport and Digital Infrastructure] (2017). Mobilität in Tabellen [Mobility in tables] [website]. Berlin: Bundesministeriums für Verkehr und digitale Infrastruktur (https://mobilitaet-in-tabellen.dlr.de/mit/login.html?brd,) (in German).

Bundesamt für Statistik [Swiss Federal Statistical Office] (2012). Mikrozensus Mobilität und Verkehr 2010 [Microcensus on mobility and transport 2010]. Neuchâtel, Bundesamt für Statistik (https://www.bfs.admin.ch/bfs/en/home/statistics/catalogues-databases/publications.gnpdetail.2012-0796.html) (in German).

Bundesamt für Statistik [Swiss Federal Statistical Office] (2015). Strassenverkehrsunfälle: beteiligte Objekte nach Objektart [Road crashes: Involved objects and types] [website]. Neuchâtel: Bundesamt für Statistik (https://www.pxweb.bfs.admin.ch/pxweb/en/px-x-1106010100_105/-/px-x-1106010100_105.px/) (in German).

Bundesamt für Statistik [Swiss Federal Statistical Office] (2017). Tagesdistanz, Tagesunterwegszeit und Anzahl Etappen mit Velo und E-Bike nach Verkehrszweck [Daily distance, daily journey time and number of stages by bicycle and e-bike according to purpose of transport] [website]. Neuchâtel: Bundesamt für Statistik. (https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/tabellen.assetdetail.2500720.html) (in German).

Buning RJ, Lulla V (2021). Visitor bikeshare usage: tracking visitor spatiotemporal behavior using big data. J Sustain Tour. 29(4):711–731. doi:10.1080/09669582.2020.1825456.

Bunn F, Colleir T, Frost C, Ker K, Roberts I, Wentz R (2003). Traffic calming for the prevention of road traffic injuries: systematic review and meta-analysis. Inj Prev. 9(3):200–204. doi:10.1136/ip.9.3.200.

Cabral L, Kim AM, Shirgaokar M (2019). Low-Stress Bicycling Connectivity: Assessment of the Network Build-Out in Edmonton, Canada. Case Stud Transp Policy. 7(2):230–238. doi:org/10.7939/r3-ef3w-9397.

Cairns J, Warren J, Garthwaithe K, Greig G, Bambra C (2015). Go slow: An umbrella review of the effects of 20 mph zones and limits on health and health inequalities. J Public Health (Oxf). 37(3):515–520. doi:10.1093/pubmed/fdu067.

Cairns S et al. (2008). Smarter Choices: Assessing the Potential to Achieve Traffic Reduction Using 'Soft Measures'. Transp Rev 28(5):593–618. doi:10.1080/01441640801892504.

Calvo M, Marqués R (2020). How Seville Became a City of Cyclists [website]. Vision Zero Cities Journal (https://medium.com/vision-zero-cities-journal/how-seville-became-a-city-of-cyclists-fba864b4be66).

Cameron TA (2010). Euthanizing the value of a statistical life. Rev Environ Econ Policy, 4(2):161–178. doi:10.1093/reep/req010.

Carlson JA, Steel C, Bejarano CM, Beauchamp MT, Davis AM, Sallis JF, et al (2020). Walking School Bus Programs: Implementation Factors, Implementation Outcomes, and Student Outcomes, 2017–2018. Prev Chronic Dis.17. doi:10.5888/pcd17.200061.

Carlson K, Ermagun A, Murphy B, Owen A, Levinson D (2019). Safety in Numbers for Bicyclists at Urban Intersections. Transp Res Rec. 2673(6):677-684. doi:10.1177%2F0361198119846480.

Castro A, Gaupp-Berghausen M, Dons E, Standaert A, Laeremans M, Clark A, et al (2019). Physical activity of electric bicycle users compared to conventional bicycle users and non-cyclists: Insights based on health and transport data from an online survey in seven European cities. Transp Res Interdiscip Perspect, 1:100017. doi:10.1016/j.trip.2019.100017.

Castro A, Kahlmeier S, Götschi T (2018). Exposure-adjusted Fatality Rates for Cycling and Walking in European Countries. London: International Transport Federation, Paris: Organisation for Economic Co-operation and Development (https://www.itf-oecd.org/exposure-adjusted-road-fatality-rates-cycling-and-walking-european-countries).

Castro A, Künzli N, Götschi T (2017). Health benefits of a reduction of PM10 and NO2 exposure after implementing a clean air plan in the Agglomeration Lausanne-Morges. Int J Hyg Environ Health. 220(5):829-839. doi:10.1016/j.ijheh.2017.03.012.

Celis-Morales CA, Lyall DM, Welsh P, Anderson J, Steell L, Guo Y, et al. (2017). Association between active commuting and incident cardiovascular disease, cancer, and mortality: prospective cohort study. BMJ. 357. doi:10.1136/bmj.j1456.

Chen C-F, Huang C-Y (2021). Investigating the effects of a shared bike for tourism use on the tourist experience and its consequences. Curr Issues Tour. 24(1):134–148. doi:10.1080/13683500.2020.1730309.

Chimba D, Mbuya C (2019). Simulating the Impact of Traffic Calming Strategies. Transportation Research Center Reports. 42 (https://scholarworks.wmich.edu/transportation-reports/42).

CHIPS Project (2022). Degree of separation from motor vehicles [website]. Lille: Interreg North- West Europe (https://cyclehighways.eu/index.php?id=225).

Choi K, Park HJ, Dewald J (2021). The impact of mixes of transportation options on residential property values: Synergistic effects of walkability. Cities. 111:103080. doi:10.1016/j.cities.2020.103080.

Department of traffic and public space of the city of Amsterdam (2017). The Long-Term Bicycle Plan. Amsterdam: City of Amsterdam (https://bikecity.amsterdam.nl/documents/14/Long-term_Bicycle_Plan_2017-2022_web.pdf).

Colmer J (2020). What is the meaning of (statistical) life? Benefit-cost analysis in the time of COVID-19. Oxf Rev Econ Policy. 36:S56–S63. doi:10.1093/oxrep/graa022.

Combs TS, Pardo CF (2021). Shifting streets COVID-19 mobility data: Findings from a global dataset and a research agenda for transport planning and policy. Transp Res Interdiscip Perspect, 9:100322. doi:10.1016/j.trip.2021.100322.

Conrow L, Mooney S, Wentz EA (2021). The association between residential housing prices, bicycle infrastructure and ridership volumes. Urban Stud, 58(4):787–808. doi:10.1177%2F0042098020926034.

Cooper A, Page A, Bourne J (2020). How coronavirus made 2020 the year of the electric bike. London: The Conversation (https://theconversation.com/how-coronavirus-made-2020-the-year-of-the-electric-bike-143158).

Cooper AR, Tibbits B, England C, Procter D, Searle A, Sebire SJ, et al. (2018). Potential of electric bicycles to improve the health of people with Type 2 diabetes: a feasibility study. Diabet Med. 35(9):1279–1282. doi:10.1111%2Fdme.13664.

Creutzig F, Roy J, Lamb WF, Azevedo IML, deBruine WB, et al. (2018). Towards demand-side solutions for mitigating climate change. Nat Clim Change. 8:4, 8(4):260–263. doi:10.1038/s41558-018-0121-1.

CROW (2021). Design manual for bicycle traffic. The Netherlands: CROW Platform. (https://crowplatform.com/product/design-manual-for-bicycle-traffic/)

Cuenot F, Fulton L, Staub J (2012). The prospect for modal shifts in passenger transport worldwide and impacts on energy use and CO2. Energy Policy. 41:98–106. doi:10.1016/j.enpol.2010.07.017.

Davis A (2005). Transport and health - What is the connection? An exploration of concepts of health held by highways committee Chairs in England. Transp Policy. 12(4):324–333. doi:10.1016/j.tranpol.2005.05.005.

D**avis AL, Obree D (2020).** Equality of restraint: Reframing road safety through the ethics of private motorised transport. J Transp Health. 19:100970. doi:10.1016/j.jth.2020.100970.

DEKRA (2019) Ermittlung der Helmtragequote bei Nutzer/innen von Fahrrädern, Pedelecs und (E)-Scootern in europäischen Hauptstädten [Determination of the helmet wearing rate among users of bicycles, pedelecs and (e)-scooters in European capitals] Stuttgart: DEKRA (https://www.dekra-roadsafety.com/media/47-studie-helmtragequote-hauptstaedte.pdf) (in German).

Delso J, Martín B, Ortega E (2018). Potentially replaceable car trips: Assessment of potential modal change towards active transport modes in Vitoria-Gasteiz. Sustainability. 10(10):3510. doi:10.3390/su10103510.

Department for Transport (2018). Transport analysis guidance. London: UK Government (https://www.gov.uk/guidance/transport-analysis-guidance-tag).

Department for Transport (2019). Reported road casualties in Great Britain: 2019 annual report. London: UK Government (https://www.gov.uk/government/statistics/reported-road-casualties-great-britain-annual-report-2019).

Departement für Umwelt, Verkehr, Energie und Kommunikation [Federal Department for the Environment, Transport, Energy and Communications] (2018). Bundesbeschluss Velowege [Federal decree on Bicycle routes] [website]. Bern. (https://www.uvek.admin.ch/uvek/de/home/uvek/abstimmungen/velo-vorlage.html) (in German).

Dill J, McNeil N (2013). Four Types of Cyclists? Transp Res Rec. 2387:129–138. doi:10.3141%2F2387-15.

Dill J, Smith O, Howe D (2017). Promotion of Active Transportation among State Departments of Transportation in the U.S. J Transp Health. 5:163-171. doi:10.1016/j.jth.2016.10.003.

Dinu M, Pagliai G, Macchi C, Sofi F (2019). Active Commuting and Multiple Health Outcomes: A Systematic Review and Meta-Analysis. Sports Med. 49:437–452. doi:10.1007/s40279-018-1023-0.

Directorate-General for Mobility and Transport (2021a). 1.8 Cycle streets [website]. Brussels: European Commission (https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/cycling/guidance-cycling-projects-eu/cycling-measures/18-cycle-streets_en).

Directorate-General for Mobility and Transport (2021b). 1.7 Mixed-use zones [website]. Brussels: European Commission (https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/cycling/guidance-cycling-projects-eu/cycling-measures/17-mixed-use-zones_en).

Directorate-General for Mobility and Transport (2021c). 1.5 Intersections [website]. Brussels: European Commission (https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/cycling/guidance-cycling-projects-eu/cycling-measures/15-intersections_en).

Dons E, Rojas-Rueda D, Anaya-Boig E, Avila-Palencia I, Brand C, Cole-Hunter T, et al. (2018). Transport Mode Choice and Body Mass Index: Cross-Sectional and Longitudinal Evidence from a European-Wide Study. Environ Int. 119:109-116. doi:10.1016/j.envint.2018.06.023.

Doorley R, Pakrashi V, Szeto WY, Ghosh B (2020). Designing cycle networks to maximize health, environmental, and travel time impacts: An optimization-based approach. Int J Sustain Transp. 14(5):361–374. doi:10.1080/15568318.2018.1559899.

Doorley R, Pakrashi V, Ghosh B (2015). Quantifying the Health Impacts of Active Travel: Assessment of Methodologies. Transp Rev. 35(5):559–582. doi:10.1080/01441647.2015.1037378.

Dora C (1999). A different route to health: implications of transport policies. BMJ. 318(7199):1686. doi:10.1136%2Fbmj.318.7199.1686

Dora C, Phillips M, WHO Regional Office for Europe (2000). Transport, environment and health, edited by Carlos Dora and Margaret Phillips. Copenhagen: WHO Regional Office for Europe. (https://apps.who.int/iris/handle/10665/107336).

Elvik R (2001). Area-wide urban traffic calming schemes: a meta-analysis of safety effects. Accid Anal Preven. 33(3):327–336. doi:10.1016/s0001-4575(00)00046-4

Elvik R (2009). The non-linearity of risk and the promotion of environmentally sustainable transport. Accid Anal Preven. 41(4):849–855. doi:10.1016/j.aap.2009.04.009.

Eren E, Uz VE (2020). A review on bike-sharing: The factors affecting bike-sharing demand. Sustainable Cities and Society. 54:101882. doi:10.1016/j.scs.2019.101882.

Euro cities (2020). COVID-19 – City Dialogue on mobility measures – Highlights. Brussels: Euro cities (https://eurocities.eu/latest/covid-19-city-dialogue-on-mobility-measures-highlights/).

European Environmental Agency (2020). Train or plane? Copenhagen: European Environmental Agency (https://www.eea.europa.eu/publications/transport-and-environment-report-2020).

European Commission (2016). Transport Emissions [website]. Brussels: European Commission. (https://ec.europa.eu/clima/policies/transport_en).

European Commission (2019). The European Green Deal [website]. Brussels: European Commission (https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en).

European Cyclists' Federation (2014). COMMUTING: WHO PAYS THE BILL? Brussels: European Cyclists' Federation (https://ecf.com/groups/commuting-who-pays-bill).

European Cyclists' Federation (2016a). ELECTROMOBILITY FOR ALL Financial incentives for e-cycling. Brussels: European Cyclists' Federation (https://ecf.com/groups/report-electromobility-all-financial-incentives-e-cycling).

European Cyclists' Federation (2016b). Cycling delivers on the global goals. Brussels: European Cyclists' Federation (https://ecf.com/groups/cycling-delivers-global-goals).

Federal Ministry Republic of Austria (2018). Declaration "Starting a new era: clean, safe and affordable mobility for Europe". Informal meeting of environment and transport ministers, Graz, Austria- 29–30 October 2018 (https://civitas.eu/news/european-ministers-adopt-graz-declaration-for-clean-mobility)

Feleke R, Scholes S, Wardlaw M, Mindell JS (2018). Comparative fatality risk for different travel modes by age, sex, and deprivation. J Transp Health. 8:307–320. doi:10.1016/j.jth.2017.08.007.

Ferenchak NN, Marshall W (2018). Age-Specific Bicycling Safety Trends, 1985–2015. Transportation Research Board 97th Annual Meeting, Washington DC, 1–11 January 2018. In: TRID, the TRIS and ITID database (https://trid.trb.org/view/1494803).

Fiorello D, Martino A, Zani L, Christidis P, Navajas-Cawood E (2016). Mobility data across the EU 28 member states: results from an extensive CAWI survey. Transp Res Proc. 14:1104–1113. doi:10.1016/j.trpro.2016.05.181. Licence: Creative Commons CC-BY-NC-ND.

Fishman E (2016). Bikeshare: A Review of Recent Literature. Transp Rev, 36(1):92-113. doi:10.1080/01441647.2015.1033036.

Fishman E, Washington S, Haworth N (2013). Bike share: a synthesis of the literature. Transp Rev, 33(2):148–165. doi:10.1080/01441647.2013.775612.

Flanagan E, Lachapelle U, El-Geneidy A (2016). Riding tandem: Does cycling infrastructure investment mirror gentrification and privilege in Portland, OR and Chicago, IL? Res Transp Econ. 60:14-24. doi:10.1016/j.retrec.2016.07.027

Flemming S (2019). The Netherlands is paying people to cycle to work [website]. Geneva: World Economic Forum https://www.weforum.org/agenda/2019/02/the-netherlands-is-giving-tax-breaks-to-cycling-commuters-and-they-re-not-the-only-ones).

FLOW Project (2016). The Role of Walking and Cycling in Reducing Congestion: A Portfolio of Measures. Brussels (http://h2020-flow.eu/uploads/tx_news/FLOW_REPORT_-_Portfolio_of_Measures_v_06_web.pdf).

Forster P (2020). For a carbon-neutral UK, the next five years are critical – here's what must happen. London: The Conversation (https://theconversation.com/for-a-carbon-neutral-uk-the-next-five-years-are-critical-heres-what-must-happen-151708).

Furth PG, Mekuria MC, Nixon H (2016). Network Connectivity for Low-Stress Bicycling. Transp Res Rec. 2587:41-49. doi:10.3141%2F2587-06.

Fyhri A, Sundfør HB, Bjørnskau T, Laureshyn A (2017). Safety in numbers for cyclists—conclusions from a multidisciplinary study of seasonal change in interplay and conflicts. 105:124–133. doi:10.1016/j.aap.2016.04.039.

Garcia L, Johnson R, Johnson A, Abbas A, Goel R, Tatah L (2021). Health impacts of changes in travel patterns in Greater Accra Metropolitan Area, Ghana. Environ Int. 155:106680. doi:10.1016/j.envint.2021.106680.

Garrard J, Handy S, Dill J (2012). Women and cycling. In Pucher, J and Buehler, R (ed), City Cycling, MIT PRESS. 211–234.

Garrard J, Rose G, Lo SK (2008). Promoting transportation cycling for women: the role of bicycle infrastructure. Prev Med. 46(1):55–59. doi:10.1016/j.ypmed.2007.07.010.

Gascon M, Götschi T, de Nazelle A, Gracia E, Ambros A, Márquez S et al. (2019). Correlates of walking for travel in seven European cities: The PASTA project. Environ Health Perspect. 127(9). doi:10.1289/EHP4603.

Gehrke SR, Akhavan A, Furth PG, Wang Q, Reardon TG (2020). A cycling-focused accessibility tool to support regional bike network connectivity. Transp Res D Transp Environ. 85:102388. doi:10.1016/j.trd.2020.102388.

de Geus B, De Bourdeaudhuji I, Jannes C, Meeusen R (2008). Psychosocial and environmental factors associated with cycling for transport among a working population. Health Educ Res. 23(4):697–708. doi:10.1093/her/cym055.

Giallouros G, Kouis P, Papatheodorou SI, Woodcock J, Tainio M (2020). The long-term impact of restricting cycling and walking during high air pollution days on all-cause mortality: Health impact Assessment study. Environ Int. 140:105679. doi:10.1016/j.envint.2020.105679.

Goel R, Goodman A, Aldred R, Nakamura R, Tatah L, Totaro-Garcia LM, et al (2021). Cycling behaviour in 17 countries across 6 continents: levels of cycling, who cycles, for what purpose, and how far? Transp Rev, 42(1):1–24. doi:10.1080/01441647.2021.1915898.

Goodman A, Fridman Rojas I, Woodcock J, Aldred R, Berkoff N, Morgan M, et al (2019). Scenarios of cycling to school in England, and associated health and carbon impacts: Application of the 'Propensity to Cycle Tool.' J Transp Health. 12:263–278. doi:10.1016/j.jth.2019.01.008.

Goodman A, Cheshire J (2014). Inequalities in the London bicycle sharing system revisited: impacts of extending the scheme to poorer areas but then doubling prices. J Transp Geogr. 41:272–279. doi:10.1016/j.jtrangeo.2014.04.004.

Goodman A, Sahlqvist S, Ogilvie D (2014). New walking and cycling routes and increased physical activity: one-and 2-year findings from the UK iConnect Study. A J Pub Health. 104(9):e38–e46. doi:10.2105%2FAJPH.2014.302059.

Gössling S, Schröder M, Späth P, Freytag T (2016). Urban Space Distribution and Sustainable Transport. Transp Rev, 36(5):659–679. doi:10.1080/01441647.2016.1147101.

Gössling S, Choi AS, Dekker K, Metzler D (2019). The Social Cost of Automobility, Cycling and Walking in the European Union. Ecol Econ. 158:65–74. doi:10.1016/j.ecolecon.2018.12.016.

Gössling S, Choi AS (2015). Transport transitions in Copenhagen: Comparing the cost of cars and bicycles. Ecol Econ. 113:106–113. doi:10.1016/j.ecolecon.2015.03.006.

Götschi T (2011). Costs and Benefits of Bicycling Investments in Portland, Oregon. J Phys Act Health, 8(Suppl 1):S49–S58. doi:10.1123/jpah.8.s1.s49.

Götschi T, de Nazelle A, Brand C, Gerike R, PASTA Consortium (2017). Towards a Comprehensive Conceptual Framework of Active Travel Behavior: a Review and Synthesis of Published Frameworks. Curr Environ Health Rep. 4(3):286–295. doi:10.1007/s40572-017-0149-9.

Götschi T, Kahlmeier S, Castro A, Brand C, Cavill N, Kelly P, et al (2020). Integrated impact assessment of active travel: Expanding the scope of the health economic assessment tool (HEAT) for walking and cycling. Int J Environ Res Public Health. 17(20). doi:10.3390/ijerph17207361.

Götschi T, Garrard J, Giles-Corti B (2016). Cycling as a Part of Daily Life: A Review of Health Perspectives. Transp Rev. 36(1):45-71. doi:10.1080/01441647.2015.1057877.

Götschi T, Hadden Loh T (2017). Advancing project-scale health impact modeling for active transportation: A user survey and health impact calculation of 14 US trails. J Transp Health. 4:334–347. doi:10.1016/j.jth.2017.01.005.

Grabow ML, Spak SN, Holloway T, Stone B, Mednick AC, Patz JA (2011). Air quality and exercise-related health benefits from reduced car travel in the midwestern United States. Environ Health Perspect. 120(1):68–76. doi:10.1289/ehp.1103440.

Griffiths S (2020). Why your internet habits are not as clean as you think - BBC Future. London: British Broadcasting Corporation (https://www.bbc.com/future/article/20200305-why-your-internet-habits-are-not-as-clean-as-you-think).

de Groote J, van Ommeren J, Koster HRA (2019). The effect of paid parking and bicycle subsidies on employees' parking demand. Transp Res Part A Policy Pract. 128:46–58. doi:10.1016/j.tra.2019.07.007.

Gudz EM, Fang K, Handy S (2016). When a Diet Prompts a Gain: Impact of a Road Diet on Bicycling in Davis, California. Transp Res Rec. 2587(1):61–67. doi:10.3141%2F2587-08.

Guerra E, Zhang H, Hassall L, Wang J, Cheyette A (2020). Who cycles to work and where? A comparative multilevel analysis of urban commuters in the US and Mexico. Transp Res D Transp Environ. 87:102554. doi:10.1016/j.trd.2020.102554.

Guthold R, Stevens GA, Riley LM, Bull FC (2018). Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. Lancet Glob. Health. 6(10):e1077–e1086. doi:10.1016/S2214-109X(18)30357-7.

Guthold R, Stevens GA, Riley LM, Bull FC (2020). Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. Lancet Child Adolesc. Health. 4(1):23–35. doi:10.1016/S2352-4642(19)30323-2.

Haas T, Sander H (2020). Decarbonizing Transport in the European Union: Emission Performance Standards and the Perspectives for a European Green Deal. Sustainability. 12(20):8381. doi:10.3390/su12208381.

Hamer M, Chida Y (2008). Active commuting and cardiovascular risk: A meta-analytic review. Prev Med. 46(1):9–13. doi:10.1016/j.ypmed.2007.03.006.

de Hartog JJ, Boogaard H, Nijland H, Hoek G (2010). Do the Health Benefits of Cycling Outweigh the Risks? Environ Health Perspect. 118(8):1109–1116. doi:10.1289%2Fehp.0901747.

HEAT v5.0 (2022). Health Economic Assessment Tool (HEAT) for walking and cycling by WHO [website]. Copenhagen: WHO Regional Office for Europe (https://www.heatwalkingcycling.org/).

Hendriksen IJ, Simons M, Galindo Garre F, Hildebrandt VH (2010). The association between commuter cycling and sickness absence. Prev Med. 51(2):132–135. doi:10.1016/j.ypmed.2010.05.007.

Hillman CH, Erickson KI, Kramer AF (2008). Be smart, exercise your heart: exercise effects on brain and cognition. Nat Rev Neurosci 2008 9:1, 9(1):58–65. doi:10.1038/nrn2298.

Hosford K, Firth C, Brauer M, Winters M (2021). The effects of road pricing on transportation and health equity: a scoping review. Transp Rev. 6:766-787. doi:10.1080/01441647.2021.1898488.

House of Commons Transport Committee (2019). Active travel: increasing levels of walking and cycling in England. London: UK Parliament (https://publications.parliament.uk/pa/cm201719/cmselect/cmtrans/1487/1487.pdf).

Howland S, McNeil N, Broach J, Macarthur J, Dill J (2018). Bike Share and Equity in Low-Income Communities of Color: What Opportunities Are There to Include Older Adults? Transportation Research Board 97th Annual Meeting, Washington DC, 1–11 January 2018. In: TRID, the TRIS and ITID database (https://trid.trb.org/view/1496588).

Huertas JA, Palacio A, Botero M, Carvajal GA, van Laake T, Higuera-Mendieta D, et al (2020). Level of traffic stress-based classification: A clustering approach for Bogotá, Colombia. Transp Res Part D Transp Environ. 85:102420. doi:10.1016/j.trd.2020.102420.

Hunter RF, Garcia L, de Sa TH, Zapata-Diomedi B, Millett C, Woodcock J, et al. (2021). Effect of COVID-19 response policies on walking behavior in US cities. Nat Commun. 2021, 12:3652. doi.org/10.1038/s41467-021-23937-9.

INFRAS, Ecoplan (2018). Externe Effekte des Verkehrs 2015 [External Effects of Transport 2015]. Zürich: INFRAS, Bern: Ecoplan (https://www.are.admin.ch/dam/are/de/dokumente/verkehr/publikationen/externe-effekte-des-verkehrs-2015-schlussbericht.pdf) (in German).

International Energy Agency (2020). Global EV Outlook 2020 Entering the decade of electric drive? Paris: International Energy Agency (https://www.iea.org/reports/global-ev-outlook-2020, accessed 6 October 2021).

International Energy Agency (2021). Changes in transport behaviour during the Covid-19 crisis – Analysis [website]. Paris: International Energy Agency. (https://www.iea.org/articles/changes-in-transport-behaviour-during-the-covid-19-crisis).

International Transport Forum, Organisation for Economic Co-operation and Development (2021). Reversing Car Dependency. Paris: International Transport Forum, Copenhagen: Organisation for Economic Co-operation and Development (https://www.itf-oecd.org/reversing-car-dependency).

Jacobsen PL (2003). Safety in numbers: more walkers and bicyclists, safer walking and bicycling. Inj Prev. 9(3):205–209. doi:10.1136/ip.9.3.205

Jaffe E (2015). The complete business case for converting street parking into bike lanes [website]. New York: Bloomberg (https://www.bloomberg.com/news/articles/2015-03-13/every-study-ever-conducted-on-the-impact-converting-street-parking-into-bike-lanes-has-on-businesses).

Jarrett J, Woodcock J, Griffiths UK, Chapabi Z, Edwards P, Roberts I, et al (2012). Effect of increasing active travel in urban England and Wales on costs to the National Health Service. Lancet. 379(9832):2198–2205. doi10.1016/s0140-6736(12)60766-1.

Johansson C, Lövenheim B, Schantz P, Wahlgren L, Almström P, Markstedt A et al. (2017). Impacts on air pollution and health by changing commuting from car to bicycle. Sci Total Environ. 584–585:55–63. doi:10.1016/j.scitotenv.2017.01.145.

Johansson R (2009). Vision Zero - Implementing a policy for traffic safety. Saf Sci. 47(6):826–831. doi:10.1016/j.ssci.2008.10.023.

Johnson T (2002). A guide to selected algorithms, distributions, and databases used in exposure models developed by the office of air quality planning and standards. Washington D.C.: United States Environmental Protection Agency (https://www.epa.gov/fera/guide-selected-algorithms-distributions-and-databases-used-exposure-models-developed-office-air).

Kahlmeier S, Racioppi F, Cavill N, Rutter H, Oja P (2010). "Health in All Policies" in Practice: Guidance and Tools to Quantifying the Health Effects of Cycling and Walking. J Phys Act Health. 7(s1):S120–S125. doi:10.1123/jpah.7.s1.s120.

Kahlmeier S, Castro A, Brand C (2017). Health economic assessment tool (HEAT) for walking and for cycling Methods and user guide on physical activity, air pollution injuries and carbon impact assessments. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/344136).

Katsis P, Papageorgiou T, Ntziachristos L (2014). Modelling the Trip Length Distribution Impact on the CO2 Emissions of Electrified Vehicles. 4(1A):57–64. doi:10.5923/s.ep.201401.05.

Kazemzadeh K, Laureshyn A, Winslott Hiselius L, Ronchi E (2020). Expanding the Scope of the Bicycle Level-of-Service Concept: A Review of the Literature. Sustainability. 12(7):2944. doi:10.3390/su12072944.

Keith DR, Houston S, Naumov S (2019). Vehicle fleet turnover and the future of fuel economy. Environ Res Lett. 14(2):021001. doi:10.1088/1748-9326/aaf4d2.

Kelly P, Kahlmeier S, Götschi T, Orsini N, Richards J, Roberts N et al (2014). Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. Int J Behav Nutr Phys Act. 11(1):132. doi:10.1186/s12966-014-0132-x.

Kelly P, Williamson C, Baker G, Davis A, Broadfield S, Coles A et al (2020). Beyond cycle lanes and large-scale infrastructure: A scoping review of initiatives that groups and organisations can implement to promote cycling for the Cycle Nation Project. Bri J Sports Med. 54(23):1405–1415. doi:10.1136/bjsports-2019-101447.

Kraus S, Koch N (2021). Provisional COVID-19 infrastructure induces large, rapid increases in cycling. Proceedings of the National Academy of Sciences of the United States of America, Prot Natl Acad Sci USA. 118(15):e2024399118. doi:10.1073/pnas.2024399118.

Krauß S, Ruhl S, Richter T (2016). Geschwindigkeitsverhalten bei Tempo-30-Beschilderungen aus Laermschutzgruenden in den Nachtstunden [Travel speeds in response to 30km/h signage due to nighttime noise mitigation]. Straßenverkehrstechnik [road traffic technology]. 60(3):159-66 (https://www.baufachinformation.de/geschwindigkeitsverhalten-bei-tempo-30-beschilderungen-aus-laermschutzgruenden-in-den-nachtstunden/z/2016039024028) (in German).

Kriit HK, Williams JS, Lindholm L, Forsberg B, Sommar JN (2019). Health economic assessment of a scenario to promote bicycling as active transport in Stockholm, Sweden. BMJ Open. 9:e030466. doi:10.1136/bmjopen-2019-030466.

Krizek KJ (2018). Measuring the wind through your hair? Unravelling the positive utility of bicycle travel. Res Transp Bus Manag. 29:71-76. doi:10.1016/j.rtbm.2019.01.001.

Kroesen M, De Vos J (2020). Does active travel make people healthier, or are healthy people more inclined to travel actively? J Transp Health. 16:100844. doi:10.1016/j.jth.2020.100844.

Kuhnimhof T, Armoogum J, Buehler R, Dargay J, Denstadli JM, Yamamoto T (2012). Men Shape a Downward Trend in Car Use among Young Adults-Evidence from Six Industrialized Countries. Transp Rev. 32(6):761–779. do i:10.1080/01441647.2012.736426.

L'Agència de Salut Pública de Barcelona [The Barcelona Public Health Agency] (2022) Salut als Carrers. Avaluació dels àmbits Superilles [Health on the streets. Evaluation of Superblock areas] [website]. Barcelona: L'Agència de Salut Pública de Barcelona (https://www.aspb.cat/documents/salutalscarrers/) (in Catalan).

Lamu AN, Jbaily A, Verguet S, Robberstad B, Norheim OF (2020). Is cycle network expansion cost-effective? A health economic evaluation of cycling in Oslo. BMC Pub Health, 20:1869. doi:10.1186/s12889-020-09764-5.

Lancet Global Burden of Disease (2020). Global Health Metrics: Low physical activity – Level 2 risk. Vol 396, October 17, 2020. Lancet (https://www.thelancet.com/pb-assets/Lancet/gbd/summaries/risks/low-physical-activity.pdf).

Le HTK, Buehler R, Hankey S (2019). Have walking and bicycling increased in the US? A 13-year longitudinal analysis of traffic counts from 13 metropolitan areas. Transp Res Part D Transp Environ. 69:329-345. doi:10.1016/j.trd.2019.02.006.

Lee I-M, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT, et al (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of diseases and life expectancy. Lancet. 380(9838):219–229. doi:10.1016/S0140-6736(12)61031-9.

Lee RJ, Sener IN, Jones SN (2017). Understanding the role of equity in active transportation planning in the United States. Transp Rev. 37(2):211-226. doi:10.1080/01441647.2016.1239660.

Lewis A, Moller SJ, Carslaw D (2019). Non-exhaust emissions from road traffic. United Kingdom: Defra (https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1907101151_20190709_Non_Exhaust_Emissions_typeset_Final.pdf)

Leyland L-A, Spencer B, Beale N, Jones T, van Reekum CM (2019). The effect of cycling on cognitive function and well-being in older adults. PLoS One. 14(2):e0211779. doi:10.1371%2Fjournal.pone.0211779.

Li, W., & Joh, K. (2016). Exploring the synergistic economic benefit of enhancing neighbourhood bikeability and public transit accessibility based on real estate sale transactions: Urban Stud. 54(15), 3480–3499. doi: 10.1177/0042098016680147.

Lieske SN, van den Nouwelant R, Han JH, Pettit C (2021). A novel hedonic price modelling approach for estimating the impact of transportation infrastructure on property prices. Urban Stud. 58(1):182–202. doi:10.1177%2F0042098019879382.

Lilly C (2022). Electric car market statistics. Bristol: Next Green Car (https://www.nextgreencar.com/electric-cars/statistics/)

Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 380(9859):2224–2260. doi10.1016/S0140-6736(12)61766-8.

Litman T (2013). Transportation and Public Health. Annu Rev Pub Health. 34(1):217–233. doi:10.1146/annurev-publhealth-031912-114502.

Lowry M, Loh TH (2017). Quantifying Bicycle Network Connectivity. Prev Med. 95 Suppl:S134-S140. doi:10.1016/j.ypmed.2016.12.007.

Lowry MB, Furth P, Hadden-Loh T (2016). Prioritizing new bicycle facilities to improve low-stress network connectivity. Transp Res Part A Policy Pract. 86:124–140. doi:10.1016/j.tra.2016.02.003.

Lozzi G, Rodrigues M, Marcucci E, Teoh T, Gatta V, Pacelli V (2020). Research for TRAN Committee – COVID-19 and urban mobility: impacts and perspectives. Brussels: European Parliament, Policy Department for Structural and Cohesion Policies (https://www.europarl.europa.eu/thinktank/en/document/IPOL_IDA(2020)652213).

Lusk AC, Furth PG, Morency P, Miranda-Moreno LF, Willett WC, Dennerlein JT (2011). Risk of injury for bicycling on cycle tracks versus in the street. Inj Prev. 17: 131–135. doi:10.1136/ip.2010.028696.

Ma L, Ye R (2019). Does daily commuting behavior matter to employee productivity? J Transp Geog. 76:130-141. doi:10.1016/j.jtrangeo.2019.03.008.

Ma L, Ye R (2021). Walking and cycling to work makes commuters happier and more productive. London: The Conversation (https://theconversation.com/walking-and-cycling-to-work-makes-commuters-happier-and-more-productive-117819).

Maizlish N, Linesch NJ, Woodcock J (2017). Health and greenhouse gas mitigation benefits of ambitious expansion of cycling, walking, and transit in California. J Transp Health. 6:490–500. doi:10.1016/j.jth.2017.04.011.

Mäki-Opas TE, Borodulin K, Valkeinen H, Stenholm S, Kunst AE, Abel T, et al (2016). The Contribution of Travel-Related Urban Zones, Cycling and Pedestrian Networks and Green Space to Commuting Physical Activity Among Adults – A Cross-Sectional Population-Based Study Using Geographical Information Systems. BMC Public Health. 16(1):760. doi:10.1186/s12889-016-3264-x.

Marqués R, Hernández-Herrador V (2017). On the effect of networks of cycle-tracks on the risk of cycling. The case of Seville. Accid Anal Prev. 102:181–190. doi:10.1016/j.aap.2017.03.004.

Marsden G, Frick KT, May AD, Deakin E (2011). How do cities approach policy innovation and policy learning? A study of 30 policies in Northern Europe and North America. Transp Policy. 18(3):501–512. doi:10.1016/j.tranpol.2010.10.006.

Marshall WE, Ferenchak NN (2019). Why cities with high bicycling rates are safer for all road users. J Transp Health. 13:100539. doi:10.1016/j.jth.2019.03.004.

Matz CJ, Egyed M, Hocking R, Seenundun S, Charman N, Edmonds N (2019). Human health effects of traffic-related air pollution (TRAP): A scoping review protocol. Syst Rev. 8(1):1–5. doi.10.1186/s13643-019-1106-5.

McNeil N, Dill J, MacArhtur J, Broach J (2018). Bikeshare for Everyone? Views of Residents in Lower-Income Communities of Color. Transportation Research Board 97th Annual Meeting, Washington DC, 1–11 January 2018. In: TRID, the TRIS and ITID database (https://trid.trb.org/view/1495936).

Melendez S (2021). Companies subsidize e-bikes as workers head back to offices. New York: Fast Company. (https://www.fastcompany.com/90659189/subsidized-e-bikes-back-to-the-office-commute).

Mizdrak A, Blakely T, Cleghorn CL, Cobiac LJ (2019). Potential of active transport to improve health, reduce healthcare costs, and reduce greenhouse gas emissions: A modelling study. PLoS ONE. 14(7):e0219316. doi:10.1371%2Fjournal.pone.0219316.

Mobilitätsagentur Wien [Mobility Agency Vienna] (2022). Schulstraße [School street] [website]. Vienna: Mobilitätsagentur Wien Mobility (www.wienzufuss.at/schulstrasse) (in German).

Molloy J, Schatzmann T, Schoeman B, Tchervenkov C, Hintermann B, Axhausen KW (2021a). Observed impacts of the Covid-19 first wave on travel behaviour in Switzerland based on a large GPS panel. Transp Pol. 104:43–51. doi:10.1016/j.tranpol.2021.01.009.

Molloy JB, Castro Fernandez A, Götschi T, Tchervenkov C, Tomic U, Hintermann B, et al (2021b). A national-scale mobility pricing experiment using GPS tracking and online surveys in Switzerland: Response rates and survey method results. Arbeitsberichte Verkehrs- und Raumplanung. 1555. doi:10.3929/ethz-b-000441958.

Mueller N, Rojas-Rueda D, Cole-Hunter T, de Nazelle A, Dons E, Gerike R, et al (2015). Health impact assessment of active transportation: A systematic review. Prev Med. 76:103–114. doi:10.1016/j.ypmed.2015.04.010.

Mueller N, Rojas-Rueda D, Salmon M, Martinez D, Ambros A, Brand C et al (2018). Health impact assessment of cycling network expansions in European cities. Prev Med. 109:62–70. doi:10.1016/j.ypmed.2017.12.011. RightsLink license number: 5157590818857

Mueller N, Rojas-Rueda D, Kheris H, Cirach M, Andrés D, Ballester J, et al (2020). Changing the urban design of cities for health: The superblock model. Env Int. 134:105132. doi:10.1016/j.envint.2019.105132

Mulley C, Tyson R, McCue P, Rissel C, Munro C (2013). Valuing active travel: Including the health benefits of sustainable transport in transportation appraisal frameworks. Res Transp Bus Manag. 7:27–34. doi:10.1016/j.rtbm.2013.01.001.

Mytton OT, Panter J, Ogilvie D (2015). Longitudinal associations of active commuting with wellbeing and sickness absence. Prev Med. 84:19-26. doi:10.1016/j.ypmed.2015.12.010.

Nanda A (2020). Superblocks: Barcelona's car-free zones could extend lives and boost mental health. London: The Conversation (https://theconversation.com/superblocks-barcelonas-car-free-zones-could-extend-lives-and-boost-mental-health-123295).

National Association of City Transportation Officials (2019). Don't give up at the intersection. [website]. New York: National Association of City Transportation Officials (https://nacto.org/publication/dont-give-up-at-the-intersection).

de Nazelle A, Bode O, Orjuela JP (2017). Comparison of air pollution exposures in active vs. passive travel modes in European cities: A quantitative review. Env Int. 99:151–160. doi:10.1016/j.envint.2016.12.023.

Neves A, Brand C (2019). Assessing the potential for carbon emissions savings from replacing short car trips with walking and cycling using a mixed GPS-travel diary approach. Transp Res Part A Pol Pract. 123:130-146. doi:10.1016/j.tra.2018.08.022.

New York City Department of Transportation (2013). The Economic Benefits of Sustainable Streets. New York: New York City Department of Transportation (https://www.nyc.gov/html/dot/downloads/pdf/dot-economic-benefits-of-sustainable-streets.pdf).

Nabavi Niaki M, Saunier N, Miranda-Moreno LF (2016). Methodology to quantify discontinuities in a cycling network: Case study in Montréal boroughs. Communication presented at 95th Annual Meeting of the Transportation Research Board, Washington D.C. (https://www.researchgate.net/publication/324201128_Methodology_to_quantify_discontinuities_in_a_cycling_network_Case_study_in_montreal_boroughs).

Nicola S, Behrmann E (2018). Car Ownership Declining: 'Peak Car' And The End Of An Industry [website]. Mumbai: BloombergQuint (https://www.bloombergquint.com/business/-peak-car-and-the-end-of-an-industry).

Nilsson JH (2019). Urban bicycle tourism: path dependencies and innovation in Greater Copenhagen. J Sustain Tour. 27(11):1648–1662. doi:10.1080/09669582.2019.1650749.

Organisation for Economic Co-operation and Development (2016). Zero Road Deaths and Serious Injuries: Leading a Paradigm Shift to a Safe System [website]. Paris: Organisation for Economic Co-operation and Development (https://www.oecd.org/publications/zero-road-deaths-and-serious-injuries-9789282108055-en.htm).

Orozco LGN, Battiston F, Iñiguez G, Szell M (2019). Data-driven strategies for optimal bicycle network growth. R Soc Open Sci. 7(12):201130–201130. doi:10.1098/rsos.201130

Otero I, Nieuwenhuijsen MJ, Rojas-Rueda D (2018). Health impacts of bike sharing systems in Europe. Env Int. 115:387–394. doi10.1016/j.envint.2018.04.014.

Panik RT, Morris EA, Voulgaris CT. (2019). Does Walking and Bicycling More Mean Exercising Less? Evidence from the US and the Netherlands. J Transp Health. 14:100590. doi:10.1016/j.jth.2019.100590.Gro

Petrunoff N, Rissel C, Wen LM (2016). The effect of active travel interventions conducted in work settings on driving to work: A systematic review. J Transp Health. 3(1):61–76. doi:10.1016/j.jth.2015.12.001.

Pisoni E, Thunis P, Clappier A (2019). Application of the SHERPA source-receptor relationships, based on the EMEP MSC-W model, for the assessment of air quality policy scenarios. Atmos Environ X. 4:100047. doi:10.1016/j.aeaoa.2019.100047.

Pojani E, Van Acker V, Pojani D (2018). Cars as a status symbol: Youth attitudes toward sustainable transport in a post-socialist city. Transpo Res Part F Traffic Psychol Behav. 58:210–227. doi:10.1016/j.trf.2018.06.003.

Porter AK, Kontou E, McDonald N, Evenson K (2020). Perceived barriers to commuter and exercise bicycling in U.S. adults: The 2017 National Household Travel Survey. J Transp Health, 16:100820. doi:10.1016/j.jth.2020.100820.

Pritchard R, Frøyen Y (2019). Location, location, relocation: how the relocation of offices from suburbs to the inner city impacts commuting on foot and by bike. Eur Transp Res Rev. 11(1):14. doi:10.1186/s12544-019-0348-6.

Pritchard R, Frøyen Y, Snizek B (2019). Bicycle Level of Service for Route Choice—A GIS Evaluation of Four Existing Indicators with Empirical Data. ISPRS Int J Geo-Inf. 8(5):214. doi:10.3390/ijgi8050214.

PTV Group Traffic (2016). PTV Vissim and Viswalk: 5 modes of transport with 200 people each – focussing on space usage [website]. In: YouTube, PTV Group Traffic (https://www.youtube.com/watch?v=g_ILtWzH3Ko).

Pucher J, Buehler R (2012). City Cycling (Pucher J, Buehler R, eds.). Cambridge, Massachusettes; London: MIT Press (https://mitpress.mit.edu/books/city-cycling).

Putta T, Furth PG (2019). Method to Identify and Visualize Barriers in a Low-Stress Bike Network. Transp Res Rec. 2673(9):452–460. doi:10.1177%2F0361198119847617.

Raser E, Gaupp-Berghausen M, Dons E, Anaya-Boig E, Avila-Palencia I, Brand C, et al (2018). European cyclists' travel behavior: Differences and similarities between seven European (PASTA) cities. J Transp Health. 9:244–252. doi:10.1016/j.jth.2018.02.006.

Reid C (2018). People Walking And Cycling Spend More In London's Shops Than Motorists. Jersey City: Forbes. (https://www.forbes.com/sites/carltonreid/2018/11/16/cyclists-spend-40-more-in-londons-shops-than-motorists/?sh=50ec8d36641e).

Rérat P (2021). The rise of the e-bike: Towards an extension of the practice of cycling? Mobilities, 16(3):423–439. doi:10.1080/17450101.2021.1897236.

Rodrigues PF, Alvim-Ferraz MCM, Martins FG, Saldiva P, Sá TH, Sousa SIV (2020). Health economic assessment of a shift to active transport. Environ Pollut. 258:113745. doi:10.1016/j.envpol.2019.113745.

Ruffino P, Jarre M (2021). Appraisal of cycling and pedestrian projects. In: Adv in Transp Pol Plann. 7:165–203. doi:10.1016/bs.atpp.2020.08.005.

Ruiz-Hermosa A, Álvarez-Bueno C, Cavero-Redondo I, Martinez-Vizcaino V, Redondo-Tébar A, Sánchez-López M (2019). Active commuting to and from school, cognitive performance, and academic achievement in children and adolescents: a systematic review and meta-analysis of observational studies. Int J Environ Res. 16(10)1839. doi:10.3390/ijerph16101839.

Rupprecht S, Brand L, Böhler-Baedeker S, Brunner LM, Rupperect Consult (2019). Guidelines for developing and implementing a Sustainable Urban Mobility Plan (2nd edition). European Platform on Sustainable Urban Mobility Plans. Cologne: Rupprecht Consult - Forschung and Beratung GmbH (https://www.eltis.org/sites/default/files/sump_guidelines_2019_interactive_document_1.pdf).

de Sá TH, Tainio M, Goodman A, Edwards P, Haines A, Gouveia N, et al (2017). Health impact modelling of different travel patterns on physical activity, air pollution and road injuries for São Paulo, Brazil. Env Int. 108:22–31. doi.org/10.1016/j.envint.2017.07.009.

National Center for Safe Routes to School (2022). Safe Routes [website]. In: National Center for Safe Routes to School (https://www.saferoutesinfo.org).

Saelens BE, Handy SL (2008). Built environment correlates of walking: a review. Med Sci Sports Exerc. 40(7 Suppl):S550-66. doi:10.1249%2FMSS.0b013e31817c67a4.

Sahlqvist S, Goodman A, Cooper AR, Ogilvie D (2013). Change in active travel and changes in recreational and total physical activity in adults: longitudinal findings from the iConnect study. Int J Behav Nutr Phys Act. 10(1):28. doi:10.1186/1479-5868-10-28.

Saunders L (2021). What is Healthy Streets? [website]. In: Healthy Streets (https://www.healthystreets.com/what-is-healthy-streets).

van Schalkwyk MCI, Mindell JS (2018). Current issues in the impacts of transport on health. Br Med Bull. 125(1):67–77. doi:10.1093/bmb/ldx048.

Scharnhorst E (2018). Quantified Parking - Comprehensive Parking Inventories for Five Major U.S. Cities, Mortgage Bankers Association [website]. (https://www.mba.org/2018-press-releases/july/riha-releases-new-report-quantified-parking-comprehensive-parking-inventories-for-five-major-us-cities).

Schepers P, Hagenzieker M, Methorst R, van Wee B, Wegman F (2014). A conceptual framework for road safety and mobility applied to cycling safety. Accid Anal Preven. 62:331–340. doi:10.1016/j.aap.2013.03.032.

Schepers P, Klein Wolt K, Helbich M, Fishman E (2020). Safety of e-bikes compared to conventional bicycles: What role does cyclists' health condition play? J Transp Health. 19:100961. doi:10.1016/j.jth.2020.100961.

Schroten A, van Wikngaarden L, Brambilla M, Maffii S, Trosky F, Kramer H, et al (2019a). Overview (of transport infrastructure expenditures and costs. Luxembourg: Publications Office of the European Union (https://op.europa.eu/en/publication-detail/-/publication/7ab899d1-a45e-11e9-9d01-01aa75ed71a1).

Schroten A, Scholten P, van Wikngaarden L, van Essen H, Brambilla M, Gatto M, et al. (2019b). Transport taxes and charges in Europe. Luxembourg: Publications Office of the European Union (https://op.europa.eu/en/publication-detail/-/publication/4de76a04-a385-11e9-9d01-01aa75ed71a1).

Shoup D (2018). Parking and the City. New York: Taylor and Francis. doi:10.4324/9781351019668.

Singleton PA (2019). Walking (and cycling) to well-being: Modal and other determinants of subjective well-being during the commute. Travel Behav and Soc. 16:249–261. doi:10.1016/J.TBS.2018.02.005.

SLOCAT Partnership (2021). SLOCAT Transport and Climate Change Global Status Report – Europe [website]. (https://tcc-gsr.com/global-overview/europe/).

Smith M, Hosking J, Woodward A, Witten K, MacMillan A, Fiels A, Baas P et al (2017). Systematic literature review of built environment effects on physical activity and active transport - an update and new findings on health equity. Int J Behav Nutr Phys Act. 14(1):158. doi:10.1186/s12966-017-0613-9.

Standen C, Greaves S, Collins AT, Crane M, Rissel C (2019). The value of slow travel: Economic appraisal of cycling projects using the logsum measure of consumer surplus. Transp Res Part A Pol Pract. 123: 255–268. doi:10.1016/j.tra.2018.10.015.

Strain T, Brage S, Sharp SJ, Richards J, Tainio M, Ding D (2020). Use of the prevented fraction for the population to determine deaths averted by existing prevalence of physical activity: a descriptive study. Lancet Glob Health. 8(7):e920–e930. doi:10.1016/S2214-109X(20)30211-4.

Street Plans Collaborative, John S. and James L. Knight Foundation, NACTO, Vision Zero Network (2016). Tactical Urbanism Materials and Design Guide. New York: The Street Plans Collaborative (http://tacticalurbanismguide.com/guides/tactical-urbanists-guide-to-materials-and-design/).

Stylianou N, Guibourg C, Briggs H (2019). Climate change food calculator: What's your diet's carbon footprint? - BBC News [website]. London: British Broadcasting Corporation (https://www.bbc.com/news/science-environment-46459714).

Sugiyama T, Carver A, Koohsari MJ, Veitch J (2018). Advantages of public green spaces in enhancing population health. Landsc Urban Plan. 178:12–17. doi:10.1016/j.landurbplan.2018.05.019.

Sustrans (2014). Sustrans Design Manual. Bristol: Sustrans (https://www.eltis.org/sites/default/files/trainingmaterials/sustrans_handbook_for_cycle-friendly_design_11_04_14.pdf).

Sustrans (2020) What are the economic impacts of making more space for walking and cycling? [website]. Bristol: Sustrans (https://www.sustrans.org.uk/our-blog/opinion/2020/may/what-are-the-economic-impacts-of-making-more-space-for-walking-and-cycling).

Swiss Federal Council (2018a). Direct counter-proposal to Bike Initiative [website]. Bern: Swiss Federal Council (https://www.admin.ch/gov/en/start/documentation/votes/20180923/bundesbeschluss-ueber-die-velowege-sowie-die-fuss--und-wanderweg.html).

Swiss Federal Council (2018b). Bundesbeschluss über die Velowege [Federal decree on Bicycle routes] [website]. In Youtube. Bern (https://www.youtube.com/watch?v=2e4Bfsb0r7M) (in German).

Synek S, Koenigstorfer J (2018). Exploring adoption determinants of tax-subsidized company-leasing bicycles from the perspective of German employers and employees. Transp Res A: Policy and Pract. 117:238–260. doi:10.1016/j.tra.2018.08.011.

Szarata A, Nosal K, Duda-Wiertal U, Franek L (2017). The impact of the car restrictions implemented in the city centre on the public space quality. Transp Res Proc. 27:752–759. doi:10.1016/j.trpro.2017.12.018.

Tainio M, de Nazelle A, Götschi T, Kahlmeier S, Rojas-Rueda D, Nieuwenhuijsen MJ et al. (2016). Can air pollution negate the health benefits of cycling and walking? Preventive Medicine. 87:233–236. doi: 10.1016/j.ypmed.2016.02.002. License: Creative Commons CC-BY.

Tainio M, Andersen ZJ, Nieuwenhuijsen MJ, Hu L, de Nazelle A, An R et al (2021). Air pollution, physical activity and health: A mapping review of the evidence. Environ Int. 147:105954. doi:10.1016/j.envint.2020.105954.

Teschke K, Harris MA, Reynolds CCO, Winters M, Babul S, Chipman M et al (2012). Route infrastructure and the risk of injuries to bicyclists: a case-crossover study. Am J Public Health. 102(12):2336–2343. doi:10.2105/AJPH.2012.300762.

The Government of the Grand Duchy of Luxembourg (2015). Declaration on Cycling as a climate friendly Transport Mode. Informal meeting of EU ministers for Transport, Luxembourg, Luxembourg, 7 October 2015 (http://www.eu2015lu.eu/en/actualites/communiques/2015/10/07-info-transports-declaration-velo/07-Info-Transport-Declaration-of-Luxembourg-on-Cycling-as-a-climate-friendly-Transport-Mode---2015-10-06.pdf)

Thaler R, Eder M (2007). Klimaaktiv mobil [website] (in German) Vienna: Klimaaktiv (https://www.klimaaktiv.at/mobilitaet/).

Thaler R, Eder M (2015a). Austrian Cycling Masterplan. Vienna: Klimaaktiv (https://www.klimaaktiv.at/service/publikationen/mobilitaet/mprad2015englisch.html).

Thaler R, Eder M (2015b). Masterplan Gehen [Austrian Walking Masterplan]. (in German) Vienna: Klimaaktiv (https://www.klimaaktiv.at/dam/jcr:de62856d-6fc9-434c-b67c-9a21d0de4253/MP-Gehen_final_forWeb.pdf).

THE PEP (2020). Mobility Management – A guide of international good practices. Geneva: United Nations Economic Commission for Europe (https://thepep.unece.org/node/805).

THE PEP (2021). Pan-European Master Plan for Cycling Promotion. Geneva: United Nations Economic Commission for Europe (https://thepep.unece.org/node/825).

THE PEP (2021a). Toolbox of Action for Cycling Promotion based on best available experience from the countries of the Pan-European Region. Geneva: United Nations Economic Commission for Europe (https://thepep.unece.org/node/826).

THE PEP (2021b). Recommendations for Green and Healthy Sustainable Transport – "Building Forward Better" Geneva: United Nations Economic Commission for Europe (https://thepep.unece.org/index.php/node/823).

THE PEP (2022). Transport Health Environment Pan-European Programme. Geneva: United Nations Economic Commission for Europe (https://thepep.unece.org/)

Torres-Barragan CA, Cottrill CD, Beecroft M (2020). Spatial inequalities and media representation of cycling safety in Bogotá, Colombia. Transp Res Interdiscip Perspect 7:100208. doi:10.1016/j.trip.2020.100208.

Transport for London (2018). Street Appeal. London: Transport of London (https://content.tfl.gov.uk/street-appeal.pdf).

TransportShaker (2018). Urban transports spatial footprint: how much space is used by transports in the city? [website]. Brussels: Wavestone (https://www.transportshaker-wavestone.com/urban-transports-spatial-footprint-much-space-used-transports-city/).

Tucker B, Manaugh K (2018). Bicycle equity in Brazil: Access to safe cycling routes across neighborhoods in Rio de Janeiro and Curitiba. Int J Sustain Transp. 12(1):29–38. doi:10.1080/15568318.2017.1324585.

Tønnesen A, Knapskog M, Uteng TP, Øksenholt KV (2020). The integration of active travel and public transport in Norwegian policy packages: A study on 'access, egress and transfer' and their positioning in two multilevel contractual agreements. Res Transp Bus Manag. 40:100546. doi:10.1016/j.rtbm.2020.100546.

Uhr A, Hertach P (2017). Verkehrssicherheit von E-Bikes mit Schwerpunkt Alleinunfälle. Beratungsstelle für Unfallverhütung [Road safety of E-Bikes with a Focus on Single-Vehicle Crashes] Bern: Beratungsstelle für Unfallverhütung. DOI 10.13100/bfu.2.340.01 [Swiss Advice centre for accident prevention] (https://www.bfu.ch/media/cvud2vwz/bfu_2-340-01_bfu-report-nr-75-verkehrssicherheit-von-e-bikes-mit-schwerpunkt-alleinunfaelle.pdf) (in German).

United Nations (2015). The Paris Agreement. The twenty-first session of the Conference of the Parties, Paris, France, 30 Nov 2015 - 11 Dec 2015 (https://unfccc.int/sites/default/files/english_paris_agreement.pdf).

United Nations (2016) Habitat III Conference, Quito, Ecuador, 17-20 October 2016 [website] (https://habitat3.org/).

United Nations (2018). World Urbanization Prospects The 2018 Revision. New York: United Nations Department of Economic and Social Affairs (https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html#:~:text=Today%2C%2055%25%20of%20the%20world's,increase%20to%2068%25%20by%202050).

United Nations (2022) Streets for life [website]. In Road Safety Week. New York: United Nations (www.unroadsafetyweek.org/en/streets-for-life).

United Nations Economic Commission for Europe (2020). Handbook on Sustainable Urban Mobility and Spatial Planning. Geneva: United Nations Economic Commission for Europe (https://unece.org/transport/publications/handbook-sustainable-urban-mobility-and-spatial-planning).

United Nations Economic Commission for Europe (2021). Vienna Declaration: Transforming to clean, safe, healthy and inclusive mobility and transport for happiness and prosperity for all. Preparatory meeting to the Fifth High-level Meeting on Transport, Health and Environment 25 January 2021 (https://thepep.unece.org/sites/default/files/2021-01/Informal%20document%201%20-%20Declaration%20from%20SC%2026.11.20%20-%20with%20Academy%20for%20the%20web.pdf).

United Nations Framework Convention on Climate Change (2021). Race To Zero Campaign [website]. Bonn: United Nations Framework Convention on Climate Change (https://unfccc.int/climate-action/race-to-zero-campaign).

United Nations in Western Europe (2022). Cycling for the Global Goals [website]. Brussels: United Nations (https://unric.org/en/cycling-for-the-global-goals/).

U.S. Department of Transportation (2021). Complete Streets [website]. Washington: U.S. Department of Transportation (https://www.transportation.gov/mission/health/complete-streets).

Venter ZS, Barton DN, Gundersen V, Figari H, Nowell MS (2021). Back to nature: Norwegians sustain increased recreational use of urban green space months after the COVID-19 outbreak. Landsc Urban Plan, 214:104175. doi:10.1016/j.lurbplan.2021.104175

Voulgaris CT, Taylor BD, Blumenberg E, Brown A, Ralph K (2017). Synergistic neighborhood relationships with travel behavior: An analysis of travel in 30,000 US neighborhoods. JTLU. 10(1):437–461. doi: 10.5198/jtlu.2016.840.

Wanner M, Götschi T, Martin-Diener E, Kahlmeier S, Martin BW (2012). Active transport, physical activity, and body weight in adults: a systematic review. Am J Prev Med. 42(5):493–502. doi:10.1016/j.amepre.2012.01.030.

van Wee B, Börjesson M (2015). How to make CBA more suitable for evaluating cycling policies. Transp Policy. 44:117–124. doi:10.1016/j.tranpol.2015.07.005

Wegman F, Aarts L, Bax C (2008). Advancing sustainable safety. National road safety outlook for The Netherlands for 2005-2020. Saf Sci. 46(2):323–343. doi:10.1016/j.ssci.2007.06.013.

Weiss M, Dekker P, Moro A, Scholz H, Patel MK (2015). On the electrification of road transportation – A review of the environmental, economic, and social performance of electric two-wheelers. Transp Res D Transp Environ. 41:348–366. doi:10.1016/j.trd.2015.09.007.

Welle B, Li W, Adriazola-Steil CA (2016). What Makes Cities Safer by Design? A Review of Evidence and Research on Practices to Improve Traffic Safety Through Urban and Street Design. Transportation Research Board 95th Annual Meeting, Washington DC, 10–14 January 2016. In: TRID, the TRIS and ITID database (https://trid.trb.org/view/1393567).

WHO Regional Office for Europe (2014). WHO Expert Meeting: Methods and tools for assessing the health risks of air pollution at local, national and international level. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/143712).

WHO Regional Office for Europe (2015). European facts and the Global status report on road safety 2015. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/326340).

WHO Regional Office for Europe (2016). Infographic – Road traffic injuries: the facts in the WHO European Region. Copenhagen: WHO Regional Office for Europe (https://www.euro.who.int/en/health-topics/disease-prevention/violence-and-injuries/data-and-statistics/infographic-road-traffic-injuries-the-facts-in-the-who-european-region).

WHO European Office for Europe (2016a). Physical activity strategy for the WHO European Region 2016–2025. Copenhagen: WHO European Office for Europe (https://apps.who.int/iris/handle/10665/329407).

WHO Regional Office for Europe (2017). Declaration of the Sixth Ministerial Conference on Environment and Health. Sixth Ministerial Conference on Environment and Health, Ostrava, Czech Republic, 13-15 June 2017 (https://apps.who.int/iris/handle/10665/347444)

WHO Regional Office for Europe (2021b). Green and blue spaces and mental health: new evidence and perspectives for action 2021. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/342931).

Wikipedia (2021a). Road diet [website]. San Fransisco: Wikipedia (https://en.wikipedia.org/wiki/Road_diet).

Wikipedia (2021b). Living street [website]. San Francisco: Wikipedia (https://en.wikipedia.org/wiki/Living_street).

Winters M, Fischer J, Nelson T, Fuller D, Whitehurst DGT (2018). Equity in Spatial Access to Bicycling Infrastructure in Mid-Sized Canadian Cities. Transp Res Rec. 2672(36):24–32. doi.org/10.1177/0361198118791630.

Winters M, Buehler R, Götschi T (2017). Policies to Promote Active Travel: Evidence from Reviews of the Literature. Curr Environ Health Rep. 4(3):278–285. doi: 10.1007/s40572-017-0148-x.

Wittwer R, Hubrich S, Wittig S, Gerike R (2018). Development of a new method for household travel survey data harmonisation. Transp Res Proc. 32:597–606. doi:10.1016/j.trpro.2018.10.017.

Woodcock J, Tainio M, Cheshire J, O'Brien O, Goodman A. (2014). Health effects of the London bicycle sharing system: health impact modelling study. BMJ. 348. doi:10.1136/bmj.g425.

World Health Organization (2004). Global Strategy on Diet, Physical Activity and Health – 2004. Geneva: World Health Organization (https://www.who.int/publications/i/item/9241592222)

World Health Organization (2009). Global Health Risks: Mortality and burden of disease attributable to selected major risks. Geneva: World Health Organization (https://www.who.int/publications/i/item/9789241563871)

World Health Organization (2013). The 8th Global Conference on Health Promotion, Helsinki, Finland, 10-14 June 2013 [website]. (https://www.who.int/teams/health-promotion/enhanced-wellbeing/eighth-global-conference).

World Health Organization (2013a). Global Action Plan for the Prevention and Control of NCDs 2013-2020. Geneva: World Health Organization (https://www.who.int/publications/i/item/9789241506236).

World Health Organization (2018). Global status report on road safety 2018. Geneva: World Health Organization (https://www.who.int/publications/i/item/9789241565684).

World Health Organization (2018a). The Global Network for Age-friendly Cities and Communities. Geneva, World Health Organization (https://www.who.int/publications/i/item/WHO-FWC-ALC-18.4).

World Health Organization (2018b). Global action plan on physical activity 2018–2030: more active people for a healthier world. Geneva: World Health Organization (https://apps.who.int/iris/handle/10665/272722).

World Health Organization (2020a). WHO guidelines on physical activity and sedentary behaviour: at a glance. Geneva: World Health Organization (https://www.who.int/publications/i/item/9789240014886)

World Health Organization (2020b). Cyclist safety: an information resource for decision-makers and practitioners. Geneva: World Health Organization (https://www.who.int/publications/i/item/cyclist-safety-an-information-resource-for-decision-makers-and-practitioners).

World Health Organization (2020c). Personal interventions and risk communication on Air Pollution. Geneva: World Health Organization (https://www.who.int/publications/i/item/9789240000278).

World Health Organization (2020d). WHO guidelines on physical activity and sedentary behaviour: at a glance. Geneva: World Health Organization (https://apps.who.int/iris/handle/10665/337001).

World Health Organization (2020e). WHO Manifesto for a Healthy Recovery from COVID-19. Geneva: World Health Organization (https://www.who.int/publications/m/item/who-manifesto-for-a-healthy-recovery-from-covid-19).

World Health Organization (2021a). UN Decade of Healthy Ageing 2021–2030 [website]. Geneva: World Health Organization (https://www.who.int/initiatives/decade-of-healthy-ageing)

Wu Y, Rowangould D, London J (2018). Modeling Health Equity in Active Transportation Planning. Transp Res D Transp Environ. 67: 528–540. doi.org/10.1016/j.trd.2019.01.011.

Yao S, Loo BPY (2016). Safety in numbers for cyclists beyond national-level and city-level data: a study on the non-linearity of risk within the city of Hong Kong. Inj Prev, 22(6):379-385. doi: 10.1136/injuryprev-2016-041964.

Zahabi SAH, Strauss J, Manaugh K, Miranda-Moreno LF (2011). Estimating potential effect of speed limits, built environment, and other factors on severity of pedestrian and cyclist injuries in crashes. Transp Res Rec. 2247(1):81–90. doi:10.3141/2247-10.

Zhao Y, Hu F, Feng Y, Yang X, Li Y, Guo C et al. (2021). Association of Cycling with Risk of All-Cause and Cardiovascular Disease Mortality: A Systematic Review and Dose–Response Meta-analysis of Prospective Cohort Studies. Sports Med, 51(7):1439–1448. doi: 10.1007/s40279-021-01452-7.

Zuo T, Wei H (2019). Bikeway prioritization to increase bicycle network connectivity and bicycle-transit connection: A multi-criteria decision analysis approach. Transp Res Part A Policy Pract. 129:52–71. doi: 10.1016/j.tra.2019.08.003.


max 15 km

Annex I. Impact assessment and other supportive tools for walking and cycling

As research and planning practice on walking and cycling have evolved, a noticeable trickle-down effect has produced a range of helpful tools. A limited selection is presented here without claim to completeness.

Impact calculators include:

- ☑ **HEAT: Health Economic Assessment Tool for walking and cycling is WHO's health and carbon impact calculator for active travel modes.**

  HEAT v5.0 (2022). Health Economic Assessment Tool (HEAT) for walking and cycling by WHO [website]. Copenhagen: WHO Regional Office for Europe (https://www.heatwalkingcycling.org/)

- ☑ **ITHIM: Integrated Transport and Health Impact Model is a multimodal health impact calculator developed by the University of Cambridge.**

  University of Cambridge (2022) Integrated Transport and Health Impact Modelling Tool (ITHIM) [website]. MRC Epidemiology Unit, University of Cambridge Integrated Transport and Health Impact Modelling tool Cambridge: University of Cambridge (https://www.mrc-epid.cam.ac.uk/research/research-areas/public-health-modelling/ithim/)

- ☑ **ICT: Impacts of Cycling Tool is a cycling health impact calculator.**

  Propensity to cycle (2019). Impacts of cycling tool [website]. Cambridge: University of Cambridge (https://www.pct.bike/ict/)

- **AirQ+: tool for calculating the health impacts of air pollution.**

  WHO Regional Office for Europe (2020). AirQ+: software tool for health risk assessment of air pollution. Copenhagen: WHO Regional Office for Europe (https://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/airq-software-tool-for-health-risk-assessment-of-air-pollution)

- **Place-Based Carbon Calculator: A carbon calculator integrating the Propensity to Cycle Tool**

  Centre for Research into Energy Demand Solutions (2021). Place-Based Carbon Calculator [website]. Oxford: Centre for Research into Energy Demand Solutions (https://www.carbon.place/)

Infrastructure, safety and travel demand tools include:

- **PCT: Propensity to Cycling Tool predicts the greatest propensity of cycling to inform investment decisions**

  Propensity to Cycle Tool (PCT) [website]
  (https://www.pct.bike/)

- **Fix my street: A crowd-sourcing platform to collect street improvement needs**

  SocietyWorks (2022). Fix my street [website]. United Kingdom:
  Fix my street Platform
  (https://www.fixmystreet.com/)

- **Safer Streets Priority Finder Tool: A tool to identify street safety risks for vulnerable road users**

  Louisiana Department of Transportation and Development's Traffic Safety Office (2022). Safer street priority finder. Beta V 1.2 [website]
  (https://www.saferstreetspriorityfinder.com/tool/)

- ☑ **Active Living Research tools: A suite of tools to audit the build environment with regards to active travel**

  (https://activelivingresearch.org/search/site/content_tools_and_measure?f[0]=bundle%3Acontent_tools_and_measure)

- ☑ **Healthy Streets: A systematic approach to consider health aspects in planning decisions**

  Transport for London (2022). Healthy streets [website].
  London: United Kingdom Government
  (https://tfl.gov.uk/corporate/about-tfl/how-we-work/planning-for-the-future/healthy-streets)

- ☑ **Bicycle network analysis tool: A tool to assess the connectivity and quality of cycling networks**

  TOOLE DESIGN GROUP (2022). Bicycle network analysis tool [website], Atlanta: Toole Design
  (https://tooledesign.com/project/bicycle-network-analysis-tool/)

- ☑ **Bikable: A tool to assess the connectivity and quality of cycling networks**

  Rails-to-Trails Conservancy (2022). Bikable [website]. Washington D.C.: Rails-to-Trails Conservancy
  (https://www.railstotrails.org/our-work/research-and-information/bikeable/)

- ☑ **Complete Streets Game: A game to visualize complete streets (i.e. streets that accommodate all types of users)**

  The Centre for Active Transport. Clean Air Partnership (2019). Complete Streets Game 3.0 [website]. Toronto; Clean Air Partnership
  (https://www.tcat.ca/resources/complete-streets-game/)

- ☑ **Streetmix: A tool to visualize bicycle- and pedestrian-friendly streets**

  Streetmix (2022). Streetmix [website]
  (https://streetmix.net/)

- ☑ **Streetplan: A tool to visualize bicycle- and pedestrian-friendly streets,**

  Urban Artisans (2022). StreetPlan [website]
  (https://streetplan.net/).

Policy audit tools and guidance:

- ☑ **Technical guidance and tools to help local authorities plan cycling and walking infrastructure**

  Department for Transport (2017) Guidance: Planning local cycling and walking networks. London: United Kingdom Government
  (https://www.gov.uk/government/publications/local-cycling-and-walking-infrastructure-plans-technical-guidance-and-tools)

- ☑ **The Bicycle Policy Audit (BYPAD) is a tool to audit local and regional cycling policy**

  Institut für Verkehrspädagogik (2022). The Bicycle Policy Audit [website].
  Graz: Institut für Verkehrspädagogik
  (https://www.bypad.org/).

For more tools, see also the CIVITAS Urban Mobility Tool Inventory:

- ☑ **CIVITAS initiative (2021). Urban Mobility Tool Inventory** [website].
  Brussels: CIVITAS initiative
  (https://civitas.eu/tool-inventory?f%5B0%5D=%20field_application_area%3A923).

THE WHO REGIONAL OFFICE FOR EUROPE

The World Health Organization (WHO) is a specialized agency of the United Nations created in 1948 with the primary responsibility for international health matters and public health. The WHO Regional Office for Europe is one of six regional offices throughout the world, each with its own programme geared to the particular health conditions of the countries it serves.

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