Environmental and Health Impacts of E-cycling

Overview

- E-bike use has the potential to reduce transport related emissions and traffic congestion to a greater extent than electric cars.
- Engaging in e-cycling can positively impact individual's physical and mental health.
- The true potential of promoting e-bike use in the UK is not fully understood due to a lack of data collection and monitoring of e-bike initiatives.

Electrically assisted bicycles (e-bikes) can have an important role in enabling UK transport to achieve net zero, improve air quality, increase levels of physical activity and improve mental and physical health. This briefing note examines the current evidence on the environmental and health impacts of e-cycling, highlighting why the promotion of e-cycling should be a key component to address UK health, climate and clean air challenges.

Background

The movement of goods and people is fundamental for the economic and social development of an area. However, the transport sector is responsible for 24% of total carbon dioxide (CO_2) emissions in the UK[1] and significantly contributes to toxic air pollution (e.g., particulate matter and nitrogen dioxide)[2]. Road transport related CO_2 emissions and air pollutants are harmful to human physical and mental health[3]. To reduce CO_2 emissions, the UK has focused on the electrification of passenger cars and light good vehicles[4]. However, to meet the UK Climate Change Committee goal of transport decarbonisation to deliver net-zero by 2050,[5] car use must also be reduced[6, 7].

E-bikes have been identified as a means through which to reduce land-based transport emissions by modal shift away from motorised transport[8, 9]. At the same time e-bike use can improve individual health through increased physical activity[10] and potentially reduce traffic and associated air pollution. An e-bike, in this context, refers to a pedal assisted electric bicycle, in which the individual must pedal for assistance to be provided. These e-bikes are legally classified as bicycles in the UK with a maximum power output of 250 Watts and a top assisted speed of 25 km/hr. Sales of e-bikes in Europe grew by 284% between 2010 and 2016, while sales of conventional bicycles decreased by 5%[11]. While trends in e-bike sales have been slower in the UK, they are rising[11], with sales of both on- and off-road e-bikes increasing. The COVID-19 pandemic significantly accelerated bike sales, including e-bikes, both in the UK and globally. Specifically in the UK, Halfords reported that 24% of all bicycles purchased in 2020 were electric[12].

Who uses e-bikes

Historically, in countries with low levels of cycling, such as the UK, older adults and women were less likely to participate in cycling[13]. E-cycling has been shown to appeal to a wide range of individuals and may therefore serve to increase the diversity of cyclists.

A survey of over 2,000 e-bike users and potential users in the UK found that many older adults switched from conventional cycling to e-cycling due to physical constraints[14]. As such, e-bikes extended active travel behaviour into later life. Similar findings have been reported in Canada, the USA, Australia and the Netherlands[15-19].

Younger adults, including women, are also adopting e-bikes, primarily for utilitarian purposes[20]. In New Zealand, a country with low rates of cycling, women reported using e-bikes to transport their children and shopping[21]. Data from the Netherlands reveals that the fastest growing e-bike user group is working mothers who use e-bikes for transport[22].

Health impacts of e-cycling

E-cycling as physical activity

Globally, one quarter of adults are physically inactive, meaning they engage in less than the recommended 150-minutes of moderate intensity activity or 75-minutes of vigorous intensity activity per week[23]. In the UK, physical inactivity is associated with 1 in 6 deaths per year, equal to smoking[24], and costs the UK economy £7.4 billion a year, including $0.9 billion to the NHS[25].

Engaging in regular physical activity of at least a moderate intensity reduces the risk of developing and dying from cardiovascular and respiratory diseases, type 2 diabetes and several cancers[26-29]. Acute physiological studies demonstrate that, for adults, e-cycling is at least a moderate-intensity activity and in some cases maybe a vigorous-intensity activity[10, 30].

Unsurprisingly, e-cycling is a less strenuous activity than conventional cycling which has led some to suggest that its promotion may reduce an individual's overall physical activity, if prompting a switch from conventional cycling. However, individuals ride e-bikes more frequently and for longer periods of time than conventional bicycles, leading to greater weekly energy expenditure and better health[31, 32].

Long term health benefits of e-cycling

Intervention studies show that e-cycling can increase individual physical fitness by up to 10% in both inactive adults and those with chronic disease[33-36]. This is significant as increased fitness reduces the risk of mortality[37, 38]. Among individuals with Type 2 diabetes e-cycling has been found to have a favourable impact on weight, waist circumference, glucose disposal and insulin resistance[33].

Regarding mental health, intervention studies show that e-cycling leads to improvements in quality of life[33, 39]. This is supported by qualitative studies among new and regular e-bike users which consistently report that e-cycling is enjoyable and has a positive impact on user well-being[40-44]. That e-cycling is consistently reported as enjoyable is important, as enjoyment of exercise is strongly associated with greater future engagement[45]. This enjoyment is a unique aspect of e-cycling compared to forms of active travel.

Exposure to air pollution

Engagement in physical activity reduces the risk of several chronic diseases. But long-term exposure to air pollution increases the risk of these diseases and can significantly harm human health[46-50]. The higher ventilation rates associated with active travel may result in greater intakes of air pollutants[51, 52] potentially negatively impacting health. It is therefore important to consider the risk-benefit trade-offs between the effect of physical activity from active travel and air pollution exposure on health.

A review of 10 European studies revealed that cyclists were, on average, less exposed to fine particulate matter, black carbon, and carbon monoxide than car drivers[53]. However, the study failed to account for the higher ventilation rates during active travel in comparison to sedentary travel. A 2020 modelling study, which accounted for differing ventilation rates, concluded that active commuting by walking or cycling reduces the risk of all-cause mortality in healthy adults even in high air pollution environments[54]. **Overall, evidence from both epidemiological and modelling studies demonstrates that the long-term benefits of being physically active through active travel outweigh the risks of exposure to air pollution in high income countries**[55].

Given that e-cycling is associated with lower physical exertion, particularly on uphill sections compared to conventional cycling[10], it is probable that e-cycling leads to lower intake of air pollutants and a potentially more favourable overall impact on health.

Using data from an e-bike share scheme in Barcelona, a recent health impact assessment modelled the effects of physical activity and air pollution exposure, specifically fine particulate matter, on premature mortality[56]. A 10% increase in e-cycling, as a result of shifts away from private car use or public transport, led to minor increases in the number of annual premature deaths of 1.6 and 13.0 respectively. However, the additional physical activity, on switching from private car use or public transport to e-bikes, led to reductions in annual premature deaths of 6.1 and 58.5 respectively. This suggests that the physical activity benefits of e-cycling outweigh the disbenefits of increase exposure to air pollution.

Environmental impacts of e-cycling

Substitution of other transport modes

Studies consistently report perceived increases in the frequency and duration of cycling following the acquisition of an e-bike[32, 57]. A recent study reported that individuals who purchased an e-bike increased their average daily cycling distance from 2.1 to 9.2km per day[58].

As individuals are willing to travel further on e-bikes, e-cycling has the potential to replace longer motorised vehicle trips than conventional bicycles. The degree of substitution of a car for an e-bike ranges from 20% to 86% [59]. Longitudinal data from the Netherlands, a country with high levels of cycling, revealed that e-bikes are substituting for car trips, particularly when used for commuting[22]. This is one of the reasons why some call them a 'game changer'.

The degree to which e-cycling substitutes for one mode of transport over another is influenced by the primary mode of transport prior to the introduction of the e-bike. As such, in the UK, where the car is the primary mode of transport[60] e-bikes have the potential to make large changes to individuals transport patterns.

Reducing emissions

E-bikes can contribute to the decarbonisation of land-based transport. Data from several studies suggest that each e-bike adopted saves 2000 kms driven and 460 kg CO_2 emitted per year[61].

E-bikes have greater decarbonisation potential than conventional bicycles as e-bike users are willing to engage in longer journeys. As such, they have the ability to replace more car journeys, particularly in suburban and rural areas. In England, one fifth of all distance travelled is for journeys of 13-25km. These are journeys that are difficult to serve by walking and cycling but are reasonable to complete on a e-bike. A recent modelling study estimated the maximum capability of e-biking to reduce CO_2 emissions by substituting for private car travel[9]: if everyone had access to an e-bike, the carbon reduction capability across England would be 24.4 million tonnes CO_2 per year (over 35% of passenger car CO_2 emissions in the UK). This equates to a mean saving of 580kgCO_2 per year per person; the potential saving is greatest in rural and sub-urban areas, where individual annual mileage is greater.

In addition to direct carbon reductions from modal shift, the substitution of motorised vehicles for e-bikes will lead to reduced emissions of nitrogen oxides and particulate matter[62] which will help improve air quality.

Whole life cycle impacts

It is important to note that e-bikes are not zero carbon. There are manufacturing and charging related emissions, increasing their carbon footprint relative to conventional bicycles[63]: an estimated average life cycle footprint of 24 gCO2e per passenger km, compared to 7 gCO2e per passenger km for a conventional bicycle[64]. Charging the e-bikes accounts for approximately 50% of total emissions[64]. However, in countries with a high share of renewable electricity generation, such as New Zealand, charging emissions account for less than 20% of total emissions[65]. Privately owned e-bikes have lower average life cycle emissions than shared e-bike systems due to lower operational emissions in redistributing them, and their longer lifespan[62, 64].

Safety concerns

Concerns have been raised regarding increased traffic incidents associated with e-cycling compared to conventional cycling. Early studies reported that e-bike users were more likely to be involved in a serious crash[66]. However, many studies failed to account for cycling frequency and duration (i.e., the amount of exposure to risk). When controlling for the distance travelled, there was no difference in emergency treatment between the two bike types[67, 68]. Furthermore, many individuals report feeling safer riding an e-bike than a conventional bike as the electrical assistance enables them to keep up with traffic[69-71]. In the UK, fears associated with riding amongst high speed motorised vehicles and a lack of segregated cycling infrastructure are key barriers to riding an e-bike[14]. It is important to note that, in regard to cycling, the perception of risk is disproportionate to the actual level of risk from motorised traffic among potential riders[72]. Fear of theft is also a key barrier to e-cycling due to poor parking facilities both at home and in public spaces[59].

Recommendations

Policy initiatives

- A network of high quality, segregated cycling infrastructure will enable e-bike use[14].
- Safe charging and parking facilities both in home and work locations will increase e-bike use and reduce theft concerns[59, 73].
- The cost of purchasing an e-bike limits uptake, particularly among younger adults[14, 59]. E-bike subsidies have had a positive impact on purchasing and use; in the UK, a subsidy of £250 could increase e-bike purchasing[74].
- These 'pull' policies should be coupled with 'push' policies such as restricting and disincentivising private car and motorcycle use in cities[62, 75].

Data monitoring

- Data from natural experiments, over long periods of time (i.e., 5-years or greater), are required to examine the effectiveness of e-bike policy initiatives on public health and the environment.
- The characteristics of e-bike users in the UK remains unclear due to the lack of monitoring. E-cycling should be classified separately in the national travel survey. This information is important to identify where e-bike promotion campaigns should be targeted.

What about e-scooters?

E-scooters do not offer the same benefits as e-bikes. Data from e-scooter users and shared e-scooter schemes in the USA highlight that e-scooter trips primarily replace walking, cycling or e-cycling trips, as opposed to motorized vehicle trips[76, 77], and potentially reduce physically active travel if switched from higher-intensity modes such as cycling or walking. E-scooters therefore have less potential to improve health than e-bikes[56]. Furthermore, private and shared e-scooters have slightly higher life cycle emissions[64] and therefore also offer less environmental benefits than e-bikes.

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References

1. Department for Business EIS. 2020 UK Geenhouse Gas Emissions, Final Figures. 2022.
2. Department for Transport. Transport and Environment Statistics 2021 Annual Report. 2021.
3. Woodcock J, Banister D, Edwards P, Prentice AM, Roberts I. Energy and transport. The Lancet. 2007;370(9592):1078-88.
4. Department for Transport. Decarbonising Transport, A Better, Greener Britain. London2021.
5. The Climate Change Act 2008 (2050 Target Amendment) Order 2019, (2019).
6. Brand C, Anable J, Ketsopoulou I, Watson J. Road to zero or road to nowhere? Disrupting transport and energy in a zero carbon world. Energy Policy. 2020;139:111334.
7. Gota S, Huizenga C, Peet K, Medimorec N, Bakker S. Decarbonising transport to achieve Paris Agreement targets. Energy Efficiency. 2019;12(2):363-86.
8. McQueen M, MacArthur J, Cherry C. The E-Bike Potential: Estimating regional e-bike impacts on greenhouse gas emissions. Transportation Research Part D: Transport and Environment. 2020;87:102482.
9. Philips I, Anable J, Chatterton T. E-bikes and their capability to reduce car CO2 emissions. Transport Policy. 2022;116:11-23.
10. Bourne JE, Sauchelli S, Perry R, Page A, Leary S, England C, et al. Health benefits of electrically-assisted cycling: a systematic review. International Journal of Behavioral Nutrition and Physical Activity. 2018;15(116).
11. CONEBI. European Bicycle Market 2017 edition. Boulevard de la Woluwe 46 b16, B – 1200 Brussels, Belgium: Confederation of the European Bicycle Industry; 2017.
12. Halfords. The Great Bike Boom Continues: A state of the nation look at the explosion of cycling. 2021.
13. Cycling UK. Cycling UK's Cycling Statistics. Surrey, England: Cycling UK; 2022.
14. Melia S, Bartle C. Who uses e-bikes in the UK and why? International Journal of Sustainable Transportation. 2021:1-13.
15. Leger SJ, Dean JL, Edge S, Casello JM. "If I had a regular bicycle, I wouldn't be out riding anymore": Perspectives on the potential of e-bikes to support active living and independent mobility among older adults in Waterloo, Canada. Transportation Research Part A: Policy and Practice. 2019;123:240-54.
16. Johnson M, Rose G. Extending life on the bike: Electric bike use by older Australians. Journal of Transport & Health. 2015;2(2):276-83.
17. Gordon E. Conventional Bicyclists and E-bike Users: Similarities and Differences from Two Qualitative Analyses: George Washington University, Washington, DC; 2012.
18. Lee A, Molin E, Maat K, Sierzchula W. Electric Bicycle Use and Mode Choice in the Netherlands. Transportation Research Record: Journal of the Transportation Research Board. 2015;2520:1-7.
19. MacArthur J, Harpool M, Scheppke D, Cherry C. Electric Boost: Insights from a National E-bike Owner Survey. Project Brief NITC-RR-1041. Portland, OR, USA: Transportation Research and Education Center (TREC); 2018.
20. Kroesen M. To what extent do e-bikes substitute travel by other modes? Evidence from the Netherlands. Transportation Research Part D: Transport and Environment. 2017;53:377-87.
21. Wild K, Woodward A, Shaw C. Gender and the E-

bike: Exploring the Role of Electric Bikes in Increasing Women's Access to Cycling and Physical Activity. Active Travel Studies. 2021;1(1).
22. de Haas M, Kroesen M, Chorus C, Hoogendoorn-Lanser S, Hoogendoorn S. E-bike user groups and substitution effects: evidence from longitudinal travel data in the Netherlands. Transportation. 2021.
23. Guthold R, Stevens GA, Riley LM, Bull FC. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1.9 million participants. The Lancet Global Health. 2018;6(10):e1077-e86.
24. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. The Lancet. 2012;380(9838):219-29.
25. Scarborough P, Bhatnagar P, Wickramasinghe KK, Allender S, Foster C, Rayner M. The economic burden of ill health due to diet, physical inactivity, smoking, alcohol and obesity in the UK: an update to 2006–07 NHS costs. Journal of Public Health. 2011;33(4):527-35.
26. Woodcock J, Franco OH, Orsini N, Roberts I. Non-vigorous physical activity and all-cause mortality: systematic review and meta-analysis of cohort studies. International Journal of Epidemiology. 2011;40(1):121-38.
27. Aune D, Norat T, Leitzmann M, Tonstad S, Vatten LJ. Physical activity and the risk of type 2 diabetes: a systematic review and dose–response meta-analysis. European Journal of Epidemiology. 2015;30(7):529-42.
28. Physical Activity Guidelines Advisory Committee. Physical Activity Guidelines Advisory Committee Scientific Report. Washington, DC, USA: Department of Health and Human Services; 2018.
29. Kyu HH, Bachman VF, Alexander LT, Mumford JE, Afshin A, Estep K, et al. Physical activity and risk of breast cancer, colon cancer, diabetes, ischemic heart disease, and ischemic stroke events: systematic review and dose-response meta-analysis for the Global Burden of Disease Study 2013. British Medical Journal. 2016;354:1-10.
30. McVicar J, Keske MA, Daryabeygi-Khotbehsara R, Betik AC, Parker L, Maddison R. Systematic review and meta-analysis evaluating the effects electric bikes have on physiological parameters. Scandinavian Journal of Medicine & Science in Sports. 2022;32(7):1076-88.
31. Stenner HT, Boyen J, Hein M, Protte G, Kück M, Finkel A, et al. Everyday Pedelec Use and Its Effect on Meeting Physical Activity Guidelines. International Journal of Environmental Research and Public Health. 2020;17(13).
32. Castro A, Gaupp-Berhausen M, Dons E, Standaert A, Laeremans M, Clark A, et al. 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. Transportation Research Interdisciplinary Perspectives. 2019:100017.
33. Bourne JE. The use of electrically assisted bicycles for promoting active transport and health. UK: University of Bristol; 2021.
34. Lobben S, Malnes L, Berntsen S, Tjelta LI, Bere E, Kristoffersen M, et al. Bicycle usage among inactive adults provided with electrically assisted bicycles. Acta Kinesiologiae Universitatis Tartuensis. 2019;24:60-73.
35. Peterman JE, Morris KL, Kram R, Byrnes WC. Pedelecs as a physically active transportation mode. European Journal of Applied Physiology. 2016;116(8):1565-73.
36. Höchsmann C, Meister S, Gehrig D, Gordon E, Li Y, Nussbaumer M, et al. Effect of E-Bike Versus Bike Commuting on Cardiorespiratory Fitness in Overweight Adults: A 4-Week Randomized Pilot Study. Clinical Journal of Sport Medicine. 2017;28(3):255-65.
37. Erikssen G, Liestøl K, Bjørnholt J, Thaulow E, Sandvik L, Erikssen J. Changes in physical fitness and changes in mortality. The Lancet. 1998;352(9130):759-62.
38. Erikssen G. Physical Fitness and Changes in Mortality. Sports Medicine. 2001;31(8):571-6.
39. Leyland L-A, Spencer B, Beale N, Jones T, van Reekum CM. The effect of cycling on cognitive function and well-being in older adults. PloS one. 2019;14(2):e0211779-e.
40. Boland P, Connell L, Thetford C, Janssen J. Exploring the factors influencing the use of electrically assisted bikes (e-bikes) by stroke survivors: a mixed methods multiple case study. Disability and Rehabilitation. 2020:1-10.
41. Searle A, Ranger E, Zahra J, Tibbitts B, Page A, Cooper A. Engagement in e-cycling and the self-management of type 2 diabetes: a qualitative study in primary care. BJGP Open. 2019;3(2):1-9.
42. Mildestvedt T, Hovland O, Bernsten S, Bere E, Fegran L. Getting Physically Active by E-Bike: An Active Commuting Intervention Study. Physical Activity and Health. 2020;4(1):120-9.
43. Spencer B, Jones T, Leyland L-A, van Reekum CM, Beale N. 'Instead of "closing down" at our ages … we're thinking of exciting and challenging things to do': older people's microadventures outdoors on (e-)bikes. Journal of Adventure Education and Outdoor Learning. 2019;19(2):124-39.
44. Behrendt F. Why cycling matters for electric mobility: towards diverse, active and sustainable e-mobilities. Mobilities. 2018;13(1):64-80.
45. Rhodes RE, Kates A. Can the Affective Response to Exercise Predict Future Motives and Physical Activity Behavior? A Systematic Review of Published Evidence. Annals of Behavioral Medicine. 2015;49(5):715-31.
46. Beelen R, Raaschou-Nielsen O, Stafoggia M, Andersen ZJ, Weinmayr G, Hoffmann B, et al. Effects of long-term exposure to air pollution on natural-cause mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project. Lancet. 2014;383(9919):785-95.
47. Konduracka E, Rostoff P. Links between chronic exposure to outdoor air pollution and cardiovascular diseases: a review. Environmental Chemistry Letters. 2022.
48. Hoek G, Krishnan RM, Beelen R, Peters A, Ostro B, Brunekreef B, et al. Long-term air pollution exposure and cardio- respiratory mortality: a review. Environ Health. 2013;12(1):43.
49. Brook RD, Rajagopalan S. "Stressed" About Air Pollution: Time for Personal Action. Circulation. 2017;136(7):628-31.
50. Chen J, Hoek G. Long-term exposure to PM and all-cause and cause-specific mortality: A systematic review and meta-analysis. Environment International. 2020;143:105974.
51. Bigazzi AY, Figliozzi MA. Review of Urban Bicyclists' Intake and Uptake of Traffic-Related Air Pollution. Transport Reviews. 2014;34(2):221-45.
52. Pasqua LA, Damasceno MV, Cruz R, Matsuda M, Garcia Martins M, Lima-Silva AE, et al. Exercising in Air Pollution: The Cleanest versus Dirtiest Cities Challenge. International Journal of Environmental Research and Public Health. 2018;15(7).
53. de Nazelle A, Bode O, Orjuela JP. Comparison of air pollution exposures in active vs. passive travel modes in

European cities: A quantitative review. Environ Int. 2017;99:151-60.
54. Giallouros G, Kouis P, Papatheodorou SI, Woodcock J, Tainio M. The long-term impact of restricting cycling and walking during high air pollution days on all-cause mortality: Health impact Assessment study. Environment International. 2020;140:105679.
55. Tainio M, Jovanovic Andersen Z, Nieuwenhuijsen MJ, Hu L, de Nazelle A, An R, et al. Air pollution, physical activity and health: A mapping review of the evidence. Environment international. 2021;147:105954-.
56. López-Dóriga I, Vich G, Koch S, Khomenko S, Marquet O, Roig-Costa O, et al. Health impacts of electric micromobility transitions in Barcelona: A scenario analysis. Environmental Impact Assessment Review. 2022;96:106836.
57. Fyhri A, Heinen E, Fearnley N, Sundfør HB. A push to cycling—exploring the e-bike's role in overcoming barriers to bicycle use with a survey and an intervention study. International Journal of Sustainable Transportation. 2017;11(9):681-95.
58. Fyhri A, Sundfør HB. Do people who buy e-bikes cycle more? Transportation Research Part D: Transport and Environment. 2020;86:102422.
59. Bourne JE, Cooper AR, Kelly P, Kinnear FJ, England C, Leary S, et al. The impact of e-cycling on travel behaviour: A scoping review. Journal of Transport & Health. 2020;19:100910.
60. Department for Transport. National Travel Survey: 2020. In: Department for Transport., editor. London, UK2021.
61. Berjisian E, Bigazzi A. Summarizing the Impacts of Electric Bicycle Adoption on Vehicle Travel, Emissions, and Physical Activity Vancouver, Canada: University of British Columbia; 2019.
62. Brand C, Dekker H-J, Behrendt F. Chapter Eleven - Cycling, climate change and air pollution. In: Heinen E, Götschi T, editors. Advances in Transport Policy and Planning. 10: Academic Press; 2022. p. 235-64.
63. Otten M, Hoen MT, Boer LD. STREAM passenger transport 2014 version 1.1; Study on Transport Emissions of All Modalities Emission Key Figures. 2011 emission figures.: CE Delft, Delft; 2015.
64. OECD/ITF. Good to Go? Assessing the Environmental Performance of NewMobility. Paris: OECD Publishing; 2020.
65. Elliot T, McLaren SJ, Sims R. Potential environmental impacts of electric bicycles replacing other transport modes in Wellington, New Zealand. Sustainable Production and Consumption. 2018;16:227-36.
66. Schepers JP, Fishman E, den Hertog P, Wolt KK, Schwab AL. The safety of electrically assisted bicycles compared to classic bicycles. Accident Analysis & Prevention. 2014;73:174-80.
67. Schepers P, Wolt KK, Fishman E. The Safety of E-bikes in The Netherlands. Paris, France: International Transport Forum; 2018.
68. Fyhri A, Johansson O, Bjørnskau T. Gender differences in accident risk with e-bikes—Survey data from Norway. Accident Analysis & Prevention. 2019;132:105248.
69. Edge S, Dean J, Cuomo M, Keshav S. Exploring e-bikes as a mode of sustainable transport: A temporal qualitative study of the perspectives of a sample of novice riders in a Canadian city. The Canadian Geographer. 2018;62(3):384-97.
70. MacArthur J, Kobel N, Dill J, Mumuni Z. Evaluation of an Electric Bike Pilot Project at Three Employment Campuses in Portland, Oregon. Portland, OR: Transportation Research and Education Center (TREC); 2017.
71. Melia S, Bartle C. Who uses e-bikes in the UK and Why? Bristol, UK: Centre for Transport and Society; 2020.
72. Fishman E, Washington S, Haworth N. Understanding the fear of bicycle riding in Australia. Journal of the Australasian College of Road Safety. 2012;23(3).
73. Jones T, Harms L, Heinen E. Motives, perceptions and experiences of electric bicycle owners and implications for health, wellbeing and mobility. Journal of Transport Geography. 2016;53:41-9.
74. Newson C, Sloman L. A Case for a UK incentive for e-bikes. 2019.
75. Anable J, Brand C. Is the future electric? In: Thunberg G, editor. The Climate Book. London: Allen Lane; 2022. p. 464.
76. Sanders RL, da Silva Brum-Bastos V, Nelson TA. Insights from a pilot investigating the impacts of shared E-scooter use on physical activity using a single-case design methodology. Journal of Transport & Health. 2022;25:101379.
77. Sanders RL, Branion-Calles M, Nelson TA. To scoot or not to scoot: Findings from a recent survey about the benefits and barriers of using E-scooters for riders and non-riders. Transportation Research Part A: Policy and Practice. 2020;139:217-27.