The Journal of Transport and Land Use jtlu.org
Vol. 18 No. 1 [2025] pp. 77–122

The benefits of active transportation interventions: A review of the evidence

Dillon T. Fitch-Polse
Institute of Transportation Studies
University of California, Davis
dtfitch@ucdavis.edu

Swati Agarwal
Institute of Transportation Studies
University of California, Davis
siagarwal@ucdavis.edu

Abstract: Interventions to promote active travel (walking and bicycling) have manifold societal benefits. This study reviews the benefits of active travel infrastructure (e.g., painted bicycle lane, pedestrian refuge island) and programmatic interventions (e.g., bike share program), synthesizes the effects by outcome categories and provides a summary of the effects, and quantifies the effects where possible. We cite 236 studies on intervention-specific findings. Additional evidence is used to synthesize the benefits of active travel interventions into different benefit categories including safety, physical activity, reduction in vehicle miles traveled and emissions, other health effects, and economic activity. There is relatively more evidence in the literature on safety effects and changes in bicycling and walking associated with active transportation interventions than on other effects such as changes in physical activity and vehicle miles traveled. In general, we find strong evidence for wide ranging societal benefits from active transportation interventions that increase public health and transportation system sustainability in cost-effective ways. Variation in effects is substantial for most infrastructure interventions, likely due to the wide variety of land use, environmental, cultural, and political contexts, as well as the wide variety of research methods and analyses employed across a diverse set of academic fields. The existing local transportation infrastructure and land-use patterns are especially likely to moderate the effects of active transportation interventions. This suggests that it is necessary to keep the local context in mind when evaluating the effects of specific interventions.

Keywords: Bicycling infrastructure, pedestrian infrastructure, bicyclist and pedestrian safety, active transportation, active travel programs and policies, active travel and health

Article history:
Received: December 11, 2023
Received in revised form: December 5, 2024
Accepted: December 20, 2024
Available online: February 14, 2025

1 Introduction

Infrastructure, program, and policy interventions to increase walking and bicycling (forms of active transportation) have been studied extensively (Dill, 2009; Ewing & Cervero, 2010; Fields et al., 2022; Panter et al., 2016; Pucher et al., 2010; Schoner et al., 2015). While difficult to pin down causal effects, evidence suggests a wide variety of interventions can be effective in normalizing walking and bicycling for day-to-day travel. However, quantification of the benefits

https://doi.org/10.5198/jtlu.2025.2468

The *Journal of Transport and Land Use* is the official journal of the World Society for Transport and Land Use (WSTLUR) and is published and sponsored by the University of Minnesota Center for Transportation Studies.

of specific interventions are difficult to find, come from a variety enviro-social contexts and academic disciplines, and are examined at a variety of analysis scales. These challenges of quantifying benefits of interventions have resulted in a scattered and inconsistent academic literature on the efficacy of active transportation interventions.

The magnitudes of effects of active travel projects and programs are likely to vary due to several contextual factors such as the local land-use mix. Land-use patterns have a strong impact on pedestrian and bicycling demand (Cui et al., 2014; Faghih-Imani et al., 2014; Noland et al., 2019; Oliver et al., 2007). For example, greater land-use diversity has been found to be associated with increased walking and bicycling (Chen et al., 2017; Forsyth & Krizek, 2010; Hankey et al., 2012; McConville et al., 2011; Saelens et al., 2003; Sallis et al., 2013; Winters, Brauer, et al., 2010). Thus, the type of land use in an area, among other factors, is likely to moderate the effects of active travel interventions. While local contextual factors can have an impact on the effects of active travel interventions, literature on the benefits of active travel interventions across different locations needs to be reviewed to provide an understanding of general baseline effectiveness of these interventions.

Because active transportation has very broad societal effects, measuring all the outcomes and downstream benefits of active transportation interventions is an interdisciplinary endeavor. This may be one reason, among others, why most studies of active transportation projects take a more limited view of outcomes, focusing, for example, on safety. Yet quantifying the broad ranging benefits of active transportation infrastructure and programs is essential to setting policy to fund such interventions and prioritizing possible investments.

In this paper, we examine the societal benefits of active transportation interventions. Through a conceptual evaluative framework and synthesis of research, we quantify benefits (where possible) of specific infrastructure and programs and synthesize those benefits by outcome categories of interest to researchers and practitioners. This review was conducted to fill the gap in current reviews on benefits of active travel interventions and to support the development of a tool (Favetti et al., 2022) that calculates the benefits of active transportation projects funded by the state of California, USA. A comprehensive evaluation of interventions is an essential step in the development of projects, and a tool based on a review of existing literature can learn lessons from previous experiences and avoid neglecting key elements during evaluation. Because of the specific policy purpose of supporting the development of the tool, this paper is United States (US)-focused, although many benefits are likely to apply in other countries that employ similar interventions.

2 Methods

This paper aims to provide a broad overview of the benefits of active travel interventions and a general understanding of the effectiveness of specific interventions. To this end, we searched literature based on the conceptual framework presented in Figure 1. In this conceptual framework, changes in access, perceptions, and behavior are assumed to be the root cause of active transportation project benefits, though the causal paths are complex in that societal outcomes then influence individual perceptions and behavior. Local contextual factors, particularly land-use patterns and existing transportation infrastructure, are likely to moderate the effects of active travel interventions. Research tends to focus on specific aspects of the framework rather than the system as a whole. Literature reviews on effects of active travel interventions by other researchers in the past have focused on specific effects such as mode shifts from cars to active modes (Scheepers et al., 2014), change in the amount of bicycling (Pucher et al., 2010), and health outcomes (Hansmann et al., 2022; Stankov et al., 2020). This paper aims to fill a gap in the literature to review multiple benefits of active travel interventions and provide ranges of intervention-specific benefits.

In reviewing the literature, we focused on four primary outcomes: change in perceptions, change in small-scale behaviors (e.g., drivers changing speeds, pedestrians using crosswalks), change in large-scale behaviors (e.g., travel mode choice, active travel frequency), and change in downstream societal benefits (e.g., improved health, lower greenhouse gas (GHG) emissions).

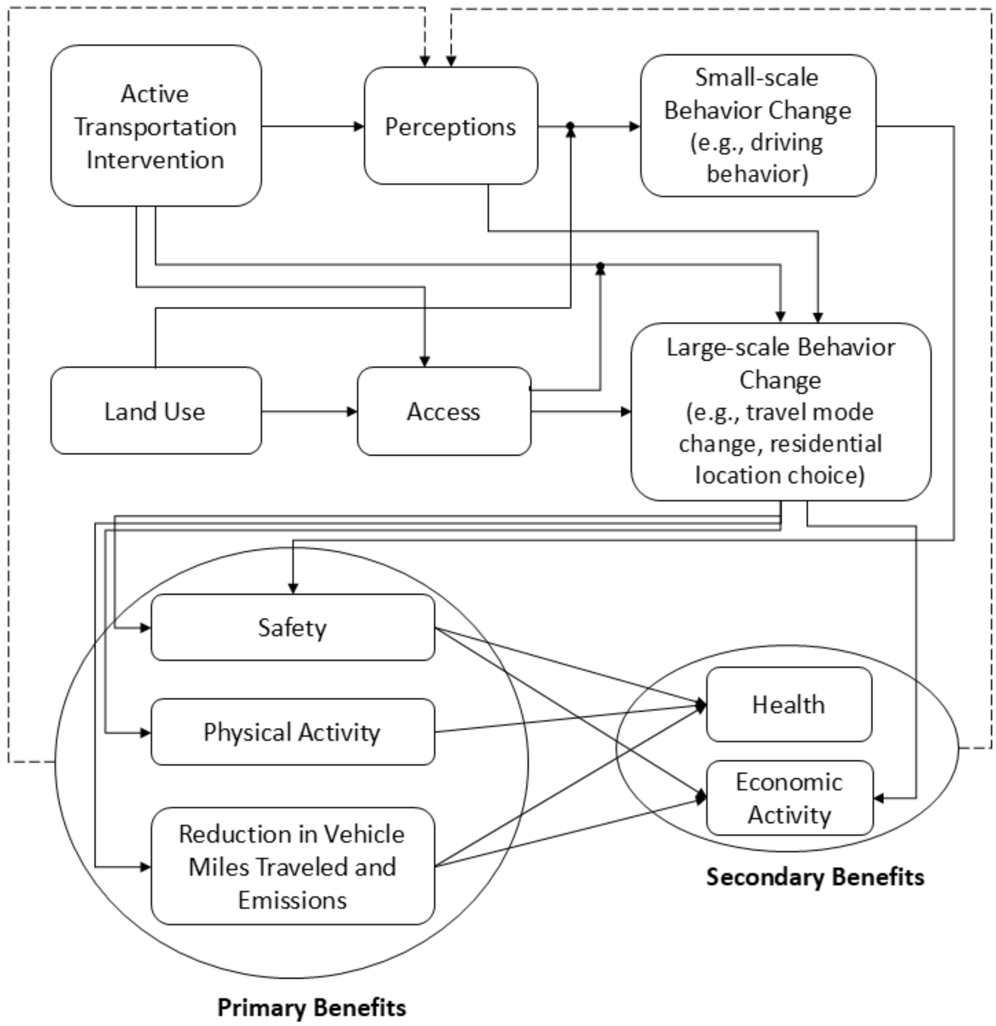

Figure 1. Conceptual framework for the effects of active transportation interventions. The effects in the diagram are examples and not an exhaustive list. Arrows pointing to boxes indicate a causal effect. Arrows pointing to other arrows indicate a moderating effect.

In conducting this review, we adopted two main approaches. The first approach consisted of a structured search process from academic search engines including Web of Science, Scopus, and Crossref. In the second approach, we used Google Scholar, which can provide a broader range of articles and reports related to a searched term and allow for a quick screening and selection process. Besides our initial searches, we also used citations from publications (especially recent review papers) to expand our review and we included literature from our prior research. About half of our citations were from the structured search process, while the other half were obtained from non-systematic means. Given the breadth of this paper, we used a wide variety of search terms related to potential benefits (e.g., increased active travel, health, cost, safety) and interventions (e.g., road diet, bike lane). In the review, we read titles and abstracts for all returned records that were published in English until the titles became increasingly irrelevant to our search term. In the case of pure academic search engines, we more often reviewed every item returned. In some cases, we revised our search term if it proved to be too broad from the initial search (e.g., returning thousands instead of hundreds of articles). In the case of Google Scholar, we used it to find material quickly and did not review all the returned documents (often in the hundreds of thousands).

When reviewing titles and abstracts, we considered the following thresholds for inclusion:

(1) Does the study include an active transportation infrastructure or program intervention?
(2) Does the study report direct and/or indirect benefits or costs from interventions?
(3) Does the study report changes in large-scale behaviors such as travel mode choice or frequency of walking and/or bicycling?
(4) Does the study report changes in perceptions which in turn could influence walking and/or bicycling?
(5) Does the study report changes in small-scale behaviors which could influence active travel?

If a report or journal article met the first and second criteria and either of the third, fourth, or fifth criteria, we included it. We report the range of expected outcomes as they are reported by the various authors to provide an understanding of the potential range of effects of each intervention. We ignore extreme outliers in our range summaries (and provide descriptions of outliers when available), and we provide confidence intervals when reporting specific study results where possible.[1]

In our synthesis of the broad benefits of active transportation interventions (see Section 3), we focus on the primary benefits (safety, physical activity, and reduction in vehicle miles traveled and emissions) and secondary benefits (other health related effects, and economic activity) of these interventions noted in the conceptual framework. In the discussion on intervention-specific findings in Section 4, we summarized the effects of specific active travel interventions on perceptions, behavior change, and downstream benefits (e.g., safety) that were reported by studies.

2.1 Intervention context and synergy

We summarize effects in this review by treating infrastructure projects independently from programs because research has tended to focus on one or the other, but evidence also suggests that integrating infrastructure with non-infrastructure programs to increase active travel is most effective (Keall et al., 2018; Pérez et al., 2017; Pucher et al., 2010). We differentiated the types of infrastructure projects in this review based on whether they were implemented on roadways or at intersections because an intervention usually targets one or the other. The outcomes of infrastructure interventions depend on their detailed designs (which vary across studies). Most research focuses on the presence of a facility or an intervention, with little regard for the details in the design or the prior conditions, but the details are likely to have a substantial effect.

Additionally, some active transportation infrastructure interventions can also contribute to improving the active transportation network connectivity or are moderated by existing connectivity. Walking and bicycling will be used as modes of travel only if destinations are within acceptable walking and bicycling distances (Handy et al., 2014; Saelens & Handy, 2008). Distances to destinations largely depend on land-use policies, but they also depend on how directly the network connects travelers to their destinations. The layout of pedestrian and bicycle networks is thus crucial in promoting active travel. The evidence is strong that people with more

---

[1] We use “95CI” to denote author reported 95% confidence intervals. 95CI indicates that 95% of individual trials will yield a result within the stated range while only 5% will not.

and better connections to destinations via active transportation infrastructure are more likely to actively travel (Braun et al., 2019; Cao & Duncan, 2019; Faghih Imani et al., 2019; Veillette et al., 2019). While existing bicyclists may be willing to increase their distance to ride on better infrastructure (Broach et al., 2012; Fitch & Handy, 2020), ultimately reducing the total trip distance for accessing destinations safely and comfortably is a way to attract new bicyclists, and this connectivity likely provides synergistic benefits with those from isolated projects. For example, measurements of bicycling connectivity have been shown to improve predictions of bicycling travel to school at the individual level (Fitch et al., 2016; Fitch et al., 2018), and are associated with the number of bicycling trips at zonal levels (Lowry & Loh, 2017).

Land-use patterns are likely to influence pedestrian and bicycling volumes, and thus, are also likely to moderate the effects of active transportation interventions. For example, mixed land-use patterns are likely to result in reduced distances to destinations (Handy et al., 2010), and thus, are likely to complement interventions to increase walking and bicycling. But, at least one study suggests that greater land-use mixture is associated with a greater number of bicycle crashes, possibly due to increased conflict points in mixed land-use areas (Chen, 2015). Areas with higher proportions of commercial and open space land-use types have been found to be associated with increased bicycle crash frequency as well (Ding et al., 2020). This suggests that interventions to improve pedestrian and bicycling safety may be especially effective in these land-use contexts. While the studies by Chen (2015) and Ding et al. (2020) account for general bicycling exposure (e.g., bicycling mode share, number of bicycling trips), inferences on the relationships between the type of land use and bicycling safety should be drawn with caution because of the lack of inclusion of more detailed bicycling exposure at crash locations in analyses.

Road context (e.g., volume, modes, speed, etc.) is also likely to enhance or restrict the effect of infrastructure projects. For example arterial (primary) roads are more dangerous for bicyclists and pedestrians, due to increased exposure to vehicles and higher vehicle speeds (Chen, 2015; Dumbaugh & Li, 2011). Bike infrastructure on arterial roads is correlated with a higher number of bike crashes compared to infrastructure off arterial roads (Chen, 2015). In general, when speeds are high, greater separation is needed. If speeds can be reduced (though traffic calming or because of congestion), the safety benefits of bike lanes are likely improved (Saha et al., 2018). While road and land-use contexts are key moderators of active transportation interventions, measuring context variables lacks consistency. This may be why evidence of infrastructure influencing walking and bicycling is mixed (Saelens & Handy, 2008).

Policy context also moderates active transportation intervention benefits. Pricing (cordon, parking, VMT tax, etc.) and constraining the capacity (lane removal, lane narrowing) for driving are likely important synergies with active transportation interventions. Interventions that increase the cost of driving in conjunction with active transportation interventions are likely to increase the use of active transportation modes and reduce car use.

2.2 Limitations

This was a targeted review of various active travel interventions, not a systematic review of each intervention. Due to time and budget constraints, we targeted high-quality evidence on the effects of active travel interventions for a variety of land-use contexts, but we did not include exhaustive literature searches for each intervention. The goal of the effects we report is to provide a general order of magnitude for intervention types, thus the reported effects should not be considered expectations for any specific project. We most commonly report results as relative effects (e.g., percent change, odds ratios) because that is how most studies report effects. Unfortunately, relative effects neglect the base rate of the phenomena they represent (e.g., current bike counts, number of existing crashes), and should not always be used to compare projects or programs. For example, a 20% reduction in crashes on a secondary road may not provide as strong of a benefit as a 3% reduction in crashes on a primary road if the number of existing crashes on the primary road is much greater. Because of this challenge, we refrain from directly comparing project types in this review, and future work is needed to calculate absolute effects from the existing literature to improve project comparisons.

3 Synthesis of benefits

In this section, we synthesize the findings from the literature on primary and secondary benefits of active transportation interventions and discuss the current evidence for generalized cost effectiveness of active transportation projects. The next section, Section 4, summarizes the intervention specific findings of this literature review.

Some benefits go undocumented in this review. Most notable are travel time savings (a long-standing yet controversial metric (Metz, 2008)), and monetary savings from vehicle use reduction. See Litman (2023) for an accounting of possible benefits for active transportation projects that are less prevalently reported in the academic literature.

As noted in the conceptual framework in the Methods section, the broad benefits of active travel interventions that we focused on in our synthesis include primary benefits (safety, physical activity, and reduction in vehicle miles traveled and emissions) and secondary benefits (other health related effects, and economic activity). Table 1 below presents a summary of the broad benefits of active transportation interventions that the literature provides evidence for, and that are discussed in more detail in the following sub-sections.

Table 1. Summary of benefits of active transportation interventions

Category	Benefits
Safety	• Reduction in exposure of active travelers to cars (e.g., frequency of potential conflicts) through separation and protection interventions • Reduction in severity of injuries for bicyclists and pedestrians resulting from potential conflicts through reduction in car speeds
Physical activity	• Increase in physical activity which in turn reduces mortality risk and reduces risk of certain diseases • Improvement in mental health
Vehicle miles traveled and vehicle emissions	• Reduction in vehicle miles traveled due to mode shifts to active transportation • Reduction in car emissions
Other health effects	• Improvement in air quality • Reduction in active travelers' exposure to vehicular emissions
Economic activity	• Increase in residential property values • Stimulate spending in commercial areas

3.1 Primary benefits

3.1.1 Traffic safety

The direct effects of infrastructure on bicycling and walking safety with respect to vehicle traffic can be labeled by three primary classes: those that decrease car speeds, those that separate active travelers from cars (thereby reducing the exposure to cars), and those that protect bicyclists and pedestrians from cars. Many infrastructure projects do all three of these things because they incorporate many design changes at once. The general road context (e.g., urban arterial, rural highway, local road) moderates the safety effects of infrastructure interventions. Because of the large variation in the effectiveness of infrastructure in urban and rural environments, crash modification factors[2] are generally developed separately for urban and rural roads.

3.1.1.1 Reducing car speeds

Many studies have established a relationship between speed and safety for pedestrians and bicyclists. Active travel injuries and deaths are most commonly caused by cars colliding with pedestrians and bicyclists, and the speed of cars is the root cause of injury and death (Grembek et al., 2020). Lowering speed limits and using other traffic calming measures have also been shown to provide positive safety benefits for all travelers. For bicycling, lower speed limits combined with other infrastructure projects have been associated with reduction in bike related crashes (Kaplan & Giacomo Prato, 2015; Klop & Khattak, 1999; Kullgren et al., 2019). When arterials allow car speeds much above 30 mph, physical separation and protection are needed to reduce injury risk (Grembek et al., 2020).

Greater intersection frequency along arterial roads has been associated with fewer and less severe pedestrian crashes because it leads to slower car speeds (Lee & Abdel-Aty, 2005; Marshall & Ferenchak, 2019). In the US, pedestrian crash risk at midblock crossings seems to be the greatest, and during low light conditions (National Highway Traffic Safety Administration, 2020). Conversely, intersections are generally the most dangerous parts of the road for bicyclists, often resulting in more crashes, especially the ones with higher vehicle volumes (Kaplan & Giacomo Prato, 2015; Klassen et al., 2014; Morrison et al., 2019; Romanow et al., 2012; Saad et al., 2019). While studies show more frequent bicycle-related crashes at intersections, the crashes tend to be less severe, likely due to slower speed of vehicles (Cripton et al., 2014), and bicyclist deaths are still less common at intersections (National Highway Traffic Safety Administration, 2014).

Reducing speed limits and implementing automatic speed enforcement offers large safety benefits (see Table 2) and are likely to be effective in cases where physical road interventions alone cannot slow traffic. For local roads, adoption of very low speed limits (15 mph) with shared space designed to prioritize pedestrian use and child play can greatly improve traffic safety (Delaware Valley Regional Planning Commission, 2018; Goeverden & Godefrooij, 2011; Sørensen, 2011). For collectors and minor arterials, road diets offer great safety benefits because they combine speed management with separation and protection for bicyclists and pedestrians.

3.1.1.2 Separating and protecting bicyclists and pedestrians from cars

Painted bike lanes act to separate bicyclists from cars, but they provide no protection (barrier) between cars and bikes. Nonetheless, painted bike lanes have been shown to decrease bicyclist crash rates and injuries more often than they increase them (See Table 3) and (Deliali et al., 2023; Goerke et al., 2019; Jensen, 2008; Kaplan & Giacomo Prato, 2015; Morrison et al., 2019; Pedroso et al., 2016; Reynolds et al., 2009; Robartes & Chen, 2018; Smith et al., 2019; Teschke et al., 2012). Where more separation is provided (e.g., buffers, off-street paths), more safety benefits are observed (Cripton et al., 2014; Minikel, 2012; Romanow et al., 2012; Winters et al., 2013). When protective elements are also added (e.g., curb, trees, parked cars), safety is further improved (Harris et al., 2013; Kaplan & Giacomo Prato, 2015; Schepers et al., 2011; Teschke et al., 2012; Winters et al., 2013).

---

[2] Crash modification factors (CMFs) are a standardized form of expressing the odds of an intervention reducing crashes. They are essentially odds ratios from regression models of various forms. While most include adjustments for traffic volume, only some studies include adjustments for bicyclist and pedestrian volume (even when attempting to estimate bicyclist and pedestrian injuries).

Separation and protection are also fundamental elements for pedestrian infrastructure. For example, sidewalks along roads, curb extensions, and crossing islands all provide important separation from cars as well as some protection, and they all provide safety benefits to pedestrians (See Table 4). However, because most pedestrian deaths occur at night and not at intersections or on sidewalks (National Highway Traffic Safety Administration, 2014), interventions aimed at improving pedestrian visibility at night and at midblock crossings are likely to provide greater safety benefits. Crossing islands, raised crossings, and flashing beacons seem to provide the best safety benefits for midblock crossings, especially if they are used in concert with other traffic calming interventions (see Tables 2 and 4).

Although crashes at intersections make up a minority proportion of bicyclist and pedestrian deaths (National Highway Traffic Safety Administration, 2014, 2020), active travelers spend far less time in intersections than they spend elsewhere, meaning that the relative rate of crashes in intersections is high. Reducing crossing distances with curb extensions while implementing traffic calming offers important safety benefits for pedestrians. Protected intersections, although little studied, show promise at providing separation and protection for bicyclists and pedestrians (Preston & Pulugurtha, 2021). At unsignalized intersections, roundabouts can provide considerable safety improvements, especially if they are designed with separated bicycling paths (See Table 2).

No road ntervention is likely to influence bicyclist safety as much as designing a bicycling network that is in large part separate from the road network. Networks of off-street paths not only provide great safety benefits, but they enable and encourage bicycling for a much wider portion of the population which itself can improve safety (see discussion of Safety in Numbers below). Although care must be taken in designing crossings between off-street paths and roads, and in integrating the two in commercial districts and other areas with destination demand, off-street paths provide the most separation and protection of any infrastructure type and can be implemented as multi-use paths for pedestrians as well.

3.1.1.3 Safety in numbers

Infrastructure projects for active transportation can influence the safety of people who walk and bike by reducing their crash (and injury) risk. In addition, infrastructure projects that improve walking and bicycling safety can increase people's perceptions of safety for walking and bicycling causing them to increase their walking and bicycling activity. This increase in walking and bicycling generates a positive feedback for safety since the relative risk for people walking and bicycling is reduced when more people walk and bike; this is commonly known as the "safety in numbers" phenomenon which was observed at least as early as 1998 (Garder et al., 1998), coined in 2003 (Jacobsen, 2003), and examined extensively since (Elvik & Bjørnskau, 2017; Fyhri et al., 2017; Jacobsen et al., 2015; Tasic et al., 2017).

The mechanisms behind the safety in numbers effect are still uncertain, but some findings support, at least in part, a behavioral explanation that drivers on routes with more bicyclists or pedestrians are more aware of them and take greater precautions (Jacobsen et al., 2015). The safety in numbers effect for active travel crashes is most recently estimated to be near 0.4 (Elvik & Goel, 2019) (i.e., a 10% increase in bicycling volume only increases crashes by 4%), and the relationship may be slightly stronger for pedestrians than for bicyclists (Elvik & Bjørnskau, 2017; Elvik & Goel, 2019). This effect may be even lower for more severe injuries and deaths, although results have been mixed thus far (Elvik & Bjørnskau, 2017; Kaplan & Giacomo Prato, 2015). While the mechanisms for reduced relative risk given increasing rates of bicycling and walking have been explored, the similar effects of vehicle volume have not. It is possible that increasing vehicle volumes are indicative of congestion (and thus slower speeds) which can increase safety. However, most studies only adjust for average annual daily traffic, rather than a measure of speed or congestion.

3.1.2 Physical activity

Disease associated with physical inactivity has been quantified since the 1950's (Fox & Haskell, 1968) and has reached pandemic status (Kohl et al., 2012). Evidence suggests that the effects of physical activity on health outcomes are non-linear (i.e. the greatest benefits come from transitioning from sedentary to moderate physical activity) (Woodcock et al., 2011). Meta-analyses of cohort studies from decades of research indicates that increasing from no physical activity (0 MET-h)[3] to 2.5 hours of moderate intensity physical activity (11 MET-h) per week is expected to result in reductions in risk of cardiovascular diseases, diabetes, breast cancer, colon cancer, obesity, depression, dementia, and mortality (Sadarangani et al., 2018; Woodcock et al., 2009; Woodcock et al.,2011).

The specific rates of mortality risk reduction from active travel (walking 11% (95CI 4-17%) and bicycling 10% (95CI 6-13%) (Kelly et al., 2014)) are slightly lower than those of all moderate intensity physical activity. While most of the active travel and health research has focused on physical health, mental health is also clearly improved (see expected effects on depression above). In general, active travel generates mental health benefits by reducing stress and increasing satisfaction (Gatersleben & Uzzell, 2007). And while less is known about the magnitude of effects on mental health, given the prevalence of mental illness (e.g., in the US, 18% of adults and 22% of young adults had some form of mental illness in 2015 (Bose et al., 2016)), mental health benefits from active travel could be substantial.

The research community is in consensus that new or improved infrastructure that increases active travel increases physical activity (Brown et al., 2017; Goodman et al., 2014; Goodman et al., 2019). However, much of the evidence linking active transportation projects to health outcomes comes from integrating research in transportation (on the link between projects/programs and travel behavior change) with research on physical activity and health. The field has recently seen a proliferation of model-based simulations that estimate the health effects from interventions based on assumptions about mode shifts or physical activity gains (Brown et al., 2019; Goodman et al., 2019; Gotschi, 2011; Grabow et al., 2012; Johansson et al., 2017; Kriit et al., 2019; Lindsay et al., 2011; Macmillan et al., 2014; Maizlish et al., 2017; Mizdrak et al., 2019; Rodrigues et al., 2020; Rojas-Rueda et al., 2016). These studies estimate the potential health benefits from active transportation projects, but they do not provide empirical evidence of benefits achieved. However, these simulations consistently show that shifting even moderate amounts of driving to walking or bicycling could result in substantial health benefits.

Results of the studies that attempt to measure physical activity changes (and thus health benefits) directly from active travel show that people with 30 minutes or more of active commuting have lower rates of obesity by 25-50% (95cIs 10-67%) (Gordon-Larsen et al., 2009; Steell et al., 2018), and lower rates of metabolic syndrome 33% (95CI 19-48%) (Steell et al., 2018). Active travel rates and obesity are also highly correlated at the population level (r = -0.76 for measured and -0.86 for self-reported obesity) (Bassett et al., 2008). Active travelers also tend to have lower diastolic blood pressure (-1.67 95CI -0.15 to -3.2) and reduced cardiovascular risk 12% (95CI 2-20%) (Gordon-Larsen et al., 2009). Although few studies attempt to show the effect of specific active transportation projects on health outcomes, there is some limited evidence. For example, when a complete painted bike lane was implemented along a new light rail line in Salt Lake City, UT, it caused a significant increase in average energy expenditure among commuters who shifted to active travel (1.16 more kilocalories per minute) (Brown et al., 2017). In three mid-sized cities in the United Kingdom where bike and pedestrian infrastructure were improved, substitution of active travel for car travel led to an average gain of 12.5 minutes of physical

[3] MET is the metabolic equivalent task, a commonly used metric to standardize energy expenditure (time and intensity) across activities. Combined time spent in activities results in an estimate of total MET-hours/week (MET-h/week).

activity per week for each kilometer closer people lived to the interventions (Goodman et al., 2014). Furthermore, up to 90% of this increase in activity can be attributed directly to new or increased use of active transportation infrastructure (Panter & Ogilvie, 2015). Similarly, a study in Vancouver, Canada showed that living within 1,000 feet of a new greenway doubled (95CI 1-4) the odds of reaching 20 minutes of moderate or vigorous physical activity per day, and halved the odds (95CI 15-75%) of being sedentary for more than 9 hours (Frank et al., 2019).

Transit use has also been associated with greater physical activity due to the nature of walking to and from transit stops and origins and destinations. In the US, about a third of transit walkers achieve 30 minutes or more of physical activity from walking to and from transit alone which is thought to meet minimum physical activity guidelines (Besser & Dannenberg, 2005; Freeland et al., 2013). One study noted that transit users walk 12.4 minutes (95CI 8.7 – 16) more than non-transit users (Saelens et al., 2014). Another study conducted in the US found that those who rode public transit, even just once a week, reported nearly three times the amount of active travel per week compared to those who did not use public transit (Bopp et al., 2015). Considering that in the US half of the population does not meet the national physical activity guidelines, getting people with less-active lifestyles to use transit can have considerable health benefits from associated walking.

Many studies have estimated large reductions in health-related costs that are associated with the increased physical activity from more active travel (Aldred & Croft, 2019; Jarrett et al., 2012; Mizdrak et al., 2019; Rodrigues et al., 2020; Standen et al., 2019; Zapata-Diomedi et al., 2018). The magnitudes of those benefits depend on the estimates of increased physical activity.

3.1.3 Vehicle miles traveled and vehicle emissions

Most reductions in GHG emissions associated with active transportation projects are due to mode-shift and consequent reductions in vehicle use. Model-based simulations of mode shifts show considerable GHG reductions are possible (Mizdrak et al., 2019; Rodrigues et al., 2020). At least one intervention study in cities in New Zealand showed that investments in active transportation of nearly 3 million dollars (2011 USD) resulted in a 1.6% reduction in vehicle kilometers traveled with a corresponding 1% reduction in CO_2 emissions (Keall et al., 2018). Assessments of car use reductions, and thus GHG reductions, from project-level interventions are less common. Of those focusing on bicycling infrastructure, there is agreement that bike infrastructure reduces vehicle miles traveled (VMT) and thus GHGs (Matute et al., 2016; Piatkowski et al., 2015; Thakuriah et al., 2012). Although the magnitudes vary by type of infrastructure and the surrounding context, Volker et al. (2019) proposed a generic method that can be used to estimate VMT change from any bicycling intervention. Using this method, Volker et al. (2019) estimated the effects of a single road diet project in Davis, CA, US (Gudz et al., 2016) decreased VMT by between 55,613 and 95,740 miles per year and reduced CO_2 emissions by between 24.4 and 42.0 metric tons per year. Estimates for hypothetical bike lanes in Los Angeles, CA from a life cycle assessment are reported to have a wide range of potential GHG reductions, where a project with a low change in bicyclist volume shows an increase in 8.2 metric tons of CO_2 per year (due mostly to emissions from construction) while the same project with a very high change in user volume would result in a net decrease of 221.7 metric tons of CO_2 per year (Matute et al., 2016).

3.2 Secondary benefits

3.2.1 Other health effects

Active transportation projects can influence physical health in four primary ways. First, they improve safety for existing bicyclists and pedestrians, as summarized above. If the projects lead individuals to shift from driving to active modes, however, these individuals are now at greater risk of injury and death (though at less risk than they would have been if they had shifted modes without the project). The net effect at the population-level depends on the increase in the amount of walking and biking versus the decrease in the risk resulting from the project.

Second, when active travelers increase their amount of walking and/or bicycling they themselves may experience greater exposure to air pollutants, although when drivers shift from car to active modes at least some evidence suggests they are likely to reduce their exposure to air pollutants (Kingham et al., 2013). The population, however, benefits from an improvement in air quality resulting from the shift from driving to active travel. Infrastructure investments that provide more separation between active travelers and cars not only provide greater protection, they also reduce active travelers' exposure to car emissions (Kendrick et al., 2011; King et al., 2009). Furthermore, the details of street design (e.g., street trees, building roof height, angle of roof) can have important effects of reducing active travelers' exposure to harmful emissions (Amorim et al., 2013; Yassin, 2011).

Third, active transportation projects influence health by increasing physical activity. The benefits of increased physical activity dwarf any downsides with respect to safety and exposure to air pollutants (de Hartog et al., 2010). As discussed above, increases in physical activity resulting from active transportation projects have clear and substantial benefits at both the individual and population levels.

Fourth, mode shifts from driving to active transportation help reduce vehicular noise pollution in general (Litman, 2023; Rabl & de Nazelle, 2012). However, individuals shifting from driving to active modes are likely to be exposed to higher levels of traffic noise (Apparicio et al., 2018).

3.2.2 Economic activity

Active transportation projects also generate co-benefits for local economies. These effects have manifested in changes in consumer behavior, property values, and cost savings. Many studies have shown that active travelers spend just as much as, if not more than drivers (Bent & Singa, 2009; Clifton et al., 2012; Gilderbloom et al., 2016; Popovich & Handy, 2014). One study in Portland, Oregon found that consumers who traveled by means other than vehicles more frequently visited businesses (such as convenience stores, bars and restaurants) on average (Clifton et al., 2012). Another study in San Francisco, California found a positive association between new bicycle lanes and sales per local-serving business that faced the streets with the new bicycle lanes (Poirier, 2018). However, at least one study did conclude that adding bike infrastructure and reducing parking would not help or harm local businesses (McCoy et al., 2019).

Active transportation projects have also been found to raise residential property values in some studies. For example, one study in Austin, Texas concluded that a 1% increase in bike score, a measure of bike infrastructure and activity, increases condominium and single-family house prices by 0.3% and 0.03%, respectively (Li & Joh, 2017). In another study, single family homes were found to have greater property value if located near an off-street bike facility, but less value if near an on-street bike facility (Welch et al., 2016). Finally, one study found that in a neighborhood with bike-share, each additional bike-share station was associated with a mean home sale value increase of 2.7% (El-Geneidy et al., 2016).

These increases in property values may not benefit everyone equally, however. Studies have shown that new biking infrastructure is associated with gentrification and is more likely to be implemented in gentrifying and affluent neighborhoods than in working class neighborhoods (Flanagan et al., 2016; Stein, 2011). Moreover, at times bicycle advocacy groups have presented infrastructure investments to attract wealthy investors to working class areas rather than a way to improve the lives of working-class people (Stehlin, 2015).

Nonetheless, active transportation infrastructure itself has not been causally linked to gentrification or the displacement of longtime residents in working class neighborhoods. One study found that the causal relationships between bicycling facility installation and socioeconomic and/or demographic changes at the block group level were generally not statistically significant (Ferenchak & Marshall, 2021). More broadly, investments in alternative transportation modes (those other than personal vehicles) in working class neighborhoods may not directly cause displacement but may prove inequitable in other ways. For example, in one study in Los Angeles, transit oriented development was determined by the authors to prevent low-income households from moving to areas which had just experienced such investments (Boarnet et al., 2020).

3.2.3 Generalized cost effectiveness

In every study we reviewed on generalized benefit-to-cost ratios for active transportation infrastructure, ratios always exceeded one, although they had wide variation (Brey et al., 2017; Macmillan et al., 2014; Meletiou et al., 2005). Simulations of investments that result in large behavior changes are expected to have large benefit-to-cost ratios between 1.5-25 to 1 (Gotschi, 2011; Macmillan et al., 2014). However, in real world before-after analyses, they tend to be slightly more uniform with a lower maximum (2-14 to 1) because of only moderate mode shifts to active travel (Chapman et al., 2018; Deenihan & Caulfield, 2014; Sælensminde, 2004; Standen et al., 2019). The benefits of active transportation projects generally exceed the costs from the health benefits alone. For example, in a review of only the generalized health benefits, the benefits exceeded costs by 9 (median) with a range from -2 to 360 (Mueller et al., 2015).

The wide variation in benefit-to-cost ratios for active transportation interventions found in the literature is likely attributable to the variation in the interventions that are examined, and variation in the type of benefits that are considered for analyses. For example, Chapman et al. (2018) examined the benefits and costs of a program that funded investments in bicycling and walking facilities, active travel promotion and bicycling training. The main benefits that Chapman et al. (2018) considered were health benefits and carbon emissions reduction benefits. The study by Brey et al. (2017) investigated the benefits and costs of construction of a bicycle lane network in a city. In addition to health and environmental benefits, Brey et al. (2017) also considered the benefits of travel time reduction, and reduction in vehicle use and maintenance costs.

4 Intervention-specific findings

This section summarizes the outcomes of specific active travel interventions. There is large variation in the magnitude of effects reported by studies for several interventions. As discussed above, this variation is likely due to the wide variety of land use, environmental, cultural, and political contexts of the areas where different studies were conducted, as well as the wide variety of study designs and research methods employed by researchers across a diverse set of academic fields. The synthesis of intervention-specific findings is reported in tabular form for a more unified presentation.

4.1 Outcomes of interventions for walking and bicycling

Table 2. Summaries of active transportation interventions for walking and bicycling and their outcomes

Intervention	Measured Perceptions and Behavior Change	Measured Benefits
Speed camera enforcement Camera that detects and captures images of vehicles violating traffic regulations including speeding.	Reductions in mean absolute speed by between 1-9.5 mph, reductions in all speeds by 2-33%, and reductions in percentage of speeding vehicles by 30-96% (Abdelhalim et al., 2021; Elvik et al., 2019; Hu & McCartt, 2016; Rodier et al., 2007; Soole et al., 2013).	Reductions in all crashes from 5-69% (Graham et al., 2019; Pilkington & Kinra, 2005; Thomas et al., 2008; Willardsen, 2021), reduction in injuries from 12-65% and deaths from 15-71% (Pilkington & Kinra, 2005; Tilahun, 2022).
Speed limit reductions	5 mph reduction in speed limit is expected to reduce mean speed by 1-2 mph (Elvik et al., 2019; Schaefer et al., 2022; Silvano & Bang, 2016), increases walking by 1-21% and bicycling by 4 – 22% (Tranter, 2018; Wier, 2019), although the large-scale behavioral effects are partially confounded. When combined with other infrastructure interventions, increase in active travel by 12-28% (Kullgren et al., 2019; Tranter, 2018).	5 mph reduction in speed limit is expected to reduce crashes by 10-15%, injuries by 8-15%, fatalities 10-30% (Elvik et al., 2019; Gayah et al., 2018), and bicyclist injuries 2.2-15.2% (Helak et al., 2017; Zahabi et al., 2011).
Dynamic speed display signs Also called dynamic speed feedback sign. Signs that detect and display current speed to approaching drivers, and/or display messages to reduce speed if an approaching vehicle exceeds a certain speed.	Reduce mean speed by 1-12 mph (3-10%), reduce 85th percentile speed by 3-8%, and reduce percent of cars exceeding speed limits by 13-48% (Cruzado & Donnell, 2009; Gehlert et al., 2012; Mahmud et al., 2021; Ullman & Rose, 2005).	Reductions in crashes from 5-7% (Fyhri et al., 2017).
Vertical deflectors Creates a change in the height of a section of the roadway to slow down vehicles. Examples include speed hump, speed table and raised crosswalk among others.	One deflector can reduce average speed by 2.7-3.4 mph, and multiple successive deflectors by 8-12 mph (Agerholm et al., 2017; Cottrell et al., 2006; Ponnaluri & Groce, 2005). Substantial reduction in average speed (28-56%) observed in a study in Tennessee (Chimba & Mbuya, 2019). Average speed reduced by 50% in a study conducted in Italy (Distefano & Leonardi, 2019).	Reduction in accidents by 35-44%, and reduction in pedestrian injuries by 50% observed in studies conducted in Italy and the UK (Distefano & Leonardi, 2019; Mountain et al., 2005).
Horizontal deflectors Creates a horizontal shift in the roadway to slow down vehicles by hindering the ability of a motorist to drive in a straight line. Examples include chicane, median/pedestrian island and traffic circle.	Reduction in average speeds by 1.3-3.2 mph in some contexts (Agerholm et al., 2017; Kacprzak & Solowczuk, 2019; Lantieri et al., 2015). Average speed reduction from 35 – 50% observed in a case study conducted in Italy (Distefano & Leonardi, 2019).	Reduction in accidents by 14-29% and reduction in pedestrian injuries by 33-40% observed in studies conducted in Italy and the UK (Distefano & Leonardi, 2019; Mountain et al., 2005).
Lane narrowing	Mixed evidence–- wider lanes separate vehicles from pedestrians and bicyclists, but narrower lanes cause drivers to slow down, which have known safety effects (Lee & Abdel-Aty, 2005; Rista et al., 2018; Turner et al., 2019). Lane narrowing on intersection	Lane narrowing on intersection approaches reduce crashes by 31% on average in one study (Gross et al., 2009). Another study based on data from New York City indicated that as road width increases, the probability of pedestrian-vehicle collision increases

Intervention	Measured Perceptions and Behavior Change	Measured Benefits
	approaches reduce speeds by 3.5-4.8 mph in one study (Gross et al., 2009). On freeways, for a lane width reduction of 1 ft or less, free flow speed is expected to reduce by 1.9 mph below that expected for the 12-ft lane width base case scenario. Narrowing lane widths to 10 ft is expected to reduce free flow speed by up to 6.6 mph (Dixon et al., 2016).	(Ukkusuri et al., 2012). Over 30% reduction in accidents and in pedestrian injuries observed in a study conducted in Italy (Distefano & Leonardi, 2019).
Shared streets Also called curbless street or “woonerf” in Dutch. Street is shared among pedestrians, bicyclists, and vehicles–- pedestrians have priority over vehicles.	Reduction of average speeds by 20-40% from meta-analysis of converted residential to shared street (Sørensen, 2011). Speed limits are typically lower on shared streets than on conventional streets. At several shared street sites in the US, speed limits were from 10-25 mph (Sauer & Mastaglio, 2017).	Some studies report fewer collisions, increasing child play, decreasing crime, increasing real estate price, but with such few details from secondary studies, effect sizes are largely unknown (Appleyard, 1983; Delaware Valley Regional Planning Commission, 2018; Eubank-Ahrens, 1984; New Jersey Bicycle and Pedestrian Resource Center, 2004; Sauer & Mastaglio, 2017). Reduction in serious traffic injuries by 50% in a Netherlands study (Delaware Valley Regional Planning Commission (2018) citing the FHWA).
Edge lane roads (ELR) Also called advisory bike lane. Roadway designed to support vehicular traffic within a single two-way center lane, and bicyclists or pedestrians in the edge lanes on either side.	Changes in mean speed range from reductions of about 3 mph to increases in 1 mph (Davidse et al., 2004; Gilpin et al., 2017), change in lateral position of cars (e.g., more space when passing bicyclists) of 16 inches of more space, to 8 inches of less space (Davidse et al., 2004). Reduction in the 85th percentile speed of vehicles by 5%, increase in average cyclist speed by 8%, increase in average lateral separation distance when vehicles passed cyclists, and a shift in the position of cyclists towards the middle of the painted bike lane were observed in a study conducted in Ottawa, Canada (Kassim et al., 2019).	Conversion of traditional two-lane two-way roads to ELRs reduced crashes by 36% in a study of 11 ELR sites in the US (Williams et al., 2022).
Multi-use paths Also called shared-use path. Pathway that is physically separate from motor vehicles. It can be located either next to a roadway or away from a road. Meant for non-motorized users.	Associated with 18 – 31% increase in bicycling (Le et al., 2018). Another study found that the mean hourly bicycle counts on multi-use paths were 193% higher than those on streets without facilities (Hankey et al., 2012). Off-street paths are preferred for bicycling compared to nearly all other bike infrastructure (Broach et al., 2012; Clark et al., 2019; Fitch & Handy, 2020). Some evidence that living near multi-use paths increases likelihood of physical activity (Kaczynski et al., 2009; Kaczynski & Henderson, 2007). A study found that a 10% greater supply of bike paths (including off-street bike paths and multi-use paths) is associated with a	Conflicting evidence of safety of multi-use paths indicates that general safety outcomes are uncertain, and context (especially about intersections with roads) is likely to determine outcomes. A study conducted in Canada noted that multi-use paths reduced risk of cycling injury by 25-40% compared to that on major streets with parked cars and no cycling infrastructure. However, multi-use paths had higher risk of injury compared to that on cycle tracks, major streets with bike lanes, and bike-only paths (Winters et al., 2012). On the other hand, some studies indicate that risk of injury for bicycling on multi-use paths is 1.6 to 3.5 times higher than cycling on the road with or without cycling infrastructure (Aultman-Hall & Hall, 1998; Aultman-Hall & Kaltenecker, 1999; Reynolds et al., 2009).

Intervention	**Measured Perceptions and Behavior Change**	**Measured Benefits**
	2.5% higher level of bike commuting (Buehler & Pucher, 2012). Multi-use paths have not been found to be significantly associated with increase in mode share of walking (Evenson et al., 2005; Wang et al., 2021).	Regarding safety at intersections, multiuse path-road intersections had a higher proportion of cycling collisions and injuries compared to road-road intersections in a study in Canada (Jestico et al., 2017).
Road diets Conversion of an existing four-lane, undivided roadway segment to a three-lane segment consisting of two through lanes and a center, two-way left-turn lane.	Reduce mean speeds 0-4 mph (Remache-Patino et al., 2022; Thomas, 2013), increase bicyclist volumes by 30-240% and pedestrian volumes by 0-30% (City of San Jose, 2015; Gudz et al., 2016; Thomas, 2013).	Reduce crash rates by between 19-47%, with greatest relative effects in rural environments (Aljamal et al., 2021; Lim & Fontaine, 2021; Thomas, 2013; Turner et al., 2019; Zhou et al., 2022).
Roundabouts Type of intersection that is characterized by a generally circular shape, where traffic moves counter-clockwise around a circle in one or more lanes. The entering traffic yields to traffic in the circle, and the geometric design features slow vehicles entering the circle. There are no stop-signs or signals at roundabouts.	Bicyclists perceive roundabouts as safer than signalized intersections (Wang & Akar, 2018). Roundabouts with separated cycle paths are safer for bicycling compared to roundabouts with on-road bike lanes or those with no bicycling facilities (Poudel & Singleton, 2021).	Variable bicyclist safety outcomes depending on design (Harris et al., 2013; Kaplan & Giacomo Prato, 2015; Meuleners et al., 2019; Reynolds et al., 2009; Shinar, 2017). Overall safety (including drivers and passengers) is increased: 15-38% reduction in crashes. 35-52% reduction in injuries, and 49-85% reduction in deaths (Elvik, 2017; Retting et al., 2001; Wang & Cicchino, 2022).
Protected intersections Also called offset or setback intersection. Intersection with treatments including corner islands that are designed to maintain the physical separation provided by bicycle lanes through the intersection.	Increased active transportation use, especially e-scooters, observed in a study (Lyons et al., 2020). Perceived as comfortable by bicyclists (Monsere et al., 2020). Higher rate of drivers glancing at the intersection prior to a right turn and reduced average vehicle speed observed in a simulation-based study (Deliali et al., 2021).	These are commonly used in the Netherlands which have high rates of cycling and low rates of bicyclist crashes (Schepers et al., 2017). Reduction in bicycle-related conflicts at intersection observed in a simulation-based study (Preston & Pulugurtha, 2021).
Flashing beacons Flashing lights designed to draw a driver's attention to the associated traffic control sign and the need to yield to a waiting pedestrian. Examples include rectangular rapid flashing beacons and pedestrian hybrid beacons.	Flashing beacons have a high yield compliance rate of 70-97%, which is substantially higher than the crosswalk compliance rate of 10-20% (Fitzpatrick et al., 2011; Fitzpatrick et al., 2015; Fitzpatrick et al., 2020; Kothuri et al., 2021; Vanwagner et al., 2011; Zegeer et al., 2017).	Reduce pedestrian crashes by an average of 35-50%, with standard errors of 21-38% and reduce all crashes by 25% (Fitzpatrick et al., 2011; Fitzpatrick et al., 2015; Fitzpatrick et al., 2020; Vanwagner et al., 2011; Zegeer et al., 2017).

Intervention	Measured Perceptions and Behavior Change	Measured Benefits
Traffic signals Traffic signal phasing interventions at intersections that improve pedestrian, bicyclist, and vehicular safety.	Increased pedestrian signal phase allows more people to cross the street, which is especially important for elderly populations (National Highway Traffic Safety Administration, 2014).	Phasing of left turns and signals with protected left phases decrease total left-turning crashes and injuries (Harkey et al., 2008; Monsere et al., 2019). Full-red and half-red signal phasing has been shown to decrease injuries by 24% and 19% respectively (Stipancic et al., 2020). Leading Pedestrian Intervals (LPIs) have shown to reduce vehicle-pedestrian- and vehicle-vehicle- crashes by 13% (Goughnour et al., 2021). In another study, LPIs reduced near-miss vehicle-pedestrian conflicts by 42% (Arun et al., 2023).
Safe Routes To School (SRTS) Program Infrastructure investments and activities (such as public awareness campaigns and outreach) aimed at increasing walking and bicycling by children to school.	SRTS interventions have been shown to increase walking and bicycling to school by 31– 37% (McDonald et al., 2014; Stewart et al., 2014). Engineering improvements increased active travel to school by 18%, and education and encouragement programs increased active travel to school by 25% over 5 years (McDonald et al., 2014). In another study, routes to school with new infrastructure had a tripling effect on walking and bicycling, although the overall school-level effects were negative suggesting that gains from infrastructure investments can be lost from other factors (Boarnet et al., 2005).	Reduced the annual rate of school-aged pedestrian injury during school-travel hours by 44% in a study conducted in New York City (DiMaggio & Li, 2013). Another study conducted in Texas showed that implementation of SRTS reduced pedestrian and bicyclist injury rates in school-aged children by 14%, controlling for the temporal trend in the reduction in adult injuries (DiMaggio et al., 2015). Pedestrian and bicycling collision declines were also observed in a study of 47 schools in California – SRTS-funded infrastructure improvements reduced collisions involving bicyclists and pedestrians of all ages by 75% (Ragland et al., 2014). In another study in 18 U.S. states, SRTS interventions reduced pedestrian and bicyclist injury risk by 14-16% during school-travel hours, and reduced pedestrian and bicyclist fatality risk by 13% during school-travel hours, controlling for the temporal trend in the reduction in adult injuries (DiMaggio et al., 2016).
Bike Share (Infrastructure/Program) Short-term bike, e-bike, e-scooter, or other micro vehicle rentals.	Bike-share trips have been found to replace car trips at a rate ranging from 7% to 45% (Barnes, 2019; Fishman et al., 2014; Fukushige et al., 2023; NACTO, 2019). Bike-share has been found to be associated with increased levels of bicycling for specific segments of populations (Fitch et al., 2021; Hosford et al., 2019).	Bike-share reduced VMT by 0.79 miles per trip on average on weekdays in one study in California (Fukushige et al., 2023). Bike-share reduced traffic congestion by about 4% in one study in Washington D.C. (Hamilton & Wichman, 2018). Bike-share was found to reduce greenhouse gas emissions by 283-581 grams of CO_2 equivalent on average per trip in one study (Kou et al., 2020).
Social Marketing (Program) Awareness campaigns and outreach activities to promote active transportation.	A few neighborhood programs in Australia and the US were found to increase bicycling by 1-2% (Pucher et al., 2010). A bicycling campaign in California was found to lead to an increase in bicycling frequency for only a certain section of the population – individuals who usually drive but are interested in taking up bicycling as a	Evidence on downstream effects of social marketing for active transportation in North America is sparse.

Intervention	Measured Perceptions and Behavior Change	Measured Benefits
	mode of transportation (Circella et al., 2022). Bicycling campaigns in Europe were found to increase bicycling in the short-term but the increases were not sustained in the long-term (Biondi et al., 2022; Höchli et al., 2019). Safe Routes To School (SRTS) Program's education and encouragement initiatives increased active travel to school by 25% over 5 years (McDonald et al., 2014).	

4.2 Outcomes of interventions for bicycling

Table 3. Summaries of active transportation interventions for bicycling and their outcomes

Intervention	Measured Effects on Perceptions and Behavior Change	Measured Effects of Downstream Benefits
Conventional bike lane Portion of the roadway (located adjacent to motor vehicle travel lanes) that has been designated for bicycling through the use of pavement markings and signage.	Painted bike lanes increase facility usage by approximately 62% on average (ranging from 4 to 438%) and increase bicycling by approximately 22% on average (ranging from -21 to 262% (Fields et al., 2022; Hankey et al., 2012; Mölenberg et al., 2019). People report greater perceptions of safety, comfort, and willingness to ride by 50-100% in comparison to no bike lanes (Clark et al., 2019), and prefer routes with bike lanes over those without (Broach et al., 2012; Chen et al., 2018; Fitch & Handy, 2020; Hood et al., 2011).	Painted bike lanes usually increase safety with estimated crash reduction between 5-66% and when bike volumes (exposure) are included, bicyclist injury reductions between 60-78% (Abdel-Aty et al., 2014; Chen et al., 2012; Dadashova et al., 2022; A. Deliali et al., 2023; DiGioia et al., 2017; Goerke et al., 2019; Hamann & Peek-Asa, 2013; Kaplan & Giacomo Prato, 2015; Kondo et al., 2018; Morrison et al., 2019; Pedroso et al., 2016; Reynolds et al., 2009; Robartes & Donna Chen, 2018; Smith et al., 2019; Teschke et al., 2012).
Buffered bike lane Conventional bicycle lane paired with a designated buffer space separating the bicycle lane from the adjacent vehicular traffic lane and/or parking lane (NACTO).	Improved cyclist perceptions of safety and comfort (Clark et al., 2019; McNeil et al., 2015), preference for routing (Fitch & Handy, 2020), and associated with increases in bicycling from 77-271% (Monsere et al., 2014). In addition, presence of a buffer can effectively move bicyclists away from parked vehicles (Duthie et al., 2010; Fees et al., 2015).	Although there is a dearth of quantitative evidence for the safety benefits specific to buffered bike lanes, we found the following relevant evidence: Narrower vehicle travel lanes and wider bike lanes show some safety benefits (Morrison et al., 2019). A study notes that provision of a buffer zone between bicycle lanes and on-street parking lanes can reduce the risk of collisions between bicyclists and opening car doors or alighting passengers. However, the magnitude of this effect was not quantified in the study (Schimek, 2018). Buffered bike lanes discourage wrong-direction riding by bicyclists compared to roads with no bike lanes (Dhakal et al., 2018).

Intervention	Measured Effects on Perceptions and Behavior Change	Measured Effects of Downstream Benefits
Protected bike lane (aka cycle tracks) Bike lanes separated from motor vehicle travel lanes using physical barriers such as bollards, concrete barriers, or a curb.	Increases in bicycling ranging from 21–500% (Karpinski, 2021; Monsere et al., 2014) with vertical physical objects resulting in higher comfort levels than painted buffers (McNeil et al., 2015; Monsere et al., 2014). A study conducted in Australia noted that while bike counts reported increase in use of a new separated bike path (23 – 97%), results of a survey indicate that this observed increase in cycling may be due to route choice changes and not mode choice changes (Rissel et al., 2015).	Cycle tracks have been found to reduce injuries by 41-99% (Harris et al., 2013; Teschke et al., 2012)(Harris et al., 2013; Teschke et al., 2012), and to reduce crash risk compared to conventional bike lane (Deliali et al., 2023). Another study reported mixed evidence – two-way protected bike lanes with heavy separation reduced risk of crashing or falling compared to major roads without bicycle facilities. But one way protected bike lanes with lighter separation had similar risk to major roads, and two way protected bike lanes with lighter separation had higher risk than major roads (Cicchino et al., 2020).
Off-street bike path Off-street paved path that is designed exclusively for bicycling.	Bicyclists tend to choose routes with off-street paths to a much greater extent compared to other options (Broach et al., 2012; Fitch & Handy, 2020; Wardman et al., 2007; Winters et al., 2010). Off-street bike paths are associated with increases in bicycling between 23–- 35% (Merom et al., 2003). Greenways (linear parks with paths) have been associated with school age children bicycling (Taylor & Coutts, 2018). A study found that a 10% greater supply of bike paths (including off-street bike paths and multi-use paths) is associated with a 2.5% higher level of bike commuting (Buehler & Pucher, 2012). A study conducted in Australia found that off-street bike paths were one of the most highly reported enablers to bike riding (Pearson et al., 2023).	Off-street bike paths have been shown to decrease injury risk by up to 41% and injury severity in some studies, but not in others (Cripton et al., 2014; DiGioia et al., 2017; Jestico et al., 2017; Meuleners et al., 2007; Reynolds et al., 2009; Rodgers, 1997; Romanow et al., 2012; Teschke et al., 2012: Teschke et al., 2014). In one study, greenways have also been shown to increase physical activity in urban residential neighborhoods (Frank et al., 2019). Another study conducted in Canada found that off-street bike paths reduced the risk of bicycle-vehicle conflicts by 70%, but increased the risk of bicycle-pedestrian conflicts by four times compared to streets without any cycling facility (Jarry & Apparicio, 2021).
Bike boulevard Also called neighborhood greenway or neighborway. Low-speed and low-volume street where all types of vehicles are allowed, but the roadway is modified using signs, pavement markings, speed calming and volume management measures to enhance bicycle safety and prioritize bicycling.	Limited results. Bicycle boulevards are appreciated by bicyclists and neighborhood residents (Broach et al., 2012; Griswold et al., 2018) and may provide reduced stress bicycling environments (Fitch et al., 2020), but it is not clear how effective they are at increasing bicycling (Dill et al., 2014). In addition, a study found that a reduction in posted speed limit is more likely to reduce speed on bicycle boulevards than on non-bicycle boulevards (Schaefer et al., 2022).	In at least one study, collision rates on bicycle boulevards were observed to be between 2 to 8 times lower than those on adjacent arterial routes (Minikel, 2012).

Intervention	Measured Effects on Perceptions and Behavior Change	Measured Effects of Downstream Benefits
Bike shared lane markings Also called sharrow. Pavement markings used to indicate lanes that are shared between bicycles and automobiles.	Some studies show behavioral changes which indicate potential improvements in safety (e.g., cars changing lanes to pass, bicyclists lateral position further from parked cars, cars shifting from the right to the left travel lane) (Brady et al., 2011; Foletta et al., 2015; Hunter et al., 2010; Pol et al., 2015). However, another study found no statistically significant differences between driver behaviors on roads with sharrows and roads without any bike facilities. This study also found that when passing cyclists on streets with sharrows, drivers are more likely to enter adjacent lanes than when passing cyclists on streets with striped or buffered bike lanes (Lindsey et al., 2021). Another study conducted in Maryland found that the overtaking motor vehicle passing distance was higher on a travel lane adjoining a bicycle lane than on a travel lane with a sharrow (Love et al., 2012).	Limited evidence. Sharrows correlated with poorer safety outcomes than bicycle lanes or no infrastructure in at least one study (Ferenchak & Marshall, 2019). A study conducted in Oregon found that sharrows reduced crash risk compared to no treatment and conventional bike lane (Deliali et al., 2023).
Bike highways Also called cycle superhighway. Continuous, long-distance bikeway that can consist of on-street bike facilities and fully separated paths.	Improvement in perceived traffic safety and personal security and increased in bicycling between 0-77% (Cabral Dias & Gomes Ribeiro, 2021; Grigoropoulos et al., 2021; Skov-Petersen et al., 2017; Taciuk & Davidson, 2018). A study found that cycle superhighways in London increased the average travel speed of bike share trips within the impact area (within 300 m of cycle superhighway route) by 13.3%, and reduced travel time of bike share trips by 11% (Li et al., 2018).	Two studies conducted on the impacts of cycle superhighways in London found no significant association between cycle superhighways and bicycle crash risk (Ding et al., 2020; Li et al., 2017).
Bike boxes Also called advanced stop line. Designated area at the front of a motor vehicle lane at a signalized intersection where bicyclists can wait during a red signal.	Bike boxes have been found to be associated with improved bicyclist movements through intersections including the following: an increase in proportion of bicyclists who approached an intersection using the bicycle lane instead of the vehicle lane, who stopped before the stop line, and who departed an intersection before motorists (Loskorn et al., 2013), and an increase in right-turning cars yielding to cyclists (Dill et al., 2012).	Increased perceived safety at intersections (Dill et al., 2012; Götschi et al., 2018; Wang & Akar, 2018) and reduced frequency of bicycle-vehicle conflicts by 31% (Dill et al., 2012; Ohlms & Kweon, 2018). Bike boxes were found to reduce severity of bicycle-vehicle conflicts in one study (Russo et al., 2023). A study in Edinburgh noted that bicycle boxes are effective at reducing cyclists' exposure to tailpipe exhaust emissions of vehicles (Luengo-Oroz & Reis, 2019).
Bike signals Bicycle signals fully separate conflicting movements between bicycles and vehicles in time to facilitate safe crossing of roads by bicyclists.	Compliance by bicyclists for bike signals seems similar to normal signals, confusion amongst all road users seems to be minimal (Monsere et al., 2019). Presence of bike signals was found to positively influence bike volume around intersections (Munira et al., 2021). Bike signals were perceived as	Bike signals were found to eliminate right-hook conflicts among compliant road users in one study (Russo et al., 2023). Cyclists crossing intersections with bicycle signals tended to allocate less visual attention towards a potentially conflicting vehicle, likely increasing crash risk with errant drivers in a

Intervention	Measured Effects on Perceptions and Behavior Change	Measured Effects of Downstream Benefits
	comfortable by bicyclists (Monsere et al., 2020), and found to be associated with low perceived crash risk at intersections (Lusk et al., 2019).	simulation-based study (Scott-Deeter et al., 2023).
Bike parking Provision of racks, lockers or covered areas to store bicycles when they are not being used.	Increasing rack supply at transit stations increases egress bicycle trips, stations with covered racks have more bike connections, and stations with bike lockers have more bike connections (Heinen & Buehler, 2019). Similarly, bicycle parking at work is associated with greater bike commuting, although exact effect sizes are unknown because of lack of causal study designs (Heinen & Buehler, 2019). The rate of bicycling as an access mode to rail stations without secure bicycle parking was found to be 0.54 times the bicycling rate to stations with secure parking in one study in Australia (Weliwitiya et al., 2019).	About 50-72% of reported stolen bicycles were 'flyparked' (bicycles secured to street furniture not designed for parking) in two studies conducted in Canada and UK, highlighting the need for formal bicycle parking (Egan et al., 2023; Johnson et al., 2008; van Lierop et al., 2015).
Bike Lending (Program) Programs that lend bicycles to participants for a specific time period.	Google's bike lending program in the San Francisco Bay area was found to increase bike commuting for participants by approximately 1.7–2.3 days and 1.3–1.9 days per week on average during and after the program, respectively (Fitch et al., 2022). Another study conducted in the Portland region also found that bike lending increased bicycling (Macarthur et al., 2017). In a study with brief e-bike lending periods conducted in Norway, e-bike trips increased from 0.9 to 1.4 per day (Fyhri & Fearnley, 2015). 38% of the participants of an e-bike lending program in the UK were expected to cycle more in the future after the end of the program (Cairns et al., 2017).	Nearly all the increases in bicycling resulting from Google's bike lending program were likely attributed to decreases in single occupancy vehicle (SOV) commuting – the program reduced SOV driving by approximately 15 miles per week for an average participant (Fitch et al., 2022). An e-bike lending program in the UK reduced VMT by 20% on average across all participants (Cairns et al., 2017).
Bike Rebates and Incentives (Program) Financial incentives that may either be a partial repayment after purchase or a point-of purchase discount to buy bicycles.	E-bike rebate programs were found to increase bicycling in the short-term (but this increase was not sustained in the long-term) in one study that evaluated three programs across Northern California (Johnson et al., 2023). The cycling mode share by kilometers traveled for people who obtained an e-bike through an e-bike incentive program in Norway was found to increase from 17% to 52% in one study (Fyhri et al., 2016).	In the short-term, e-bike rebate programs were found to replace car VMT by about 35-44%, reduce greenhouse gas emissions by 12-44 kilograms of CO_2 per month per participant, and induce recreational travel (which could provide health and wellbeing benefits) in one study (Johnson et al., 2023). One study noted that e-bike rebate programs are likely to be rebate-limited rather than demand-limited – all available rebates are expected to be claimed, and program impacts are expected to increase proportionally with the budget (Bigazzi & Berjisian, 2021).

4.3 Outcomes of interventions for walking

Table 4. Summaries of active transportation interventions for walking and their outcomes

Intervention	Measured Effects on Perceptions and Behavior Change	Measured Effects of Downstream Benefits
Sidewalks Raised curb with a paved walkway.	Greater width is associated with 12-33% more walking in small and large cities (Aziz et al., 2017; Barnes & Schlossberg, 2013; Guo, 2009; Guo & Loo, 2013). Some studies have found that higher sidewalk quality measured in terms of sidewalk coverage, density, curb prevalence, curb ramps, or improved corners is positively associated with walking trips (Eldeeb et al., 2021; Tian & Ewing, 2017). A study based on data from Australia found that for each 10-km increase in sidewalk length, the probability of neighborhood-based walking for transportation increased by about 3%, and the time spent walking by an individual increased by about 5 minutes per week (McCormack et al., 2012).	Sidewalks are associated with lower pedestrian and bicyclist crash risk (Berhanu, 2003; Kim et al., 2012; Raihan et al., 2019; Saad et al., 2019), lower pedestrian injury severity (Hwang, 2022; Khan & Habib, 2022), and relative safety effects are greater in rural settings, while absolute safety effects are greatest in urban settings (Arellana et al., 2020). One observational study found that sidewalks were associated with 40% less pedestrian crashes (Abou-Senna et al., 2022). Another study found that a 1% increase in proportion of road with sidewalk reduced the odds of pedestrian fatality by 1.5% on average (Hwang, 2022).
Lighting	Street lighting positively contributes to perceived safety and security for pedestrians and cyclists (Campos Ferreira et al., 2022; Herrmann-Lunecke et al., 2021; Lusk et al., 2019; Park & Garcia, 2020). Street lighting is associated with increased walking and cycling after dark (Fotios et al., 2019; Uttley et al., 2020).	Lighting is associated with 32-55% fewer crashes (combined 95CI 18-71%), 22-32% fewer injuries (combined 95CI 3-39%), and 66% fewer deaths (95CI 32-8%) (Beyer & Ker, 2009), with even greater pedestrian safety effects (Siddiqui et al., 2006; Wanvik, 2009). In addition, 27% fewer (95CI 9-47%) crimes in areas with street lights compared to control areas (Welsh & Farrington, 2008). A recent study found that street lighting was associated with a 58.3% lower risk of fatality in pedestrians hit by vehicles at night (Ferenchak et al., 2022). Pedestrian crashes in poorly lit or unlit conditions were associated with 34 – 49% higher risk of injury compared to crashes in well-lit or daylight conditions (Islam et al., 2022; Kemnitzer et al., 2019).
Crossing islands Also called pedestrian refuge island or median refuge island. Median located in the center of a multilane road that provides a safe waiting area for pedestrians and bicyclists crossing the road.	Crossing islands in one study showed a 10-20 percentage point increase in driver yielding, 2-5 mph reduction in speed, and a 10 percentage point increase in crosswalk use (Mead et al., 2014).	Islands results in 23-50% reduction in pedestrian crashes (Kang, 2019; Mead et al., 2014; Zegeer et al., 2017) and some evidence suggests that they are perceived as unsafe for bicyclists at intersections (Wang & Akar, 2018); although islands have mixed results on bicycling crash risk (Kim & Kim, 2015; Kim et al., 2012; Raihan et al., 2019). At least two studies found that crossing islands were associated with poorer safety outcomes – presence of central refuge islands increased the likelihood of collisions involving pedestrian violations at large intersections (Ghomi & Hussein, 2021); critical gap accepted by pedestrians for crossing from the crossing

Intervention	Measured Effects on Perceptions and Behavior Change	Measured Effects of Downstream Benefits
		island to the curb was much shorter than that from the curb to the crossing island (Saleh et al., 2020).
Crosswalks Path designated for pedestrians to cross a road.	Marked crosswalks increase pedestrian channeling and thus reduce variation in crossing behavior (Sisiopiku & Akin, 2003; Zegeer et al., 2001). A study conducted in UK found that a marked crosswalk was associated with increased likelihood of pedestrians using the crosswalk to cross the road, increased perceived safety, and reduced waiting time to cross (Havard & Willis, 2012). Conversion of a crosswalk to a high-visibility crosswalk was found to increase driver yielding by 11% and increase pedestrian compliance by 7.1% in one study (O'Brien et al., 2022).	Marking crosswalks alone is unlikely to provide much safety benefit (Zegeer et al., 2001). However, combining crosswalks with other traffic calming mechanisms can have substantial safety benefits for pedestrians (Poswayo et al., 2019). Proximity to a crosswalk was found to be associated with reduced risk of a fatal crash for pedestrians (Younes et al., 2023). High-visibility crosswalks positively modify driving behavior, reducing the risk of vehicle-pedestrian conflicts (Pantangi et al., 2021).
Raised crossings Roadway crossing where the pavement is raised typically up to the same level as the level of the sidewalk.	Raised crossings decrease vehicle speed (Garunović et al., 2020; Kruszyna & Matczuk-Pisarek, 2021; Loprencipe et al., 2019; Mohammadipour et al., 2020), increase driver yielding (Torres et al., 2020), and increase use of the designated crosswalk or crossing, although they are associated with reductions in pedestrian stop rates prior to crossing (Gitelman et al., 2017).	Limited evidence suggests decreases in pedestrian crashes by 40% and injuries by 24% (Stipancic et al., 2020; Turner et al., 2019) in addition to safety improvements for bicyclists (Schepers et al., 2011).
Curb extensions Also called bulb-out or neckdown. Extension of the curb line into the lane of the road adjacent to the curb.	Curb extensions reduce turning speed for vehicles (Fitzpatrick & Schneider, 2005), reduce 85th-percentile speed on urban roads (Mahmoud et al., 2021), and reduce crossing distances for pedestrians (reducing exposure and therefore crash risk) (Schneider et al., 2010; Schneider et al., 2017). A combination of temporary curb extensions and painted crosswalks was found to increase pedestrian activity by 23% in one study (Carlson et al., 2019).	Limited evidence suggests reduced pedestrian injuries by 24% on average with 95CI of 4-40% (Stipancic et al., 2020), and reduced pedestrian-vehicle collisions (Kang, 2019).

5 Conclusion

Infrastructure and programmatic interventions to promote walking and bicycling have manifold societal benefits. The evidence is generally strong that active transportation projects and programs have many positive societal effects, with few negative ones. Potential negative effects of active travel interventions include exposure of active travelers to air pollutants, risk of injury, and possibly gentrification. Although some of the literature that we reviewed suggests possible negative effects, evidence for the benefits of active travel interventions is overwhelmingly stronger. The evidence is stronger for some kinds of interventions than others – there is generally more evidence in the literature on effects of active travel infrastructure interventions than on programmatic interventions. Moreover, investment in multiple active travel interventions simultaneously is likely to be more effective in generating benefits than investment in only a specific intervention.

This review paper synthesizes the findings from the literature on broad benefits (including primary and secondary benefits) of active transportation interventions. It also provides detailed information on the effects of specific active transportation interventions. Thus, this paper can serve as a reference document for transportation researchers, planners, and policymakers who need information either on general benefits of active travel interventions or on effects of specific types of interventions or both. Care should be taken when comparing benefits by mode and infrastructure type as nearly all the evidence reported is relative to an unknown baseline benefit in which context likely plays an important role. Nonetheless, the ranges of effects in Tables 2-4 can help practitioners think about how to potentially combine different elements for achieving greater benefits for walking and bicycling.

Many variables are likely to moderate the expected effects of specific projects. Among several moderating factors, the existing local transportation infrastructure and land-use patterns are especially likely to influence the effects of walking and bicycling interventions, yet specifics about these interactions for each active transportation intervention is lacking in the literature. This also suggests that care is needed in generalizing these effects to specific projects, and more targeted evaluation of projects and programs that control for land use and road context variation is needed. This is especially the case for California's Active Transportation Program wherein future project-level evaluations can be conducted through standardized data collection. The outcomes of these evaluations in conjunction with the results provided by the supporting tool (Favetti et al., 2022) developed in part from this review can provide deeper insights into the specific effects of active travel interventions. These insights will be useful in estimating the effects of similar active travel interventions in other states in the US and in other countries as well.

Acknowledgements

The authors would like to thank the California Department of Transportation (Caltrans) for funding the California ATP Benefit-Cost tool and this literature review. We also thank all the authors who helped write the prior report that initiated this review paper: Salvador Grover, Sonia Anthoine, Grant Sles, and Christine Gemperle. A special thanks to Susan Handy for her guidance and comments on this work.

Author contribution

Conceptualization, methodology, writing, supervision, funding acquisition: Dillon Fitch-Polse; conceptualization, writing: Swati Agarwal.

References

Abdel-Aty, M., Lee, C., Park, J., Wang, J.-H., Abuzwidah, M., & Al-Arifi, S. (2014). *Validation and application of highway safety manual (Part D) in Florida*. Retrieved from https://rosap.ntl.bts.gov/view/dot/27272

Abdelhalim, A., Bailey, L., Dalphy, E., & Raboy, K. (2021). Data enforced: An exploratory impact analysis of automated speed enforcement in the District of Columbia. *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC*, 2478–2483. https://doi.org/10.1109/ITSC48978.2021.9565046

Abou-Senna, H., Radwan, E., & Mohamed, A. (2022). Investigating the correlation between sidewalks and pedestrian safety. *Accident Analysis and Prevention*, *166*, 106548. https://doi.org/10.1016/j.aap.2021.106548

Agerholm, N., Knudsen, D., & Variyeswaran, K. (2017). Speed-calming measures and their effect on driving speed – Test of a new technique measuring speeds based on GNSS data. *Transportation Research Part F: Traffic Psychology and Behavior*, *46*, 263–270. https://doi.org/10.1016/j.trf.2016.06.022

Aldred, R., & Croft, J. (2019). Evaluating active travel and health economic impacts of small streetscape schemes: An exploratory study in London. *Journal of Transport and Health*, *12*, 86–96. https://doi.org/10.1016/j.jth.2018.11.009

Aljamal, M. A., Voight, D., Green, J., Wang, J., & Ashqar, H. I. (2021). Evaluation of the use of a road diet design: An urban corridor case study in Washington, DC. *Sustainability*, *13*, 8964. https://doi.org/10.3390/su13168964

Amorim, J. H., Valente, J., Cascão, P., Rodrigues, V., Pimentel, C., Miranda, A. I., & Borrego, C. (2013). Pedestrian exposure to air pollution in cities: Modeling the effect of roadside trees. *Advances in Meteorology*, *2013*, 1–7. https://doi.org/10.1155/2013/964904

Apparicio, P., Gelb, J., Carrier, M., Mathieu, M. È., & Kingham, S. (2018). Exposure to noise and air pollution by mode of transportation during rush hours in Montreal. *Journal of Transport Geography*, *70*(June), 182–192. https://doi.org/10.1016/j.jtrangeo.2018.06.007

Appleyard, D. (1983). Case studies of citizen action and citizen participation in Brussels, Covent Garden, Delft, and Camden. In *Paternalism, conflict, and coproduction. Environment, development, and public policy* (pp. 69–118). Berlin: Springer. https://doi.org/https://doi.org/10.1007/978-1-4899-0360-0_3

Arellana, J., Saltarín, M., Larrañaga, A. M., Alvarez, V., & Henao, C. A. (2020). Urban walkability considering pedestrians' perceptions of the built environment: A 10-year review and a case study in a medium-sized city in Latin America. *Transport Reviews*, *40*(2), 183–203. https://doi.org/10.1080/01441647.2019.1703842

Arun, A., Lyon, C., Sayed, T., Washington, S., Loewenherz, F., Akers, D., …, & Haque, M. M. (2023). Leading pedestrian intervals – Yay or nay? A before-after evaluation of multiple conflict types using an enhanced non-stationary framework integrating quantile regression into Bayesian hierarchical extreme value analysis. *Accident Analysis and Prevention*, *181*, 106929. https://doi.org/10.1016/j.aap.2022.106929

Aultman-Hall, L., & Hall, F. L. (1998). Ottawa-Carleton commuter cyclist on and off-road incident rates. *Accident Analysis and Prevention*, 30(1), 29–43. https://doi.org/10.1016/S0001-4575(97)00059-6

Aultman-Hall, L., & Kaltenecker, M. G. (1999). Toronto bicycle commuter safety rates. *Accident Analysis and Prevention*, *31*(6), 675–686. https://doi.org/10.1016/S0001-4575(99)00028-7

Aziz, H. M. A., Nagle, N. N., Morton, A. M., Hilliard, M. R., White, D. A., & Stewart, R. N. (2017). Exploring the impact of walk–bike infrastructure, safety perception, and built-environment on active transportation mode choice: A random parameter model using New York City commuter data. *Transportation*, *45*(5), 1207–1229. https://doi.org/10.1007/s11116-017-9760-8

Barnes, E., & Schlossberg, M. (2013). Improving cyclist and pedestrian environment while maintaining vehicle throughput. *Transportation Research Record*, *2393*, 85–94. https://doi.org/10.3141/2393-10

Barnes, F. (2019). *UCLA capstone projects a scoot, skip, and a jump away: Learning from shared micromobility systems in San Francisco*. Retrieved from https://doi.org/10.17610/T6QP40

Bassett, D. R., Pucher, J., Buehler, R., Thompson, D. L., & Crouter, S. E. (2008). Walking, cycling, and obesity rates in Europe, North America and Australia. *Journal of Physical Activity and Health*, *5*(6), 795–814. https://doi.org/10.1123/jpah.5.6.795

Bent, E. M., & Singa, K. (2009). Modal choices and spending patterns of travelers to downtown San Francisco, California: Impacts of congestion pricing on retail trade. *Transportation Research Record*, *2115*, 66–74. https://doi.org/10.3141/2115-09

Berhanu, G. (2003). Models relating traffic safety with road environment and traffic flows on arterial roads in Addis Ababa. *Accident Analysis and Prevention*, *36*(5), 697–704. https://doi.org/10.1016/j.aap.2003.05.002

Besser, L. M., & Dannenberg, A. L. (2005). Walking to public transit: Steps to help meet physical activity recommendations. *American Journal of Preventative Medicine*, *29*(4), 273–280. https://doi.org/10.1016/j.ampre.2005.06.010

Beyer, F. R., & Ker, K. (2009). Street lighting for preventing road traffic injuries. *Cochrane Database of Systematic Reviews*, *2009*(1), CD004728. https://doi.org/10.1002/14651858.CD004728.pub2

Bigazzi, A., & Berjisian, E. (2021). Modeling the impacts of electric bicycle purchase incentive program designs. *Transportation Planning and Technology*, *44*(7), 679–694. https://doi.org/10.1080/03081060.2021.1956806

Biondi, B., Romanowska, A., & Birr, K. (2022). Impact evaluation of a cycling promotion campaign using daily bicycle counters data: The case of cycling may in Poland. *Transportation Research Part A: Policy and Practice*, *164*, 337–351. https://doi.org/10.1016/j.tra.2022.08.017

Boarnet, M. G., Anderson, C. L., Day, K., McMillan, T., & Alfonzo, M. (2005). Evaluation of the California safe toutes to school legislation: Urban form changes and children's active transportation to school. *American Journal of Preventive Medicine*, *28*(2), 134–140. https://doi.org/10.1016/j.amepre.2004.10.026

Boarnet, M. G., Painter, G., Burinskiy, E., & Swayne, M. R. E. (2020). *Residential moves into and away from Los Angeles rail transit neighborhoods: Adding insight to the gentrification and displacement debate*. Los Angeles: University of Southern California.

Bopp, M., Gayah, V. V., & Campbell, M. E. (2015). Examining the link between public transit use and active commuting. *International Journal of Environmental Research and Public Health*, *12*(4), 4256–4274. https://doi.org/10.3390/ijerph120404256

Bose, J., Hedden, S. L., Lipari, R. N., & Park-Lee, E. (2016). *Key substance use and mental health indicators in the United States: Results from the 2015 National Survey on Drug Use and Health*. Retrieved from https://www.samhsa.gov/data/sites/default/files/NSDUH-FFR1-2015/NSDUH-FFR1-2015/NSDUH-FFR1-2015.pdf

Brady, J., Loskorn, J., Mills, A., Duthie, J., Machemehl, & Randy B. (2011). Effects of shared lane markings on bicyclist and motorist behavior. *Institute of Transportation Engineers. ITE Journal*, *81*(8), 33–38. https://trid.trb.org/view/1126863

Braun, L. M., Rodriguez, D. A., & Gordon-Larsen, P. (2019). Social (in)equity in access to cycling infrastructure: Cross-sectional associations between bike lanes and area-level sociodemographic characteristics in 22 large U.S. cities. *Journal of Transit Geography*, *80*, 102544. https://doi.org/https://doi.org/10.1016/j.jtrangeo.2019.102544

Brey, R., Castillo-Manzano, J. I., Castro-Nuño, M., López-Valpuesta, L., Marchena-Gómez, M., & Sánchez-Braza, A. (2017). Is the widespread use of urban land for cycling promotion policies cost effective? A cost-benefit analysis of the case of Seville. *Land Use Policy*, *63*, 130–139. https://doi.org/10.1016/j.landusepol.2017.01.007

Broach, J., Dill, J., & Gliebe, J. (2012). Where do cyclists ride? A route choice model developed with revealed preference GPS data. *Transportation Research Part A: Policy and Practice*, *46*(10), 1730–1740. https://doi.org/10.1016/j.tra.2012.07.005

Brown, B. B., Tharp, D., Tribby, C. P., Smith, K. R., Miller, H. J., & Werner, C. M. (2017). Changes in bicycling over time associated with a new bike lane: Relations with kilocalories energy expenditure and body mass index. *Journal of Transport & Health*, *3*(3), 357–365. https://doi.org/10.1016/j.jth.2016.04.001

Brown, V., Barr, A., Scheurer, J., Magnus, A., Zapata-Diomedi, B., & Bentley, R. (2019). Better transport accessibility, better health: A health economic impact assessment study for Melbourne, Australia. *International Journal of Behavioral Nutrition and Physical Activity*, *16*(1), 89. https://doi.org/10.1186/s12966-019-0853-y

Buehler, R., & Pucher, J. (2012). Cycling to work in 90 large American cities: New evidence on the role of bike paths and lanes. *Transportation*, *39*, 409–432. https://doi.org/10.1007/s11116-011-9355-8

Cabral Dias, G. J., & Gomes Ribeiro, P. J. (2021). Cycle highways: A new concept of infrastructure. *European Planning Studies*, *29*(6), 1003–1020. https://doi.org/10.1080/09654313.2020.1752154

Cairns, S., Behrendt, F., Raffo, D., Beaumont, C., & Kiefer, C. (2017). Electrically assisted bikes: Potential impacts on travel behaviour. *Transportation Research Part A: Policy and Practice*, *103*, 327–342. https://doi.org/10.1016/j.tra.2017.03.007

Campos Ferreira, M., Dias Costa, P., Abrantes, D., Hora, J., Felício, S., Coimbra, M., & Galvão Dias, T. (2022). Identifying the determinants and understanding their effect on the perception of safety, security, and comfort by pedestrians and cyclists: A systematic review. *Transportation Research Part F: Traffic Psychology and Behavior*, *91*, 136–163. https://doi.org/10.1016/j.trf.2022.10.004

Cao, J., & Duncan, M. (2019). Associations among distance, quality, and safety when walking from a park-and-ride facility to the transit station in the Twin Cities. *Journal of Planning Education and Research*, *39*(4), 496–507. https://doi.org/10.1177/0739456X19883858

Carlson, J. A., Grimes, A., Green, M., Morefield, T., Steel, C., Reddy, A., …, & Rogers, E. (2019). Impacts of temporary pedestrian streetscape improvements on pedestrian and vehicle activity and community perceptions. *Journal of Transport and Health*, *15*, 100791. https://doi.org/10.1016/j.jth.2019.100791

Chapman, R., Keall, M., Howden-Chapman, P., Grams, M., Witten, K., Randal, E., & Woodward, A. (2018). A cost benefit analysis of an active travel intervention with health and carbon emission reduction benefits. *International Journal of Environmental Research and Public Health*, *15*(5), 1–11. https://doi.org/10.3390/ijerph15050962

Chen, L., Chen, C., Srinivasan, R., McKnight, C. E., Ewing, R., & Roe, M. (2012). Evaluating the safety effects of bicycle lanes in New York City. *American Journal of Public Health*, *102*(6), 1120–1127. https://doi.org/10.2105/AJPH.2011.300319

Chen, P. (2015). Built environment factors in explaining the automobile-involved bicycle crash frequencies: A spatial statistic approach. *Safety Science*, *79*, 336–343. https://doi.org/10.1016/j.ssci.2015.06.016

Chen, P., Shen, Q., & Childress, S. (2018). A GPS data-based analysis of built environment influences on bicyclist route preferences. *International Journal of Sustainable Transportation*, *12*(3), 218–231. https://doi.org/10.1080/15568318.2017.1349222

Chen, P., Zhou, J., & Sun, F. (2017). Built environment determinants of bicycle volume: A longitudinal analysis. *Journal of Transport and Land Use*, *10*(1), 655–674. https://doi.org/10.5198/jtlu.2017.892

Chimba, D., & Mbuya, C. (2019). *Simulating the impact of traffic calming strategies*. Retrieved from https://wmich.edu/sites/default/files/attachments/u883/2019/TRCLC_RR_17-10.pdf

Cicchino, J. B., McCarthy, M. L., Newgard, C. D., Wall, S. P., DiMaggio, C. J., Kulie, P. E., …, & Zuby, D. S. (2020). Not all protected bike lanes are the same: Infrastructure and risk of cyclist collisions and falls leading to emergency department visits in three U.S. cities. *Accident Analysis and Prevention*, *141*, 105490. https://doi.org/10.1016/j.aap.2020.105490

Circella, G., Alemi, F., & Malik, J. (2022). *Travel behavior impacts of transportation demand management policies: May is bike month in Sacramento, California*. Retrieved from https://doi.org/10.7922/G2W09481

City of San Jose. (2015). *Lincoln avenue road diet trial data collection report*. Retrieved from http://sjdistrict6.com/wp-content/uploads/2015/06/Lincoln-Road-Diet-Report.pdf

Clark, C., Mokhtarian, P., Circella, G., & Watkins, K. (2019). User preferences for bicycle infrastructure in communities with emerging cycling cultures. *Transportation Research Record*, *2673*(12), 89–102. https://doi.org/10.1177/0361198119854084

Clifton, K., Currans, K. M., Muhs, C. D., Ritter, C., Morrissey, S., & Roughton, C. (2012). Consumer behavior and travel choices: A focus on cyclists and pedestrians. *Transportation Research Board 92nd Annual Meeting*, *January*, 1–21.

Cottrell, W. D., Kim, N., Martin, P. T., & Perrin, H. J. (2006). Effectiveness of traffic management in Salt Lake City, Utah. *Journal of Safety Research*, *37*(1), 27–41. https://doi.org/10.1016/j.jsr.2005.08.007

Cripton, P. A., Shen, H., Brubacher, J. R., Chipman, M., Friedman, S. M., Harris, M. A., …, & Teschke, K. (2014). Severity of urban cycling injuries and the relationship with personal, trip, route and crash characteristics: Analyses using four severity metrics. *BMJ Open*, *5*, e006654. https://doi.org/10.1136/bmjopen-2014-006654

Cruzado, I., & Donnell, E. T. (2009). Evaluating effectiveness of dynamic speed display signs in transition zones of two-lane, rural highways in Pennsylvania. *Transportation Research Record*, *2122*(1), 1–8. https://doi.org/10.3141/2122-01

Cui, Y., Mishra, S., & Welch, T. F. (2014). Land use effects on bicycle ridership: A framework for state planning agencies. *Journal of Transport Geography*, *41*, 220–228. https://doi.org/10.1016/j.jtrangeo.2014.10.004

Dadashova, B., Dixon, K., Hudson, J., Benz, R., Dai, B., Li, X., …, & Sarda, S. (2022). *Addressing bicyclist safety through the development of crash modification factors for bikeways*. Retrieved from https://tti.tamu.edu/documents/0-7043-R1.pdf

Davidse, R., van Driel, C. & Goldenbeld, C. (2004). *The effect of altered road markings on speed and lateral position: A meta-analysis*. The Hague, Netherlands: SWOV, Institute for Road Safety. https://swov.nl/system/files/publication-downloads/r-2003-31.pdf

de Hartog, J. J., Boogaard, H., Nijland, H., & Hoek, G. (2010). Do the health benefits of cycling outweigh the risks? *Environmental Health Perspectives*, *118*(8), 1109–1116. https://doi.org/10.1289/ehp.0901747

Deenihan, G., & Caulfield, B. (2014). Estimating the health economic benefits of cycling. *Journal of Transport and Health*, *1*(2), 141–149. https://doi.org/10.1016/j.jth.2014.02.001

Delaware Valley Regional Planning Commission. (2018). *Curbless streets*. Retrieved from https://www.dvrpc.org/reports/16044.pdf

Deliali, A., Fournier, N., Christofa, E., & Knodler, M. (2023). Investigating the safety impact of segment- and intersection-level bicycle treatments on bicycle–motorized vehicle crashes. *Transportation Research Record*, *2677*(2), 1315-1330 https://doi.org/10.1177/03611981221112670

Deliali, K., Christofa, E., & Knodler, M. (2021). The role of protected intersections in improving bicycle safety and driver right-turning behavior. *Accident Analysis and Prevention*, *159*, 106295. https://doi.org/10.1016/j.aap.2021.106295

Dhakal, N., Cherry, C. R., Ling, Z., & Azad, M. (2018). Using CyclePhilly data to assess wrong-way riding of cyclists in Philadelphia. *Journal of Safety Research*, *67*, 145–153. https://doi.org/10.1016/j.jsr.2018.10.004

DiGioia, J., Watkins, K. E., Xu, Y., Rodgers, M., & Guensler, R. (2017). Safety impacts of bicycle infrastructure: A critical review. *Journal of Safety Research*, *61*, 105–119. https://doi.org/10.1016/j.jsr.2017.02.015

Dill, J. (2009). Bicycling for transportation and health: The role of infrastructure. *Journal of Public Health Policy*, *30*(Suppl 1), S95-110. https://doi.org/10.1057/jphp.2008.56

Dill, J., McNeil, N., Broach, J., & Ma, L. (2014). Bicycle boulevards and changes in physical activity and active transportation: Findings from a natural experiment. *Preventive Medicine*, *69*(S), S74–S78. https://doi.org/10.1016/j.ypmed.2014.10.006

Dill, J., Monsere, C. M., & McNeil, N. (2012). Evaluation of bike boxes at signalized intersections. *Accident Analysis and Prevention*, *44*(1), 126–134. https://doi.org/10.1016/j.aap.2010.10.030

DiMaggio, C., Brady, J., & Li, G. (2015). Association of the safe routes to school program with school-age pedestrian and bicyclist injury risk in Texas. *Injury Epidemiology*, *2*(15). https://doi.org/10.1186/s40621-015-0038-3

DiMaggio, C., Frangos, S., & Li, G. (2016). National safe routes to school program and risk of school-age pedestrian and bicyclist injury. *Annals of Epidemiology*, *26*(6), 412–417. https://doi.org/10.1016/j.annepidem.2016.04.002

DiMaggio, C., & Li, G. (2013). Effectiveness of a safe routes to school program in preventing school-aged pedestrian injury. *Pediatrics*, *131*(2), 290–296. https://doi.org/10.1542/peds.2012-2182

Ding, H., Sze, N. N., Li, H., & Guo, Y. (2020a). Roles of infrastructure and land use in bicycle crash exposure and frequency: A case study using Greater London bike sharing data. *Accident Analysis and Prevention*, *144*, 105652. https://doi.org/10.1016/j.aap.2020.105652

Distefano, N., & Leonardi, S. (2019). Evaluation of the benefits of traffic calming on vehicle speed reduction. *Civil Engineering and Architecture*, *7*(4), 200–214. https://doi.org/10.13189/cea.2019.070403

Dixon, K., Fitzpatrick, K., & Avelar, R. (2016). Operational and safety trade-offs: Reducing freeway lane and shoulder width to permit an additional lane. *Transportation Research Record*, *2588*, 89–97. https://doi.org/10.3141/2588-10

Dumbaugh, E., & Li, W. (2011). Designing for the safety of pedestrians, cyclists, and motorists in urban environments. *Journal of the American Planning Association*, *77*(1), 69–88. https://doi.org/10.1080/01944363.2011.536101

Duthie, J., Brady, J. F., Mills, A. F., & Machemehl, R. B. (2010). Effects of on-street bicycle facility configuration on bicyclist and motorist behavior. *Transportation Research Record*, *2190*, 37–44. https://doi.org/10.3141/2190-05

Egan, R., Dowling, C. M., & Caulfield, B. (2023). Exploring the elements of effective public cycle parking: A literature review. *Journal of Urban Mobility*, *3*, 100046. https://doi.org/10.1016/j.urbmob.2023.100046

El-Geneidy, A., van Lierop, D., & Wasfi, R. (2016). Do people value bicycle sharing? A multilevel longitudinal analysis capturing the impact of bicycle sharing on residential sales in Montreal, Canada. *Transport Policy*, *51*, 174–181. https://doi.org/10.1016/j.tranpol.2016.01.009

Eldeeb, G., Mohamed, M., & Páez, A. (2021). Built for active travel? Investigating the contextual effects of the built environment on transportation mode choice. *Journal of Transport Geography*, *96*, 103158. https://doi.org/10.1016/j.jtrangeo.2021.103158

Elvik, R. (2017). Road safety effects of roundabouts: A meta-analysis. *Accident Analysis and Prevention*, *99*, 364–371. https://doi.org/10.1016/j.aap.2016.12.018

Elvik, R., & Bjørnskau, T. (2017). Safety-in-numbers: A systematic review and meta-analysis of evidence. *Safety Science*, *92*(0349), 274–282. https://doi.org/10.1016/j.ssci.2015.07.017

Elvik, R., & Goel, R. (2019). Safety-in-numbers: An updated meta-analysis of estimates. *Accident Analysis and Prevention*, *129*(May), 136–147. https://doi.org/10.1016/j.aap.2019.05.019

Elvik, R., Vadeby, A., Hels, T., & van Schagen, I. (2019). Updated estimates of the relationship between speed and road safety at the aggregate and individual levels. *Accident Analysis and Prevention*, *123*, 114–122. https://doi.org/10.1016/j.aap.2018.11.014

Eubank-Ahrens, B. (1984). The impact of Woonerven on children's behavior. *Children's Environments Quarterly*, *1*(4), 39–45.

Evenson, K. R., Herring, A. H., & Huston, S. L. (2005). Evaluating change in physical activity with the building of a multi-use trail. *American Journal of Preventive Medicine*, *28*(Supp 2), 177–185. https://doi.org/10.1016/j.amepre.2004.10.020

Ewing, R., & Cervero, R. (2010). Travel and the built environment: A meta-analysis. *Journal of the American Planning Association*, *76*(3), 265–294. https://doi.org/10.1080/01944361003766766

Faghih-Imani, A., Eluru, N., El-Geneidy, A. M., Rabbat, M., & Haq, U. (2014). How land-use and urban form impact bicycle flows: Evidence from the bicycle-sharing system (BIXI) in Montreal. *Journal of Transport Geography*, *41*(2012), 306–314. https://doi.org/10.1016/j.jtrangeo.2014.01.013

Faghih Imani, A., Miller, E. J., & Saxe, S. (2019). Cycle accessibility and level of traffic stress: A case study of Toronto. *Journal of Transport Geography*, *80*, 102496. https://doi.org/10.1016/j.jtrangeo.2019.102496

Favetti, M., Kamalapuram, S., & Fitch-Polse, D. T.(2022). *California active transportation benefit-cost tool*. Retrieved from https://activetravelbenefits.ucdavis.edu

Fees, C. A., Torbic, D. J., Bauer, K. M., Van Houten, R., Roseberry, N., & LaPlante, J. (2015). Design guidance for bicycle lane widths. *Transportation Research Record*, *2520*, 78–89. https://doi.org/10.3141/2520-10

Ferenchak, N. N., Gutierrez, R. E., & Singleton, P. A. (2022). Shedding light on the pedestrian safety crisis: An analysis across the injury severity spectrum by lighting condition. *Traffic Injury Prevention*, *23*(7), 434–439. https://doi.org/10.1080/15389588.2022.2100362

Ferenchak, N. N., & Marshall, W. E. (2019). Advancing healthy cities through safer cycling: An examination of shared lane markings. *International Journal of Transportation Science and Technology*, *8*(2), 136–145. https://doi.org/10.1016/j.ijtst.2018.12.003

Ferenchak, N. N., & Marshall, W. E. (2021). Bicycling facility inequalities and the causality dilemma with socioeconomic/sociodemographic change. *Transportation Research Part D: Transport and Environment*, *97*(June), 102920. https://doi.org/10.1016/j.trd.2021.102920

Fields, B., Cradock, A. L., Barrett, J. L., Hull, T., & Melly, S. J. (2022). Active transportation pilot program evaluation: A longitudinal assessment of bicycle facility density changes on use in Minneapolis. *Transportation Research Interdisciplinary Perspectives*, *14*, 106604. https://doi.org/10.1016/j.trip.2022.100604

Fishman, E., Washington, S., & Haworth, N. (2014). Bike share's impact on car use: Evidence from the United States, Great Britain, and Australia. *Transportation Research Part D: Transport and Environment*, *31*, 13–20. https://doi.org/10.1016/j.trd.2014.05.013

Fitch, D. T., Gao, Z., Noble, L., & Mac, T. (2022). Effectiveness of free bikes and e-bikes for commute mode shift: The case of Google's lending program. *Frontiers in Future Transportation*, *3*. https://doi.org/10.3389/ffutr.2022.886760

Fitch, D. T., & Handy, S. L. (2020). Road environments and bicyclist route choice: The cases of Davis and San Francisco, CA. *Journal of Transport Geography*, *85*, 102705. https://doi.org/10.1016/j.jtrangeo.2020.102705

Fitch, D. T., Mohiuddin, H., & Handy, S. L. (2021). Examining the effects of the sacramento dockless e-bike share on bicycling and driving. *Sustainability*, *13*(1), 368. https://doi.org/10.3390/su13010368

Fitch, D. T., Rhemtulla, M., & Handy, S. L. (2018). The relation of the road environment and bicycling attitudes to usual travel mode to school in teenagers. *Transportation Research Part A: Policy and Practice*, *123*, 35–53. https://doi.org/10.1016/j.tra.2018.06.013

Fitch, D. T., Sharpnack, J., & Handy, S. L. (2020). Psychological stress of bicycling with traffic: Examining heart rate variability of bicyclists in natural urban environments. *Transportation Research Part F: Traffic Psychology and Behavior, 70*, 81–97. https://doi.org/10.1016/j.trf.2020.02.015

Fitch, D. T., Thigpen, C. G., & Handy, S. L. (2016). Traffic stress and bicycling to elementary and junior high school: A case study in Davis, California. *Journal of Transport & Health*, *3*(4), 457–466. https://doi.org/10.1016/j.jth.2016.01.007

Fitzpatrick, K., Chrysler, S. T., Van Houten, R., Hunter, W. W., & Turner, S. (2011). *Evaluation of pedestrian and bicycle engineering countermeasures: Rectangular rapid-flashing beacons, HAWKs, sharrows, crosswalk markings, and the development of an evaluation methods report*. Retrieved from http://www.fhwa.dot.gov/publications/research/safety/pedbike/11039/11039.pdf

Fitzpatrick, K., Cynecki, M. J., Pratt, M. P., & Beckley, M. (2020). Analysis of pedestrian hybrid eeacon operation on higher-speed roadways. *Transportation Research Record*, *2674*(5), 22–32. https://doi.org/10.1177/0361198120913558

Fitzpatrick, K., Potts, I. B., Brewer, M. A., & Avelar, R. (2015). Comparison of rectangular and circular rapid-flashing beacons in an open-road setting. *Transportation Research Record*, *2492*, 69–77. https://doi.org/10.3141/2492-08

Fitzpatrick, K., & Schneider, W. H. (2005). *Turn speeds and crashes within right-turn lanes*. College Station, TX: Texas A&M Transportation Institute. https://static.tti.tamu.edu/tti.tamu.edu/documents/0-4365-4.pdf

Flanagan, E., Lachapelle, U., & El-Geneidy, A. (2016). Riding tandem: Does cycling infrastructure investment mirror gentrification and privilege in Portland, OR and Chicago, IL? *Research in Transportation Economics*, *60*, 14–24. https://doi.org/10.1016/j.retrec.2016.07.027

Foletta, N., Nielson, C., Patton, J., Parks, J., & Rees, R. (2015). Green shared lane markings on urban arterial in Oakland, California: Evaluation of super sharrows. *Transportation Research Record*, *2492*, 61–68. https://doi.org/10.3141/2492-07

Forsyth, A., & Krizek, K. J. (2010). Promoting walking and bicycling: Assessing the evidence to assist planners. *Built Environment*, *36*(4), 429–446. https://doi.org/10.2148/benv.36.4.429

Fotios, S., Uttley, J., & Fox, S. (2019). A whole-year approach showing that ambient light level influences walking and cycling. *Lighting Research and Technology*, *51*(1), 55–64. https://doi.org/10.1177/1477153517738306

Fox, S. M., & Haskell, W. L. (1968). Physical activity and the prevention of coronary heart disease. *Bulletin of the New York Academy of Medicine 44*(8), 950-67. https://pmc.ncbi.nlm.nih.gov/articles/PMC1750298/

Frank, L. D., Hong, A., & Ngo, V. D. (2019). Causal evaluation of urban greenway retrofit: A longitudinal study on physical activity and sedentary behavior. *Preventive Medicine*, *123,* 109–116. https://doi.org/10.1016/j.ypmed.2019.01.011

Freeland, A. L., Banerjee, S. N., Dannenberg, A. L., & Wendel, A. M. (2013). Walking associated with public transit: Moving toward increased physical activity in the United States. *American Journal of Public Health*, *103*(3), 536–542. https://doi.org/10.2105/AJPH.2012.300912

Fukushige, T., Fitch, D. T., & Handy, S. (2023). Estimating vehicle-miles traveled reduced from dock-less E-bike-share: Evidence from Sacramento, California. *Transportation Research Part D: Transport and Environment*, *117*, 103671. https://doi.org/10.1016/j.trd.2023.103671

Fyhri, A., & Fearnley, N. (2015). Effects of e-bikes on bicycle use and mode share. *Transportation Research Part D: Transport and Environment*, *36*, 45–52. https://doi.org/10.1016/j.trd.2015.02.005

Fyhri, A., Sundfør, H., Bjørnskaua, T., & Laureshyn, A. (2017). Safety in numbers for cyclists – Conclusions from a multidisciplinary study of seasonal change in interplay and conflicts. *Accident Analysis and Prevention*, *105*, 124–133. https://doi.org/10.1016/j.aap.2016.04.039

Fyhri, A., Sundfør, H. B., & Weber, C. (2016). *Effect of subvention program for e-bikes in Oslo on bicycle use, transport distribution and CO2 emissions*. Retrieved from https://www.toi.no/getfile.php?mmfileid=43454

Garder, P., Leden, L., & Pulkkinen, U. (1998). Measuring the safety effect of raised bicycle crossings. *Transportation Research Record, 1636*, 64–70.

Garunović, N., Bogdanović, V., Simić, J. M., Kalamanda, G., & Ivanović, B. (2020). The influence of the construction of raised pedestrian crossing on traffic conditions on urban segments. *Gradjevinar*, *72*(8), 681–691. https://doi.org/10.14256/JCE.2705.2019

Gatersleben, B., & Uzzell, D. (2007). Affective appraisals of the daily commute: Comparing perceptions of drivers, cyclists, walkers, and users of public transport. *Environment and Behavior*, *39*(3), 416–431. https://doi.org/10.1177/0013916506294032

Gayah, V. V., Donnell, E. T., Yu, Z., & Li, L. (2018). Safety and operational impacts of setting speed limits below engineering recommendations. *Accident Analysis and Prevention*, *121*, 43–52. https://doi.org/10.1016/j.aap.2018.08.029

Gehlert, T., Schulze, C., & Schlag, B. (2012). Evaluation of different types of dynamic speed display signs. *Transportation Research Part F: Traffic Psychology and Behavior*, *15*(6), 667–675. https://doi.org/10.1016/j.trf.2012.07.004

Ghomi, H., & Hussein, M. (2021). An integrated clustering and copula-based model to assess the impact of intersection characteristics on violation-related collisions. *Accident Analysis and Prevention*, *159*, 106283. https://doi.org/10.1016/j.aap.2021.106283

Gilderbloom, J., Grooms, W., Mog, J., & Meares, W. (2016). The green dividend of urban biking? Evidence of improved community and sustainable development. *Local Environment*, *21*(8), 991–1008. https://doi.org/10.1080/13549839.2015.1060409

Gilpin, J., Falbo, N., & Williams, M. (2017). *Advisory bike lanes in North America*. Minneapolis: Alta Planning and Design. https://altago.com/wp-content/uploads/Advisory-Bike-Lanes-In-North-America_Alta-Planning-Design-White-Paper.pdf

Gitelman, V., Carmel, R., Pesahov, F., & Chen, S. (2017). Changes in road-user behaviors following the installation of raised pedestrian crosswalks combined with preceding speed humps, on urban arterials. *Transportation Research Part F: Traffic Psychology and Behavior*, *46*, 356–372. https://doi.org/10.1016/j.trf.2016.07.007

Goerke, D., Zolfaghari, E., Marek, A. P., Endorf, F. W., & Nygaard, R. M. (2019). Incidence and profile of severe cycling injuries after bikeway infrastructure changes. *Journal of Community Health*, *45*, 542–549. https://doi.org/10.1007/s10900-019-00773-z

Goeverden, K. Van, & Godefrooij, T. (2011). *The Dutch reference study: Cases of interventions in bicycle infrastructure reviewed in the framework of Bikeability*. Delft, the Netherlands: Delft University of Technology.

Goodman, A., Rojas, I. F., Woodcock, J., Aldred, R., Berkoff, N., Morgan, M., …, & Lovelace, R. (2019). Scenarios of cycling to school in England, and associated health and carbon impacts: Application of the 'propensity to cycle tool.' *Journal of Transport and Health*, *12*(2018, April), 263–278. https://doi.org/10.1016/j.jth.2019.01.008

Goodman, A., Sahlqvist, S., & Ogilvie, D. (2014). New walking and cycling routes and increased physical activity: One- and two-year findings from the UK iConnect study. *American Journal of Public Health*, *104*(9), 38–46. https://doi.org/10.2105/AJPH.2014.302059

Gordon-Larsen, P., Boone-Heinonen, J., Sidney, S., Sternfeld, B., Jacobs, D. R., & Lewis, C. E. (2009). Active commuting and cardiovascular disease risk: The CARDIA study. *Archives of Internal Medicine*, *169*(13), 1216–1223. https://doi.org/10.1001/archinternmed.2009.163

Gotschi, T. (2011). Costs and benefits of bicycling investments in Portland, Oregon. *Journal of Physical Activity & Health*, *8*(Suppl 1), 49–58. https://doi.org/10.1123/jpah.8.s1.s49

Götschi, T., Castro, A., Deforth, M., Miranda-Moreno, L., & Zangenehpour, S. (2018). Towards a comprehensive safety evaluation of cycling infrastructure including objective and subjective measures. *Journal of Transport and Health*, *8*, 44–54. https://doi.org/10.1016/j.jth.2017.12.003

Goughnour, E., Carter, D., Lyon, C., Persaud, B., Lan, B., Chun, P., …, & Bryson, M. (2021). Evaluation of protected left-turn phasing and leading pedestrian intervals effects on pedestrian safety. *Transportation Research Record*, *2675*(11), 1219–1228. https://doi.org/10.1177/03611981211025508

Grabow, M. L., Spak, S. N., Holloway, T., Brian, S. S., Mednick, A. C., & Patz, J. A. (2012). Air quality and exercise-related health benefits from reduced car travel in the midwestern United States. *Environmental Health Perspectives*, *120*(1), 68–76. https://doi.org/10.1289/ehp.1103440

Graham, D. J., Naik, C., McCoy, E. J., & Li, H. (2019). Do speed cameras reduce road traffic collisions? *PLoS ONE*, *14*(9), 1–15. https://doi.org/10.1371/journal.pone.0221267

Grembek, O., Chen, K., Taylor, B., Hwang, Y., Fitch, D. T., Anthoine, S., …, & Grover, S. (2020). *Research synthesis for the california zero traffic fatalities task force*. Berekely, CA: University of California Institute of Transportation Studies. https://doi.org/10.7922/G2KP80DW

Grigoropoulos, G., Hosseini, S. A., Keler, A., Kaths, H., Spangler, M., Busch, F., & Bogenberger, K. (2021). Traffic simulation analysis of bicycle highways in urban areas. *Sustainability*, *13*, 1–25. https://doi.org/10.3390/su13031016

Griswold, J. B., Yu, M., Filingeri, V., Grembek, O., & Walker, J. L. (2018). A behavioral modeling approach to bicycle level of service. *Transportation Research Part A: Policy and Practice*, *116*, 166–177. https://doi.org/10.1016/j.tra.2018.06.006

Gross, F., Jagannathan, R., & Hughes, W. (2009). Two low-cost safety concepts for two-way, stop-controlled intersections in rural areas. *Transportation Research Record*, *2092*(1), 11–18. https://doi.org/10.3141/2092-02

Gudz, E., Fang, K., & Handy, S. L. (2016). When a diet prompts a gain. *Transportation Research Record*, *2587*, 61–67. https://doi.org/10.3141/2587-08

Guo, Z. (2009). Does the pedestrian environment affect the utility of walking? A case of path choice in downtown Boston. *Transportation Research Part D: Transport and Environment*, *14*(5), 343–352. https://doi.org/10.1016/j.trd.2009.03.007

Guo, Z., & Loo, B. P. Y. (2013). Pedestrian environment and route choice: Evidence from New York City and Hong Kong. *Journal of Transport Geography*, *28*, 124–136. https://doi.org/10.1016/j.jtrangeo.2012.11.013

Hamann, C., & Peek-Asa, C. (2013). On-road bicycle facilities and bicycle crashes in Iowa, 2007-2010. *Accident Analysis and Prevention*, *56*, 103–109. https://doi.org/10.1016/j.aap.2012.12.031

Hamilton, T. L., & Wichman, C. J. (2018). Bicycle infrastructure and traffic congestion: Evidence from DC's capital bikeshare. *Journal of Environmental Economics and Management*, *87*, 72–93. https://doi.org/10.1016/j.jeem.2017.03.007

Handy, S. L., Xing, Y., & Buehler, T. J. (2010). Factors associated with bicycle ownership and use: A study of six small U.S. cities. *Transportation*, *37*(6), 967–985. https://doi.org/10.1007/s11116-010-9269-x

Handy, S., van Wee, B., & Kroesen, M. (2014). Promoting cycling for transport: Research needs and challenges. *Transport Reviews*, *34*(1), 4–24. https://doi.org/10.1080/01441647.2013.860204

Hankey, S., Lindsey, G., Wang, X., Borah, J., Hoff, K., Utecht, B., & Xu, Z. (2012). Estimating use of non-motorized infrastructure: Models of bicycle and pedestrian traffic in Minneapolis, MN. *Landscape and Urban Planning*, *107*(3), 307–316. https://doi.org/10.1016/j.landurbplan.2012.06.005

Hansmann, K. J., Grabow, M., & McAndrews, C. (2022). Health equity and active transportation: A scoping review of active transportation interventions and their impacts on health equity. *Journal of Transport and Health*, *25*(January), 101346. https://doi.org/10.1016/j.jth.2022.101346

Harkey, D. L., Srinivasan, R., Baek, J., Council, F. M., Eccles, K., Lefler, N., …, & Bonneson, J. (2008). *NCHRP 617: Accident Modification Factors for Traffic Engineering and ITS Improvements*. Washington, DC: Transportation Research Board. https://doi.org/10.17226/13899

Harris, A. M., Reynolds, C. C. O., Winters, M., Cripton, P. A., Shen, H., Chipman, M. L., …, & Teschke, K. (2013). Comparing the effects of infrastructure on bicycling injury at intersections and non-intersections using a case-crossover design. *Injury Prevention*, *19*(5), 303–310. https://doi.org/10.1136/injuryprev-2012-040561

Havard, C., & Willis, A. (2012). Effects of installing a marked crosswalk on road crossing behaviour and perceptions of the environment. *Transportation Research Part F: Traffic Psychology and Behavior*, *15*(3), 249–260. https://doi.org/10.1016/j.trf.2011.12.007

Heinen, E., & Buehler, R. (2019). Bicycle parking: A systematic review of scientific literature on parking behavior, parking preferences, and their influence on cycling and travel behavior. *Transport Reviews*, *39*(5), 630–656. https://doi.org/10.1080/01441647.2019.1590477

Helak, K., Jehle, D., McNabb, D., Battisti, A., Sanford, S., & Lark, M. C. (2017). Factors influencing injury severity of bicyclists involved in crashes with motor vehicles: Bike lanes, alcohol, lighting, speed, and helmet use. *Southern Medical Journal, 110*(7), 441–444. https://doi.org/doi:10.14423/SMJ.0000000000000665

Herrmann-Lunecke, M. G., Mora, R., & Vejares, P. (2021). Perception of the built environment and walking in pericentral neighbourhoods in Santiago, Chile. *Travel Behavior and Society*, *23*, 192–206. https://doi.org/10.1016/j.tbs.2021.01.002

Höchli, B., Brügger, A., Abegglen, R., & Messner, C. (2019). Using a goal theoretical perspective to reduce negative and promote positive spillover after a bike-to-work campaign. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.00433

Hood, J., Sall, E., & Charlton, B. (2011). A GPS-based bicycle route choice model for San Francisco, California. *Transportation Letters*, *3*(1), 63–75. https://doi.org/10.3328/TL.2011.03.01.63-75

Hosford, K., Winters, M., Gauvin, L., Camden, A., Dubé, A. S., Friedman, S. M., & Fuller, D. (2019). Evaluating the impact of implementing public bicycle share programs on cycling: The international bikeshare impacts on cycling and collisions study (IBICCS). *International Journal of Behavioral Nutrition and Physical Activity*, *16*, 1–11. https://doi.org/10.1186/s12966-019-0871-9

Hu, W., & McCartt, A. T. (2016). Effects of automated speed enforcement in Montgomery County, Maryland, on vehicle speeds, public opinion, and crashes. *Traffic Injury Prevention*, *17*, 53–58. https://doi.org/10.1080/15389588.2016.1189076

Hunter, W. W., Thomas, L., Srinivasan, R., & Martell, C. A. (2010). *Evaluation of shared lane markings*. Washington, DC: Federal Highway Administration. https://rosap.ntl.bts.gov/view/dot/37759

Hwang, J. (2022). The reinforcement of pedestrian safety in the central business district: A spatial analysis of Austin, Texas. *Journal of Urban Affairs*, *45*(10), 1899–1915. https://doi.org/10.1080/07352166.2021.2007776

Islam, A., Mekker, M., & Singleton, P. A. (2022). Examining pedestrian crash frequency, severity, and safety in numbers using pedestrian exposure from Utah traffic signal data. *Journal of Transportation Engineering, Part A: Systems*, *148*(10). https://doi.org/10.1061/jtepbs.0000737

Jacobsen, P. L. (2003). Safety in numbers: More walkers and bicyclists, safer walking and bicycling. *Injury Prevention*, *9*(3), 205–209. http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1731007&tool=pmcentrez&rendertype=abstract

Jacobsen, P. L., Ragland, D. R., & Komanoff, C. (2015). Safety in numbers for walkers and bicyclists: Exploring the mechanisms. *Injury Prevention*, *21*(4), 217–220. https://doi.org/10.1136/injuryprev-2015-041635

Jarrett, J., Woodcock, J., Chalabi, Z., Edwards, P., Roberts, I., & Haines, A. (2012). Effect of increasing active travel in urban England and Wales on costs to the National Health Service. *The Lancet*, *379*(9832), 2198–2205.

Jarry, V., & Apparicio, P. (2021). Ride in peace: How cycling infrastructure types affect traffic conflict occurrence in Montréal, Canada. *Safety*, *7*(3), 63. https://doi.org/10.3390/SAFETY7030063

Jensen, S. U. (2008). Bicycle tracks and lanes: A before-after study. *Accident Analysis and Prevention*, *40*(2), 742–750. http://www.vehicularcyclist.com/copenhagen2.pdf

Jestico, B., Nelson, T. A., Potter, J., & Winters, M. (2017). Multiuse trail intersection safety analysis: A crowdsourced data perspective. *Accident Analysis and Prevention*, *103*, 65–71. https://doi.org/10.1016/j.aap.2017.03.024

Johansson, C., Lövenheim, B., Schantz, P., Wahlgren, L., Almström, P., Markstedt, A., …, & Sommar, J. N. (2017). Impacts on air pollution and health by changing commuting from car to bicycle. *Science of the Total Environment*, *584–585*, 55–63. https://doi.org/10.1016/j.scitotenv.2017.01.145

Johnson, N., Fitch-Polse, D. T., & Handy, S. L. (2023). Impacts of e-bike ownership on travel behavior: Evidence from three northern California rebate programs. *Transport Policy*, *140*, 163–174. https://doi.org/10.1016/j.tranpol.2023.06.014

Johnson, S. D., Sidebottom, A., & Thorpe, A. (2008). *Bicycle theft*. Washington, DC: U.S. Dept. of Justice, Office of Community Oriented Policing Services. https://portal.cops.usdoj.gov/resourcecenter/ric/Publications/cops-p141-pub.pdf

Kacprzak, D., & Solowczuk, A. (2019). Effectiveness of road chicanes in access zones to a billage at 70 km/h speed limit. *IOP Conference Series: Materials Science and Engineering*, *471*(6), 062010. https://doi.org/10.1088/1757-899X/471/6/062010

Kaczynski, A. T., & Henderson, K. A. (2007). Environmental correlates of physical activity: A review of evidence about parks and recreation. *Leisure Sciences*, *29*(4), 315–354. https://doi.org/10.1080/01490400701394865

Kaczynski, A. T., Potwarka, L. R., Smale, B. J. A., & Havitz, M. F. (2009). Association of Parkland proximity with neighborhood and park-based physical activity: Variations by gender and age. *Leisure Sciences*, *31*(2), 174–191. https://doi.org/10.1080/01490400802686045

Kang, B. (2019). Identifying street design elements associated with vehicle-to-pedestrian collision reduction at intersections in New York City. *Accident Analysis and Prevention*, *122*, 308–317. https://doi.org/10.1016/j.aap.2018.10.019

Kaplan, S., & Giacomo Prato, C. (2015). A spatial analysis of land use and network effects on frequency and severity of cyclist–motorist crashes in the Copenhagen region. *Traffic Injury Prevention*, *16*(7), 724–731. https://doi.org/10.1080/15389588.2014.1003818

Karpinski, E. (2021). Estimating the effect of protected bike lanes on bike-share ridership in Boston: A case study on Commonwealth Avenue. *Case Studies on Transport Policy*, *9*(3), 1313–1323. https://doi.org/10.1016/j.cstp.2021.06.015

Kassim, A., Culley, A., & McGuire, S. (2019). Operational evaluation of advisory bike lane treatment on road user behavior in Ottawa, Canada. *Transportation Research Record*, *2673*(11), 233–242. https://doi.org/10.1177/0361198119851450

Keall, M. D., Shaw, C., Chapman, R., & Howden-Chapman, P. (2018). Reductions in carbon dioxide emissions from an intervention to promote cycling and walking: A case study from New Zealand. *Transportation Research Part D: Transport and Environment*, *65*(October), 687–696. https://doi.org/10.1016/j.trd.2018.10.004

Kelly, P., Kahlmeier, S., Götschi, T., Orsini, N., Richards, J., Roberts, N., …, & Foster, C. (2014). Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. *International Journal of Behavioral Nutrition and Physical Activity*, *11*(1), 132. https://doi.org/10.1186/s12966-014-0132-x

Kemnitzer, C. R., Pope, C. N., Nwosu, A., Zhao, S., Wei, L., & Zhu, M. (2019). An investigation of driver, pedestrian, and environmental characteristics and resulting pedestrian injury. *Traffic Injury Prevention*, *20*(5), 510–514. https://doi.org/10.1080/15389588.2019.1612886

Kendrick, C., Moore, A., Haire, A., Bigazzi, A., Figliozzi, M., Monsere, C., & George, L. (2011). Impact of bicycle lane characteristics on exposure of bicyclists to traffic-related particulate matter. *Transportation Research Record*, *2247*, 24–32. https://doi.org/10.3141/2247-04

Khan, N. A., & Habib, M. A. (2022). Exploring the impacts of built environment on pedestrian injury severity involving distracted driving. *Journal of Safety Research*, *80*, 97–108. https://doi.org/10.1016/j.jsr.2021.11.001

Kim, D., & Kim, K. (2015). The influence of bicycle oriented facilities on bicycle crashes within crash concentrated areas. *Traffic Injury Prevention*, *16*(1), 70–75. https://doi.org/10.1080/15389588.2014.895924

Kim, M., Kim, E., Oh, J., & Jun, J. (2012). Critical factors associated with bicycle accidents at 4-legged signalized urban intersections in South Korea. *KSCE Journal of Civil Engineering*, *16*(4), 627–632. https://doi.org/10.1007/s12205-012-1055-1

King, E. A., Murphy, E., & McNabola, A. (2009). Reducing pedestrian exposure to environmental pollutants: A combined noise exposure and air quality analysis approach. *Transportation Research Part D: Transport and Environment*, *14*(5), 309–316. https://doi.org/10.1016/j.trd.2009.03.005

Kingham, S., Longley, I., Salmond, J., Pattinson, W., & Shrestha, K. (2013). Variations in exposure to traffic pollution while travelling by different modes in a low density, less congested city. *Environmental Pollution*, *181*, 211–218. https://doi.org/10.1016/j.envpol.2013.06.030

Klassen, J., El-Basyouny, K., & Islam, M. T. (2014). Analyzing the severity of bicycle-motor vehicle collision using spatial mixed logit models: A city of Edmonton case study. *Safety Science*, *62*, 295–304. https://doi.org/10.1016/j.ssci.2013.09.007

Klop, J. R., & Khattak, A. J. (1999). Factors influencing bicycle crash severity on two-lane , undivided roadways in North Carolina. *Transportation Research Record*, *99–1109*, 78–85.

Kohl, H. W., Craig, C. L., Lambert, E. V., Inoue, S., Alkandari, J. R., Leetongin, G., …, Wells, J. C. (2012). The pandemic of physical inactivity: Global action for public health. *The Lancet*, *380*(9838), 294–305. https://doi.org/10.1016/S0140-6736(12)60898-8

Kondo, M. C., Morrison, C., Guerra, E., Kaufman, E. J., & Wiebe, D. J. (2018). Where do bike lanes work best? A Bayesian spatial model of bicycle lanes and bicycle crashes. *Safety Science*, *103*, 225–233. https://doi.org/10.1016/j.ssci.2017.12.002

Kothuri, S., Appiah, F. B., & Monsere, C. (2021). Driver yielding and pedestrian performance at midblock crossings on three-lane roadways with rectangular rapid flashing beacons. *Transportation Research Record*, 2675(9), 910–923. https://doi.org/10.1177/03611981211004962

Kou, Z., Wang, X., Chiu, S. F., & Cai, H. (2020). Quantifying greenhouse gas emissions reduction from bike share systems: A model considering real-world trips and transportation mode choice patterns. *Resources, Conservation and Recycling*, *153*, 062010. https://doi.org/10.1016/j.resconrec.2019.104534

Kriit, H. K., Williams, J. S., Lindholm, L., Forsberg, B., & Sommar, J. N. (2019). Health economic assessment of a scenario to promote bicycling as active transport in Stockholm, Sweden. *BMJ Open*, *9*(9), 1–9. https://doi.org/10.1136/bmjopen-2019-030466

Kruszyna, M., & Matczuk-Pisarek, M. (2021). The effectiveness of selected devices to reduce the speed of vehicles on pedestrian crossings. *Sustainability*, *13*(17), 9678. https://doi.org/10.3390/su13179678

Kullgren, A., Stigson, H., Ydenius, A., Axelsson, A., Engström, E., & Rizzi, M. (2019). The potential of vehicle and road infrastructure interventions in fatal bicyclist accidents on Swedish roads—What can in-depth studies tell us? *Traffic Injury Prevention*, *20*(sup1), S7–S12. https://doi.org/10.1080/15389588.2019.1610171

Lantieri, C., Lamperti, R., Simone, A., Costa, M., Vignali, V., Sangiorgi, C., & Dondi, G. (2015). Gateway design assessment in the transition from high to low speed areas. *Transportation Research Part F: Traffic Psychology and Behavior*, *34*, 41–53. https://doi.org/10.1016/j.trf.2015.07.017

Le, H. T. K., Buehler, R., & Hankey, S. (2018). Correlates of the built environment and active travel: Evidence from 20 US metropolitan areas. *Environmental Health Perspectives*, *126*(7). https://doi.org/10.1289/EHP3389

Lee, C., & Abdel-Aty, M. (2005). Comprehensive analysis of vehicle-pedestrian crashes at intersections in Florida. *Accident Analysis and Prevention*, *37*(4), 775–786. https://doi.org/10.1016/j.aap.2005.03.019

Li, H., Ding, H., Ren, G., & Xu, C. (2018). Effects of the London cycle superhighways on the usage of the London cycle hire. *Transportation Research Part A: Policy and Practice*, *111*, 304–315. https://doi.org/10.1016/j.tra.2018.03.020

Li, H., Graham, D. J., & Liu, P. (2017). Safety effects of the London cycle superhighways on cycle collisions. *Accident Analysis and Prevention*, *99*, 90–101. https://doi.org/10.1016/j.aap.2016.11.016

Li, W., & Joh, K. (2017). Exploring the synergistic economic benefit of enhancing neighbourhood bikeability and public transit accessibility based on real estate sale transactions. *Urban Studies*, *54*(15), 3480–3499. https://doi.org/10.1177/0042098016680147

Lim, L., & Fontaine, M. D. (2021). *Crash modification factors for road diets in Virginia*. Retrieved from https://ascelibrary.org/doi/10.1061/9780784483534.017

Lindsay, G., Macmillan, A., & Woodward, A. (2011). Moving urban trips from cars to bicycles: Impact on health and emissions. *Australian and New Zealand Journal of Public Health*, *35*(1), 54–60. https://doi.org/10.1111/j.1753-6405.2010.00621.x

Lindsey, G., Hourdos, J., Duhn, M., Lehrke, D., & Singer-Berk, L. (2021). Note on motorist behaviors when overtaking cyclists. *Journal of Transportation Engineering, Part A: Systems*, *147*(1). https://doi.org/10.1061/jtepbs.0000471

Litman, T. (2023). *Evaluating active transport benefits and costs.* Victoria, BC, Canada: Victoria Transport Policy Institute.

Loprencipe, G., Moretti, L., Pantuso, A., & Banfi, E. (2019). Raised pedestrian crossings: Analysis of their characteristics on a road network and geometric sizing proposal. *Applied Sciences*, *9*(14), 2844. https://doi.org/10.3390/app9142844

Loskorn, J., Mills, A. F., Brady, J. F., Duthie, J. C., & Machemehl, R. B. (2013). Effects of bicycle boxes on bicyclist and motorist behavior at intersections in Austin, Texas. *Journal of Transportation Engineering*, *139*(10), 1039–1046. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000584

Love, D. C., Breaud, A., Burns, S., Margulies, J., Romano, M., & Lawrence, R. (2012). Is the three-foot bicycle passing law working in Baltimore, Maryland? *Accident Analysis and Prevention*, *48*, 451–456. https://doi.org/10.1016/j.aap.2012.03.002

Lowry, M., & Loh, T. H. (2017). Quantifying bicycle network connectivity. *Preventive Medicine, 95*, S134–S140. https://doi.org/10.1016/j.ypmed.2016.12.007

Luengo-Oroz, J., & Reis, S. (2019). Assessment of cyclists' exposure to ultrafine particles along alternative commuting routes in Edinburgh. *Atmospheric Pollution Research*, *10*(4), 1148–1158. https://doi.org/10.1016/j.apr.2019.01.020

Lusk, A. C., Willett, W. C., Morris, V., Byner, C., & Li, Y. (2019). Bicycle facilities safest from crime and crashes: Perceptions of residents familiar with higher crime/lower income neighborhoods in Boston. *International Journal of Environmental Research and Public Health*, *16*(3), 484. https://doi.org/10.3390/ijerph16030484

Lyons, T., Choi, D. A., Park, K., & Hassan Ameli, S. (2020). Safety and nonoptimal usage of a protected intersection for bicycling and walking: A before-and-after case study in Salt Lake city, Utah. *Sustainability*, *12*(21), 1–15. https://doi.org/10.3390/su12219195

Macarthur, J., Kobel, N., Dill, J., & Mumuni, Z. (2017). *Evaluation of an electric bike pilot project at three employment campuses in Portland, Oregon*. Retrieved from https://rosap.ntl.bts.gov/view/dot/36825

Macmillan, A., Connor, J., Witten, K., Kearns, R., Rees, D., & Woodward, A. (2014). The societal costs and benefits of commuter bicycling: Simulating the effects of specific policies using system dynamics modeling. *Environmental Health Perspectives*, *122*(4), 335–344. https://doi.org/10.1289/ehp.1307250

Mahmoud, N., Abdel-Aty, M., & Cai, Q. (2021). Factors contributing to operating speeds on arterial roads by context classifications. *Journal of Transportation Engineering, Part A: Systems*, *147*(8). https://doi.org/10.1061/jtepbs.0000548

Mahmud, M. S., Motz, M., Holpuch, T., Hankin, J., Ingle, A. J., Gates, T. J., & Savolainen, P. T. (2021). Driver response to a dynamic speed feedback sign on freeway exit ramps based on sign location, interchange type, and time of day. *Transportation Research Record*, *2675*(10), 1236–1247). https://doi.org/10.1177/03611981211015250

Maizlish, N., Linesch, N. J., & Woodcock, J. (2017). Health and greenhouse gas mitigation benefits of ambitious expansion of cycling, walking, and transit in California. *Journal of Transport and Health*, *6*(April), 490–500. https://doi.org/10.1016/j.jth.2017.04.011

Marshall, W. E., & Ferenchak, N. N. (2019). Why cities with high bicycling rates are safer for all road users. *Journal of Transport and Health*, *13*, 100539. https://doi.org/10.1016/j.jth.2019.03.004

Matute, J., Huff, H., Lederman, J., de la Peza, D., & Johnson, K. (2016). *Toward accurate and valid estimates of greenhouse gas reductions from bikeway projects*. Los Angeles: University of California Center on Economic Competitiveness in Transportation, UCLA Institute of Transportation Studies.

McConville, M. E., Rodríguez, D. A., Clifton, K., Cho, G., & Fleischhacker, S. (2011). Disaggregate land uses and walking. *American Journal of Preventive Medicine*, *40*(1), 25–32. https://doi.org/10.1016/j.amepre.2010.09.023

McCormack, G. R., Shiell, A., Giles-Corti, B., Begg, S., Veerman, J. L., Geelhoed, E., …, & Emery, J. C. H. (2012). The association between sidewalk length and walking for different purposes in established neighborhoods. *International Journal of Behavioral Nutrition and Physical Activity*, *9*, 92. https://doi.org/10.1186/1479-5868-9-92

McCoy, R., Poirier, J. A., & Chapple, K. (2019). Bikes or bust? Analyzing the impact of bicycle infrastructure on business performance in San Francisco. *Transportation Research Record, 2673*(12), 277–289. https://doi.org/10.1177/0361198119850465

McDonald, N. C., Steiner, R. L., Lee, C., Smith, T. R., Zhu, X., & Yang, Y. (2014). Impact of the safe routes to school program on walking and bicycling. *Journal of the American Planning Association*, *80*(2), 153–167. https://doi.org/10.1080/01944363.2014.956654

McNeil, N., Monsere, C. M., & Dill, J. (2015). Influence of bike lane buffer types on perceived comfort and safety of bicyclists and potential bicyclists. *Transportation Research Record, 2520*, 132–142. https://doi.org/10.3141/2520-15

Mead, J., Zegeer, C., & Bushell, M. (2014). *Evaluation of pedestrian-related roadway measures: A summary of available research*. Washington, DC: Federal Highway Administration. http://www.pedbikeinfo.org/cms/downloads/PedestrianLitReview_April2014.pdf

Meletiou, M. P., Lawrie, J. J., Cook, T. J., O'Brien, S. W., & Guenther, J. (2005). Economic impact of investments in bicycle facilities: Case study of North Carolina's northern Outer Banks. *Transportation Research Record*, *1939*, 15–21. https://doi.org/10.3141/1939-02

Merom, D., Bauman, A., Vita, P., & Close, G. (2003). An environmental intervention to promote walking and cycling — The impact of a newly constructed rail trail in western Sydney. *Preventive Medicine*, *36*(2), 235–242. https://doi.org/10.1016/S0091-7435(02)00025-7

Metz, D. (2008). The myth of travel time saving. *Transport Reviews*, *28*(3), 321–336. https://doi.org/10.1080/01441640701642348

Meuleners, L. B., Lee, A. H., & Haworth, C. (2007). Road environment, crash type and hospitalization of bicyclists and motorcyclists presented to emergency departments in Western Australia. *Accident Analysis and Prevention*, *39*(6), 1222–1225. https://doi.org/10.1016/j.aap.2007.03.006

Meuleners, L. B., Stevenson, M., Fraser, M., Oxley, J., Rose, G., Johnson, M., …, & Marilyn, J. (2019). Safer cycling and the urban road environment: A case control study. *Accident Analysis and Prevention*, *129*, 342–349. https://doi.org/10.1016/j.aap.2019.05.032

Minikel, E. (2012). Cyclist safety on bicycle boulevards and parallel arterial routes in Berkeley, California. *Accident Analysis and Prevention*, *45*, 241–247. https://doi.org/10.1016/j.aap.2011.07.009

Mizdrak, A., Blakely, T., Cleghorn, C. L., & Cobiac, L. J. (2019). Potential of active transport to improve health, reduce healthcare costs, and reduce greenhouse gas emissions: A modelling study. *Plos One*, *14*(7), e0219316. https://doi.org/10.1371/journal.pone.0219316

Mohammadipour, A., Mohammadipour, A., & Alavi, S. H. (2020). Statistical analysis of geometric characteristics and speed reductions for raised pedestrian crosswalks (RPC). *Journal of Transportation Safety and Security*, *12*(3), 380–399. https://doi.org/10.1080/19439962.2018.1490366

Mölenberg, F. J. M., Panter, J., Burdorf, A., & Van Lenthe, F. J. (2019). A systematic review of the effect of infrastructural interventions to promote cycling: Strengthening causal inference from observational data. *International Journal of Behavioral Nutrition and Physical Activity*, *16*(1), 1–31. https://doi.org/10.1186/s12966-019-0850-1

Monsere, C., Dill, J., McNeil, N., Clifton, K., Foster, N., Goddard, T., …, & Parks, J. (2014). *Lessons from the green lanes: Evaluating protected bike lanes in the U.S.* Retrieved from https://doi.org/10.15760/trec.115

Monsere, C., Kothuri, S., Hurwitz, D., D Cobb, Fink, C., Schultheiss, B., …, & Boudart, J. (2019). *Road user understanding of bicycle signal faces on traffic signals* (NCHRP 273). Washington, DC: Transportation Research Board. https://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_wod_273.pdf

Monsere, C. M., McNeil, N. W., & Sanders, R. L. (2020). User-rated comfort and preference of separated bike lane intersection designs. *Transportation Research Record*, *2674*(9), 216–229. https://doi.org/10.1177/0361198120927694

Morrison, C. N., Thompson, J., Kondo, M. C., & Beck, B. (2019). On-road bicycle lane types, roadway characteristics, and risks for bicycle crashes. *Accident Analysis and Prevention*, *123*, 123–131. https://doi.org/10.1016/j.aap.2018.11.017

Mountain, L. J., Hirst, W. M., & Maher, M. J. (2005). Are speed enforcement cameras more effective than other speed management measures? The impact of speed management schemes on 30 mph roads. *Accident Analysis and Prevention*, *37*(4), 742–754. https://doi.org/10.1016/j.aap.2005.03.017

Mueller, N., Rojas-Rueda, D., Cole-Hunter, T., de Nazelle, A., Dons, E., Gerike, R., …, & Nieuwenhuijsen, M. (2015). Health impact assessment of active transportation: A systematic review. *Preventive Medicine*, *76*, 103–114. https://doi.org/10.1016/j.ypmed.2015.04.010

Munira, S., Sener, I. N., & Zhang, Y. (2021). Estimating bicycle demand in the Austin, Texas Area: Role of a bikeability index. *Journal of Urban Planning and Development*, *147*(3), 1–12. https://doi.org/10.1061/(asce)up.1943-5444.0000725

NACTO. (2019). *Shared micromobility in the U.S.* Retrieved from https://nacto.org/shared-micromobility-2019/

National Highway Traffic Safety Administration. (2014). *Traffic safety facts*. Retrieved from https://doi.org/http://dx.doi.org/10.1016/j.annemergmed.2013.12.004

National Highway Traffic Safety Administration. (2020). *Traffic Safety Facts 2018 data: Pedestrians* (Issue March) (DOT HS 812 850). Washington, DC: National Highway Traffic Safety Administration

New Jersey Bicycle and Pedestrian Resource Center (2004). *Home zone concepts and New Jersey*. New Jersey Department of Transportation. https://vtc.rutgers.edu/wp-content/uploads/2014/07/Home_Zones_NJ_Final_Report.pdf

Noland, R. B., Smart, M. J., & Guo, Z. (2019). Bikesharing trip patterns in New York City: Associations with land use, subways, and bicycle lanes. *International Journal of Sustainable Transportation*, *13*(9), 664–674. https://doi.org/10.1080/15568318.2018.1501520

O'Brien, S. W., Zegeer, C. V, Chase, T., Ahmed, I., Searcy, S., Kearns, B., & Pyo, K. (2022). *Yielding compliance at high visibility crosswalks*. Raleigh, NC: NCDOT.

Ohlms, P. B., & Kweon, Y. J. (2018). Facilitating bicycle travel using innovative intersection pavement markings. *Journal of Safety Research*, *67*, 173–182. https://doi.org/10.1016/j.jsr.2018.10.007

Oliver, L. N., Schuurman, N., & Hall, A. W. (2007). Comparing circular and network buffers to examine the influence of land use on walking for leisure and errands. *International Journal of Health Geographics*, *6*, 1–11. https://doi.org/10.1186/1476-072X-6-41

Pantangi, S. S., Ahmed, S. S., Fountas, G., Majka, K., & Anastasopoulos, P. C. (2021). Do high visibility crosswalks improve pedestrian safety? A correlated grouped random parameters approach using naturalistic driving study data. *Analytic Methods in Accident Research*, *30*, 100155. https://doi.org/10.1016/j.amar.2020.100155

Panter, J., Heinen, E., Mackett, R., & Ogilvie, D. (2016). Impact of new transport infrastructure on walking, cycling, and physical activity. *American Journal of Preventative Medicine*, *50*(2), 45–53. https://doi.org/10.1016/j.amepre.2015.09.021

Panter, J., & Ogilvie, D. (2015). Theorizing and testing environmental pathways to behavior change: Natural experimental study of the perception and use of new infrastructure to promote walking and cycling in local communities. *BMJ Open*, *5*(9), 1–12. https://doi.org/10.1136/bmjopen-2015-007593

Park, Y., & Garcia, M. (2020). Pedestrian safety perception and urban street settings. *International Journal of Sustainable Transportation*, *14*(11), 860–871. https://doi.org/10.1080/15568318.2019.1641577

Pearson, L., Gabbe, B., Reeder, S., & Beck, B. (2023). Barriers and enablers of bike riding for transport and recreational purposes in Australia. *Journal of Transport and Health*, *28*, 101538. https://doi.org/10.1016/j.jth.2022.101538

Pedroso, F. E., Angriman, F., Bellows, A. L., & Taylor, K. (2016). Bicycle use and cyclist safety following boston's bicycle infrastructure expansion, 2009-2012. *American Journal of Public Health*, *106*(12), 2171–2177. https://doi.org/10.2105/AJPH.2016.303454

Pérez, K., Olabarria, M., Rojas-Rueda, D., Santamariña-Rubio, E., Borrell, C., & Nieuwenhuijsen, M. (2017). The health and economic benefits of active transport policies in Barcelona. *Journal of Transport & Health*, *4*, 316–324, https://doi.org/10.1016/j.jth.2017.01.001.

Piatkowski, D. P., Krizek, K. J., & Handy, S. L. (2015). Accounting for the short-term substitution effects of walking and cycling in sustainable transportation. *Travel Behavior and Society*, *2*(1), 32–41. https://doi.org/10.1016/j.tbs.2014.07.004

Pilkington, P., & Kinra, S. (2005). Effectiveness of speed cameras in preventing road traffic collisions and related casualties: Systematic review. *British Medical Journal*, *330*(7487), 331–334. https://doi.org/10.1136/bmj.38324.646574.AE

Poirier, J. A. (2018). Bicycle lanes and business success: A San Francisco examination. *Transportation Research Record*, *2672*(7), 47–57. https://doi.org/10.1177/0361198118792321

Pol, A. A., Prasad, S., Costello, S., Patel, A., & Hancock, K. (2015). Evaluation of shared-use markings for cyclists in Auckland. Paper presented at the *IPENZ Transportation Group Conference*, Christchurch, New Zealand, March 22–25.

Ponnaluri, R. V., & Groce, P. W. (2005). Operational effectiveness of speed humps in traffic calming. *ITE Journal*, *75*(7), 26–30.

Popovich, N., & Handy, S. L. (2014). Bicyclists as consumers mode choice and spending behavior in downtown Davis, California. *Transportation Research Record*, *2468*(2468), 47–54. https://doi.org/10.3141/2468-06

Poswayo, A., Kalolo, S., Rabonovitz, K., Witte, J., & Guerrero, A. (2019). School area road safety assessment and improvements (SARSAI) program reduces road traffic injuries among children in Tanzania. *Injury Prevention*, *25*(5), 414–420. https://doi.org/10.1136/injuryprev-2018-042786

Poudel, N., & Singleton, P. A. (2021). Bicycle safety at roundabouts: A systematic literature review. *Transport Reviews*, *41*(5), 617–642. https://doi.org/10.1080/01441647.2021.1877207

Preston, A., & Pulugurtha, S. S. (2021). Simulating and assessing the effect of a protected intersection design for bicyclists on traffic operational performance and safety. *Transportation Research Interdisciplinary Perspectives*, *9*, 100329. https://doi.org/10.1016/j.trip.2021.100329

Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: An international review. *Preventive Medicine*, *50*(Suppl 1), S106-25. https://doi.org/10.1016/j.ypmed.2009.07.028

Rabl, A., & de Nazelle, A. (2012). Benefits of shift from car to active transport. *Transport Policy*, *19*(1), 121–131. https://doi.org/10.1016/j.tranpol.2011.09.008

Ragland, D. R., Pande, S., Bigham, J., & Cooper, J. F. (2014). Examining long-term impact of California safe routes to school program: Ten years later. *Transportation Research Record*, *2464*, 86–92. https://doi.org/10.3141/2464-11

Raihan, M. A., Alluri, P., Wu, W., & Gan, A. (2019). Estimation of bicycle crash modification factors (CMFs) on urban facilities using zero inflated negative binomial models. *Accident Analysis and Prevention*, *123*, 303–313. https://doi.org/10.1016/j.aap.2018.12.009

Remache-Patino, B. A., Comeau, D. J., Brennan, T. M., & Park, S. (2022). Measuring congestion at road-diet reductions using probe vehicle data. *Proceedings of the Institution of Civil Engineers: Urban Design and Planning*. Retrieved from https://doi.org/10.1680/jurdp.21.00049

Retting, R. A., Persaud, B. N., Garder, P. E., & Lord, D. (2001). Crash and injury reduction following installation of roundabouts in the United States. *American Journal of Public Health*, *91*(4), 628–631. https://doi.org/10.2105/AJPH.91.4.628

Reynolds, C. C. O., Harris, M. A., Teschke, K., Cripton, P. A., & Winters, M. (2009). The impact of transportation infrastructure on bicycling injuries and crashes: A review of the literature. *Environmental Health, 8*(47). https://doi.org/10.1186/1476-069X-8-47

Rissel, C., Greaves, S., Wen, L. M., Crane, M., & Standen, C. (2015). Use of and short-term impacts of new cycling infrastructure in inner-Sydney, Australia: A quasi-experimental design. *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 1. https://doi.org/10.1186/s12966-015-0294-1

Rista, E., Goswamy, A., Wang, B., Barrette, T., Hamzeie, R., Russo, B., …, & Savolainen, P. T. (2018). Examining the safety impacts of narrow lane widths on urban/suburban arterials: Estimation of a panel data random parameters negative binomial model. *Journal of Transportation Safety and Security*, *10*(3), 213–228. https://doi.org/10.1080/19439962.2016.1273291

Robartes, E., & Donna Chen, T. (2018). Crash histories, safety perceptions, and attitudes among Virginia bicyclists. *Journal of Safety Research*, *67*, 189–196. https://doi.org/10.1016/j.jsr.2018.10.009

Rodgers, G. B. (1997). Factors associated with the crash risk of adult bicyclists. *Journal of Safety Research*, *28*(4), 233–241. https://doi.org/10.1016/S0022-4375(97)00009-1

Rodier, C. J., Shaheen, S., & Cavanagh, E. (2007). *Automated speed enforcement in the U.S.: A review of the literature on denefits and barriers to implementation*. Retrieved from https://escholarship.org/uc/item/41k1k365

Rodrigues, P. F., Alvim-Ferraz, M. C. M., Martins, F. G., Saldiva, P., Sá, T. H., & Sousa, S. I. V. (2020). Health economic assessment of a shift to active transport. *Environmental Pollution*, *258*, 113745. https://doi.org/10.1016/j.envpol.2019.113745

Rojas-Rueda, D., De Nazelle, A., Andersen, Z. J., Braun-Fahrländer, C., Bruha, J., Bruhova-Foltynova, H., …, & Nieuwenhuijsen, M. J. (2016). Health impacts of active transportation in Europe. *PLoS ONE*, *11*(3), 1–14. https://doi.org/10.1371/journal.pone.0149990

Romanow, N. T. R., Couperthwaite, A. B., McCormack, G. R., Nettel-Aguirre, A., Rowe, B. H., & Hagel, B. E. (2012). Environmental determinants of bicycling injuries in Alberta, Canada. *Journal of Environmental and Public Health*, *2012*, 1–12. https://doi.org/10.1155/2012/487681

Russo, B., Kothuri, S., Smaglik, E., & Hurwitz, D. (2023). Analyzing the impacts of intersection treatments and traffic characteristics on bicyclist safety: Development of data-driven guidance on the application of bike boxes, mixing zones, and bicycle signals. *Transportation Research Record*, *2677*(12), 036119812311674. https://doi.org/10.1177/03611981231167414

Saad, M., Abdel-Aty, M., Lee, J., & Cai, Q. (2019). Bicycle safety analysis at intersections from crowdsourced data. *Transportation Research Record*, *2673*(4), 1–14. https://doi.org/10.1177/0361198119836764

Sadarangani, K. P., Von Oetinger, A., Cristi-Montero, C., Cortínez-O'Ryan, A., Aguilar-Farías, N., & Martínez-Gómez, D. (2018). Beneficial association between active travel and metabolic syndrome in Latin-America: A cross-sectional analysis from the Chilean national health survey 2009–2010. *Preventive Medicine*, *107*(April 2017), 8–13. https://doi.org/10.1016/j.ypmed.2017.12.005

Saelens, B. E., & Handy, S. L. (2008). Built environment correlates of walking: A review. *Medicine and Science in Sports and Exercise*, *40*(7), S550–S566. https://doi.org/doi:10.1249/MSS.0b013e31817c67a4

Saelens, B. E., Moudon, A. V., Kang, B., Hurvitz, P. M., & Zhou, C. (2014). Relation between higher physical activity and public transit use. *American Journal of Public Health*, *104*(5), 854–859. https://doi.org/10.2105/AJPH.2013.301696

Saelens, B. E., Sallis, J. F., & Frank, L. D. (2003). Environmental correlates of walking and cycling: Findings from the transportation, urban design, and planning literatures. *Annals of Behavioral Medicine*, *25*(2), 80–91. https://doi.org/10.1207/S15324796ABM2502_03

Sælensminde, K. (2004). Cost-benefit analyses of walking and cycling track networks taking into account insecurity, health effects and external costs of motorized traffic. *Transportation Research Part A: Policy and Practice*, *38*(8), 593–606. https://doi.org/10.1016/j.tra.2004.04.003

Saha, D., Alluri, P., Gan, A., & Wu, W. (2018). Spatial analysis of macro-level bicycle crashes using the class of conditional autoregressive models. *Accident Analysis and Prevention*, *118*(February), 166–177. https://doi.org/10.1016/j.aap.2018.02.014

Saleh, W., Grigorova, M., & Elattar, S. (2020). Pedestrian road crossing at uncontrolled mid-block locations: Does the refuge island increase risk? *Sustainability (Switzerland)*, *12*(12), 4891. https://doi.org/10.3390/su12124891

Sallis, J. F., Conway, T. L., Dillon, L. I., Frank, L. D., Adams, M. A., Cain, K. L., & Saelens, B. E. (2013). Environmental and demographic correlates of bicycling. *Preventive Medicine*, *57*(5), 456–460. https://doi.org/10.1016/j.ypmed.2013.06.014

Sauer, C. E., & Mastaglio, B. R. (2017). Assessing the state of practice of the role and siting issues related to curbless streets in an urban context. *Transportation Research Record*, *2605*(1), 61–71. https://doi.org/10.3141/2605-06

Schaefer, J. S., Figliozzi, M. A., & Unnikrishnan, A. (2022). Evaluation of posted speed limits reductions on urban roads with a high percentage of cyclists. *Transportation Research Record*, *2676*(6), 685–695. https://doi.org/10.1177/03611981221076115

Scheepers, C. E., Wendel-Vos, G. C. W., den Broeder, J. M., van Kempen, E. E. M. M., van Wesemael, P. J. V., & Schuit, A. J. (2014). Shifting from car to active transport: A systematic review of the effectiveness of interventions. *Transportation Research Part A: Policy and Practice*, *70*, 264–280. https://doi.org/10.1016/j.tra.2014.10.015

Schepers, J. P., Kroeze, P. A., Sweers, W., & Wüst, J. C. (2011). Road factors and bicycle-motor vehicle crashes at unsignalized priority intersections. *Accident Analysis and Prevention*, *43*(3), 853–861. https://doi.org/10.1016/j.aap.2010.11.005

Schepers, P., Twisk, D., Fishman, E., Fyhri, A., & Jensen, A. (2017). The Dutch road to a high level of cycling safety. *Safety Science*, *92*, 264–273. https://doi.org/10.1016/j.ssci.2015.06.005

Schimek, P. (2018). Bike lanes next to on-street parallel parking. *Accident Analysis and Prevention*, *120*, 74–82. https://doi.org/10.1016/j.aap.2018.08.002

Schneider, R. J., Diogenes, M. C., Arnold, L. S., Attaset, V., Griswold, J., & Ragland, D. R. (2010). Association between roadway intersection characteristics and pedestrian crash risk in Alameda County, California. *Transportation Research Record*, *2198*, 41–51. https://doi.org/10.3141/2198-06

Schneider, R. J., Qin, X., Razaur, M., Shaon, R., Sanatizadeh, A., He, Z., …, & Bill, A. (2017). *Evaluation of Driver Yielding to Pedestrians at Uncontrolled Crosswalks*. Madison, WI: WisDOT.

Schoner, J. E., Cao, J., & Levinson, D. M. (2015). Catalysts and magnets: Built environment and bicycle commuting. *Journal of Transport Geography*, *47*, 100–108. https://doi.org/10.1016/j.jtrangeo.2015.07.007

Scott-Deeter, L., Hurwitz, D., Russo, B., Smaglik, E., & Kothuri, S. (2023). Assessing the impact of three intersection treatments on bicyclist safety using a bicycling simulator. *Accident Analysis and Prevention*, *179*, 106877. https://doi.org/10.1016/j.aap.2022.106877

Shinar, D. (2017). *Traffic safety and human behavior* (2nd edition). Leeds, England: Emerald Group Publishing Ltd.

Siddiqui, N. A., Chu, X., & Guttenplan, M. (2006). Crossing locations, light conditions, and pedestrian injury severity. *Transportation Research Record*, *1982*, 141–149. https://doi.org/10.3141/1982-19

Silvano, A. P., & Bang, K. L. (2016). Impact of speed limits and road characteristics on free-flow speed in urban areas. *Journal of Transportation Engineering*, *142*(2), 1–9. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000800

Sisiopiku, V. P., & Akin, D. (2003). Pedestrian behaviors at and perceptions towards various pedestrian facilities: An examination based on observation and survey data. *Transportation Research Part F: Traffic Psychology and Behavior*, *6*(4), 249–274. https://doi.org/10.1016/j.trf.2003.06.001

Skov-Petersen, H., Jacobsen, J. B., Vedel, S. E., Thomas Alexander, S. N., & Rask, S. (2017). Effects of upgrading to cycle highways — An analysis of demand induction, use patterns and satisfaction before and after. *Journal of Transport Geography*, *64*, 203–210. https://doi.org/10.1016/j.jtrangeo.2017.09.011

Smith, A., Zucker, S., Lladó-Farrulla, M., Friedman, J., Guidry, C., McGrew, P., …, & Duchesne, J. (2019). Bicycle lanes: Are we running in circles or cycling in the right direction? *Journal of Trauma and Acute Care Surgery*, *87*(1), 76–81. https://doi.org/10.1097/TA.0000000000002328

Soole, D. W., Watson, B. C., & Fleiter, J. J. (2013). Effects of average speed enforcement on speed compliance and crashes: A review of the literature. *Accident Analysis and Prevention*, *54*, 46–56. https://doi.org/10.1016/j.aap.2013.01.018

Sørensen, M. W. J. (2011). Shared space in Norway (... and in Europe). Paper presented at the Nordic Road Saftey Forum, May 13, 2011.

Standen, C., Greaves, S., Collins, A. T., Crane, M., & Rissel, C. (2019). The value of slow travel: Economic appraisal of cycling projects using the logsum measure of consumer surplus. *Transportation Research Part A: Policy and Practice*, *123*, 255–268. https://doi.org/10.1016/j.tra.2018.10.015

Stankov, I., Garcia, L. M. T., Mascolli, M. A., Montes, F., Meisel, J. D., Gouveia, N., …, & Diez Roux, A. V. (2020). A systematic review of empirical and simulation studies evaluating the health impact of transportation interventions. *Environmental Research*, *186*(2019, August), 109519. https://doi.org/10.1016/j.envres.2020.109519

Steell, L., Garrido-Méndez, A., Petermann, F., Díaz-Martínez, X., Martínez, M. A., Leiva, A. M., …, & Celis-Morales, C. A. (2018). Active commuting is associated with a lower risk of obesity, diabetes and metabolic syndrome in Chilean adults. *Journal of Public Health*, *40*(3), 508–516. https://doi.org/10.1093/pubmed/fdx092

Stehlin, J. (2015). Cycles of investment: Bicycle infrastructure, gentrification, and the restructuring of the San Francisco bay area. *Environment and Planning A*, *47*(1), 121–137. https://doi.org/10.1068/a130098p

Stein, S. (2011). Bike lanes and gentrification: New York City's shades of green. *Progressive Planning*, *188*, 34–37.

Stewart, O., Moudon, A. V., & Claybrooke, C. (2014). Multistate evaluation of safe routes to school programs. *American Journal of Health Promotion*, *28*(3_suppl), S89–S96. https://doi.org/10.4278/ajhp.130430-QUAN-210

Stipancic, J., Miranda-Moreno, L., Strauss, J., & Labbe, A. (2020). Pedestrian safety at signalized intersections: Modelling spatial effects of exposure, geometry and signalization on a large urban network. *Accident Analysis and Prevention*, *134*, 105265. https://doi.org/10.1016/j.aap.2019.105265

Taciuk, A., & Davidson, G. (2018). *Practitioner's guide to planning, designing, and implementing bicycle highways in North America*. Paper presented at the 2018 Conference and Exhibition of the Transportation Association of Canada, Saskatoon, SK, Canada.

Tasic, I., Elvik, R., & Brewer, S. (2017). Exploring the safety in numbers effect for vulnerable road users on a macroscopic scale. *Accident Analysis and Prevention*, *109*(October), 36–46. https://doi.org/10.1016/j.aap.2017.07.029

Taylor, C., & Coutts, C. (2018). Greenways as safe routes to school in a Latino community in East Los Angeles. *Cities & Health*, *3*(1–2), 141–157. https://doi.org/10.1080/23748834.2018.1462964

Teschke, K., Frendo, T., Shen, H., Harris, M. A., Reynolds, C. C., Cripton, P. A., …, & Winters, M. (2014). Bicycling crash circumstances vary by route type: A cross-sectional analysis. *BMC Public Health*, *14*(1). https://doi.org/10.1186/1471-2458-14-1205

Teschke, K., Harris, M. A., Reynolds, C. C. O., Winters, M., Babul, S., Chipman, M., …, & Cripton, P. A. (2012). Route infrastructure and the risk of injuries to bicyclists: A case-crossover study. *American Journal of Public Health*, *102*(12), 2336–2343. https://doi.org/10.2105/AJPH.2012.300762

Thakuriah, P. V., Metaxatos, P., Lin, J., & Jensen, E. (2012). An examination of factors affecting propensities to use bicycle and pedestrian facilities in suburban locations. *Transportation Research Part D: Transport and Environment*, *17*(4), 341–348. https://doi.org/10.1016/j.trd.2012.01.006

Thomas, L. (2013). *White paper series road diet conversions: A synthesis of safety research*. Retrieved from www.pedbikeinfo.org

Thomas, L. J., Srinivasan, R., Decina, L. E., & Staplin, L. (2008). Safety effects of automated speed enforcement programs: Critical review of international literature. *Transportation Research Record*, *2078*, 117–126. https://doi.org/10.3141/2078-16

Tian, G., & Ewing, R. (2017). A walk trip generation model for Portland, OR. *Transportation Research Part D: Transport and Environment*, *52*, 340–353. https://doi.org/10.1016/j.trd.2017.03.017

Tilahun, N. (2022). Safety impact of automated speed camera enforcement: Empirical findings based on Chicago's speed cameras. *Transportation Research Record*, *2677*(1), 2169–4052. https://doi.org/10.1177/03611981221104808

Torres, C., Sobreira, L., Castro-Neto, M., Cunto, F., Vecino-Ortiz, A., Allen, K., Hyder, A., & Bachani, A. (2020). Evaluation of pedestrian behavior on mid-block crosswalks: A case study in Fortaleza—Brazil. *Frontiers in Sustainable Cities, 2*. https://doi.org/10.3389/frsc.2020.00003

Tranter, P. (2018). Taming traffic to encourage children's active transportation. *Children's Active Transportation*, *2018,* 229–242. https://doi.org/10.1016/B978-0-12-811931-0.00016-8

Turner, B., Partridge, R., Turner, S., Corben, B., Woolley, J., Stokes, C., …, & Steinmetz, L. (2019). Safety solutions on mixed use urban arterial roads. *Journal of the Australasian College of Road Safety*, *30*(3), 11–17.

Ukkusuri, S., Miranda-Moreno, L. F., Ramadurai, G., & Isa-Tavarez, J. (2012). The role of built environment on pedestrian crash frequency. *Safety Science*, *50*(4), 1141–1151. https://doi.org/10.1016/j.ssci.2011.09.012

Ullman, G. L., & Rose, E. R. (2005). Evaluation of dynamic speed display signs. *Transportation Research Record*, *1918*(1), 92–97.

Uttley, J., Fotios, S., & Lovelace, R. (2020). Road lighting density and brightness linked with increased cycling rates after-dark. *PLoS ONE*, *15*(5), e0233105. https://doi.org/10.1371/journal.pone.0233105

van Lierop, D., Grimsrud, M., & El-Geneidy, A. (2015). Breaking into bicycle theft: Insights from Montreal, Canada. *International Journal of Sustainable Transportation*, *9*(7), 490–501. https://doi.org/10.1080/15568318.2013.811332

Vanwagner, M., van Houten, R., & Betts, B. (2011). The effects of a rectangular rapid-flashing beacon on vehnicle speed. *Journal of Applied Behavior Analysis*, *44*(3), 629–633. https://doi.org/10.1901/jaba.2011.44-629

Veillette, M. P., Grisé, E., & El-Geneidy, A. (2019). Does one bicycle facility type fit all? Evaluating the stated usage of different types of bicycle facilities among cyclists in Quebec City, Canada. *Transportation Research Record*, *2673*(6), 650–663. https://doi.org/10.1177/0361198119844741

Volker, J., Handy, S., Kendall, A., & Barbour, E. (2019). *Quantifying reductions in vehicle miles traveled from new bike paths, lanes, and cycle tracks.* Sacramento, CA: California Air Resources Board.

Wang, C. H., Chen, N., & Tian, G. (2021). Do accessibility and clustering affect active travel behavior in Salt Lake City? *Transportation Research Part D: Transport and Environment*, *90*, 102655. https://doi.org/10.1016/j.trd.2020.102655

Wang, J., & Cicchino, J. B. (2022). Safety effects of roundabout conversions in Carmel, Indiana, the Roundabout City. *Journal of Safety Research*, *82*, 159–165. https://doi.org/10.1016/j.jsr.2022.05.007

Wang, K., & Akar, G. (2018). Street intersection characteristics and their impacts on perceived bicycling safety. *Transportation Research Record*, *2672*(46), 41–54. https://doi.org/10.1177/0361198118801349

Wanvik, P. O. (2009). Effects of road lighting: An analysis based on Dutch accident statistics 1987-2006. *Accident Analysis and Prevention*, *41*(1), 123–128. https://doi.org/10.1016/j.aap.2008.10.003

Wardman, M., Tight, M., & Page, M. (2007). Factors influencing the propensity to cycle to work. *Transportation Research Part A: Policy and Practice*, *41*(4), 339–350. https://doi.org/10.1016/j.tra.2006.09.011

Welch, T. F., Gehrke, S. R., & Wang, F. (2016). Long-term impact of network access to bike facilities and public transit stations on housing sales prices in Portland, Oregon. *Journal of Transport Geography*, *54*(2015, September), 264–272. https://doi.org/10.1016/j.jtrangeo.2016.06.016

Weliwitiya, H., Rose, G., & Johnson, M. (2019). Bicycle train intermodality: Effects of demography, station characteristics and the built environment. *Journal of Transport Geography*, *74*, 395–404. https://doi.org/10.1016/j.jtrangeo.2018.12.016

Welsh, B. C., & Farrington, D. P. (2008). Effects of improved street lighting on crime. *Campbell Systematic Reviews*, *4*(1), 1–51. https://doi.org/10.4073/csr.2008.13

Wier, M. (2019). *Executive summary: Safe speeds SF high visibility enforcement campaign findings*. San Francisco: Vision Zero San Francisco.

Willardsen, K. (2021). Effects of speed cameras on intersection accidents: Evidence from Dayton. *The Review of Regional Studies*, *51*, 266–291.

Williams, M., Pande, A., Lamera, M., Bauranov, A., & Voulgaris, C. (2022). Safety performance of edge-lane roads. *Journal of Transportation Engineering, Part A: Systems*, *148*(11) https://doi.org/10.1061/jtepbs.0000739

Winters, M., Babul, S., Becker, J., Brubacher, J. R., Chipman, M., Cripton, P., … & Teschke, K. (2012). Safe cycling: How do risk perceptions compare with observed risk? *Canadian Journal of Public Health*,*103*, S42–S47. 10.1007/BF03403834

Winters, M., Brauer, M., Setton, E. M., & Teschke, K. (2010). Built environment influences on healthy transportation choices: Bicycling versus driving. *Journal of Urban Health*, *87*(6), 969–993. https://doi.org/10.1007/s11524-010-9509-6

Winters, M., Harris A, M., Reynolds, C., Cripton A, P., Chipman, M., Cusimano D, M., ..., & Teschke, K. (2013). Bicyclists' injuries and the cycling environment: The impact of route infrastructure. *92nd Annual Meeting of the Transportation Research Board*, January 13–17, Washington, DC.

Winters, M., Teschke, K., Grant, M., Setton, E. M., & Brauer, M. (2010). How far out of the way will we travel? *Transportation Research Record*, *2190*(1), 1–10. https://doi.org/10.3141/2190-01

Woodcock, J., Edwards, P., Tonne, C., Armstrong, B. G., Ashiru, O., Banister, D., …, & Roberts, I. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: Urban land transport. *The Lancet*, *374*(9705), 1930–1943. https://doi.org/10.1016/S0140-6736(09)61714-1

Woodcock, J., Franco, O. H., Orsini, N., & Roberts, I. (2011). Non-vigorous physical activity and all-cause mortality: Systematic review and meta-analysis of cohort studies. *International Journal of Epidemiology*, *40*(1), 121–138. https://doi.org/10.1093/ije/dyq104

Yassin, M. F. (2011). Impact of height and shape of building roof on air quality in urban street canyons. *Atmospheric Environment*, *45*(29), 5220–5229. https://doi.org/10.1016/j.atmosenv.2011.05.060

Younes, H., Noland, R. B., Von Hagen, L. A., & Meehan, S. (2023). Pedestrian- and bicyclist-involved crashes: Associations with spatial factors, pedestrian infrastructure, and equity impacts. *Journal of Safety Research*, *86*, 137–147. https://doi.org/10.1016/j.jsr.2023.05.005

Zahabi, S. A. H., Strauss, J., Manaugh, K., & Miranda-Moreno, L. F. (2011). Estimating potential effect of speed limits, built environment, and other factors on severity of pedestrian and cyclist injuries in crashes. *Transportation Research Record*, *2247*, 81–90. https://doi.org/10.3141/2247-10

Zapata-Diomedi, B., Gunn, L., Giles-Corti, B., Shiell, A., & Lennert Veerman, J. (2018). A method for the inclusion of physical activity-related health benefits in cost-benefit analysis of built environment initiatives. *Preventive Medicine*, *106*(2017, July), 224–230. https://doi.org/10.1016/j.ypmed.2017.11.009

Zegeer, C., Srinivasan, R., Lan, B., Carter, D., Smith, S., Sundstrom, C., …, & van Houten, R. (2017). *Development of crash modification factors for uncontrolled pedestrian crossing treatments*. Washington, DC: Transportation Research Board. https://doi.org/10.17226/24627

Zegeer, S. R., Huang, H., & Lagerwey, P, C. (2001). *Safety effects of marked vs unmarked crosswalks at uncontrolled locations: Executive summary and recommended guidelines* (FHWA-RD-01-075). Washington, DC: Federal Highway Administration.

Zhou, Y., Himes, S., Le, T., Gooch, J., Northup, K., & Pavao, P. (2022). Safety effectiveness of the road diet treatment in Rhode Island. *Transportation Research Record*, *2676*(7), 24–31. https://doi.org/10.1177/03611981221076433