Competing Priorities in U.S. Urban Intersection Design

An STS Research Paper
Presented to the faculty of the
School of Engineering and Applied Science
University of Virginia

by

Joshua Callanan Frye

March 27, 2025

On my honor as a University of Virginia student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Joshua Callanan Frye

STS Advisor: Peter Norton

Introduction

Like road users at a congested urban intersection, the needs of pedestrians, cyclists, micromobility, motorists, policymakers, and engineers clash in the problem of urban intersection design. Drivers' needs have shaped urban mobility for decades, typically at the expense of other road users. Demands to improve safety, relieve congestion, reduce pollution, and promote health, equitability and livability necessitate a more balanced approach.

Social groups compete to resist, promote or influence intersection redesigns. Sustainability advocates demand transit-oriented design, urban planners recommend protected bike lanes and walkability, and engineers favor vehicular throughput that conforms to codified design standards (NACTO, 2019). Improvements in cycling infrastructure and walkability can drive up property values, stimulate gentrification, and ultimately displace marginalized communities (Agyeman & Doran, 2021; Lee et al., 2017). Despite accessibility mandates under the Americans with Disabilities Act, older intersections often fail disabled users. Intersection design is not solely a traffic engineering problem. Urbanists, transportation engineers, advocacies and policymakers compete for influence as well.

In intersection design, safety, mobility, sustainability and social equity are in competition.

Review of Research

Urban intersection design reflects competing priorities from urbanists, policymakers, engineers, and advocacies. Their goals differ, but all influence planning, design, and implementation decisions. Some participants emphasize pedestrian, cyclist, and micro-mobility safety, while others highlight economic, social, and sustainable consequences of urban

intersection design. Technical standards offer guidance, but inconsistent implementation reveals persistent conflicts.

Agyeman and Doran (2021) and Lee et al. (2017) argue that while protected bike lanes and crossings are seen as solutions for improving safety, these measures can inadvertently contribute to gentrification. Their research highlights the negative impacts of urban renewal, such as displacement of lower-income individuals in marginalized communities, as a result of urban intersection design safety improvements. This challenges the idea that safety improvements benefit everyone equally, and underscores the need to integrate equity into intersection design. While aimed at improving safety, they may exacerbate existing social inequalities if not implemented equitably (Braun et. al 2019). Similarly, some participants contend that infrastructure upgrades, particularly at urban intersections, fail to account for disability needs (Whaley et. al, 2024). The Americans with Disabilities Act mandates accessibility, yet many intersections still lack basics like curb ramps (CRD, 2020).

Congested U.S. intersections cause frequent idling and stop-and-go traffic. As cities continue to grow in population, the increasing severity and duration of traffic congestion have the potential to greatly increase pollutant emissions and degrade air quality" (Zhang & Batterman, 2013). Particularly at intersections where idling is common, "the concentration of harmful particles was 29 times higher at stoplights than when people were driving down the road" (Red Lights are Air Pollution Hot Spots, 2015). Addressing these issues requires compact, mixed-use development that encourages alternate modes of transportation to the automobile (Cervero & Kockelman, 1997). Reducing car dependency helps lower emissions at busy intersections. Prioritizing multimodal efficiency is key to mitigating emissions and reducing congestion at urban intersections (Newman & Kenworthy, 2015).

Alternate studies emphasize protected infrastructure as key to reducing fatalities. The Institute for Transportation and Development Policy (2022) shows that protected intersections and bike lanes are essential to minimizing conflicts between unprotected road users and motor vehicles (ITDP, 2022). This view aligns with NACTO's (2019) findings, which advocate for infrastructure changes such as narrower lanes and road diets to create safer, more micro-mobility-friendly environments. These interventions reduce speeds and promote sustainable travel. Similarly, adjustments to signal timing, particularly with vehicle optimization in mind, can reduce fatal and injury crash types at busy urban intersections (Roshandeh et. al, 2016). Though often overlooked in crash models, "exclusive pedestrian phases decreased the probability of conflicts and pedestrian crashes" (Stipanic et. al, 2020).

Technical frameworks like the Complete Streets Capability Maturity Model, developed by the American Society of Civil Engineers (Jordan et al., 2021), provide a structured approach for assessing how well agencies are integrating inclusive and safe design strategies. These frameworks stress pedestrian and cyclist safety and show that good design must balance traffic flow and accessibility. The Institute of Transportation Engineers (ITE) supports these findings, underscoring the necessity for technical standards that ensure urban intersections meet both safety and accessibility goals (Jordan et al., 2021). Despite available guidance, inconsistent implementation puts all users at risk. Consistent geometric design of the roadway and pedestrian safety countermeasures "is a critical factor in road safety and driving performance" (Stipanic & Bhavathrathan, 2024).

Overall, the research highlights that effective intersection design depends not just on technical solutions, but on equitable and consistent application.

Comprehensive Design Solutions

Urban intersection design must balance safety and mobility for pedestrians, cyclists, and drivers. As transportation systems evolve, “maximizing both the mobility and safety of road users at urban and suburban intersections is of utmost importance to city leaders and citizens today”(Vandervalk, 2021). Balancing safety and mobility grows harder as cities expand and new travel modes emerge. Rising travel demand and new travel modes challenge the car-first approach long used in U.S. cities (Krajcovic Jr., 2018).

Cities embracing alternatives to car-centric design must prioritize movement for all users. Zhang et al. (2023) emphasize that shared street space should be designed to reduce conflict and promote intuitive user behavior across all mobility types, especially where drivers and pedestrians interact frequently. Seamless, safe interaction between all users is essential. As one global planning resource emphasizes, “Many of the world’s cities can become safer, healthier places by changing the design of their streets and communities. Where public streets have been designed to serve primarily or even exclusively private motor vehicle traffic, they can be made immensely safer for all users if they are designed to effectively serve pedestrians, public transport users, bicyclists, and other public activity” (Welle et. al, 2015). Such approaches not only reduce traffic deaths but also improve social cohesion and neighborhood vibrancy through more human-scaled streets.

Urban intersections with strong non-vehicular infrastructure see better safety, lower congestion, and improved mobility (Zhang et. al, 2023). A comprehensive urban intersection design will encourage users to select alternate travel modes, leading to a reduction in congestion despite the increase in pedestrian and micro-mobility infrastructure. Balanced design is essential as cities grow and redesign their networks, such that intersections can “facilitate visibility and

predictability for all users, creating an environment in which complex movements feel safe, easy, and intuitive" (NACTO, n.d.).

Designing for safety and mobility requires addressing urban travel behaviors and space limits. Overdesigning non-vehicular space may improve safety, but overlooks America's car dependence. Prioritizing traffic calming measures aimed at reducing vehicle speeds and movements can result in gridlock (FHWA, n.d.), frustrating drivers and undermining support for future non-auto-centric design. In a case study involving implementation of a speed hump, two speed values observed "are significant deviations from an otherwise normal distribution" (FHWA, n.d.). While safety increases, speeds significantly decrease from normal, presenting a problem: dense cities make it difficult to provide dedicated space for all users while ensuring needs are met.

Comprehensive intersection design strategy in such situations is best guided by user behavior, crash patterns, and travel demand. According to the Institute of Traffic Engineers Connected Intersections Implementation Guide, effective solutions integrate optimized signal timing and lane geometry, visibility improvements for all users, and designated infrastructure that encourages predictable and efficient movements across the intersection (CI Committee, 2022). This approach balances safety and mobility for all users. To work effectively, however, these solutions require a cultural shift in how engineers and planners perceive intersection space. Envisioning these complex points of interaction between users as not just a conduit for vehicles, but as a shared public infrastructure that must respond to diverse needs is crucial for comprehensive design (Newman & Kenworthy, 2015).

Ultimately, successful design won't trade safety for speed, or mobility for protection. Accommodating all users and modes is key. Growth of urban populations and diversification of

travelling habits, along with "an explosion of available data" will "result in both challenges and opportunities" (Vandervalk, 2021).

Pedestrian, Cyclist, and Micro-Mobility Users as a Priority

Pedestrian, cyclist, and micromobility safety is now a leading concern in urban transport networks. In fact, "we are in the midst of a historic and alarming increase in the number of people struck and killed while walking," according to Transportation for America, a trend rising for 15 years and now at a 30-year high (Dacius, 2024). As cities grow and car use declines, intersection design must evolve to reflect their presence. Outdated, car-centric infrastructure present at the majority of urban intersections in the United States does not address the basic safety needs of non-vehicular users (Ionescu, 2024). Dacius (2024) argues "Walk signals are just one example of how our infrastructure prioritizes the speed of vehicles over the safety of other road users. This practice comes at a deadly cost." Until the design process is iterated to protect these groups, the rise of fatalities and severe injuries will continue.

To reverse this trend, cities are redesigning infrastructure to prioritize vulnerable road users. Adjustments to standard urban roads, such as road diets and narrower lanes, reduce vehicle speeds and create safer, more inclusive streets for non-vehicle users (DePaolis, 2024). Countermeasures must accompany physical changes to ensure non-driver safety. To promote pedestrian safety, the Federal Highway Administration (FHWA) advises states to reduce crossing distances and promote predictable crossing patterns at intersections (FHWA, 2013). Geometric adjustments contribute to statistically significant reductions in pedestrian conflict points at signalized intersections, particularly where vehicle turning movements intersect with foot traffic (Stipanic et. al, 2020). According to The National Association of City Transportation Officials

(NACTO) bicyclists and micro-mobility users benefit from implementation of protected intersections (fig. 1), where "fewer vehicle-bike conflicts than even a dedicated turn lane with a dedicated bike signal phase" occur (NACTO, 2019).

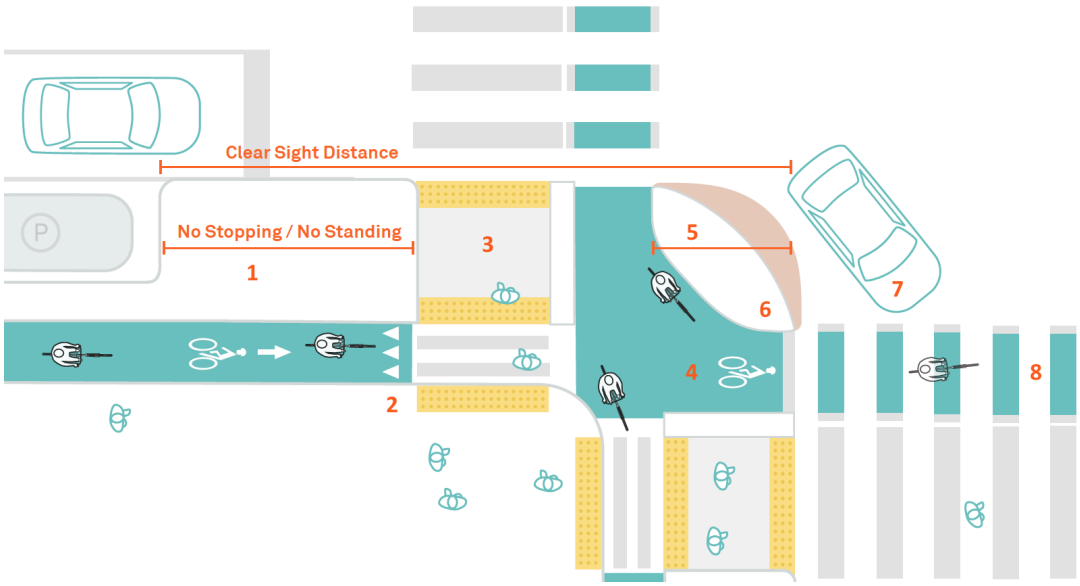

Figure 1. Protected intersection (NACTO, 2019)

National agencies, such as FHWA, and urbanists, represented by groups like NACTO have laid out the framework for non-vehicular focused urban intersection design. Walking and cycling advocacies, such as PeopleForBikes and America Walks, play a vital role in raising awareness of issues in car-centric design and pushing for change. They advocate for complete streets mandates and protected bike lanes, emphasizing that the current system disproportionately favors drivers at the expense of vulnerable road users (PeopleForBikes, n.d.). These policy frameworks offer not just physical protection but institutionalized commitments to equity and safety. Advocacies also aim to influence design and criminal policy through education and legislative action to ensure a tangible impact is left. For example, the Alexandria Bicycle and Pedestrian Advisory Committee urged residents: "Please vote to make the Duke St service road one-way to make the safest possible walking and bicycle route" (ABPAC, 2024). America Walks

speaks consistently on decriminalizing jaywalking, as “it has been proven time and time again that jaywalking laws do not improve pedestrian safety or prevent fatalities” (Freedom To Move, n.d.).

These efforts show a growing consensus: pedestrian, cyclist, and micro-mobility safety must be the priority of urban intersection design. Advocacies and urbanists envision intersections that serve all users, with special protection for the most vulnerable. Their work demonstrates how advocacy and grassroots policy engagement are critical levers for reshaping design practices nationwide.

Sustainable Urban Intersection Design

In a nationwide shift towards a more sustainable way of life, the transportation sector must make progress in reducing pollution. Transportation produced 28% of U.S. greenhouse gas emissions in 2022, more than any other sector. Among transportation modes, light-duty vehicles, which transport passengers, are responsible for 57% of emissions. (EPA, 2024). A significant proportion of light-duty vehicle emissions stem from inefficient, stop-and-go traffic patterns at intersections (Gokhale, 2012). Idling, braking, and congestion at crowded intersections form pollution hotspots. (Pandian et. al, 2009).

Reducing intersection-related emissions requires designs that limit idling and inefficient acceleration. Adaptive signals, which use software to make signal timing adjustments to traffic signals in response to real-time traffic conditions, reduce CO_2 emissions by 16%. They improve travel times while reducing stops and idle periods. (Wu et. al, 2025). Despite advancements in efficiency of signal timing, signalized intersections waste more fuel than free-flowing traffic. Roundabouts reduce idling and promote continuous movement, mimicking free-flowing traffic.

When redesigning intersections as small roundabouts in the Swedish city of Växjö, the result was "an average decrease in CO emissions by 29%, NO_x emissions by 21%, and fuel consumption by 28% per car within the influence area of the junction" (Varhelyi, 2002).

Beyond reducing emissions through traffic control devices, cities must promote transit and non-motorized travel to cut congestion and pollution. Safe and efficient pedestrian, bicycle, and micro-mobility facilities play a large role in reducing vehicle dependency in cities, and must be robust at urban intersections where conflict points are highest (Jones et. al, 2023). Expanding and enhancing public transit will "discourage driving altogether" (We Need to Make Cities Less Car-Dependent, 2024). At urban intersections, inclusion of dedicated bus lanes and priority signals improve transit travel time, encouraging users with lengthy trips to opt for public transportation. (Walsh, 2017). Encouraging users to choose alternate travel modes over automobiles reduces greenhouse gas emissions, as "Life cycle CO_2 emissions decreased by -14% per additional cycling trip and decreased by -62% for each avoided car trip" (Brand et. al, 2021). These behavior changes, when reinforced by design and policy, can shift long-term travel patterns and reduce systemic emissions.

Implementing these sustainable changes, however, often runs into political and institutional barriers. Even when traffic data supports mode-shift interventions, many local governments struggle to balance competing interests. Engineers are frequently asked to deliver safety improvements without reducing mobility, a contradiction that can stall progress (Krajcovic Jr., 2018). Public opposition is another challenge: neighborhood groups sometimes reject intersection redesigns that reduce vehicle space, even when those changes improve walkability and air quality. According to Forde (2024), such conflicts emerge when infrastructure decisions are made without inclusive planning frameworks that account for race, class, and mobility

access. Political will and community trust are crucial to overcoming these hurdles. Sustainable intersection design does not happen in a vacuum—it requires sustained collaboration, strong data communication, and equitable public outreach. Without these components, even the most promising environmental and safety solutions risk being shelved, leaving harmful design norms in place.

It is understood that the transport sector has faced the most challenges in terms of reducing its impacts of fossil energy use and associated greenhouse gas emissions (Brand et. al, 2021). Reduced emissions, improved air quality, and minimal congestion at urban intersections require sustainable transport solutions. Adaptive signals and roundabouts reduce idling and erratic acceleration, conserving fuel use. Better infrastructure for vulnerable users and improved transit reduces car dependence, as "effective interventions are required to reduce car use and change travel behavior to sustainable modes" (Cleland et. al, 2023). Integrating these strategies will help cities meet climate goals while serving all users.

Equitable Urban Intersection Design

Advancements in infrastructure have made possible equitable design choices, where disadvantaged groups can be uplifted at times where they were previously dismissed. However, within urban intersection design, inequalities are still perpetuated (Forde, 2024). For example, "Cycling advocates have recently argued that low-income and minority communities across the U.S. have disproportionately low access to bike lanes" (Braun et. al 2019). The reasoning is nuanced and speaks to the complexity of urban intersection design.

Urban infrastructure projects aimed at improving quality of life often come with unintended social consequences, particularly in the form of gentrification and displacement.

Protected bike lanes and walkable corridors improve safety and mobility, but raise property values (Liu & Shi, 2017). Agyeman and Doran (2021) contend that without equity-focused planning and design, transportation improvements can disproportionately benefit wealthier, often white, demographics while displacing low-income communities. Similarly, Lee et al. (2017) urge planners to integrate equity into transportation planning rather than addressing it as an afterthought.

Cities like Portland, Oregon have seen increased housing costs in areas where extensive bike lane networks were introduced, illustrating how safety and efficiency focused infrastructure projects can accelerate displacement (Liu & Shi, 2017). To prevent this, urban planners and transportation engineers must work in conjunction with policymakers to pair intersection redesigns with protections for long-term residents who are at risk of being priced-out of their home. Ensuring local economic inclusion before undergoing infrastructure implementation and improvement helps ensure "local policies stabilize current residents, ensure they benefit from expanded opportunity, and protect them from displacement" (Dorazio, 2022).

Accessible intersections ensure safe, independent travel for people with disabilities (ADA National Network, n.d.). The Americans with Disabilities Act mandates accessible infrastructure for individuals with disabilities in all scopes of urban living (ITE, 2015). Thus, newly designed urban intersections are required to be accessible to all.

However, "design characteristics of existing physical elements of public spaces are often found not to comply with accessibility guidelines. Height differences, limited widths, and excessive slope gradients are common factors for the observed incongruence." (Kapsalis et. al, 2022). These flaws create barriers for users with visual or mobility impairments.

Design decisions must also account for how historical disinvestment has shaped current infrastructure and access disparities. Equity in urban intersection design requires a proactive approach that minimizes unintended social consequences such as gentrification, displacement, and accessibility barriers. Policies that protect existing and disadvantaged residents must be paired with countermeasures that enhance mobility and safety. Cleland et al. (2023) suggests that equity goals are most likely to be achieved when paired with community-based engagement strategies, which help ensure local knowledge is incorporated into design decisions. Integrating equity into intersection design requires collaboration from engineers, planners, policymakers, and community members.

Final Thoughts

Urban intersection design extends beyond managing traffic, and reflects how cities prioritize safety, mobility, sustainability, and equity. As pedestrian and cyclist incidents rise, congestion and emissions worsen, and social consequences increase, cities must rethink intersection design to meet the diverse needs of all users.

Advocacies, technical specialists, and policymakers must work in tandem to develop solutions and countermeasures that serve the needs of all users equitably. While engineers and policymakers drive technical design decisions, community groups ensure such designs align with the needs of users, particularly those who have been disadvantaged by urban infrastructure design in the past. It is imperative to consider a comprehensive approach that balances safety measures, sustainable transportation options, accessibility and equity for all. Enhancing safety and connectivity amongst a community starts at urban intersections, and does not have to come at the cost of efficiency and mobility.

Future urban intersection design success will rely on the ability to integrate all priorities without sacrificing one for another. A holistic approach that recognizes transportation as a social, technical, and environmental issue is necessary to reshape urban intersection design as cities are reshaped around their most critical transportation nodes. This will require continuous evaluation, adaptation, and collaboration across sectors as urban needs and technologies evolve.

References

ABPAC (2024). Alexandria Bicycle & Pedestrian Advisory Committee. Action Alert: Duke Street. alexandriabpac.org/action-alerts/action-alert-duke-service-road/.

ADA National Network. (n.d.). The ADA & Accessible Ground Transportation. adata.org/factsheet/ADA-accessible-transportation

Agyeman, J., & Doran, A. (2021, December 1). "You Want Protected Bike Lanes, I want Protected Black Children. Let's Link": Equity, Justice, and the Barriers to Active Transportation in North America. *Local Environment, 26(12)*, 1480 - 1497.

Brand, C., Dons, E., & Anaya-Boig, E. *et. al.* (2021, April). The climate change mitigation effects of daily active travel in cities. *Transportation Research Part D: Transport and Environment, 93.* doi.org/10.1016/j.trd.2021.102764.

Braun, L. M., Rodriguez, D. A., & Gordon-Larsen, P. (October 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. *Transportation Geography, 80*. doi.org/10.1016/j.jtrangeo.2019.102544.

Cervero, R., & Kockelman, K. (1997, September). Travel Demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment, 2(3),* 199-219. doi.org/10.1016/S1361-9209(97)00009-6.

Cleland, C. L., Jones, S., & Moeinaddini, M. *et. al*. (2023, July). Complex Interventions to reduce car use and change travel behaviour: An umbrella review. *Journal of Transport & Health, 31*. doi.org/10.1016/j.jth.2023.101652.

CI Committee (2022, June). Connected Intersections Committee. Connected Intersections Implementation Guide. Institute of Traffic Engineers, American Association of State Highway and Transportation Officials, National Electrical Manufacturers Association, and SAE International. ite.org/ITEORG/assets/File/Standards/CTI%204501v0101.pdf.

Dacius, I. (2024, March 26). Rethinking the intersection to prioritize safety over speed. Transportation for America. t4america.org/2024/03/26/rethinking-the-intersection-to-prioritize-safety-over-speed/.

DePaolis, J. (2024, February 22). *The Path to Safety: How Road Diets Can Save Lives*. American Planning Association. planning.org/planning/2024/feb/the-path-to-safety-how-road-diets-can-save-lives.

Dorazio, J. (2022, September 26). Localized Anti-Displacement Policies. Center for American Progress. americanprogress.org/article/localized-anti-displacement-policies/.

EPA (2024). Environmental Protection Agency. *Fast Facts on Transportation Greenhouse Gas Emissions.* epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions.

FHWA (2013). U.S. Federal Highway Administration. *Pedestrian Accommodations at Intersections*. safety.fhwa.dot.gov/ped_bike/univcourse/pdf/swless15.pdf.

FHWA (n.d.). U.S. Federal Highway Administration. *Module 4: Effects of Traffic Calming Measures on Motor Vehicle Speed and Volume*. highways.dot.gov/safety/speed-management/traffic-calming-eprimer/module-4-effects-traffic-calming-measures-motor.

Forde, S. (2024, April). Spatial intersectionality and transformative justice as frameworks for equitable urban planning in divided and post-conflict cities. *Cities, 147.* doi.org/j.cities.2024.104796.

Freedom To Move (n.d). America Walks. americawalks.org/campaigns/freedom-to-move/.

Gokhale, S. (2012, January). Impacts of traffic-flows on vehicular-exhaust emissions at traffic junctions. *Transportation Research Part D: Transport and Environment, 17(1),* 21-27. doi.org/10.1016/j.trd.2011.08.006.

Ionescu, D. (2024, March 7). The Harms of a Car-Centric World. Planetizen. planetizen.com/news/2024/03/127770-harms-car-centric-world.

ITDP (2022). Institute for Transportation & Development Policy. itdp.org.

ITE (2015). Institute for Transportation Engineers. *ADA and Pedestrian Considerations.* toolkits.ite.org/uiig/ada.aspx.

Kapsalis, E., Jaeger, N., & Hale, J. (2022). Disabled-by-design: effects of inaccessible urban public spaces on users of mobility assistive devices – a systematic review. *Disability and Rehabilitation: Assistive Technology*, *19*(3), 604–622. doi.org/10.1080/17483107.2022.2111723.

Krajcovic Jr., R. (2018, February, 15). 5 Traffic Engineering Strategies For Safer Urban Intersections. GAI Consultants. gaiconsultants.com/5-traffic-engineering-strategies-for-urban-intersections/.

Lee, R. J., Sener, I. N., & Jones, S. N. (2016). Understanding the role of equity in active transportation planning in the United States. *Transport Reviews*, *37*(2), 211–226. doi.org/10.1080/01441647.2016.1239660.

Liu, J. H., & Shi, W. (2017). Impact of Bike Facilities on Residential Property Prices. Portland State University. web.pdx.edu/~jbroach/537/readings/cba/Liu%20and%20Shi%20(2017)%20-%20Impact%20of%20Bike%20Facilities%20on%20Residential%20Property%20Prices%20(TRR)_stamped.pdf

NACTO (2019). National Association of City Transportation Officials. *Don't Give Up at the Intersection: Designing All Ages and Abilities Bicycle Crossings*. nacto.org/publication/dont-give-up-at-the-intersection/protected-intersections.

NACTO (n.d.). National Association of City Transportation Officials. *Intersection Design Principles.* nacto.org/publication/urban-street-design-guide/intersections/intersection-design-principles/.

Newman, Peter & Kenworthy, Jeffrey. (2015). The End of Automobile Dependence: How Cities Are Moving Beyond Car-Based Planning. 10.5822/978-1-61091-613-4. researchgate.net/publication/329311386_The_end_of_automobile_dependence_How_cities_are_moving_beyond_car-based_planning.

PeopleForBikes (n.d.). *Legislative Strategies for Safe and Connected Bike Infrastructure.* prismic-io.s3.amazonaws.com/peopleforbikes/f06c92ca-0ad5-41e4-97b5-bc26090639f6_PeopleForBikes-Great-Bike-Infrastructure-Project-Legislative-Guide.pdf.

Pandian, S., Gokhale, S., & Ghoshal, A. K. (2009, May). Evaluating effects of traffic and vehicle characteristics on vehicular emissions near traffic intersections. *Transportation Research Part D: Transport and Environment, 14(3),* 180-196. doi.org/10.1016/j.trd.2008.12.001.

Red Lights are Air Pollution Hot Spots (2015, February 24). University of Utah Health. healthcare.utah.edu/healthfeed/2015/02/red-lights-are-air-pollution-hot-spots.

Roshandeh, A. M., Li, Z., Zhang, S., Levinson, H. S., & Lu, X. (2016, February). Vehicle and pedestrian safety impacts of signal timing optimization in a dense urban street network. *Journal of Traffic and Transportation Engineering (English Edition), 3(1),* 16-27. doi.org/10.1016/j.jtte.2016.01.001.

Shilpa, R. N., & Bhavathrathan, B. K. (2024, September). Incorporating inconsistency patterns on road networks into crash modeling. *Analytic Methods in Accident Research, 43.* doi.org/10.1016/j.amar.2024.100340.

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

CRD (2020, Feb. 24). Civil Rights Division, U.S. Department of Justice. The ADA and City Governments: Common Problems. Guidance and Resource Management. ada.gov/resources/ada-city-governments/.

Vandervalk, A. (2021, February, 17). Balancing Mobility and Safety at Intersections. iteris. iteris.com/blog/balancing-mobility-and-safety-intersections.

Varhelyi, A. (2002, January). The effects of small roundabouts on emissions and fuel consumption: a case study. *Transportation Research Part D: Transport and Environment, 7(1),* 65-71. doi.org/10.1016/S1361-9209(01)00011-6.

Walsh, D. (2017, December 13). Reducing our reliance on cars: The shifting future of urban transportation. Massachusetts Institute of Technology Sloan School of Management. mitsloan.mit.edu/ideas-made-to-matter/reducing-our-reliance-cars-shifting-future-urban-transportation.

We Need to Make Cities Less Car-Dependent. (2024, April 16). Scientific American. scientificamerican.com/article/we-need-to-make-cities-less-car-dependent/.

Welle, B., Liu, Q., Li, W., Adriazola-Steil, C., King, R., Sarmiento, C., Obelheiro, M. (2015, July 23). Cities Safer by Design. World Resources Institute. publications.wri.org/citiessafer/

Whaley, B. A., Martinis, J. G., Pagano, G. F., Barthol, S., Senzer, J., Williamson, P. R., & Blanck, P. D. (2024). The Americans with Disabilities Act and Equal Access to Public Spaces. *Laws*, *13*(1), 5. doi.org/10.3390/laws13010005.

Wu, K., Ding, J., Lin, J. *et al.* (2025, February 27). Big-data empowered traffic signal control could reduce urban carbon emission. *Nat Commun 16*. doi.org/10.1038/s41467-025-56701-4.

Zhang K., & Batterman S. (2013, April 15). Air pollution and health risks due to vehicle traffic. *Science of The Total Environment, 450-451,* 307-316. doi.org/10.1016/j.scitotenv.2013.01.074.

Zhang, C., Du, B., Zheng, Z., & Shen, J. (2023, March). Space sharing between pedestrians and micro-mobility vehicles: A systematic review. *Transportation Research Part D: Transport and Environment, 116.* doi.org/10.1016/j.trd.2023.103629.