Undergraduate Thesis Prospectus

Retrofitting the Otterdale Branch Bridge for Flooding and Other Hazards

(Technical Research Project in Civil Engineering)

Competing Priorities in U.S. Urban Intersection Design

(Sociotechnical Research Project)

By

Joshua Frye

November 8, 2024

Technical Project Collaborators:

Logan Brock
Amel Marzougui
Sullivan Higgins
Niko Bousquet

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

Joshua Frye

Technical Advisor: Jonathan L. Goodall, Department of Civil and Environmental Engineering

STS advisor: Peter Norton, Department of Engineering and Society

General Research Problem

How can U.S. transportation infrastructure policy optimally balance competing imperatives?

Optimized U.S. transportation infrastructure development is crucial for economic growth and public safety. In 2023, federal spending on transportation totaled 126.3 billion dollars (USAFacts, n.d.). Traffic fatalities, which account for 98% of deaths tied to transportation infrastructure, reached 40,990 in 2023–a 25% increase from 32,892 a decade ago (TripNet, 2024). This rise in fatalities highlights challenges in decision-making and the need for collaboration.

Policymakers, engineers, and advocacies must navigate competing priorities in transportation system management. Balancing safety, durability, operability, and cost is difficult when stakeholders have diverging interests. These conflicts impact project outcome and user trust in infrastructure, with public health and well-being at stake (FHWA, 2013). A holistic approach integrating technical expertise, policy, and community engagement is essential for developing and maintaining infrastructure that meets diverse needs.

Enhancing Flood Resilience and Safety of the Otterdale Branch Bridge

How can the bridge over Otterdale Branch along Otterdale Road best be prepared for flooding and other hazards?

The technical project aims to improve roadway safety and reduce flood risk through hydrological analysis and bridge structure redesign. The project is advised by Jonathan Goodall, with collaboration from Logan Brock, Amel Marzougui, Sullivan Higgins, and Niko Bousquet in the Civil Engineering Department. It is a capstone project within the Civil Engineering Capstone course.

Otterdale Road, a two-lane, undivided roadway crossing Otterdale Branch, was originally a rural collector for a rural population. In 2022, the road saw an Average Daily Traffic (ADT) of 3,800 vehicles per day (VDOT, 2022). It serves as a local connector, providing access to Virginia State Route 604 (Genito Road) north and U.S. Route 360 (Hull Street Road) south of Otterdale Branch. Multiple residential developments rely on Otterdale Road for access to necessities. In recent years, "flooding along Otterdale Road has occurred during periods of heavy rainfall leaving neighborhoods completely landlocked" (VLWA, 2022). The road's geometry has also raised safety concerns due to sudden narrowing and poor sight distance (Hipolit, 2018). At a Chesterfield County Board of Supervisors meeting, Otterdale Road was dubbed "suicide road" (Chesterfield County Board of Supervisors, 2005).

The primary goal is to design a bridge structure and roadway alignment that withstands severe flood events and enhances safety. The two existing box culverts will be replaced with a bridge that can handle stormwater from a 100-year storm event, or a rainfall event with a 1% annual chance of occurrence. The redesigned roadway will tie into the new bridge structure at an elevation to keep Otterdale Road operational during severe storms. The project must comply with federal, state, and local constraints, as floodplain management is crucial for regulation compliance. The design will adhere to Federal Emergency Management Agency (FEMA) standards for Zone A floodplains, ensuring that significant storm events do not threaten surrounding infrastructure. It must also integrate with existing roadway geometry, meeting Virginia Department of Transportation (VDOT) standards for lane width, shoulder design, and guardrail installation. A wetland impact assessment will evaluate the redesign's effect on local ecosystems and recommend necessary mitigations in compliance with the Clean Water Act.

Achieving these goals while adhering to project constraints requires leveraging softwares and innovative approaches.

Hydrologic Engineering Centers River Analysis System (HEC-RAS) and Hydrologic Engineering Centers Hydrologic Modeling System (HEC-HMS) are softwares that simulate stormwater flow to assess the performance of existing and proposed bridge structures. OpenRoads Designer is a roadway design software that uses elevation data to aid in the design of roadway alignments. These softwares will be used in the technical project to redesign Otterdale Road as it crosses Otterdale Branch. Despite software advancements, challenges remain, particularly with hydrodynamic forces on bridge safety (Tubaldi et al., 2022). The Federal Highway Administration (FHWA) has adopted equations to determine the forces of drag, lift, and moments acting on the bridge deck based on stormwater properties and bridge configuration, which will be implemented once the bridge structure is finalized (FHWA, 2009). Traffic rerouting during construction will be planned based on community feedback through outreach surveys. Traffic Synchro is a traffic simulation software that can simulate peak-hour conditions and evaluate delay and level of service (LoS) at intersections, optimizing signal timing splits. Similarly, PTV Vistro will simulate traffic in both existing and construction scenarios. It will assess delay and LoS for each scenario during AM and PM peak hours, optimizing signal timing if unusual delays are observed at study intersections.

The Otterdale Branch bridge redesign will improve roadway safety and flood resilience for Chesterfield County Residents. An informational guide will be created, providing stormwater model data, roadway and bridge redesigns, and traffic re-routing plans during construction. This guide will keep residents informed about construction timelines and how to navigate Otterdale Road, maintaining transparency between designers and users.

Competing Priorities in U.S. Urban Intersection Design

In the U.S., how are walking and cycling advocacies, urbanists, transportation engineers, local governments, and NACTO competing to determine how pedestrians, cyclists, and motorists will be prioritized at busy urban intersections?

Urban intersections are critical nodes where congestion and safety must be balanced to optimize connectivity throughout the city. As roadway networks expand, competing priorities make transportation planning complex. Understanding how these groups influence design decisions is key to improving safety and mobility at urban intersections, where "walking, biking, and driving interact most" (Engel, 2019).

Advocacies demand protected bike lanes and crossings, but Agyeman and Doran (2021) and Lee et al. (2017) contend that such infrastructure can perpetuate inequalities, largely in low-income areas. Gentrification often follows urban renewal, raising the question: "Who was the bike lane intended to serve?" Former Bicycle Transportation Alliance member Gerik Kransky contends that "bike lanes that are physically separated from moving traffic by parked cars- are harder to sell politically because they tend to cater to a certain demographic" (Roberts, 2014). However, countermeasures like protected crossings and bike lanes are crucial for reducing fatalities. To achieve equity and safety in urban intersection design, planners must take competing interests into account (Chauhan et al., 2024).

Walking and cycling advocacies, such as PeopleForBikes and America Walks, demand intersection designs that accommodate people who are not in vehicles. They advocate for complete streets mandates and protected bike lanes (PeopleForBikes, n.d.). For example, the Alexandria Bicycle and Pedestrian Advisory Committee urges residents: "Please vote to make

the Duke St service road one-way to make the safest possible walking and bicycle route" (ABPAC, 2024). This would ensure walking and cycling safety is prioritized at the expense of drivers' convenience. Urbanists, represented by groups like the American Planning Association (APA) and National Association of City Transportation Officials (NACTO), advocate for sustainable, walkable cities. They promote infrastructure changes like road diets and narrower lanes, which reduce vehicle speeds and create safer, more inclusive streets for non-vehicle users (DePaolis, 2024). NACTO also supports protected intersections (fig. 1), where "fewer vehicle-bike conflicts than even a dedicated turn lane with a dedicated bike signal phase" occur (NACTO, 2019).

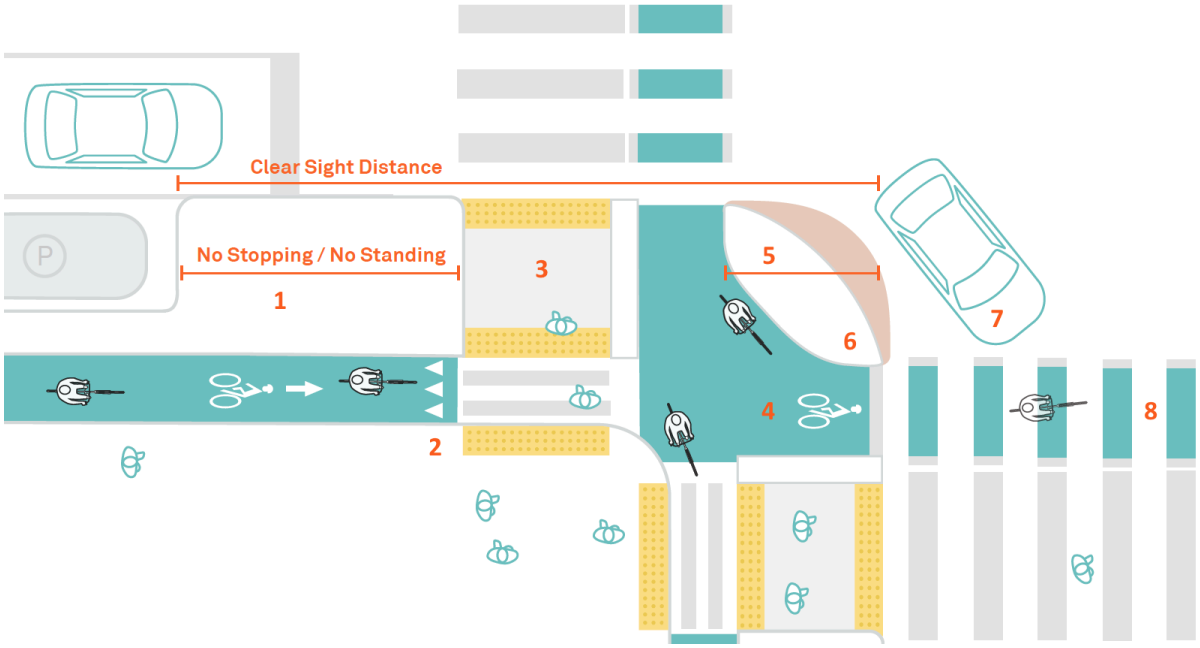

Figure 1. Protected intersection (NACTO, 2019)

Transportation engineers, represented by groups like the American Society of Civil Engineers (ASCE) and the Institute of Transportation Engineers (ITE), ensure urban intersection design designs meet roadway and accessibility standards. For instance, ASCE's Complete Streets Capability Maturity Model helps agencies improve strategies for safer, more inclusive roadway

design (Jordan et al., 2021). To promote pedestrian safety, the FHWA advises states to improve visibility, reduce crossing distances, and promote predictable crossing patterns at intersections (FHWA, 2013).

References

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.

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

Chesterfield County Board of Supervisors (2005, May 19). Matoaca Magisterial District (minutes). documents.chesterfield.gov/Weblink_BOS/DocView.aspx?dbid=0&id=4550&page=47&cr=1

Chauhan, S., Dave, S., Shah, J., & Kedia, A. (2024, May 15). Assessing Traffic Characteristics for Safe Pedestrian Crossings: Developing Warrants for Sustainable Urban Safety. *Sustainability (2071-1050), 16(10)*, 4182 - 4198.

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

Engel, L. (2019, May 20). *Don't Give Up at the Intersection: NACTO Releases Best Practices for Next-Generation Street Intersection Design.* National Association of Transportation Officials nacto.org/2019/05/20/dont-give-up-at-the-intersection

FHWA (2009, May). U.S. Federal Highway Administration. *Hydrodynamic Forces on Inundated Bridge Decks*. fhwa.dot.gov/publications/research/infrastructure/hydraulics/09028/002.cfm

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

Hipolit, M. (2018, December 18). In booming Chesterfield, families are concerned about dangers of Otterdale Road. WTVR. wtvr.com/2018/12/18/in-booming-chesterfield-families-are-concerned-about-dangers-of-otterdale-road

Jordan, S. W., Ivey, S., Levy, M., Lipinski, M., Palazolo, P., & Waldron, B. (2021, December 01). Complete Streets: A New Capability Maturity Model. American Society of Civil Engineers. doi.org/10.1061/(ASCE)UP.1943-5444.0000812

Lee, R. J., Sener, I. N., & Jones, S. N. (2017, March 1). Understanding the role of equity in active transportation planning in the United States. *Transport Reviews, 37(2)*, 211 - 226.

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

Roberts, L.E. (2014, May). 'Bike Lanes are White lanes!': The Social Implications of Urban Active Transportation Planning in the Built Environment of Portland, OR. jimproctor.us/archive/envs/wp-content/uploads/sites/24/2016/04/RobertsFinalThesis.pdf

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

TripNet (2024, July 2). News Release: 2023 U.S. Traffic Fatalities 25 Percent Higher than a Decade Before, Despite Dropping Each Year Since 2021. tripnet.org/reports/addressing-americas-traffic-safety-crisis-national-news-release-07-02-2024

Tubaldi, E., White, C. J., Patelli, E., Mitoulis, S. A., de Almeida, G., Brown, J., Cranston, M., Hardman, M., Koursari, E., Lamb, R., McDonald, H., Mathews, R., Newell, R., Pizarro, A., Roca, M., & Zonta, D. (2022, March 10). Invited Perspectives: Challenges and Future Directions in Improving Bridge Flood Resilience. National Hazards and Earth System Sciences. nhess.copernicus.org/articles/22/795/2022/nhess-22-795-2022.pdf

USAFacts (n.d.). What does America spend on transportation and infrastructure? Is infrastructure improving? usafacts.org/state-of-the-union/transportation-infrastructure

VDOT (2022). Virginia Department of Transportation. Virginia Bidirectional Traffic Volume Map (map). arcgis.com/apps/mapviewer/index.html?webmap=bff29e1bc0fd4908b2c035fe67695088

VLWA (2022, January 28). Virginia Lakes and Watersheds Association. Otterdale Road Drainage Improvement Project. vlwa.org/abstracts_archive/otterdale-road-drainage-improvement-project