TRANSPORTATION RESEARCH

CIRCULAR

Number E-C301 May 2025

Access Management

Safety and Design from the Curb to the Interchange for All Users

June 24–26, 2024
Boston, Massachusetts

NATIONAL ACADEMIES *Sciences Engineering Medicine*

TRB TRANSPORTATION RESEARCH BOARD

TRANSPORTATION RESEARCH CIRCULAR E-C301

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Transportation Research Board
500 Fifth Street, NW
Washington, D.C.
www.trb.org

TRANSPORTATION RESEARCH CIRCULAR E-C301
ISSN 0097-8515

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Introduction and Preface

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This publication contains extended abstracts from selected presentation presented at the Transportation Research Board (TRB) 4th International/13th National Conference on Access Management, held June 24–26, 2024, in Boston, Massachusetts. The conference was sponsored by the TRB Standing Committee on Access Management and hosted by the Massachusetts Department of Transportation (DOT).

Special thanks to the Conference Chair, Lionel Lucien (Massachusetts DOT) and the Conference Co-Chair, John Karachepone (Kimley-Horn and Associates), and numerous other volunteers for their efforts in planning and organizing the conference. Although we had several delays in hosting the conference due to the COVID-19 pandemic, the conference was a huge success. Thank you as well to our co-sponsoring committees, the Standing Committee on Performance Effects of Geometric Design, the Standing Committee on Safety Performance and Analysis, the Standing Committee on Strategic Management, and the International Coordination Council.

The first International Conference on Access Management was held in Athens, Greece in 2011; the 2nd International Conference was held in Shanghai, China, in 2014; and the 3rd International Conference was held in Pretoria, South Africa, in 2016. In addition to the International Conferences, 12 previous national conferences on access management have been held throughout the United States, most recently in Madison, Wisconsin, in 2018.

The 4th International Conference on Access Management provided a global forum to exchange ideas and information related to access management. Access management is defined as “the coordinated planning, regulation, and design of access between roadways and land development.” Typical highways in the United States, and to a lesser extent across the world, face access problems due to linear development, frequent driveway access, lack of supporting networks, frequent traffic signals, lack of raised medians or frequent median openings, no consideration of pedestrians or bicycles, and crashes, congestion, and poor aesthetics. Access management is designed to enhance mobility with reduced conflict and improved safety for all modes.

The goals of access management are to

1. Provide access to developed land, while maintaining the safe and efficient movement of people and goods.
2. Minimize and separate conflict points on the roadway system, along the curb, and at the interface of travel modes.
3. Achieve a roadway hierarchy that is designed and managed according to its planned function and land use context.

Examples of access management techniques include a wide range of treatments such as

- Limiting and separating driveways along major roadways through access spacing standards.
- The use of median treatments to limit left turns and provide mid-block pedestrian crossings on busy roads.
- Locating traffic signals to support signal coordination and efficient traffic progression.
- Providing right- and left-turn deceleration and storage lanes to remove turning vehicles from through lanes.
- Restricting driveways in the vicinity of signalized intersections and interchanges.
- Providing internal bus transit access to development.
- Providing direct sidewalk connects to transit and safe midblock crossing locations.
- Installing measures to reduce on-site circulation conflicts between pedestrians and motor vehicles.
- Requiring pedestrian and vehicular connections between adjacent businesses to allow internal circulation.
- Promoting mixed-use activity centers with unified on-site circulation and access.

The conference included a wide range of workshops, technical sessions, and poster sessions covering many of these topics. This e-circular begins with a summary of the conference's keynote address then provides 12 extended abstracts from attendees. The opportunity to publish abstracts was provided to all presenters, and the selection included in this publication are those which were submitted.

Attendance at the conference included 200 experts, researchers, and practitioners from across the United States as well as several international participants. Attendees represented federal, state, and local public governmental agencies; private contractors and consultants; universities and colleges; and nongovernmental organizations.

PUBLISHER'S NOTE

Keynote Summary

Luisa Paiewonsky, Director of the Center for Infrastructure Systems and Technology at the US DOT's Volpe Center and former Massachusetts DOT Highway Administrator was the luncheon keynote speaker at TRB's Access Management Conference in Boston on June 24, 2024.

She opened by providing some background on the US DOT's Volpe Center, located in Cambridge, Massachusetts. Named for former Massachusetts Governor and former US Secretary of Transportation John Volpe, the Volpe Center is a federal organization that provides world-renowned, multidisciplinary, multimodal transportation expertise on behalf of US DOT. As part of the US Secretary of Transportation's office, Volpe's nearly 700 federal transportation professionals provide expertise, deployment and testing, research and analysis to other US DOT agencies, the Department of Defense and other federal agencies, international state and local governments, academia, and industry. Volpe's extensive cross-modal partnerships have led to innovative solutions that advance national and global transportation systems.

Paiewonsky noted that while reviewing the Access Management Conference's agenda it was clear to her that the field of access management has changed since she served as manager of Massachusetts DOT's Public–Private Development Unit many years ago. While the fundamentals—safety, traffic impacts, and infrastructure implications—remain as key considerations in project reviews and negotiations, the practice of access management is more collaborative, encourages more involvement by developers, has a more multimodal focus, and more explicitly considers equity, climate resilience and other factors in its assessments of impacts. There is also more focus on communicating the value of access management, an effort that helps the public as well as developers, state DOTs communities appreciate the broader goals that access management aims to achieve.

These changes are reflected in the broader changes in transportation itself, as many agencies have shifted from focusing purely on infrastructure to considering safety and reliable mobility as part of their core mission. The profession, as with access management, has become more mobility-focused, collaborative multimodal, and technology-enhanced. This broader approach may be seen in access management decision-making as bicycle and pedestrian accommodation, subsidized transit, and electric vehicle chargers begin to appear in packages of mitigation strategies. This ensures that state DOTs can advance their infrastructure and mobility goals while engaging meaningfully with developers and business organizations to promote vital land use and development.

Paiewonsky also addressed the “remarkable advances in transportation technologies” over the past 20 to 30 years. She observed that it is easy to forget how much has changed since many of those attending the conference started their careers, e.g., using paper-based systems, vehicles with hand-cranked windows, and minimal electronics. Tolls were collected one-by-one, alternatively fueled vehicles were on the distant horizon, and high numbers of crash fatalities seemed to be an intractable problem.

Since then, advances in computing and sensing technologies that that made it possible to transform surface transportation and offer new possibilities for a safer and more efficient transportation system. As millions of Americans became familiar with personal technologies and wi-fi networks and cloud technologies grew, new opportunities emerged to connect vehicles to one another and to infrastructure itself with tremendous potential to improve highway safety. Now, transportation technologies have not only made our work lives much more efficient, but they have also opened new possibilities, such as automated driving, reduced congestion, and even a Vision Zero future for crash fatalities.

Paiewonsky said that many of these advancements are in the vehicle itself, and state DOTs have had to adjust from their traditional focus on what’s underneath the tires, not above. Now, she said vehicles and infrastructure are becoming connected to the point where it will be necessary to broaden focus to consider new possibilities for improving mobility. She described technologies with potential or demonstrated safety benefits, including cooperative driving automation, vehicle-to-infrastructure (VTI), vehicle-to-everything (V2X), pedestrian crash avoidance and mitigation (PCAM) systems, and unmanned aerial systems (UAS). She added that there will be further advancement of connected and automated vehicle technologies, with potential expanded use of artificial intelligence (AI) to support safety efforts, and a continuation of automated and connected vehicle research.

Paiewonsky noted that there are challenges that accompany the rapid advance of transportation technologies. Just keeping up with the constant introduction of new technologies and deciding which are practical in their environment can be difficult for agencies responsible for operating and building transportation systems. She added that not all technologies would be useful in all areas of a state or region; for example, some may be more useful in urban data-rich environments than in rural areas with fewer data inputs. Agencies must also weigh the benefits of new technologies against the training, staffing, and funding implications.

Returning to her earlier description of increased collaboration in the transportation profession, Paiewonsky cited the Partnership for Analytics Research in Traffic Safety (PARTS). PARTS is a partnership between automakers and the US DOT’s National Highway Traffic Safety

Administration, in which participants voluntarily share safety-related data for collaborative safety analysis. She also noted the Cooperative Automation Research Mobility Applications Program which is leading research on cooperative driving automation, and the work of the US DOT's ITS (Intelligent Transportation Systems) Joint Program Office as examples of collaboration at the federal level.

Paiewonsky concluded by observing that the rapid advance of transportation technologies would not have been possible without cooperation and collaboration among all levels of government, researchers, technology developers, and private-sector partners. Despite occasional differences in perspectives, all share a goal of safe, reliable mobility for all. This holds true for access management as well, given the inherent need for partnership among developers, government agencies, host communities, consultants, and citizens. This type of effort is not without challenges, she said, but it does result in the kind of transportation investments and results we can all be proud of.

Typology-Informed Solutions for Sustainable and Accessible Transportation Networks

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Groupings of cities and systems into typologies of distinct types based on similar characteristics of interest have long been exploited for insights to guide decision-making. Typologies have a long history in architecture, emerging in the 18th century as a tool for understanding building design (*1*), and later adopted in urban planning as a means of conceptualizing design rules and understanding urban form and function (*2–4*). Beyond city function and characteristics, typology analysis has been applied to obtain typologies of urban form (*5*), street patterns (*6*), urban growth (*7*) and mobility networks (*8*). More recently, typology analysis has now been also been used to study patterns in mobility (*9*, *10*), energy consumption (*11*), water accessibility (*12*), bicycle ownership (*13*) at varying scales (census tracts, cities, countries).

The standard typology method, first demonstrated in an application to US cities (*4*), proceeds as follows:

1. Gather relevant features or indicators on observations or items in a population of systems. If the number of features is large, then perform dimensionality reduction, such as factor analysis (*14*) or principal components analysis, to obtain an interpretable low-level factor representation.
2. Apply a clustering algorithm is applied [e.g., *K*-means (*15*), hierarchical methods (*16*), among other variants] to group the items into an ideal number of types based on similarity in the feature space (factors or indicators).
3. Deploy types and their characteristics to perform further analyses or modeling.

Two pertinent questions that arise are can typologies help us better understand our transportation infrastructure, and how can typologies be harnessed to inform decision-making and planning considering ongoing transportation access challenges? In the next two sections, I will present studies that demonstrate how typology analysis can generate insights to guide policy and decision-making efforts for sustainability and accessibility in our cities and on our road networks. I will then close with an overview of the safety challenge and propose a framework for typology solutions regarding access management priorities.

URBAN TYPOLOGY FOR SUSTAINABLE FUTURE MOBILITY

Transportation accounts for about eight $gtCO_2e$ (grams of carbon dioxide equivalent) in global annual emissions, and urban passenger traffic contributes nearly a third of this amount (*9*). In the next quarter century, over two-thirds of the world's population is expected to be urbanized (*17*). This implies that the demand for urban motorized transportation will likely double. If no significant decarbonization of passenger mobility occurs in that timeframe, then emissions from urban passenger traffic will increase by 60%.

In a recent study (*9*), we embarked on a typology analysis of 331 global cities, uncovering underlying factors of urban mobility and sustainability, while creating a framework for type-specific analysis of mobility futures. From 64 variables, nine driving factors of urban sustainability were derived. Based on these, we obtained 12 urban types. Cities fell into groups broadly based on dominant modes (e.g. cars, bus, urban rail, bicycle) and network/congestion outcomes. A map of the cities, type, names, and key examples is given in Figure 1. The study yielded some key insights, including:

- Car-dominant (Auto) city types have the greatest emissions and vehicle ownership but are the least dense and polluted in contrast to the congested types.
- A clear wealth gap persists between the MassTransit and auto cities, and the rest.
- MetroBike cities have both the greatest highway proportion and pollution.
- Most of the cities in the developing, rapidly growing and urbanizing world are congested.

In a series of experiments, we further considered how various automated mobility on demand (AMOD) policies might impact accessibility, congestion and sustainability in Auto and MassTransit cities, specifically, using simulation on prototypical test beds (*18*, *19*). We found that simply introducing AMOD in these cities would worsen congestion and further drive down transit use. However, integrating AMOD as a first–last mile or localized solution could buttress transit use, while increasing accessibility in low-density areas.

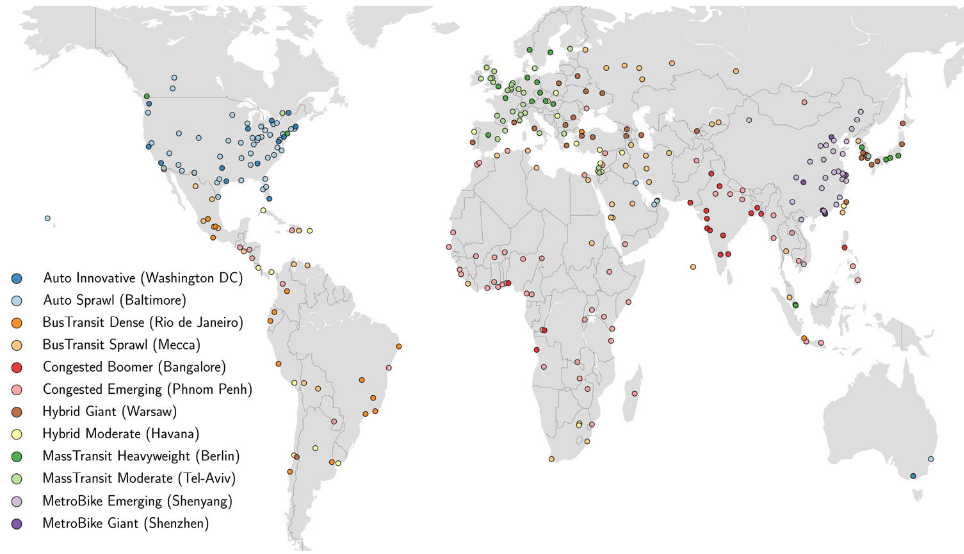

FIGURE 1 Global urban typology map of 331 cities showing their types and key examples.

ROAD NETWORKS AND CONGESTION

Our road networks are essential for effective, accessible and equitable deployment mobility of people and goods. The United States constitutes 6% of the world's landmass, yet accounts for 16% of the 40 million mi of global road inventory (*20*). Consequently, roadway emissions comprise 25% of the US total (*21*), while globally, the roadway share of emissions about 15% (*22*). Congestion is also a major issue, with impacts ranging from air pollution and emissions to quality of life and economic losses. However, simply expanding road networks has not solved congestion. For instance, from 1993 to 2017, freeway miles across the top 100 urban areas in the US increased by 40% while population grew by 30% but congestion by 140% (*23*). Demand for personal mobility is only expected to grow. In an ongoing study, we obtained 18 road network indicators from 372 metropolitan statistical areas (MSAs) in the US. After conducting dimensionality reduction and clustering, we obtained four road network types, which we list below with key examples and descriptors:

- Type 1. Small Dense (e.g., Worcester, Massachusetts–Connecticutt; Grand Rapids, Michigan).
- Type 2. Circuitous Sparse (e.g., Portland, Maine; Tallahassee, Florida).
- Type 3. Large Dense (e.g., Austin, Texas; Boston, Massachusetts; San Francisco, California).

- Type 4. Connected Sparse (e.g., Des Moines, Iowa; Fargo, North Dakota; Syracuse, New York).

A map of the MSAs showing their type, along with boxplots of selected characteristics are shown in Figure 2. We observe that certain types are predominant in various regions of the country. Denser networks (Types 1 and 3) tend to be found more in the eastern half of the country. Connected and sparse networks (Type 4) are predominantly found in the midwestern region. Circuitous and sparse networks (Type 2), however, appear to be evenly distributed across the country.

This proposed road network typology can be harnessed to provide further insights into congestion patterns, explore access management policies and processes and ultimately facilitate decision-making for sustainable policy improvements. Through this framework, planners and researchers can examine type-specific cities with historical data and outcomes of interest and use insights gained to guide efforts in other cities.

ROADWAY SAFETY

Road traffic crashes are the leading cause of death for people in the 5-to-29-year age range. In 2021, 1.2 million people died in roadway crashes. While this is a 5% decline compared to 2010, vulnerable road users (pedestrians, two-/three-wheelers, cyclists) are still significantly affected,

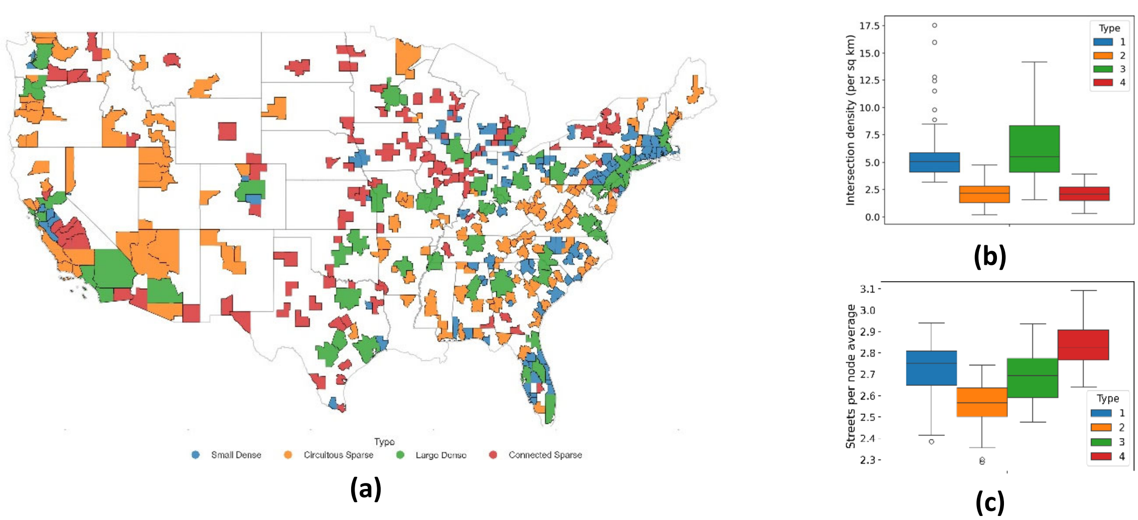

FIGURE 2 (*a*) Map of 372 MSAs in the United States, showing their road network type; (*b*) boxplot of intersection density by type; and (*c*) boxplot of streets per node average (measuring sparsity) by type.

as they account for 50% of the fatalities recorded. The fact that 92% of global roadway deaths occur in low- and middle-income countries indicates that the poor still bear a greater part of the safety burden (*24*). In the United States, vulnerable roadway users accounted for one-third of road traffic fatalities, as of 2021 (*25*). Yet, there is an urban–rural divide, as 44% of fatalities were vulnerable users in urban areas, whereas 19% was the share in rural areas. Furthermore, two-thirds of communities in the top 20% of fatalities are transportation disadvantaged, which are defined as:

> *Census tracts that are or above the 90th percentile for diesel particulate matter exposure OR transportation barriers OR traffic proximity and volume AND are at or above the 65th percentile for low income (*26*).*

We are currently investigating (*27*) how a typology of census tracts based on high-dimensional dataset of spatiotemporal crash characteristics can generate novel insights into crash patterns and provide decision support for mitigation.

OUTLOOK AND THE CASES FRAMEWORK

In an age of artificial intelligence, e-commerce, looming mobility automation and climate change, there are several opportunities for the access management subfield. There are three key emerging areas: decarbonization, fairness, and micromobility. I posit that typology analysis can uncover groups at multiple scales (from census tracts to regions) that can yield novel insights and provide efficient frameworks to explore relationships and design experiments. Further, I propose five specific challenges that typology analysis can impact: **C**ongestion, **A**ccessibility, **S**ustainability, **E**quity and **S**afety (CASES). By focusing typology analysis on the CASES, we can speed up policy learning and guide decision-makers to appropriately generate and replicate successful access management policies in their locales.

REFERENCES

1. Güney, Y. Type and Typology in Architectural Discourse. *BAUFBE Dergisi*, Vol. 9, No. 1, 2007, pp. 3–18.
2. Harris, C. D. A Functional Classification of Cities in the United States. *Geographical Review,* Vol. 33, No. 1, 1943, pp. 86–99. https://www.jstor.org/stable/210620. Accessed July 23, 2023.
3. Atchley, R. C. A Size-Function Typology of Cities. *Demography,* Vol. 4, No. 2, 1967, pp.

721–733.

4. Bruce, G. D., and R. E. Witt. Developing Empirically Derived City Typologies: An Application of Cluster Analysis. *The Sociological Quarterly*, Vol. 12, No. 2, 1971, pp. 238–246. https://www.jstor.org/stable/4105715. Accessed July 23, 2023.
5. Txomin Hermosilla, T., J. Palomar-Vázquez, A. Balaguer-Beser, J. Balsa-Barreiro, and L. A. Ruiz. Using Street Based Metrics to Characterize Urban Typologies. *Computers, Environment and Urban Systems*, Vol. 44, 2014, pp. 68–79. https://www.sciencedirect.com/science/article/pii/S0198971513001166. Accessed July 23, 2023.
6. Louf, R., and M. Barthelemy. A Typology of Street Patterns. *Journal of the Royal Society Interface,* Vol. 11, No.101, 2014, p. 20140924. https://royalsocietypublishing.org/.doi/10.1098/rsif.2014.0924. Accessed July 23, 2023.
7. Mahtta, R., A. Mahendra, and K. C. Seto. Building Up or Spreading Out? Typologies of Urban Growth Across 478 Cities of 1 Million+. *Environmental Research Letters*, Vol. 14, No. 12, 2019, p. 124077. https://dx. doi.org/10.1088/1748-9326/ab59bf. Accessed July 23, 2023.
8. Louail, T., M. Lenormand, M. Picornell, O. García Cantu´, R. Herranz, E. Frias-Martinez, J. J. Ramasco, and M. Barthelemy. Uncovering the Spatial Structure of Mobility Networks. *Nature Communications,* Vol. 6, No. 1, 2015, p. 6007. https://www.nature.com/articles/ncomms7007. Accessed July 23, 2023.
9. Oke, J. B., Y. M. Aboutaleb, A. Akkinepally, C. L. Azevedo, Y. Han, P. C. Zegras, J. Ferreira, and M. E. Ben-Akiva. A Novel Global Urban Typology Framework for Sustainable Mobility Futures. *Environmental Research Letters*, Vol. 14, No. 9, 2019, p. 095006. https://dx.doi.org/10.1088/1748-9326/ab22c7. Accessed March 6, 2023.
10. Popovich, N., C. A. Spurlock, Z. Needell, L. Jin, T. Wenzel, C. Sheppard, and M. Asudegi. A Methodology to Develop a Geospatial Transportation Typology. *Journal of Transport Geography*, Vol. 93, 2021, p. 103061. https://www.sciencedirect.com/science/article/pii/S0966692321001149. Accessed July 4, 2023.
11. Creutzig, F., G. Baiocchi, R. Bierkandt, P.-P. Pichler, and K. C. Seto. Global Typology of Urban Energy Use and Potentials for an Urbanization Mitigation Wedge. *Proceedings of the National Academy of Sciences*, Vol. 112, No. 20, 2015, pp. 6283–6288. https://www.pnas.org/doi/10.1073/pnas.1315545112. Accessed March 6, 2023.
12. Chung, H., E. Kumpel, and J. Oke. Drinking Water Accessibility Typologies in Low- and Middle-Income Countries. *Environmental Research Letters*, Vol. 18 No. 2, 2023, p.

025009. https://dx.doi.org/10.1088/1748-9326/acb662. Accessed June 13, 2023.

13. Oke, O., K. Bhalla, D. C. Love, and S. Siddiqui. Tracking Global Bicycle Ownership Patterns. *Journal of Transport & Health*, Vol. 2 No. 4, 2015, pp. 490–501. http://www.sciencedirect.com/science/article/pii/S2214140515006787. Accessed April 28, 2023.
14. Spearman, C. General Intelligence. Objectively Determined and Measured. *The American Journal of Psychology*, 1904. http://archive.org/details/jstor-1412107. Accessed July 25, 2023.
15. Joe H. Ward. “Hierarchical Grouping to Optimize an Objective Function”. In: Journal of the American Statistical Association 58.301 (1963), pp. 236–244. url: https://www.tandfonline.com/doi/abs/10.1080/01621459.1963.10500845 (visited on 07/23/2023).
16. MacQueen, J. Some Methods for Classification and Analysis of Multivariate Observations. *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability*, Vol. 1: Statistics 5.1, 1967, pp. 281–298. https://projecteuclid.org/ebooks/berkeley-symposium-on-mathematical-statistics-and-probability/Proceedings-of-the-Fifth-Berkeley-Symposium-on-Mathematical-Statistics-and/chapter/Some-methods-for-classification-and-analysis-of-multivariate-observations/bsmsp/1200512992. Accessed March 12, 2023.
17. UN-Habitat. World Cities Report 2022. United Nations Human Settlements Programme (UN-Habitat), Nairobi, Kenya, 2022. https://unhabitat.org/wcr/. Accessed June 25, 2024.
18. Oke, J. B., A. P. Akkinepally, S. Chen, Y. Xie, Y. M. Aboutaleb, C. L. Azevedo, P. C. Zegras, J. Ferreira, and M. Ben-Akiva. Evaluating the Systemic Effects of Automated Mobility-on-Demand Services via Large-Scale Agent-Based Simulation of Auto-Dependent Prototype Cities. *Transportation Research Part A: Policy and Practice*, Vol. 140, 2020, pp. 98–126. http://www.sciencedirect.com/science/ article/pii/S0965856420306327. Accessed September 7, 2020.
19. Raboteau, E. How Our Roads Hurt Us and Everything Around Us. *The New York Times,* 2023. https://www.nytimes.com/2023/09/10/books/review/ crossings-ben-goldfarb.html. Accessed March 19, 2024
20. Nahmias-Biran, B., J. B. Oke, and N. Kumar. Who Benefits from AVs? Equity Implications of Automated Vehicles Policies in Full-Scale Prototype Cities. *Transportation Research Part A: Policy and Practice*, Vol. 154, 2021, pp. 92–107. https://www.sciencedirect.com/science/article/pii/S0965856421002469. Accessed January 19, 2023.
21. OAR US EPA. Inventory of U.S. Greenhouse Gas Emissions and Sinks. 2017. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

Accessed March 19, 2024

22. OAR US EPA. Global Greenhouse Gas Emissions Data. 2016. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data. Accessed March 19, 2024.
23. Bellis, R., S. L. Davis, C. McCahill, E. Mangan, and B. Osborne. The Congestion Con. *Transportation for America*, 2020. https://t4america.org/wp-content/uploads/2020/03/Congestion-Report-2020-FINAL.pdf. Accessed March 19, 2024.
24. WHO. Global Status Report on Road Safety 2023. World Health Organization, Geneva, 2023. https://www.who.int/publications/i/item/9789240086517. Accessed June 25, 2024.
25. Stewart, T. Overview of Motor Vehicle Traffic Crashes in 2021. DOT HS 813 435. National Highway Traffic Safety Administration, 2023. https://trid.trb.org/View/ 2149831. Accessed June 25, 2024.
26. Council on Environmental Quality. Climate and Economic Justice Screening Tool, 2022. https://screeningtool.geoplatform.gov. Accessed Oct. 28, 2024.
27. Abdalazeem, M., and J. Oke. A Spatial Typology Analysis of Crash Characteristics Across 2,480 Census Tracts in Two New England States. *Data Science for Transportation*, 2024.

Access Management, Complete Streets, and the 21st Century Thoroughfare Plan

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Contemporary thoroughfare planning practice is evolving. It no longer only includes provisions for right-of-way protection and considerations for motor vehicles, but it now also guides the integration of bicycle, pedestrian, and transit modes. Advances in technology, such as smart corridors, as well as the need for resiliency and responsiveness to climate change are also introducing new considerations in thoroughfare planning. This paper explores recent trends in thoroughfare planning, focusing on access management strategies, with practical guidance for planners. Though the study was completed for a county in Florida, the analysis revealed innovative approaches that are applicable nationwide.

METHODOLOGY

The study began with an internet scan to identify and obtain contemporary multimodal thoroughfare plans in the United States. After this scan, the project team reviewed and compared thoroughfare plans, codes of ordinance, and comprehensive plans from seven Florida counties and six notable agencies nationwide. The most recent planning documents available online were examined, and additional insights were gained through interviews with relevant agency staff. These findings represent contemporary thoroughfare planning practices as of February 2022.

FINDINGS

Based on the review and comparative analysis of thoroughfare planning documents in thirteen regions in the U.S., the following innovations in practice (trends) were observed.

Trend 1: Comprehensive and Visionary

Traditionally, thoroughfare planning has focused on building major roadways for vehicle travel, depicted through maps and classifications. However, recent plans, exemplified by those from Indianapolis–Marion County, Indiana, and the cities of Fort Worth and Bastrop in Texas, offer a more comprehensive and visionary approach. These plans integrate various modes of transportation and design elements into concise visual documents. For instance, the Indianapolis–Marion County 2019 Thoroughfare Plan classifies roadways, provides design guidelines, preserves right-of-way, and coordinates modal plans into a unified network. Similarly, the 2020 City of Fort Worth Master Thoroughfare Plan employs a detailed process to determine right-of-way needs, integrating assessments from multiple maps and special corridor designations. Moreover, the thoroughfare plan serves as a regulatory document, outlining clear procedures for updates and exceptions.

Trend 2: Multimodal and Context Sensitive

Modern thoroughfare plans prioritize multimodal and context-sensitive approaches, diverging from past practices. For instance, thoroughfare plans from Broward County, Florida, and Fort Worth, Texas, integrate area types and street designations to align transportation corridors with land use contexts and accommodate diverse modes of transportation. The El Paso, Texas, comprehensive plan and Indianapolis–Marion County Thoroughfare Plan further exemplify this trend by classifying thoroughfares based on function and area type, guiding future development, and addressing conflicting modal priorities. These plans serve as regulatory documents, offering frameworks for detailed cross-section design assessments and guiding decisions on right-of-way usage, amendments, and updates.

Trend 3: Implementing the Grid

Some regions are embracing grid networks to enhance traffic flow and alleviate congestion. Indian River County, Florida, for instance, introduced an Extended Roadway Grid Network map, extending rights-of-way beyond urban areas to accommodate future development and distribute traffic more evenly. Similarly, the city of Bastrop, Texas, implemented a street grid framework in response to flood mitigation and resilience needs, integrating it into land-use regulations and master transportation plans to create a comprehensive approach to urban development. These initiatives illustrate the effectiveness of grid systems in managing traffic and supporting sustainable growth.

Trend 4: Resilience and Redundancy

Transportation agencies are increasingly addressing climate change impacts in their planning processes. Initiatives like the "Resilient Tampa Bay" project are exploring adaptation strategies for vulnerable infrastructure, such as strengthening stormwater systems and elevating roads. These efforts, undertaken by regional organizations like the Tri-County TMA (Transportation Management Area)—comprised of the metropolitan planning organizations (MPOs) for Hillsborough, Pinellas, and Pasco, as well as the Florida DOT, and the Tampa Bay Regional Planning Council—aim to integrate resilience considerations into long-range transportation plans. Additionally, optimizing network spacing to enhance redundancy and reduce congestion is recognized as crucial for resilience. Strategies outlined in reports like *NCHRP Report 917: Right-Sizing Transportation Investments: A Guidebook for Planning and Programming* emphasize the importance of flexible application of network spacing guidelines and promoting alternative routes to improve throughput and support non-auto modes of transportation.

Trend 5: Considering Emerging Technology

While specific practices for emerging technology were not identified in this review, interviewees acknowledged early consideration of topics like automated and electric vehicles. Anticipating these advancements within thoroughfare plans could help mitigate conflicts related to right-of-way, connectivity, and accessibility. For instance, incorporating designated corridors for electric vehicle charging infrastructure could streamline installation and land management. Moreover, ongoing research on integrating automated and connected vehicles into existing corridors suggests potential for future inclusion in thoroughfare plans, particularly as understanding of their design and right-of-way implications evolves.

Trend 6: Dedicated Funding for Thoroughfare Planning

Recognizing the substantial costs of corridor management, some local governments have established dedicated funding sources. For instance, Tallahassee–Leon County, Florida, created Blueprint Intergovernmental Agency, utilizing sales tax proceeds for right-of-way acquisition and land banking. They also employ proportionate fair-share programs and road impact fees, with surplus funds invested for future projects. Similarly, Indian River County, Florida pursues “opportunity purchases" using traffic impact fees and local taxes. In Florida, the 2011 Community Planning Act enabled mobility fee programs as alternatives to transportation concurrency, with numerous cities and counties adopting such plans, including Broward County's transportation concurrency assessment and Alachua County's multimodal impact mitigation program.

DISCUSSION AND RECOMMENDATIONS

Contemporary thoroughfare plans increasingly emphasize context sensitivity and multimodal design principles, promoting dense and connected networks to accommodate diverse transportation needs. The following recommendations were derived from this state of practice review and aim to guide planners in evaluating and updating thoroughfare plans effectively:

1. Establish a clear and integrated vision of the future thoroughfare system, packaged as a concise, visual document referenced in a comprehensive plan and/or ordinance.
2. Classify thoroughfares by function, area type, and modal accommodations, and integrating context-sensitive design.
3. Adapt thoroughfare plans to an idealized grid and include supporting network concepts to improve capacity and connectivity.
4. Anticipate and integrate new designations as technology evolves, such as Smart Corridors and electric corridors.
5. Increase network redundancy and designate vulnerable routes for management to enhance resilience.
6. Establish dedicated funding sources for corridor management projects and right-of-way acquisition, considering approaches like special regional agencies or innovative funding programs.

By implementing these recommendations, planners can ensure thoroughfare plans effectively address current and future transportation challenges while promoting safety, accessibility, and efficiency for all users.

CONCLUSION

Thoroughfare plans serve as crucial documents for preserving right-of-way and facilitating orderly transportation network development to accommodate future growth. While historically focused on auto-centric corridors, recent trends show a shift towards more context-sensitive and multimodal approaches, embracing concepts like complete streets. These contemporary plans incorporate transparent procedures for stakeholder involvement and are supported by dedicated funding sources, reflecting a broader vision for the future transportation system.

Using Case Studies to Enhance Driveway Safety Analysis

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Case studies provide insight into how driver behavior and specific roadway and site access conditions may interact to influence vehicle, bicycle, and pedestrian safety. As such they are a useful supplement to safety analysis involving statistical modeling of large data sets. This study used exploratory case studies to provide an in-depth look at specific conditions contributing to crashes on six high-crash corridors and interchange areas in Florida. The corridors were identified as part of a statewide study involving statistical modeling of large datasets. Through detailed assessments of roadway and site access conditions and crash diagrams illustrating safety issues, researchers were able to verify research findings from high-level analysis and explore the root causes of identified safety issues. Potential countermeasures for specific safety issues were also identified. The resulting case studies presented opportunities to cross-check and relocate inaccurately geolocated crashes in large datasets for more accurate evaluations of the study sites and to expand the project scope from strictly exploratory to a before and after assessment of one of the study sites. This study demonstrates some of the ways that case studies are useful for communicating the value of access management to stakeholders and for improving access management decisions.

METHODOLOGY

This case study analysis was part of a larger study evaluating safety issues associated with commercial driveway access location and design. Qualitative and quantitative assessments were conducted for 192 roadway segments with 9,889 commercial driveways and 10,596 driveway-related crashes; and 69 interchanges with 832 commercial driveways and 853 driveway-related crashes in the vicinity of the interchanges. Using the findings of these analyses, case study sites were selected from a geographically diverse subset of areas with a high proportion of commercial driveway-related crashes between 2015 and 2019. The sample was further reduced based on evidence of crash clusters at commercial driveways in areas having different corridor or interchange area designs and volume characteristics.

After reducing the sample, the research team identified a representative cross-section of crash clusters at commercial driveways along corridors and near interchanges. For each site, the research team used crash reports, geographic information system (GIS) data, and other available resources to document the crash types and severity in the high-crash locations. The analysis included vehicular crashes and bicycle–pedestrian crashes. A key step in the case study site analysis was verifying the crash locations based on crash reports. Sites identified as being inaccurately geolocated were relocated in ArcGIS, and the project team conducted a second review of these study sites. In some instances, crashes were relocated outside of the crash clusters, reducing the intensity of crashes in the clusters. In other cases, crashes were relocated and added to the crash clusters, increasing the intensity of crashes in the clusters. This phenomenon emphasized the importance of appropriate training for those involved in obtaining and geolocating crash report data to support effective safety analysis.

Using the previously mentioned approach, a total of six sites were selected for exploratory case studies. For each site, the research team assessed the driveway interactions with other corridor and/or interchange characteristics. Corridor or interchange area characteristics evaluated included traffic volumes, planning-related classifications (e.g., functional, access, context), and existing land uses and access features. Crash types that frequently occur at a particular site and those that highlight unique incidents were selected to be developed into crash diagrams. A brief discussion of potential strategies and countermeasures to mitigate the identified safety issues was developed for each study site.

FINDINGS

The sites selected for this study represent high-crash corridors and interchange areas in different regions of Florida. These corridors include:

1. John Young Parkway at West Colonial Drive in Orlando;
2. East Bay Drive [State Road (SR) 686] in Largo;
3. West Tennessee Street in Tallahassee;
4. North West 103rd Street and West 49th Street (State Road 932) in Hialeah;
5. West Hallandale Beach Boulevard at I-95 interchange area in Hallandale Beach; and,
6. Scenic Highway at I-10 Interchange area in Escambia County.

A summary of findings from each of these sites and the general findings from the bicycle–pedestrian analysis of all six sites are included in this section.

John Young Parkway, Orange County

Crashes at the corridor segment evaluated for John Young Parkway were clustered at a commercial driveway on the east side of the segment. The driveway was approximately 650 ft south of a signalized intersection and was served by a directional median opening. Long queues that formed at the signalized intersection disrupted driveway operations and reduced vehicle visibility. Conflicts were observed opposite the directional median opening between through-moving vehicles and those attempting to enter and exit the driveway. Crashes happened as well-intentioned drivers waiting in queues allowed vehicles to cross through lanes as they proceeded into or out of the driveway.

East Bay Drive, Largo

Most crashes along the study segment of East Bay Drive were clustered in the proximity of two parallel shopping centers. The driveways for these shopping centers were opposite a full median opening with left-turn lanes. The location of the median opening in relation to the shopping center driveways resulted in crashes between through-moving vehicles and those attempting to cross the roadway or enter or exit the driveways from–to the full median opening. Crashes also occurred at this site when multiple vehicles attempted to exit the driveways and maneuver into the median opening simultaneously.

West Tennessee Street, Tallahassee

The largest cluster of crashes along the West Tennessee Street corridor segment was near the intersection of the arterial with a signalized side street. These crashes were located near a fast-food restaurant and were influenced by queues at the signalized intersection as well as backups due to inadequate on-site circulation at the upstream coffee shop. Additional crashes were seen between through-moving vehicles and those exiting the fast-food restaurant and attempting to enter the left-turn lane at the intersection.

State Road 932, Hialeah

Of the six sites evaluated for the exploratory case studies, SR 932 had the most recorded crashes during the study period (189). This site clearly demonstrated how driveway density increases crash rates. Due to the volume of crashes, the assessment of this corridor segment focused on a cluster of crashes adjacent to a driveway for a mall that was east of the entrance ramp for the Palmetto Express Lane. A closer look at these crashes revealed that vehicles exiting the driveway stopped suddenly to yield to through traffic or those accessing the entrance ramp for the express lane. In some instances, drivers backed up to remove themselves from the roadway and backed into the vehicle behind them. Other crashes occurred when vehicles turning right to exit the mall attempted to cross through lanes to access the left-turn lane and collided with through traffic traveling west or vehicles accessing the entrance ramp for the express lane.

I-95 at West Hallandale Beach Boulevard Interchange Area

Crash clusters were identified near the interchange of I-95 and Hallandale Beach Boulevard. Most of these collisions were angle and rear-end crashes that occurred as drivers entered and exited commercial connections closest to the interchange on or off ramps. A frontage road on the west side of the interchange connected directly to the southbound on-ramp of I-95 and served several commercial uses. Vehicles must cross the ramp to enter or exit the shopping area via the frontage road. Drivers looking left to exit the driveway failed to notice vehicles in the right lane were braking to slow down in advance of the interchange signal or possibly to turn into a driveway–street connection or enter the on-ramp. Crashes occurred when following drivers expected vehicles to continue onto the on-ramp rather than suddenly slow to turn into a driveway. Vehicles merging suddenly into the right lane to enter the on-ramp or a driveway also caused rear-end collisions with following vehicles.

Scenic Highway at I-10 Interchange Area

This case study became a high priority for the research team when it was discovered that the reconstruction of the study site occurred in 2016, during the study period (2015–2019). This timing provided the research team with an opportunity to examine the before and after effects of the reconstruction. Before reconstruction, numerous crashes were recorded in the immediate vicinity of the I-10 interchange. A narrow median installed during reconstruction prevented direct left turns into and out of the commercial driveways surrounding the interchange. A driveway access to the site was removed and reconstructed, creating a full movement signalized intersection at the interchange ramps. Only one of the recorded crashes occurred following reconstruction, although lingering construction may have contributed to this crash.

Bicycle and Pedestrian Crashes

Most of the bicycle and pedestrian crashes at the study sites occurred as drivers looked left for oncoming traffic while attempting to exit the driveways and failed to notice the cyclists or pedestrians crossing the driveway from the opposing direction (right side). In some of these cases, the cyclists were traveling the wrong way on the bicycle lane, in other cases the cyclists were traveling on the sidewalk. Other conflicts were seen in cases where a vehicle exiting a driveway would block the sidewalk while waiting for a gap in the traffic to enter the roadway. In some instances, site elements, such as fencing, obscure the visibility of bicyclists and pedestrians as vehicles exit the driveway. At sites with driveways adjacent to median openings, conflicts were observed when drivers attempted to avoid through traffic as they crossed the through lanes to enter the driveway, not noticing bicyclists or pedestrians crossing the entrance.

CONCLUSION

Commercial driveway location and design, including proximity to intersections and interchange ramps, has a clear influence on safety. Alignment of high-volume driveways with unsignalized median openings, driveway density, and traveler behavior (e.g., the Good Samaritan) also influence driveway safety. It is important to evaluate how these various elements interact when making access decisions and assessing the safety implications for motorists, bicyclists, and pedestrians. Case study-level analyses are an essential part of any roadway safety study, especially those with large datasets. They are useful for communicating safety issues to stakeholders and agency staff and for cross-checking large datasets with the potential for inaccuracies. For example, through the case studies, the research team found that many of the crashes in the data set were incorrectly geolocated. The improper location of these crashes masked the intensity of crash clusters at certain driveways. Post-crash strategies such as providing appropriate training for those involved in obtaining and geolocating crash report data support effective safety analysis.

Solving Fayetteville's Connectivity Crisis

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INTRODUCTION

Transportation in the city of Fayetteville, North Carolina, is generally characterized by local streets and cul-de-sacs that lack connectivity between subdivisions. Traditional urban grid streets in Fayetteville constitute less than 7% of the city's total area. Instead, the city's major arterial roadways radiate out from the urban core, and residential streets typically branch out from those spines and dead end at creeks, railroads, or backyards. As a result, travel between nearby neighborhoods almost exclusively requires a trip onto the arterial network rather than on local streets. Additionally, the city routinely experiences severe flooding events and is at risk of more flooding in the future. The Cape Fear River, which runs along Fayetteville's eastern border, has swelled on multiple occasions, causing damage to nearby residences and properties. During flood events, automobile crashes, utility maintenance and repairs, and other major incidents, transportation access to some communities with a single point of access has been reduced such that some people cannot reach their homes, evacuate, or be reached by emergency responders. To address these concerns, the city initiated a connectivity analysis as part of their Comprehensive Transportation Plan (CTP), with the goal of identifying and prioritizing new street connections for single-access subdivisions throughout the city.

METHODOLOGY

The city identified 231 subdivisions in the city that are greater than 10 acres in size with only one access point. As shown in Figure 1, these subdivisions are spread throughout the city, but they are particularly concentrated further from the urban core, especially in the southwest and northernmost parts of the city. The subdivisions are also typically concentrated around major arterials, railroad lines, and environmental features. In coordination with city staff, several

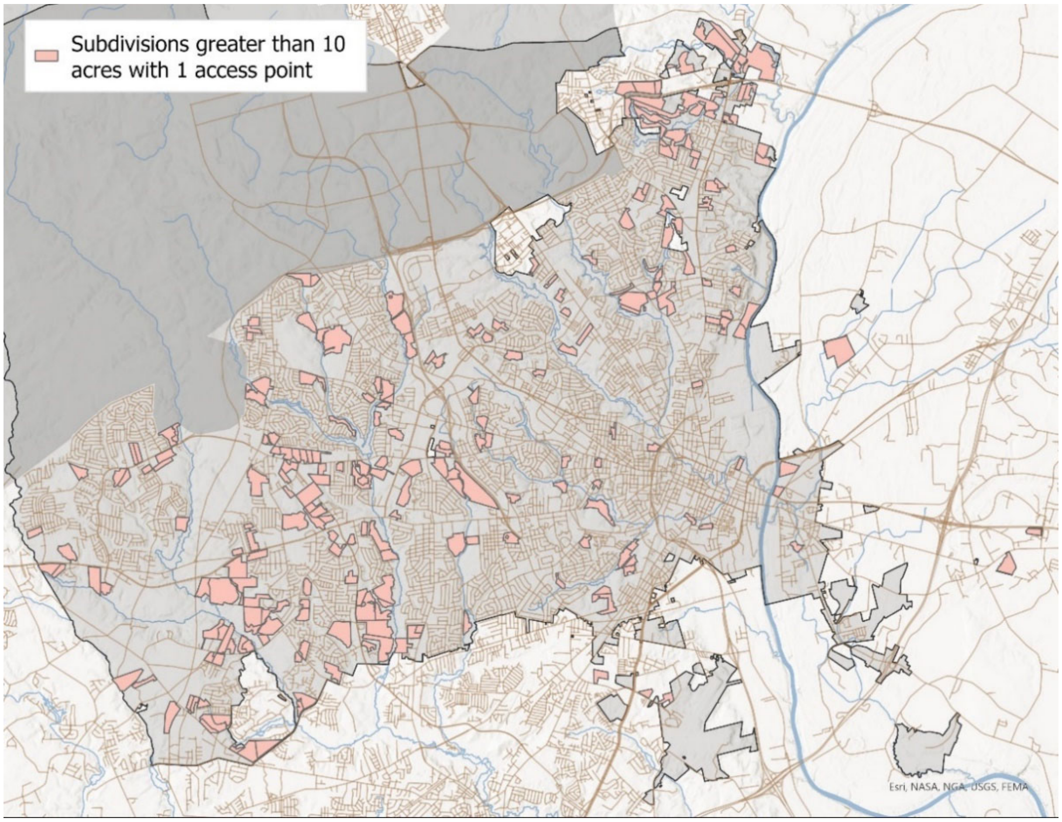

FIGURE 1 Study area of Fayetteville, North Carolina.

performance metrics were identified to address the following goals of the Connectivity Study:

- Increasing safety and resiliency during flooding and other emergency events;
- Serving residents equitably;
- Identifying feasible street network connections;
- Providing multimodal connectivity and prioritizing active transportation options; and
- Improving access between residents and key community destinations.

The project team then performed a series of calculations to identify the proximity of the units within each subdivision to applicable resources in the surrounding area. The unit located the farthest distance from the existing subdivision access was identified, and then the shortest path connecting that unit to each of the following features was calculated using the existing street network:

- Arterial/collectors,
- Bus stops,
- Sidewalk,

- Schools,
- Commercial uses,
- Parks and community centers, and
- Fire stations.

For each subdivision, up to two potential new street connections were identified by using aerial imagery to draw reasonable conclusions about where additional street connectivity would add the greatest value in an equitable and feasible way. For some subdivisions, there was only one logical connection that would significantly reduce the distance between the furthest residence and the nearest key destination. For a few subdivisions, there were several potential connections that might add value. In total, 175 total possible connections were identified. The shortest distance to each of the resources identified above was then recalculated using the same unit to assess the net benefit to each subdivision.

The performance metrics used to identify street connections also served as the foundation for ranking them. A series of five scores were assigned to each potential connection, including

1. A resiliency score,
2. An equity score,
3. A feasibility score,
4. A multimodal access score, and
5. A community access score.

These scores were primarily calculated using the decrease in travel distance as a function of the calculations described above.

FINDINGS

After ranking the 175 connections based on the performance metrics and corresponding scores, the project team reviewed the highest scoring connections with the city to confirm that the results met the city's expectations and aligned with localized challenges and public comments. The city set a threshold total score of 0.44 or more to be considered "high-scoring". This eliminated all but the 38 highest connection points, which is approximately the top 20%. Of those top 20% of connections, some were not advanced because of one or more issues raised from city staff such as the following:

- The connection would join privately maintained streets.

- The connection would not be connected to the larger street network.
- The connection was partially outside the city limits.
- The connection could be consolidated with one or more other high-scoring connections.

The project team and city staff also considered how the connections might pair with other ongoing transportation projects in the CTP. A total of 17 high-scoring connections were ultimately moved forward as project recommendations and will be developed as conceptual designs incorporating a full-width typical section including sidewalk, curb and gutter, etc.

CONCLUSION

The city of Fayetteville has a unique opportunity to address street connectivity and create more sustainable, active, and affordable transportation options. This can be achieved through both building vital connections that reduce vehicle miles traveled, reduce emergency response times, and serve pedestrians and bicyclists as well as modifying the development code to ensure that private construction is also expanding rather than limiting transportation access. The methodology developed within this study is intended to be repeated as additional resources become available to provide connectivity improvements, thereby identifying additional high-scoring connections to move forward in the project development process.

A critical next step for advancing the recommendations identified in this study is to engage with community members and local elected officials. Given the multiple points of sensitivity surrounding further infill of the existing street network, including construction and right-of-way costs, environmental constraints, and the implications of connecting adjacent neighborhoods, it is important to approach each community affected by the connectivity study recommendations early and thoughtfully.

Planning a Safe System for a Growing Area

West Richmond Small Urban Area Study

BRENT SWEGER

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At roughly 35,000 residents, Richmond, is only the seventh most populous city in Kentucky, but one of the fastest growing. This growth can be attributed, amongst other things, to the lower cost of housing relative to the nearby regional center of Lexington, and its convenient proximity to I-75.

Much of Richmond's existing development, including its downtown, is located east of I-75 as shown in Figure 1. However, much of the recent growth, including new housing, retail, dining, a middle school, and a regional sports park, has happened to the west. At the time of the study, 10 development sites (over 1,300 acres) were in process of approval or under construction. In addition, thousands of acres of rural land are identified in the comprehensive local plan for potential development in the west.

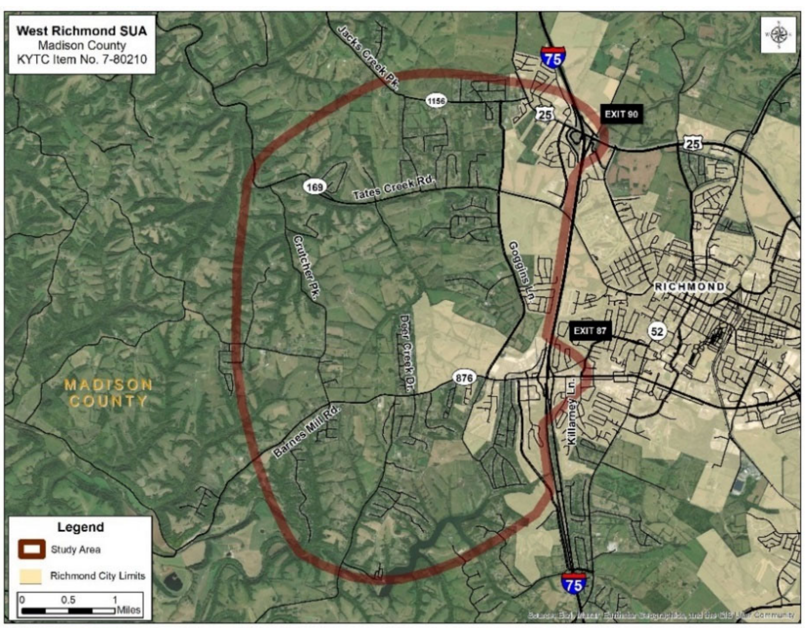

FIGURE 1 West Richmond study area.

The current network of arterials and collectors west of I-75 has a low road density. It only contains three primary corridors generally running east–west (KY 876, KY 169, and KY 1156/US 25) and one running north-south (Goggins Lane), offering little redundancy and connectivity.

One key concern for this area is if the conventional development pattern continues, each new development would have direct access to the existing road network with limited connectivity between developments. With increases in traffic and little redundancy to the network, there will be an increased strain on roadway and intersection capacity. The West Richmond Small Urban Area Study was conducted to examine existing safety and operational conditions and to recommend a list of transportation improvement concepts to address existing and long-term transportation needs.

METHODOLOGY

Conditions of the existing transportation network were examined, including roadway facilities and geometrics, crash history, and traffic volumes. The Lexington Area MPO travel demand model was updated and used to estimate future traffic under current conditions as well as different scenarios involving new and expanded routes.

To assist with the planning for improvements along KY 876 and at the I-75 interchange, a traffic simulation model was developed to analyze existing and projected future peak hour traffic. This model was used to estimate traffic patterns and impacts for interchange alternatives and median U-turn concepts on KY 876.

Additionally, the project team met with local officials and stakeholders to coordinate on key issues. Surveys were distributed at each meeting to solicit feedback on transportation issues in the study area and prioritization of improvement concepts.

A socioeconomic study was also conducted that showed alternative transportation options, including sidewalks and shared-use paths, were needed to provide connections across I-75 to link the low-income residential areas with growing employment opportunities to the west.

Ultimately, the study team prioritized the improvement concepts based on results from the traffic analysis, safety analysis, benefit-to-cost analysis, and local official feedback.

FINDINGS

Improvement Concepts

Improvement concepts were split into three categories: short-term concepts which include less resource intensive, quick-win type projects, long-term concepts which will require more time and resources, and local concepts which can be implemented by the city, county, or private developers. The concepts aimed to improve safety and congestion and included interchange reconstruction, installing a raised median, roundabouts, U-turns, shared-use paths, and a network of new local routes.

Benefit-to-Cost Analysis

The benefit-to-cost analysis (BCA) provided a means for determining which improvements have the greatest benefit relative to the cost. The BCA was conducted based on crash savings and travel time savings. Improvement concepts which could be evaluated using the traffic simulation model (along KY 876) were assigned a 10-year congestion relief savings based on the vehicle hours traveled saved and the 2022 average hourly wage in Madison County of $21.38. Crash modification factors (CMFs) were used to quantify crash reduction savings by estimating the number of crashes that would be reduced by implementing the improvement concept. The total benefit was then divided by the cost to produce a benefit–cost ratio (BCR). A BCR greater than 1.0 indicates the benefits outweigh the costs.

KEY CONCLUSIONS

KY 876 Widening and Access Management

KY 876 not only serves as the primary connection between the growing west side and I-75, but also to downtown Richmond to the east. Creating a safe and practical corridor means controlling conflicts, making intersections efficient, and providing for nonmotorized users. As such, the solutions for this roadway included extending the four-lane section and installing a raised median, providing U-turn opportunities, and a roundabout at the important crossroad of Goggins Lane, along which much of the development is anticipated. A new sidewalk and shared-use path connecting across I-75 will help pedestrians feel safe and comfortable traversing the corridor as well, as shown in Figure 2.

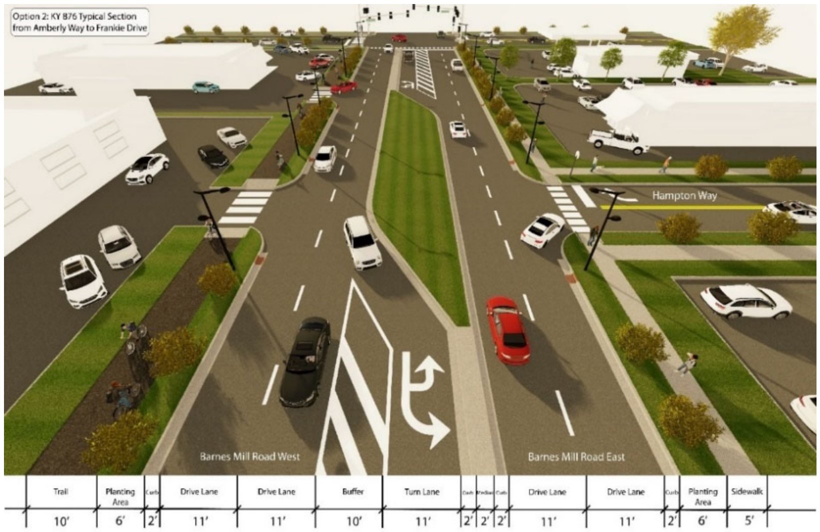

FIGURE 2 KY 876 proposed typical section.

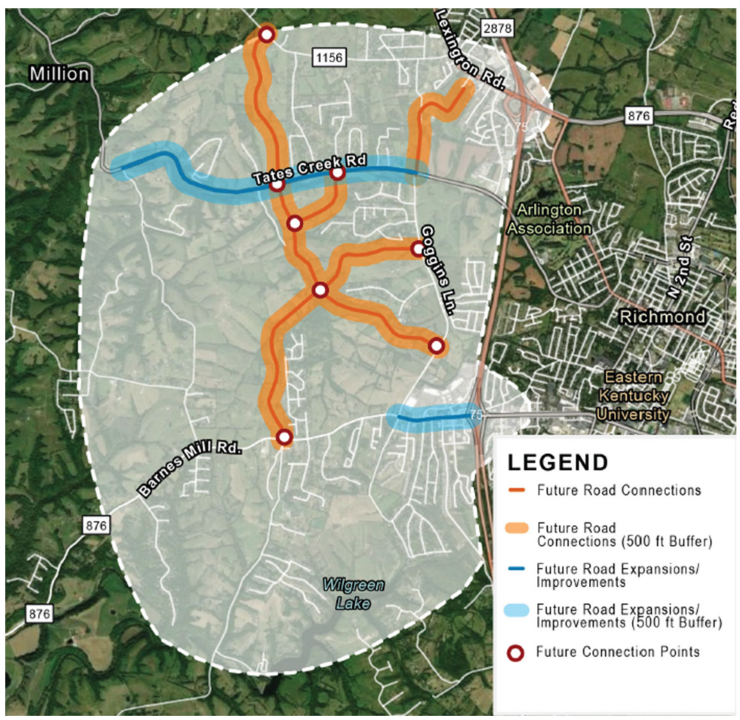

FIGURE 3 Future road connections and expansions.

Planning Transportation for Growth

The study was conducted in consultation with the local land-use planning staff. Preliminary alignments for potential new roads to form a more robust network were developed as shown in Figure 3. These routes will allow for interconnectivity between residential and other developments, such as the school and park. They can also add efficiency to public services such as garbage collection, school bus routing, and mail and package delivery.

With the identification of new collector routes, in addition to existing routes needing to be widened, the local planning and development process can help facilitate their implementation. First, development plans can account for preserving future rights-of-way. In some cases, the development plan can be designed in a way to integrate a section of the new collector as part of the development.

Kentucky Transportation Cabinet is continuing to work with the planning and zoning commission and local officials to integrate these recommendations into their comprehensive plan, subdivision standards, and review processes.

Tree Protection for Transit Corridor Development

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Trees and urban forests are an integral part of Massachusetts communities, providing a wide variety of benefits. Ecosystem services include filtering and sequestering air pollutants, mitigating stormwater run-off, and shading and cooling neighborhoods. There are a variety of online tools that provide property owners with estimates of the value of the benefits provided by their trees. While harder to quantify, the mental and physical health of residents are also impacted by the presence of street trees and urban greening. Trees provide identity in communities, and many people forge strong connections with the trees they encounter daily. The presence of trees in neighborhoods is also associated with stress reduction, improved mental health, and safer streets for all users.

Complete Streets is an effort by Smart Growth America and the National Complete Streets Coalition to reimagine roadways across the country to improve safety and accessibility for all users. The main priorities of Complete Streets address the planning, design, construction, and use of roadways. They include improving (1) safety of vulnerable users such as cyclists and pedestrians, and (2) connections across metropolitan areas to serve all communities. The initiative tackles systemic problems of safety and equity, and intends to improve safety, mobility, and connection for individuals nationwide. Two common themes in building a complete street are the redevelopment of the roadway corridor to accommodate changing traffic patterns and the addition of pedestrian facilities and bike lanes. In the process of effecting these changes, roadway corridors may be widened, resurfaced, or otherwise altered in ways that have significant impacts on existing vegetation in the corridor.

Construction projects can severely damage trees unless precautions are taken to preserve and protect trees on site. Damage to the aboveground portions of the tree (trunk and branches) is usually most obvious and must be avoided, but unseen damage to the root system is typically the most serious and has the greatest adverse impact on long-term tree health. Construction that involves digging, trenching, resurfacing, and grade changes has the greatest potential to harm trees. Roots typically grow shallow and wide, usually within the top 18 in. of soil and extending well beyond the dripline of the tree. The critical root zone (CRZ) is the area in which any damage to the roots is critical to the overall health of the tree; precautions must be taken to protect both the roots and soil within this zone. The tree protection zone is the area in which activity is restricted to prevent construction activities from impacting trees.

Root system damage and trunk injuries are frequently the result of equipment movement or operations, particularly in digging or trenching operations. Root systems can further be damaged from soil compaction during the project. Soil compaction can be caused by vehicle or pedestrian traffic, or the storage of equipment and materials around the base of the tree. Root health is critical to overall tree health. Roots are essential for tree growth and stability, providing water and nutrient uptake and storage, as well as anchoring the tree in the ground. For roots to grow and function effectively, the surrounding soil must be good enough for roots to grow and keep trees healthy.

METHODOLOGY

The objective of this project was to review and revise the existing tree preservation guidelines for Massachusetts DOT projects—the Project Development and Design Guide—in anticipation of increased construction impacts to trees following transit corridor development. We developed the following tasks to meet the outlined objective:

1. A literature review of topics relevant to tree preservation;
2. Assembling a panel of cross-disciplinary experts to advise on topics and project progress; and
3. A survey of industry professionals from across the country.

We reviewed the literature to assess the current state of tree preservation practices during construction projects. The three core areas of focus in the literature review were:

1. Preserving trees during construction (including preliminary assessment of trees that may be impacted);
2. Restoring or enhancing trees following construction; and
3. Design alternatives and site enhancements to improve survival and growth rate of trees planted following construction.

The expert panel had nine members from Massachusetts. It included two consulting arborists with extensive experience with transit corridor improvement projects, the state's urban forester, a town tree warden and town engineer, the manager of the University of Massachusetts Transportation Center (UMTC) and BayState Roads, and four Massachusetts

DOT personnel: the supervisor of landscape design, a senior landscape architect, a project manager, and the transit manager. There were more than 150 years of cumulative experience among members of the panel.

The survey followed conventional methods and included 40 questions of several formats, including multiple choice, ranking and rating, and open-ended responses. Questions concerned respondents' demographics, operational use of tree protection guidelines, the timing of tree protection discussions, potential obligations in construction projects, the effectiveness of tree protection and establishment strategies, stormwater management methods, and measures of active tree protection during construction.

The survey was distributed via email to the following organizations: Massachusetts Chapter of the American Council of Engineering Companies, Boston Chapter of the American Society of Landscape Architects, American Society of Consulting Arborists, New England Chapter of the International Society of Arboriculture, Massachusetts Tree Wardens and Foresters Association, New York City Parks Department, and UMTC.

FINDINGS

Eighteen US states were represented, with most respondents from California, Massachusetts, New York, and Florida. Respondents represented a variety of professions, including arborists, urban foresters, tree wardens landscape architects, civil engineers, and managers. Most respondents stated that they operated with tree protection guidance, and most guidance was sourced from International Society of Arboriculture (ISA) best management practices (BMPs), the ANSI A300, or municipal and local guidelines. Some methods of improving tree success considered to be very effective included soil remediation and aeration. Approximately half of the participants reported that their definition of a CRZ was site dependent; a smaller amount reported using the ISA standard definition of 1.5 ft of root zone per inch of diameter at breast height. Several respondents reported that they considered preemptive root pruning to be detrimental to the success of trees following construction projects. Most respondents reported that for the projects they work on, a tree inventory is conducted and required, and some stated that an inventory was conducted but not required. The majority of recipients responded that they were personally involved in the tree inventory and assessment project. The majority of respondents said they had a reference document for tree protection and management during construction projects. Methods to ensure awareness on site about tree preservation included signage, meetings, and memos. The majority of respondents stated that they did conduct site visits to ensure tree protection measures were being adhered to.

DISCUSSION

There were several overarching themes from the survey that were also reflected in the literature review and in panel discussions. All emphasized adapting design plans to mitigate impacts to existing plantings. The option to remove specimens that conflict with plans and replant with new plantings may seem like an easy solution. However, the removal of a mature tree, assumed to be in good condition and not deemed hazardous, results in the loss of ecosystem services. New plantings will take decades to match the shading extent, carbon sequestration capabilities, and aesthetic value of a mature planting. The accommodation of healthy existing plantings should be a high priority in the project planning phase.

Respondents underscored the varying nature of this process, and how different governing bodies may approach assessment techniques. Despite the varying procedures in place for each project, it is critical that a credentialed individual conduct the inventory and then assemble the information to be distributed among the entire project team. This ensures that all parties involved have access to the same information regarding the tree inventory and accompanying preservation recommendations and procedures.

Respondents repeatedly emphasized the necessity of regular site monitoring and communication. Many stated that consistent supervision was necessary to ensure preservation measures were being followed on site. They also noted that it is important to begin to consider preservation early in the design process and reinforce the reasons behind these measures through education and communication with project staff. Here recipients noted that a lack of resources often impedes their ability to conduct site visits to the degree and frequency desired for maximum effectiveness.

ACKNOWLEDGMENTS

The project team would like to acknowledge the efforts of George Ackerson, George Batchelor, Kristina Bezanson, Julie Coop, Madeline DeClerck, David Hawkins, Jamie Magaldi, Matt Mann, Andrew Schlenker, Elle Waite, and Violet Wilkins. This study was undertaken as part of the Massachusetts DOT Research Program. This program is funded with FHWA State Planning and Research (SPR) funds.

Connected and Automated Vehicles as a Booster for Public Transportation System

Performance Analysis of Urban Corridor Design

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The transport sector is responsible for 29% of all emissions in the European Union (EU). According to the latest analysis by Transport & Environment (T&E)[1] emissions from transport have almost doubled compared to emissions in 1990, which were around 17%, while those from the economy have decreased by 38%. The T&E report demonstrates the growing relevance and urgency of the challenge to decarbonize the sector. Despite today's Green Deal[2] climate policies, transport could account for 44% of total greenhouse gas emissions by 2030. With the sector decarbonizing at more than three times the rate of the nontransport sector, these figures make achieving Europe's net-zero target by 2050 look increasingly utopian. Currently, cars, together with heavy-duty vehicles, are responsible for 13% of global pollution, and endothermic cars are responsible for 40% of transport emissions in Europe. Since the 1990s, car dependency has increased, encouraged by the construction of new road infrastructure and an increase in the number of vehicles. This phenomenon is particularly evident in cities with a dense urban structure resulting from outdated planning not suited to support high traffic demand, or with inefficient connections between strategic infrastructure such as ports, airports, bus and train terminals, which are often far apart or located far from the redeveloped city center. Replacing traditional cars with electric technology could be a powerful strategy to reverse this trend and improve internal connections. Electrification of road transportation is proving to be much more efficient than other methods of reducing emissions (T&E Briefing Rewarding Renewable Efficiency).

LITERATURE REVIEW

Life-cycle costing (LCC) provides a focused approach for assessing the economic and environmental sustainability of transportation infrastructure. It considers factors such as reduced fuel costs, reduced maintenance requirements, and potentially lower environmental costs over the life cycle of the vehicle. The LCC assessment tool shows that the use of a battery electric vehicle reduces CO_2 emissions by about three times compared to a gasoline-powered vehicle, highlighting how electric vehicles offer a more affordable and sustainable transportation option. The technological transition is not limited to vehicle electrification; the new frontier in transportation is automation. Technological advances aim not only at climate neutrality, but also at increasing user safety, reducing congestion and travel time, saving energy, and providing driver comfort (Benevolo et al, 2016). ITSs have been deployed in several cities to reduce congestion and pollution. These systems improve intelligent mobility, energy efficiency, accessibility and safety. ITS can bring significant benefits to traffic and air quality without the need to build new roads or transport infrastructure (Šurdonja et al, 2020). In the European context, several cities in Italy and Croatia are testing various public transport systems to address these issues, while recent innovations in the automotive sector, such as connected and automated vehicles (CAVs), can provide a valuable upgrade for existing and new systems. The combination of electric vehicles and the development of a highly efficient automated public transport system could ensure a gradual shift away from private cars, resulting in improved road congestion and a concrete step towards climate neutrality. Self-driving public transportation could bring many benefits to urban safety, in terms of reducing accidents, operating costs, traffic congestion and emissions, but current legislation limits the deployment of autonomous buses. Despite the legislative slowdown, interest in public vehicle automation has been steadily growing since 2016, as evidenced by numerous projects and experiments in many European countries. In Italy, concrete examples of automation include the autonomous subway of Turin (VAL184 system)[3], in operation since 2006, or the SHOW[4] project (Shared automation Operating models for Worldwide adoption), in which Turin[5] was chosen as a satellite city for experimentation (Caito, 2020).

CASE STUDIES

The aim of this study is to carry out an in-depth analysis and comparison of the two selected case studies, focusing in particular on the port–city link and imagining a future scenario in which this route is exclusively characterized by the use of self-driving public transport (CAVs) and to investigate correlations and differences between the two case studies, providing insights into factors related to urban road infrastructure design and safety (Figure 1).

Termini Imerese

Termini Imerese city has around 30,000 inhabitants with very densely built-up city center concentrated near the port. The primary accessibility to the port infrastructure is directly related to the proximity of the urban center and the typical network of small towns and the co-presence of the service roads to the industrial area of Termini Imerese. The variety of the commercial flows that are currently active in the port is evidently an element of strength of the infrastructure, and at the same time a character of the service performed that the infrastructural support network can withstand with limited constraints. The influence between different traffic components is very marked and the effects are limited on the current capacity of the network only because the programming of the main maritime services is oriented towards the peak periods of urban traffic.

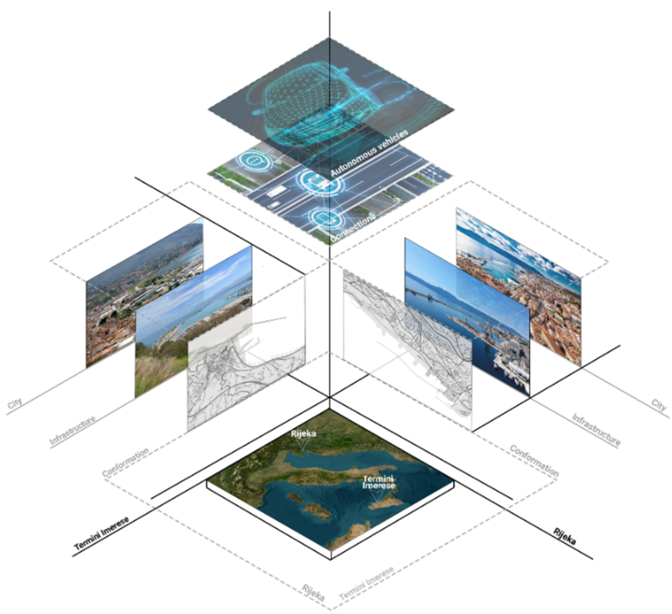


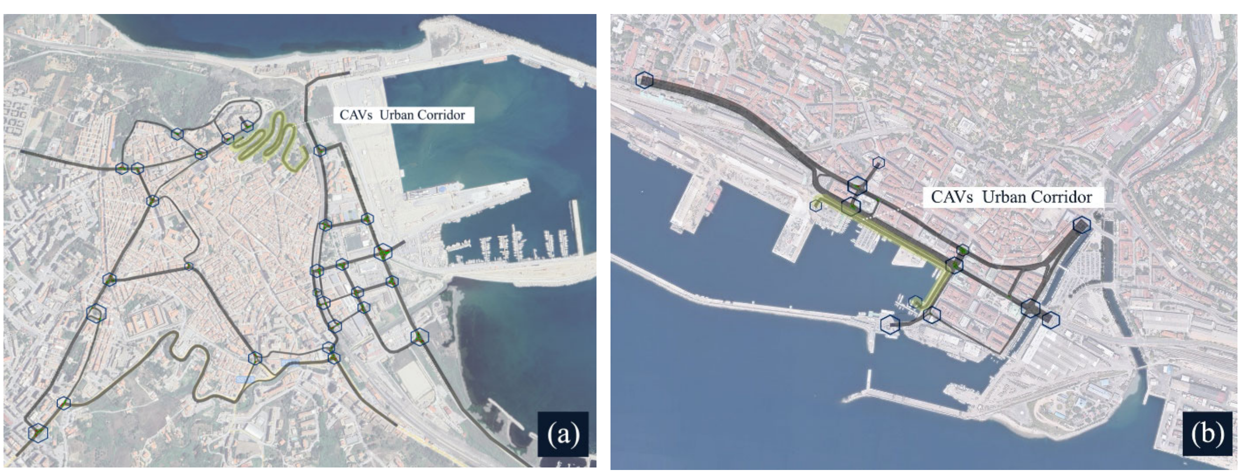
FIGURE 1 Comparison of the composition, infrastructure, and city of Termini Imerese (Italy) and Rijeka (Croatia).

Rijeka

Rijeka city has around 110,000 inhabitants with a densely built-up city center concentrated near the main pedestrian zone and the port. Analysis of the possible implementation of public transport CAVs in Rijeka was carried out for the area of the city center within which important facilities are located on two longitudinally placed main traffic corridors. The main road situated near the coastal line connects the bus, railway, and connection road to the port passenger terminal and at the same time certain parking areas located next to the mentioned facilities. Between these focal points there is intense traffic going on during the whole day which additionally increases during the summer tourist season. Presently trips between these points are mainly done by car or on foot as public transport does not offer direct connection between the bus–train terminal (or the city center) and port terminal. Road connecting passenger points of interest is main city road with four lanes in one direction, sidewalks placed on both sides and additional space just nearby the sea used for mixed purposes—parking, walking, free time activities.

METHODS

Two case studies have been selected: the previously described urban road networks of Termini Imerese (Italy) and Rijeka (Croatia) (Figure 2). The first phase of this study involved integrating each urban network model into the VISSIM software. Vehicle routes were configured using the "dynamic assignment" option, which was preferred for its ability to generate dynamic routes



(a) (b)

FIGURE 2 Network graph simulation on (*a*)Termini Imerese and (*b*) Rijeka.

between network nodes rather than static routes. To include CAVs in the simulation model, a new vehicle category corresponding to cars was configured. In the calibration phase, driving behavior parameters specific to autonomous driving were assigned. These parameters include four types of behaviors that CAVs can adopt, considering factors such as the availability of road context data.

The integration of CAVs into the road network model in VISSIM was completed by configuring speed distribution functions and driving behavior parameters based on (Evanson, 2017) and the specific assumptions discussed by (Abdelkader et al, 2021). The values of driving behavior parameters for CAVs and human-driven vehicles were determined through the author's evaluation, incorporating insights from (Evanson, 2017; Gazde et al, 2020). Moreover, each parameter reported indicates a specific value of pursuit behavior belonging to the Wiedemann 99 (W99) model for car-following, as detailed in (Giuffrè et al, 2021; Vortisch, 2023).

To estimate potential traffic disruptions, data collection measurements and queue counters were conducted in almost all critical areas of the road network. For each case study, two scenarios were simulated. For the research objectives origin–destination (O-D) matrices were implemented for Termini and Rijeka, respectively, referring to the peak hour of 8:00 to 9:00 a.m. Each O-D matrix was then modified according to a specific future scenario, characterized by the implementation of a new route connecting the port and the city, allowing the potential preference of tourist flows from the port to make this route with a public transport system characterized exclusively by self-driving shuttles. In conclusion, seven simulations were carried out for each scenario, since a larger number of simulations did not lead to major changes in the performance of the transport network.

DISCUSSION AND CONCLUSIONS

Introduction of CAVs within road network circulation will play a big role within the city and transportation planning over the world. The research showed has been focused on CAVs application for urban public transport. The case studies considered for Italy and Croatia are similar (urban center layout, harbor operations, commutation service) but quite different from road network upgrade needs for CAVs operations.

Figure 3 shows overall road network performance estimated from traffic microsimulation model for the Termini Imerese and Rijeka environment. Traffic parameters (e.g,. delay, vehicles stops, and other) show correlation with the CAVs scenario in the case of Termini Imerese while in the case of Rijeka City there are practically no changes in traffic flows parameters. The

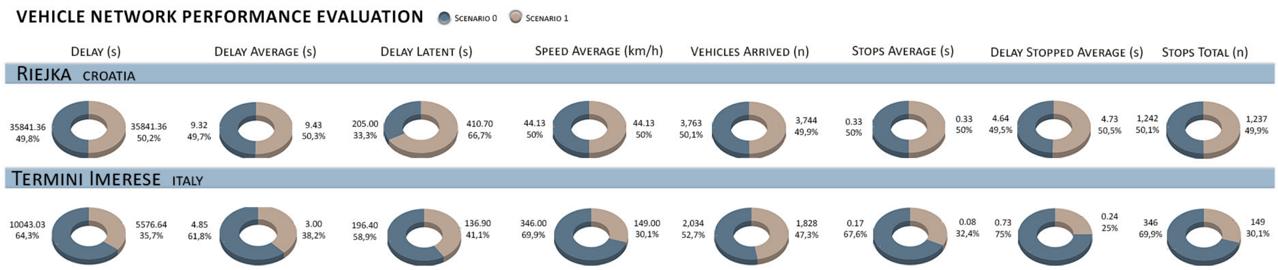


FIGURE 3 Vehicle's overall network performance evaluation.

reason could relate to specific road environment in Termini Imerese (Italy) which shows some advantages of the network reorganization in terms of reserved corridor for public transport route performed by CAVs. In the case of Rijeka, where the intermodal transportation route is linear, the potential CAVs corridor is less effective in terms of traffic parameters compared with more complex CAVs network in Termini Imerese. In any case, the findings obtained could lead to interesting design consideration for urban corridor to reserve for CAVs operations.

NOTES

1. T&E is an independent European environmental organization focusing on issues related to transport and environmental sustainability.
2. The Green Deal is an EU action plan that aims to make the economy sustainable by achieving climate neutrality by 2050 by reducing greenhouse gas emissions, promoting energy efficiency and introducing renewable energy.
3. The Turin Metro is the first in Italy to use the light automatic vehicle (VAL) system. It is designed to ensure maximum safety through an automatic train control (ATC) system specifically developed for this type of vehicle.
4. With more than 20 European cities chosen for testing, SHOW is the largest-ever project for autonomous vehicles in urban environments.
5. The city of Turin plans to become the first municipality in Italy to experiment with autonomous vehicles. This will facilitate the transportation of people with disabilities from their homes to medical facilities and vice versa.

REFERENCES

Abdelkader, G., K. Elgazzar, and A. Khamis. (2021). Connected Vehicles: Technology Review, State of the Art, Challenges and Opportunities. *Sensors*, Vol. *21, No.* 22, 2021, p. 7712.

Benevolo, C., R. P. Dameri, and B. D'Auria. *Smart Mobility in Smart City: Action Taxonomy, ICT Intensity and Public Benefits*, Springer International Publishing, Switzerland, 2016.

Caito, E.. La diffusione della guida automatica nel trasporto pubblico: impatti sul sistema dei trasporti e sul territorio (The spread of automatic driving within public transport: impacts on the transport system and the territory). PhD dissertation, Politecnico di Torino, 2020.

Evanson, A. Connected Autonomous Vehicle (CAV) Simulation Using PTV VISSIM. Proc., *IEEE Winter Simulation Conference,* December 2017, pp. 4420–4420).

Gazder, U., K. Alhalabi, and O. AlAzzawi. Calibration of Autonomous Vehicles in PTV VISSIM. *IET 3rd Smart Cities Symposium,* 2020, pp. 39–42.

Giuffrè, T., S. Trubia, A. Canale, and B. Persaud. Using Microsimulation to Evaluate Safety and Operational Implications of Newer Roundabout Layouts for European Road Networks. *Sustainability*, Vol. 9, No. 11, 2017, p. 2084.

Sukennik, P. Micro-Simulation Guide for Automated Vehicles. Charlotte Fléchon, PTV Group, 2019.

Transport & Environment. Emergenza clima: nel 2030 il 44% delle emissioni in Ue proverrà dai trasporti. Press release, March 21, 2024. https://www.transportenvironment.org/te-italia/articles/emergenza-clima-nel-2030-il-44-delle-emissioni-in-ue-proverra-dai-trasporti-2.

PTV Planung Transport Verkehr AG, PTV Verkehr In Städten. Simulationsmodell (VISSIM) Version 10, User Manual Karlsruhe, Germany, 2018.

Šurdonja, S., T. Giuffrè, and A. Deluka-Tibljaš. Smart Mobility Solutions: Necessary Precondition for a Well-Functioning Smart City. *Transportation Research Procedia*, Vol. 45, 2020, pp. 604–611.

Transport & Environment. Rewarding renewable efficiency—the energy efficiency of charging Electric Vehicles with renewable electricity must be rewarded in the RED. Briefing, February 2022.

Transport & Environment. State of European Transport 2024. https://transport2024.transportenvironment.org/ sot/topics/cars/index.html;

Vortisch, P. Wiedemann-99 Source Code https://www.researchgate.net/post/Where-I-can-find-the-mathematical-formulation-of-Wiedemann-99-car-following-model. Accessed November 20, 2023.

Installing Roundabouts to Manage Speeds and Access

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Improvements to US Route 20 (US 20 or Hartford Turnpike) in the town of Shrewsbury, Massachusetts, have been a priority for local officials for several years. The roadway has traffic congestion during peak periods and several locations where safety is a concern due to the number of and risk for crashes. Additionally, the roadway has few facilities for people walking and biking. Significant development is proposed or planned in the vicinity of US 20, which is anticipated to increase the number of vehicular trips and trucks using the roadway.

In March 2020, the Massachusetts DOT finalized a US 20 Corridor Master Plan that described a future roadway improvement concept to address existing and future safety and operational deficiencies faced by all users of the corridor while supporting anticipated future economic development. The US 20 Corridor Master Plan includes two travel lanes in each direction on US 20, facilities for bicyclists and pedestrians, safety improvements at high crash locations, upgrades to existing traffic signal equipment, and providing additional turning lanes as needed at existing signalized intersections.

After the master plan study was finalized, the town asked Massachusetts DOT to initiate design of a project for the easternmost section of US 20, an approximately 1.0-mi long section from the South Street–Green Street signalized intersection in the west to the Shrewsbury Village Driveway–Valente Drive intersection in the east (Figure 1). This section was prioritized for improvement due to existing safety concerns at three unsignalized intersections: South Street (south), Walnut Street (south), and Shrewsbury Village Driveway–Valente Drive. Additionally, it was noted that a portion of this section is in the top fifth percentile of segments for fatal and injury crashes in Massachusetts and is a secondary risk site for lane departure crashes based on a statewide ranking for the period from 2013 to 2017.

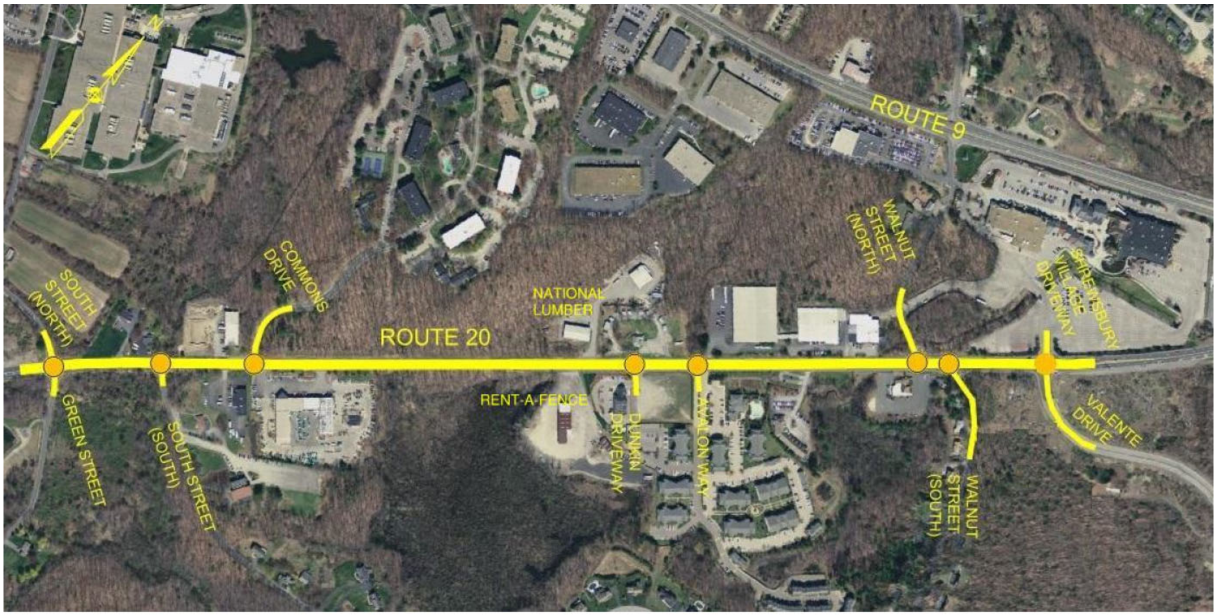

FIGURE 1 Aerial view of Shrewsbury–US 20 project extents.

Massachusetts DOT assigned HNTB to complete an alternatives analysis for this section of US 20 using the concept included in the master plan as a baseline alternative, and then to advance the selected alternative through design. The project purpose has been defined as

1. To improve traffic safety for all road users including non-motorists along US 20 from the Green Street–South Street intersection to the Valente Drive intersection,
2. To reduce high travel speeds,
3. To accommodate future traffic conditions with respect to the planned developments along US 20, and
4. To improve congestion issues within the project area.

METHODOLOGY

To evaluate the various alternatives for intersection control, Massachusetts DOT's Intersection Control Evaluation (ICE) tool was utilized. Massachusetts DOT's ICE tool was developed to allow for the evaluation of many intersection control strategies (such as traffic signal control, roundabout, and median u-turns) in a quantitative way, by comparing the LCCs relative to construction, maintenance, and operations costs, along with societal costs for traffic delay and crashes. Initially, the ICE tool was used for three locations along this section: US 20–South Street (north)–Green Street, currently a signalized intersection; US 20–Dunkin Donuts Driveway, currently an unsignalized two-way stop control (TWSC) intersection (Figure 2); and US 20–Shrewsbury Village Driveway–Valente Drive, currently an unsignalized TWSC intersection.

Alternatives to address the high travel speeds and better manage access were also evaluated. The master plan concept for much of the corridor where there is a high density of driveways proposed a two-way left-turn lane (TWLTL), however a detailed review of the crash data as well as a review of Massachusetts DOT's risk-based mapping during the alternatives analysis indicated that left turning crashes were of concern for the eastern half of the project limits. Specifically, the crash data between a fast food restaurant driveway and Walnut Street showed that 23 of the 25 crashes over a 3-year period involved a vehicle making a left turn either into or out of a side street or driveway. Therefore, three additional alternatives were evaluated for the eastern portion of the project. All three alternatives proposed a roundabout at the intersection of US 20–Shrewsbury Village Driveway–Valente Drive. Alternative 1 did not include any control modifications for intersections west of Valente Drive and proposed a TWLTL for the eastern portion, like the Route 20 Corridor Master Plan. Alternatives 2 and 3 proposed the addition of a roundabout at two different driveway locations roughly midway along the corridor and a raised median treatment to restrict left turn into and out of the side streets–driveways between the two roundabouts.

Massachusetts DOT's *Safety Alternatives Analysis Guide* provides a set procedure to evaluate the impact design decisions will have on the expected number of crashes in the future. The guide mathematically explains the steps of the analysis and describes methods for

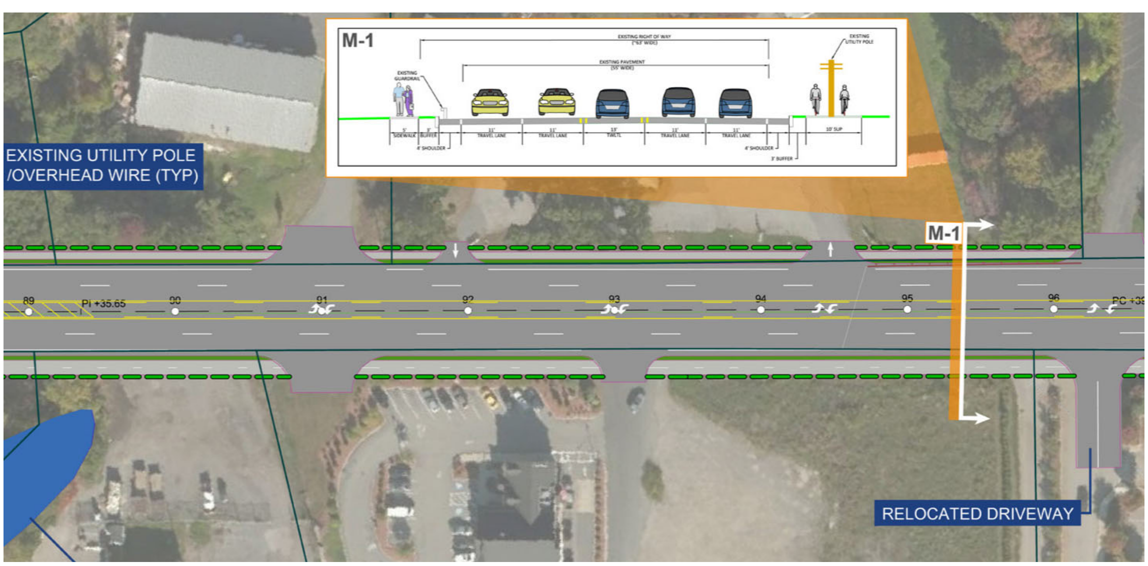

FIGURE 2 US 20 corridor master plan–concept plan near a fast food restaurant driveway.

documenting and interpreting the results. The safety alternatives analysis allowed the project designer to evaluate the decisions regarding intersection control and cross section as a system rather than individually. CMFs that were included in the alternatives analysis varied by alternative and considered design features such as: intersection control (such as conversion from TWSC to a roundabout), median treatment (undivided, TWLTL, raised median), turn prohibitions, and the potential to reduce the median operating speeds on the corridor.

As both Massachusetts DOT's ICE procedure and *Safety Alternatives Analysis Guide* were new during the alternatives analysis phase of the project, the alternatives analysis occurred as an iterative process with a multidisciplinary team of Massachusetts DOT staff, HNTB staff, as well as participation from town of Shrewsbury staff.

A draft alternatives analysis technical memorandum was prepared by HNTB in December 2021 which evaluated the intersection alternatives and two of the three cross section alternatives. The technical memorandum also discussed other criteria that would inform the selection of a preferred alternative including environmental constraints, utility impacts, and permitting–regulatory considerations. The safety alternatives analysis was completed in June 2022, which led to a recommendation on a preferred alternative, which was then advanced to preliminary (25%) design. The complete alternatives analysis process was documented in the Functional Design Report submitted by HNTB as part of the 25% design submission made to Massachusetts DOT in September 2023.

FINDINGS

Based on the results of the alternatives analysis and evaluation, the selected alternative retained the proposed "improved" traffic signal control alternative from the Route 20 Corridor Master Plan for the US 20–South Street–Green Street intersection, largely due to high anticipated construction costs for a multilane roundabout due to the significant regrading that would be required. The results from Massachusetts DOT's ICE Tool for this location are shown in Figure 3. At the US 20–Shrewsbury Village Driveway–Valente Drive intersection, the ICE analysis showed that a roundabout would provide the lowest LCCs and was selected over the proposed traffic signal from the master plan.

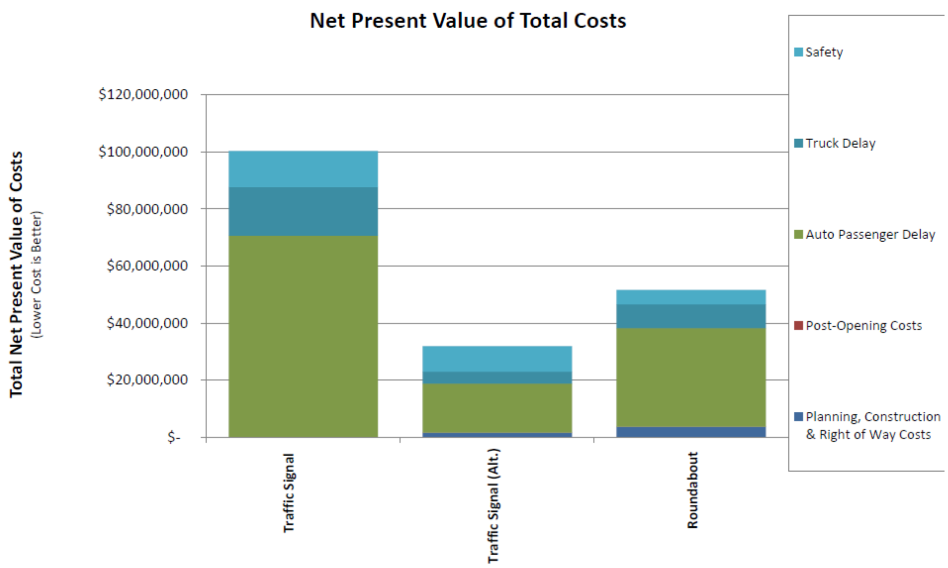

FIGURE 3 Intersection control evaluation results: US 20–South Street–Green Street.

The safety alternatives analysis significantly informed the design decision regarding the median treatment, as well as determining whether a roundabout would be placed midway along the corridor, and if so, which location (Avalon Way or the Lumber Liquidators Driveway) would be selected. The analysis showed that all three alternatives for the eastern portion of the project would significantly reduce the expected number of crashes in the design year (2042) over the expected number of crashes if no improvements to the existing condition were made. Alternative 3 was selected as the expected number of fatal and injury crashes would be 85% fewer than the no-build condition and 62% fewer than the TWLTL alternative that was proposed in the master plan. While the additional of the midway roundabout would add to the overall construction cost, the safety alternatives analysis determined that the safety BCR (based on 2022 order of magnitude construction costs) would be 2.04, the highest of the three alternatives. The results of the safety alternatives analysis are summarized in Figure 4.

CONCLUSIONS

The qualitative approach used for this project demonstrated that an alternative that combined a raised median to address left turning crashes with roundabouts to provide accommodation for turning vehicles would provide a significant safety benefit, particularly with regards to expected fatal and injury crashes. Additional benefits include: the roundabouts provide geometry to

	No-Build	Alt 1: TWLTL	Alt 2: Roundabout at Avalon	Alt 3: Roundabout at Rent a Fence
Estimated Crashes During the Design Year				
Total (FI)	4.97	1.95	1.23	0.75
Total (PDO)	15.17	8.64	6.34	5.52
Total (KABCO)	20.14	10.60	7.58	6.27
Lifetime Present Value		$ 15,232,916	$ 19,010,507	$ 21,417,898
Construction Cost		$ 8,500,000	$ 11,500,000	$ 10,500,000
B/C Ratio		1.79	1.65	2.04

FIGURE 4 Safety alternatives analysis results.

reduce speeds along the corridor which supports the selection of a design speed that more closely matches the desired operating speeds along the corridor, the middle roundabout also provides an additional location for pedestrians and cyclists to cross the roadway.

The project team used the results of the analysis to explain to the public why the roundabouts and the raised median were selected as part of the preferred alternative. A public information meeting was held in June 2022 and the design public hearing was held in May 2024. One of the renderings shown at the hearing in May 2024 is shown below in Figure 5. The design of the project to implement these improvements to better manage access and safety is expected to be completed for advertisement for construction in late summer 2026.

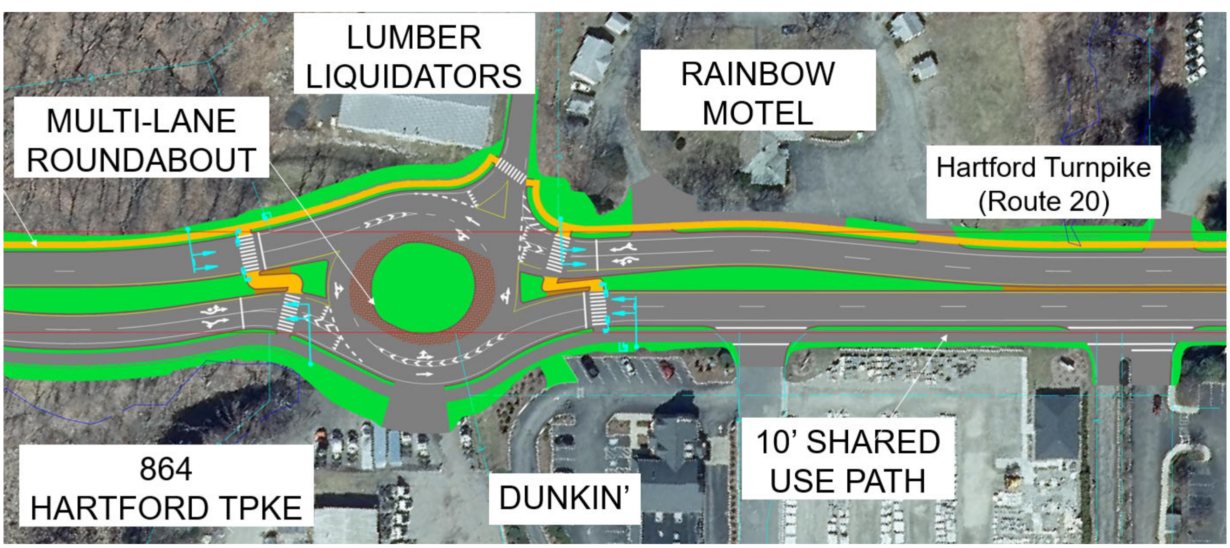

FIGURE 5 Project 25% design public hearing rendering: plan near Dunkin Donuts driveway.

RESOURCES

1. Massachusetts DOT and H. S. Hudson. *Route 20 Corridor Improvements Master Plan Report*. 2020. https://www.mass.gov/lists/shrewsbury-route-20-corridor-study-executive-summary-and-master-plan-report.
2. Massachusetts DOT and VHB. *Development of Safety Performance Functions for Rural and Urban Arterials and Collectors for Network Screening.* 2020. https://www.mass.gov/doc/the-development-of-safety-performance-functions-for-rural-and-urban-arterials-and-collectors-for-network-screening/download.
3. Massachusetts DOT and VHB. *MassDOT IMPACT Phase II - Identification of Risk Factors for SHSP Emphasis Areas - Rural and Urban Roadway Departures.* 2021. https://www.mass.gov/doc/rural-and-urban-roadway-departures-massdot-impact-phase-ii-identification-of-risk-factors-for-shsp-emphasis-areas/download.
4. Massachusetts DOT. *MassDOT Intersection Control Evaluation (ICE) Tool*. 2020. https://www.mass.gov/info-details/massdot-intersection-control-evaluation-ice.
5. Rodegerdts, L. A., J. W. Bessman, D. B. Reinke, M. J. Kittelson, J. K. Knudsen, C. D. Batten, and M. T. Wilkerson. *NCHRP Web-Only Document 220: Estimating the Life-Cycle Cost of Intersection Designs*. Transportation Research Board of the National Academies, Washington, DC, 2016. https://doi.org/10.17226/21928.
6. Massachusetts DOT. *MassDOT Safety Alternatives Analysis Guide*. 2021. https://www.mass.gov/doc/massdot-safety-alternatives-analysis-guide/download.

Hyannis Great Streets

Roads Reimagined for Regional Access and Safety

Whitney Burdge

Stantec

Downtown Hyannis is one of Massachusetts' notable seaside destinations and, as the Gateway to Cape Cod, is an economic center. For years, local and regional transportation access to and through downtown has been directed through two parallel roads facilitating one-way travel in opposite directions. One of these roads, Main Street, hosts the bulk of local businesses and visitor destinations while the other, South Street, directs visitors towards the waterfront and ferry–boat connections. Under this configuration, Main Street and South Street encourage speeding when traffic volumes are low; an absence of intuitive bicycle and pedestrian accommodations perpetuates this unsafe behavior. The circulation causes confusion for visitors and has created an imbalance where Main Street is a destination and South Street is a cut through. A particularly vulnerable intersection on South Street nicknamed "Six Points" was also a critical location requiring intervention.

Stantec employee, renowned urbanist, and author Jeff Speck have worked with the town to completely reimagine access and improve safety connections, successfully securing broad community consensus to revert these essential corridors back to their historical two-way configurations. In addition, a bold move was made to eliminate traffic signals in the downtown in favor of either stop-controlled or roundabout intersections. These changes will have significant implications for slowing vehicle speeds, attracting bicyclists with the accommodation of new, continuous bike paths, improving pedestrian crossings for seasonal visitors arriving by train or boat, and support the flow of safety vehicles to a nearby hospital and regional transportation hubs more efficiently.

METHODOLOGY

Stantec and the town of Barnstable used a number of quantitative and qualitative methods to establish a strong foundation to shape project recommendations that support improved access for the many types of visitors through downtown Hyannis. Comprehensive analysis was conducted to understand in great depth how the physical characteristics of the street network inform how they are used by various modes and how this influences user behavior when trying to access various destinations. Data analyzed included vehicle volumes, crashes, speeds, turning movement counts, vehicle flow patterns, and lane widths. These were analyzed in comparison to the location and access to shops and the downtown parking inventory, walking routes to the waterfront, school access, the regional transportation center, and other attractors to better assess travel patterns and barriers. Another important layer of analysis focused on systemic crash and threat factors, including sidewalk widths, block lengths, crosswalk frequency and protection, and gaps in interconnectivity between existing networks. Analysis of the transit network was also conducted to understand the flow of routes, levels of ridership, and ease of access to regional destinations.

Qualitative data was also captured through several site walks with town leadership and downtown stakeholders. Through firsthand experience, this included documenting conditions relating to the experience of traveling through the streets of Hyannis—including video footage—to help identify areas where it feels intimidating or confusing to cross the street, places which feel unsafe or uncomfortable due to a lack of amenities, or routes that cause stress due to unintuitive navigation and lack of signage.

The analysis provided an important lens of understanding and context in parallel with a deep review of previous plans and studies in the town's recent history that had revealed similar challenges and defined priorities in line with the goals of the Great Streets Project.

An essential layer of the evaluation was a series of outreach events. An initial workshop week included a large, broadcast public meeting to discuss the town's project priorities, introduce walkability principles, and to identify issues and opportunities in the study area. This was accompanied by seven roundtable sessions with stakeholder groups. A second public workshop presented a series of street design concepts for interactive public review and comment. This was paired with an online survey and further stakeholder discussions to help narrow down preferences. A third public meeting was held to introduce the preferred final concept designs and the final report. Throughout the entire process, a project website was actively maintained, allowing the community to view videos and materials of past meetings, and to provide virtual feedback.

FINDINGS

Data collected for the study revealed a high propensity for speeding and driver confusion that was directly impacting public safety because of the one-way network limiting options and forcing a two-lane cross-section for pedestrians to cross. Lane widths often exceeding interstate standards contributed to safety concerns but provided the opportunity through narrowing to insert a much-needed protected bicycle network downtown.

The one-way network was also identified to be a cause of congestion and delay due to forcing many different trips through the same downtown intersections, which operated unsafely for pedestrians to maximize vehicle throughput. The two-way network demonstrated lower delays, even with stop control, thanks to a redistribution of traffic across many new paths made available. Emergency responders immediately recognized the value of approaching incidents from two directions or having multiple paths to take to an incident across town.

The combination of narrower lanes and two-way travel without two one-way lanes greatly contributed to lower delays at crosswalks for both motorists and crossing pedestrians, even though overall vehicle speeds were much lower.

DISCUSSION

Once making the case for the town to revert to two-way streets, Stantec created a series of proposed street reconfigurations for the entire downtown network to both increase local and regional access, and take a fresh approach to a more multimodal, safe, and intuitive network. This vision not only supports the downtown economy by more simply directing visitors through its key commercial hub and ensuring planned developments have more options for access, but also supports a natural shift towards more walking, bicycling, and taking transit to and through the downtown. Stantec's expertise resulted in the community immediately hiring the team again to advance the design and construction of the two-way reversion, including extra focus on the highest priority challenge in the street network, the Six Points intersection.

The intersection design includes a complete revision of the current configuration by proposing a roundabout that will improve flow, reduce travel times, remove significant waiting times for pedestrians at the current signals, and support the ease of movement for emergency vehicles and other large freight vehicles that rely heavily on the intersection as a key waterfront access route.

Driver's Attention and Cognitive Behavior

T-Consciousness Impact

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Naghmeh Rezaie
University of Delaware

Mohammad Ali Taheri
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This study introduces an innovative research concept—T-Consciousness Fields (TCFs)—and explores their applicability in enhancing driver attentiveness and improving road safety. By integrating TCFs within access management strategies, this study proposes a supplementary model to enhance roadway access and ensure safe and efficient traffic movement. TCFs aim to address behavioral issues like distracted driving and improve driver attentiveness, contributing to a significant reduction in crashes and fatalities.

BACKGROUND AND MOTIVATION

The rise in traffic crash fatalities from 2020 to 2021 underscores the urgency of effective access management strategies. Factors such as speeding and distraction pose significant risks to road safety, affecting drivers, insurers, and society at large. Recent incidents are indicative of the insufficiency of technology alone in addressing these challenges. Previous research has demonstrated the beneficial effects of mindfulness practices on attention, cognition, and mental health. This study introduces T-Consciousness, theorized by M.A. Taheri, as the main constituent of the universe, to investigate the influence of TCFs on cognitive habits and behavioral changes.

OBJECTIVES

1. Integrate TCFs into Access Management. Leverage TCFs to enhance driver attentiveness and improve road safety within access management strategies.
2. Develop an Educational Plan. Design an educational plan to improve long-distance driving concentration and promote mindful decision-making.
3. Implement In-Vehicle Feedback Control Devices. Use in-vehicle devices to put drivers under TCFs, enhancing real-time attentiveness and road safety.
4. Safety Enhancements. Implement car alarms, real-time feedback, and strategies to address distracted driving.
5. Minimize Reliance on Technology. Integrate technology, behavior, and education efforts to create a holistic approach to road safety.

RESEARCH METHODOLOGY

The proposed research methodology involves a three-phase project to be completed within 12 months

1. Phase 0. Currently underway at the University of Maryland (UMD), focusing on foundational research and preliminary testing, with UMD IRB approval (IRB 2099665-1) and Collaborative Institutional Training Initiative Training License for two group admins.
2. Phase I. Starts after funding approval and includes controlled experiments. Drivers will be assigned to a control group and a TCF-treatment group. The Flanker Task and Attention Network Test (ANT) will measure attention levels for the test and control groups and compare the results.
3. Phase II and III. Focusing on real-world applications and extensive data collection. The study will collect brain signals via electroencephalogram, detect movements using cameras and sensors, and analyze the signals using AI/ML to estimate driver attention. The results will address access management strategies, optimizing roadway access and ensuring safe traffic flow.

EXPECTED OUTCOMES

1. Enhanced Attentiveness. The study aims to establish that TCFs can significantly enhance driver attentiveness and reduce stress in both short and long-distance driving.
2. Behavioral Improvements. By addressing behavioral issues like aggressive, anxious, and unstable driving, the study seeks to reduce accidents and fatalities.
3. In-Vehicle Devices. Implementing feedback-control devices in vehicles will provide real-time support to drivers, improving attentiveness and decision-making on the road.
4. Safety and Efficiency. TCFs are expected to improve road safety by fostering more attentive drivers and implementing better detection systems, thus reducing car and truck collisions involving pedestrians and bicyclists.
5. Accessibility and Cost. The TCF treatment is user-friendly, eco-friendly, and cost-free for drivers regardless of age, gender, race, or driving history.

CONCLUSIONS

Integrating TCFs into access management strategies offers a promising approach to optimizing roadway access and ensuring safe and efficient traffic movement. This interdisciplinary project addresses human factors in transportation safety management systems, merging cognitive and behavioral aspects to provide a comprehensive solution for mitigating distracted driving and enhancing overall road safety. The innovative use of TCFs not only improves driver attentiveness but also contributes to the development of safer, more efficient transportation systems for all users.

Destination Accessibility Through GIS-Based Public Transport Analysis

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Accessibility serves as a critical parameter in evaluating the performance of public transportation systems. Consequently, it is imperative for the public transport network to be well-connected and easily accessible. The effectiveness of mass transit systems is based on their accessibility, leading to the incorporation of feeder services to enhance their utility. Feeder services play a vital role by extending the reach of these primary transit lines, linking them to more remote O-D points. It is, therefore, significant to efficiently design the routes of these feeder services to ensure comprehensive coverage.

METHODOLOGY

This study assesses the accessibility of key destinations within the city, primarily focusing on their connectivity to feeder routes. This, in turn, serves as an evaluation of the accessibility aspect of the feeder service itself.

To conduct this evaluation, we have analyzed the accessibility of various prominent destinations serviced by the Speedo bus service, which is specifically designed as a feeder service to complement the Lahore Bus Rapid Transit system. The evaluation tool for this purpose is ArcGIS, enabling us to precisely measure both distance-based and time-based accessibility.

To assess destination accessibility via public transport, we established two criteria. The first criterion is about the number of available routes, while the second criterion considers the time required to reach a destination from a bus stop on foot. The cumulative accessibility score was calculated by summing the scores from both criteria and assigned to each selected destination. These two measures allowed us to explore geographic aspects of public transit accessibility in the city. After this assessment, we conducted a statistical analysis on the land use classification and the total accessibility scores.

FINDINGS AND DISCUSSION

The findings provide a measure to identify areas with low levels of accessibility. GIS approaches are adopted to calculate the accessibility score and illustrated the level of accessibility for the 1,372 destinations in the selected Lahore region. The findings provide a measure to identify areas with low levels of accessibility. This accessibility score not only measures the level of accessibility but also it can be a better predictor when it is applied in a travel behavior model.

Statistical analysis also categorizes the overall land use. In this study, 57% destinations out of 1,372 are in commercial use and 3% are industrial. The remaining destinations are residential, recreational, health, and educational. There are 34% destinations that have a total accessibility score of 5 which means that they have moderate level of accessibility and only 3% destinations have high accessibility level and 3% destinations have lowest accessibility score and they gained accessibility score of 7 and 3 respectively.

The major portion of this research evaluates topological type of accessibility. It also paved the way to use both types of accessibility, i.e., topological, and contiguous in a single research study. Because the results of this study are used to assign accessibility score to a specific piece of land.

This small-scale study is feasible for those areas where walking is a substitution for the use of motorized vehicle to travel and maintain reasonable level of accessibility to the destination from bus stop. The presented techniques are straightforward to apply, while they showed better and more accurate measurements for public transportation accessibility. The quantitative approaches developed can be employed for different type of public modes in other cities around the world. It is designed to be applied with available census and transport modelling tools. This study provides a useful tool for exploring public transit accessibility and it provides the ability to investigate both overall public transit accessibility and the public transit accessibility of a single domain or destination type. Because this research study elaborates both the criteria based on access time and routes. Accessibility is calculated based on land use types, it allows for investigation at a variety of scales (land use types, and a variety of possible aggregations). Thus, accessibility could be useful for neighborhood level studies and for citywide and regional studies.

Reforming Parking Standards and Travel Demand Management

Case Studies in Overland Park, Kansas, and Boston, Massachusetts

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Communities across the country are re-examining how they manage travel demand for new development projects. In large cities like Boston, this means ensuring developers build upon the robust multimodal travel networks already in place. In suburbs like Overland Park, Kansas, which greatly expanded in the second half of the 20th century, this means chipping away at the presumption that new projects are designed around automobile travel.

Development standards in each community perpetuate the trends of single-occupancy vehicle (SOV) travel. Projects can face inwards, rather than out towards the street network, making access on foot, bike, or bus more challenging. Where mandated, minimum parking requirements can be higher than national and peer city standards, obligating the construction of more parking than is demanded.

Stantec's collaboration on the Overland Park Parking Standards Update and Community Parking Strategy and with the Boston Transportation Department (BTD) on its Transportation Demand Management (TDM) Point System address these deficiencies and support development standards which place walking, bicycling, and taking transit on more equal footing with driving.

METHODOLOGY

Overland Park

Stantec and the city of Overland Park used a number of quantitative and qualitative methods to inform its analysis and recommendations. A peer review of seven communities across the country, representing large suburbs outside major cities like Overland Park, was conducted in order to provide a point of comparison with the parking standards in Overland Park's Unified Development Ordinance (UDO). This included an evaluation of the minimum parking requirements for common land uses such as housing, office, retail, and residential as well as identification of other policy solutions such as parking maximums, shared parking allowances, multimodal standards for development (such as required bicycle parking) and site design standards for parking areas.

Another quantitative evaluation used Census data, aerial imagery, location-based survey data from Replica, parcel data, and previously collected parking occupancy counts to determine how observed parking demand in the community differed by land use and by location in the community.

A final angle to the evaluation was three stakeholder roundtable sessions with local developers. These roundtables established how developers navigate the UDO today, how potential changes to the UDO could encourage or prohibit development activity, and how much impact potential changes to Overland Park's UDO would have in the context of real estate development throughout the Kansas City area.

Boston

The project team reviewed over 50 academic papers, research reports, and key documentation from TDM programs and trip reduction literature to document benefits of individual TDM strategies. Much of the same research which was used to inform the San Francisco's TDM Program was used for this effort. This is due to both the breadth of research uncovered by that program as well as the body of more recent research since the San Francisco program came online in 2017.

Additionally, interviews with eight peer cities and research stakeholders were conducted to inform formulation of the point system framework. Stantec and the BTD engaged with an extensive internal stakeholder group as well as the development community, including consultants frequently involved in permitting, to better understand how different TDM strategies supported larger citywide goals (such as ambitious mode share targets associated with the Go Boston 2030 long-range transportation plan) and avoided posing undue burdens on developers.

FINDINGS

Overland Park

Usage data collected for travel patterns as well as an evaluation of peer city standards found that Overland Park encourages access to new projects at unsustainable rates. For every 1,000

ft^2 of new retail (and other non-office uses), office, and restaurant uses, at least 2,000 ft^2 of associated parking must be built; for every 1,000 ft^2 of restaurant use, over 8,000 ft^2 of parking must be built, for instance. Residential, office, retail/commercial, and restaurant land uses called out in the UDO require the construction of more parking than in the seven peer communities evaluated.

For commercial projects, including retail, observations at 32 locations found that half of these developments featured parking demand between one and two vehicles per 1,000 ft^2; by comparison, the city's parking standards require four spaces per 1,000 ft^2. Observations at 24 office locations found similar oversupply. Demand for residential projects was also noted to be lower for renter-occupied housing and along corridors such as Metcalf Avenue where development opportunities exist.

Furthermore, design standards in the UDO prioritize vehicle flow, further reinforcing a built environment structured around vehicle travel, and lessening the safety and comfort of pedestrians, bicyclists, and transit users. Specifications designed to improve pedestrian visibility, prioritize pedestrian safety in areas (like parking lots) where walkers and drivers mix, and reduce the prominence of parking areas along street frontages can help create a streetscape which encourages less car usage and easier multimodal access.

Boston

High-level research findings found many common threads. Parking-related TDM measures and those involving subsidies have the greatest impact; across the board, the availability and cost of parking near a project site was found to be the most critical factor in determining travel choices. Programmatic strategies boost the success of all other TDM strategies by increasing awareness and facilitating use of these strategies. Bicycling strategies work best when bundled (for instance, pairing a bikeshare membership with changing rooms) and carpooling was found to be effective at reducing vehicle miles traveled for those with longer commutes.

One common thread (and limitation) of the available research was an inability to account for the environmental context by which a TDM strategy was instituted. Many vehicle trip reduction estimates are likely to trend higher in the city of Boston, and particularly higher in downtown Boston, owing to the transit and multimodal travel network. As these travel modes are improved over time, a "knock-on" effect will continue to accrue, as the presence of more individuals bicycling, walking, and taking transit signal to others that these modes of travel are best for satisfying travel needs.

DISCUSSION

Overland Park

Stantec worked with the city to support development standards which place walking, bicycling, and taking transit on more equal footing with driving. Stantec's feedback resulted in the community revising its parking-related code in February 2023 to update policy and design standards related to off-street parking construction.

New parking requirement ratios have been developed which provide flexibility for standards to best match different land use types and areas in Overland Park. Minimum and maximum standards are provided for key land use in the community; developers constructing parking within these standards are not subject to further review. Projects with parking below minimum standards or above maximum standards must design parking to be shared as part of the public supply (whether or not the need currently exists) as well as provide demand reduction amenities. This innovative model allows developers more by-right flexibility to construct the parking they feel is necessary while protecting the municipality from the harmful effects of over-provision of parking throughout the community and the political uncertainty associated with under-provision of parking at the site level.

Other new provisions of the UDO include shared parking standards to support sharing of on-site parking between two or more uses with different demand profiles or allow vacant parking near a project to be counted towards the on-site supply. Specifications designed to improve pedestrian visibility, prioritize pedestrian safety in areas (like parking lots) where walkers and drivers mix, and reduce the prominence of parking areas along street frontages will help create a streetscape which encourages less car usage and easier multimodal access.

Boston

With the findings of the research and stakeholder interviews, Stantec and BTD crafted the TDM Point System to best match citywide policy goals, the experiences of practitioners elsewhere, and the logistical and economic realities faced by developers in Boston. The custom framework provides a menu of TDM measures including high-impact policy solutions such as parking pricing, transit subsidies, and network enhancements such as bicycle racks and ridesharing support. Point targets for projects vary based on characteristics like location, land use type, and accessory parking provision.

The policy supports related maximum parking ratios developed by the city which reflect the belief that new developments should align their planned parking to complement rather than counteract the amount of access to transit, walking, and micromobility surrounding the site.

Prior to the release of this new system, TDM measures for large new developments were typically negotiated with the city of Boston on a case-by-case basis. As a result, TDM approaches and outcomes among previously approved developments tend to vary widely. This policy applies clear standards for implementing TDM for development projects using proven means to encourage more sustainable travel behavior. As noted by A Better City, by taking a cohesive approach to disincentivizing SOV usage at large new developments, standardization of the process also supports progress toward Go Boston 2030 mode shift goals and the related Carbon Free Boston goal of net neutrality by 2050.

Pedestrian Signal Usability

A Focus on Access Management and Perception

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The increasing frequency of vehicular accidents in urban centers like Lahore, Pakistan, has become a pressing concern. Pedestrian–vehicle collisions are a significant threat to public safety, emphasizing the need for effective access management strategies. Access management encompasses various techniques to regulate traffic flow, enhance safety, and optimize transportation infrastructure use. A crucial aspect of access management is the strategic placement of pedestrian signals at controlled intersections. Properly designed and placed pedestrian signals can significantly reduce conflicts and accidents, ensuring the safety of pedestrians.

Recent studies have highlighted the importance of access management in reducing pedestrian-vehicle collisions. A study published in the *Journal of Transportation Engineering* (2019) found that properly designed controlled intersections can reduce pedestrian–vehicle conflicts by up to 75%. Another study in the *International Journal of Injury Control and Safety Promotion* (2024) emphasized the critical role of pedestrian signals in enhancing pedestrian safety, with well-designed signals reducing pedestrian crashes by 40%. *The Journal of Safety Research* (2020) stressed the need for pedestrian-centric access management strategies, given the disproportionate risk of pedestrian–vehicle collisions in urban areas. A review of literature in the *Transportation Research Part C: Emerging Technologies* journal (2020) underscored the potential of intelligent transportation systems and smart traffic management in optimizing access management and improving pedestrian safety. These studies collectively emphasize the urgency for effective access management strategies, including the strategic placement of pedestrian signals, to mitigate pedestrian-vehicle collisions and ensure usability of pedestrian signals with an assurance of public safety in urban centers like Lahore.

METHODOLOGY

This research focuses on the Mall Road Corridor in Lahore, a bustling area with 12 signalized intersections that attract pedestrians from diverse backgrounds. The corridor is home to government offices, educational institutions, hospitals, and recreational spots, making it an ideal location for studying pedestrian signal management and pedestrian behavior. To collect data, a self-completion questionnaire survey was conducted, targeting pedestrians at intersections throughout the corridor. The survey gathered information on socioeconomic characteristics, and usage of pedestrian signals with perceived impact with reference to access management. A total of 600 surveys were collected. The survey included 23 observed variables aimed at capturing users' perceptions of pedestrian signal usability, which were then subjected to factor analysis. The results were analyzed to identify key factors influencing pedestrian signal usability.

FINDINGS AND DISCUSSION

The demographic analysis of the participants revealed that the majority (59%) were male, aged between 18 to 25 years, highlighting the need for accessible pedestrian signals that cater to the needs of diverse age groups. The sample comprised individuals with varying educational backgrounds, including graduates (36%), as well as those with intermediate education, below matriculation, and no formal education, ensuring a diverse representation of educational levels. The monthly income of most participants ranged from PKR 25K to PKR 70K, indicating the need for pedestrian signals that are accessible to people from various socioeconomic backgrounds. Regarding transportation habits, 31% of the respondents used a combination of public transportation and walking, while 19% relied solely on walking, accenting the significance of pedestrian-friendly infrastructure and signal management. The daily walking duration of the respondents varied, with 41% walking for a maximum of 30 min, 36% of participants walking for 15 min or less, highlighting the need for pedestrian signals that accommodate different walking speeds and abilities. Notably, all respondents crossed the road at the Mall Road intersection at least five times a week, underscoring the importance of effective usage to ensure safe and convenient crossing experiences. In terms of signal usability, the data showed that 54% of the respondents utilized the signal directly or indirectly, while 46% did not use the signal at all, indicating a need for more intuitive and accessible pedestrian signal design to encourage usage and enhance safety.

Factor analysis revealed seven latent variables derived from 23 observed variables, shedding light on the complex factors influencing pedestrian signal usability and accessibility. Table 1 presents the latent variables, associated observed variables with factor loading, and Cronbach's alpha value. The majority of latent variables linked to observed variables indicate incorrect signal placement, hindering usability. Furthermore, observed variables reveal that crossing times at these placements are excessively long, prompting users to disregard signals. Additionally, variables highlight safety concerns due to accident risks at these locations, with factor loading ranging from 0.6 to 0.8 for each variable. Therefore, safety, time, and

TABLE 1 Latent Variables with Observed Variables and Factor Loading

		Composite Reliability	
Latent Variables	**Observed Variables**	**Factor Loading**	**Cronbach's Alpha**
Decision to follow the signal	Safe	0.691	0.75
	Accessible	0.824	
	Convenient	0.757	
	Crossing duration	0.636	
Decision to not follow the signal	Not safe	0.736	0.9
	Time taking	0.718	
	Vehicles cover zebra crossing	0.645	
	Not convenient	0.787	
	Chances of being robbed	0.590	
	Crossing from midblock	0.648	
	Signals do not work	0.709	
	Not accessible	0.630	
Placement site	Effective placement	0.893	0.9
	Clear visibility	0.877	
Safety perspective	Pedestrian accident due to heavy traffic volume	0.793	0.8
	Pedestrian accident due to high traffic speed	0.807	
Traffic characteristics	Traffic volume	0.844	0.8
	Traffic speed	0.840	
Regulation	Signal implementation	0.856	0.7
	Raising awareness	0.859	
	Law enforcement	0.782	
User satisfaction	Safety	0.741	0.6
	Comfort	0.693	

convenience emerge as key variables influencing user decisions, alongside other variables requiring attention to enhance signal usability. These latent variables demonstrate a strong correlation with pedestrian signal accessibility management that accounts the need for authorities to prioritize this aspect in future design initiatives.

REFERENCES

Paul, M., and I. Ghosh. Analysis of Pedestrian Conflict with Right-Turning Vehicles at ignalized Intersections in India. *Journal of Transportation Engineering, Part A: Systems*, Vol. 143, No. 6, 2019, p. 04017024. https://doi.org/10.1061/JTEPBS.0000239.

Mukherjee, D. Analyzing Key Determinants of Pedestrian Risky Behaviors at Urban Signalized Intersections: Insights from Kolkata City, India. I*nternational Journal of Injury Control and Safety Promotion*, 2024, pp. 1–29. https://doi.org/10.1080/17457300.2025.2494213.

Wang, Y. C., R. D. Foss, A. H. Goodwin, A. E. Curry, and B. C. Tefft. The Effect of Extending Graduated Driver Licensing to Older Novice Drivers in Indiana. *Journal of Safety Research*, Vol. 74, 2020, pp. 103–108. https://doi.org/10.1016/j.jsr.2020.04.001.

Alhajyaseen, W. K. M., A. Al Mamun, and M. M. Ahmed. Pedestrian Support in Intelligent Transportation Systems: Challenges, Solutions, and Open Issues. *Transportation Research Part C: Emerging Technologies*, Vol. 121, 2020, p. 102856. https://doi.org/10.1016/j.trc.2020.102856.