A NATIONAL INVESTIGATION ON THE IMPACTS OF LANE WIDTH ON TRAFFIC SAFETY:

Narrowing Travel Lanes as an Opportunity to Promote Biking and Pedestrian Facilities Within the Existing Roadway Infrastructure

November 2023

JOHNS HOPKINS
BLOOMBERG SCHOOL
of PUBLIC HEALTH

Bloomberg American
Health Initiative

ACKNOWLEDGMENTS

This report was supported by a grant from the
Bloomberg American Health Initiative at the
Johns Hopkins Bloomberg School of Public Health

Principal Investigator
Shima Hamidi, PhD, Bloomberg Assistant Professor of American Health and Director of the Center for Climate-Smart Transportation (CCST)

Co-Principal Investigator
Reid Ewing, PhD, Distinguished Professor of City and Metropolitan Planning and Distinguished Chair for Resilient Places at the University of Utah

Research Team:
Ebrahim Azimi, PhD, Johns Hopkins University
Mohamad Tayarani, PhD, Cornell University
Bahar Azin, PhD, University of Utah
Justyna Kaniewska, MS, University of Utah
Dong-ah Choi, PhD, University of Utah
Hassan Ameli, PhD, University of Utah
Duman Bahrami-Rad, PhD, Bowdoin College

EXECUTIVE SUMMARY

This project is one of the first and the most comprehensive efforts to date to address a long overdue built environmental challenge to health: the lack of conclusive quantitative evidence on the effects of lane width on safety which has led to unnecessarily wide travel lanes that are designed to accommodate fast and convenient driving.

This national study investigates the feasibility of narrowing vehicle lanes as the easiest and most cost-effective way to accommodate better sidewalk and bike lane facilities within the existing roadway infrastructure. The study asks whether, and to what extent, we can narrow existing vehicle lanes (for different road classifications) without adverselyimpacting traffic safety.

This study employed a sample of 1,117 street sections (a series of homogeneous road segments) from seven different cities and conducted one of the most comprehensive data collections on geometric and street design characteristics of street sections including bike lane type and width, median type and width, sidewalk type and width, street's sense of visual motion, on-street parking type, width and occupancy rates, number of lanes and number of bus stops, street trees, and the degree of street curvature.

We conducted a series of four negative binomial regression analyses to investigate the relationship between lane width and the number of non-intersection crashes, after controlling for the aforementioned confounding factors. This study, to our knowledge, is the largest and most comprehensive study focusing on the impacts of travel lane width on traffic safety outcomes such as the number of vehicle accidents.

Overall, this study found no evidence that narrower lanes are associated with the higher number of crashes and that narrow lanes (9-foot and 10-foot) increase the risk of vehicle accidents, after controlling for cross-sectional street design characteristics and other confounding variables. Quite contrary, our models confirm that in some cases (in the speed class of 30–35 mph), narrowing travel lanes is associated with significantly lower numbers of non-intersection traffic crashes and could actually contribute to improvement in safety. These findings are novel with groundbreaking and immediate policy/practical implications for identifying streets in each road class as the best candidates for lane width reduction projects.

Our in-depth interviews with state DOT officials in five states also offer valuable insights on the challenges of executing lane width reduction projects and revising existing guidelines to promote narrower lanes. We also offer a range of innovative solutions that have been adopted by these states to overcome this challenge and best practices that could be applicable to other state and local departments of transportation in the country. Practical implications and policy recommendations of these findings are further explained in the report.

KEY FINDINGS

- Our survey of AASHTO member state DOTs indicate that the majority of state DOTs prefer to follow the conventional design standards adopted by their DOT, and the context-sensitive design approach has not been widely used within their jurisdiction.
- In practice we are far from implementation of the context-sensitive design solutions by most state DOTs. The design exception for lane width reduction projects seems to be a rare event in most state DOTs that participated in our survey.
- Overall, the results of our AASHTO survey demonstrate the extent of the gap and highlight how little we know about the traffic safety impacts of lane width due to the lack of data and rigorous and comprehensive quantitative studies.
- This study is one of the first and the most comprehensive quantitative efforts on the relationship between lane width and the number of non-intersection crashes.
- With a sample of 1,117 street sections from seven cities and more than 20 geometric and street design variables, we found no evidence that wider lanes are safer in terms of the number of non-intersection crashes.
- We found that the number of crashes does not significantly change in streets with a lane width of 9 feet compared to streets with lane widths of 10 feet or 11 feet, after controlling for cross-sectional and street design confounding factors such as posted speed limit, traffic volume, on-street parking, median type, number of lanes, bus stops, and similar sense of visual motions, most likely because the difference in lane width is not noticeable to drivers.
- The difference becomes noticeable once changing the lane width from 9 feet to 12 feet which, in fact, increases the number of crashes.
- We also found that the relationship between lane width and the number of non-intersection crashes varies substantially across different speed classes.
- In the speed class of 20—25 mph, the driving speed is slow enough that drivers do not notice changes in lane widths. This hypothesis was confirmed by our findings that there is no significant difference in terms of the number of non-intersection crashes between 9-foot, 10-foot, 11-foot, 12-foot, or even 13-foot lanes.
- On the other hand, street sections with 10-foot, 11-foot, and 12-foot lanes have significantly higher numbers of non-intersection crashes than their counterparts with 9-foot lanes in the speed class of 30—35 mph.
- In other words, in the speed class of 30—35 mph, wider lanes not only are not safer, but exhibit significantly higher numbers of crashes than 9-foot lanes, after controlling for geometric and cross-sectional street design characteristics of street sections.
- Street sections in the speed classes of 20—25 mph and 30—35 mph have the greatest potential to be utilized by pedestrians and bicyclists due to their relatively lower speeds.

- This is not to say that 9-foot or 10-foot lanes are appropriate and recommended in different contexts. In streets in the speed class of >35 mph that serve as a transit or freight corridor, 11-foot lanes would be more appropriate to accommodate oversized trucks.

- The most immediate candidates for lane width reduction projects are street sections with lane widths of 11 feet, 12 feet, or 13 feet in urban street in the class of 20—25 mph and 30—35 mph that do not serve a transit or freight corridor.

- More specifically, of these candidates, those that have lower traffic volume (AADT), no or small proportion of on-street parking, low degrees of street curvature, fewer numbers of lanes, and with no travelable (raised) median are the best candidates for the lane width reduction projects, according to our study.

- In practice, justifying, designing, and implementing narrow travel lanes (9-foot to 10-foot) is very challenging as cited in our interview with several state DOTs.

- Our interview with VTrans (as the first state to adopt 9 feet as a minimum lane width standard in specific contexts) found that implementation of a minimum lane width of 9 feet has not been done in any case in the past couple of decades, which makes such standards stay in the book with very little success in execution.

- One way to address these challenges is to rethink and redesign the procedure for specifying lane width standards and guidelines in an urban setting to start with a 10-foot length and ask traffic engineers to justify for a wider lane. It counters the existing practice of lane width design in most states where lane width in the urban core (speed of 35 mph or less) starts with 12 feet and (if any) justification from design engineers aims to narrow it further. Florida DOT is one of very few states that follow this practice.

- Another innovative intervention would be to develop a context classification system for road design. The context classification system allows Florida DOT to look at the area's needs in picking the best road design measurements. Using context-based design guidelines substantially facilitates the design justification that engineers need to apply to roadways. Florida DOT is one of the pioneering states on developing its own context-sensitive system.

- In sum, the lane width reduction or any isolated roadway design improvement alone may not be sufficient to provide a design practice that is appropriate for the context or to adjust driver/user behavior. A holistic approach to street design is necessary, using all available context cues and design elements, to provide a design alternative that matches the context of the roadway segment and make it safer for all street users.

TABLE OF CONTENTS

1. Introduction 7

2. Review of Existing Evidence 10

Conventional Street Design Practice in the U.S. 10

Lane Widths and Safety 11

A More Comprehensive Picture of Safety and Street Determinant Factors 12

- Street Tree Coverage 13
- On-street Parking 13
- Traffic Calming Devices 14
- Pedestrian and Bicyclist Countermeasure 14
- Street Network Design 15

Context-Sensitive Design 16

Summary of Findings 19

3. Lane Width and Traffic Safety: A Three-Part Mixed Method Investigation 20

PART 1: Survey of AASHTO Committee Members 21

- 3.1.1. Summary of AASHTO Survey Responses 33
- 3.1.2. Key Takeaways from the AASHTO Survey 36

PART 2: Lane Width Reduction from Theory to Practice: Evidence from Five States in the U.S. 34

- Florida's Practice and Experience with Lane Width Reduction 34
- Vermont's Practice and Experience with Lane Width Reduction 41
- Oregon's Practice and Experience with Lane Width Reduction 45
- California's Practice and Experience with Lane Width Reduction 49
- Delaware's Practice and Experience with Lane Width Reduction 56

PART 3: A National Quantitative Investigation of Lane Width and Safety 61

- Unit of Analysis 61
- Variables 65
- Data Collection 68
- Analytical Methods 72
- Key Findings 72
- Learning from the Existing Lane Width Reduction Projects (Before—After Studies) 84

4. Discussion and Policy Recommendations 85

Key Takeaways 86

Policy Recommendations 87

List of References 90

Appendices 93

Appendix A. Survey Questionnaire 93

Appendix B. Contact Information & Affiliation of AASHTO Survey Respondents 98

Appendix C. Florida DOT Lane Width Guiding Documents 99

Appendix D. Vermont DOT Lane Width Guiding Documents 107

Appendix E. Oregon DOT Lane Width Guiding Documents 111

Appendix F. Caltrans (California DOT) Lane Width Guiding Documents 124

Appendix G. Delaware DOT Lane Width Guiding Documents 127

1. INTRODUCTION

In 2021 alone, 42,915 deaths from car accidents were reported in the U.S. which makes traffic-related fatalities a leading cause of death for people between the ages of one to 54 in the country. The U.S. also exhibited by far the highest fatality rates from car accidents among developed counties with about 11.67 fatalities, compared to only 1.3 to 3.2 deaths per 100,000 population in European cities (Amsterdam, Berlin, Copenhagen, and Paris) in 2020.

The traffic fatality rates in the U.S. are even more striking for pedestrian and cyclists as the most vulnerable street users. The year 2020 marked the deadliest year for pedestrians in 40 years. Pedestrian fatalities increased more than 40% from 2010 to 2018 while most other countries experienced a decline in pedestrian deaths during the same time. Biking fatalities are no exception and experienced an increase of more than 44%from 2010 to 2020.

One key reason for such striking statistics is that Americans drive more than their counterparts in other developed nations and so are increasingly exposed to car accidents. American cities are among the most sprawling and car-oriented cities where, in most cases, driving is the only travel mode available to households for commuting and other transportation needs. Higher numbers of car trips and longer distances significantly increase the likelihood of car crashes and fatalities.

Another key reason for such high rates of traffic fatalities in the U.S. has to do with its car-oriented street design. One of the most controversial street design characteristics is travel lane width. In most American cities, streets are designed to accommodate fast and convenient driving with the conventional traffic engineering theory that wider streets are often safer. High-speed designs are assumed to be more forgiving of driver error and, therefore, reduce the likelihood of traffic accidents and fatalities. As stated in the American Association of State Highway and Transportation Officials (AASHTO) Green Book (2004a, 67): "every effort should be made to use as high a design speed as practical to attain a desired degree of safety."

Yet, the evidence on the relationship between travel lane width and safety is mixed. The safety impacts of lane width have been the subject of empirical studies since 1950 and the majority of studies on rural highways found that increasing travel lane width up to 12 feet would reduce crashes (Milton & Mannering, 1998; Gross et al., 2009), but beyond 12 feet may be detrimental to safety (Miaou, 1996).

However, there is little consensus about the safety impacts of reducing lane width in urban areas. While some studies of urban arterials found no significant difference in safety with respect to lanes narrower than 12 feet (Strathman et al., 2001; Potts et al., 2007), others have shown that wide lanes adversely impact traffic safety in urban areas likely because drivers tend to adapt to their environment and may feel less safe and drive more cautiously on narrow streets (Manuel et al., 2014; Noland, 2003; Noland and Oh, 2004; Lee and Mannering, 1999).

The mixed evidence may be due to the fact that these empirical studies and the conventional engineering wisdom fail to account for confounding built environmental and design characteristics that would affect safety performance indicators. There are several design characteristics that have been largely missed in previous studies and could affect the safety of roads with the same lane width. Design elements such as the presence of trees, building setbacks, sidewalks, bike lanes, on-street parking, and other cross-sectional characteristics could play a key role in slowing driving speed and making the street safer and, therefore, should be factored in the analysis of the link between travel lane width and traffic safety.

In addition to the safety concerns, travel lane width is a critical indicator of the right-of- way for motorist and non-motorist users. There has been a constant competition for space in roadways' right-of-way. In most American cities, the automobile is the winner of this competition, making it a challenge to find space for bike lanes and sidewalks.

Nevertheless, American cities have experienced an increasing demand for walking and biking in recent years, particularly since the emergence of the COVID-19 pandemic, making 2020—2021 the biggest year for cycling since 1973. At the same time, pedestrian and cyclist fatality rates have been increased during the pandemic, despite a significant decline in traffic volume. The most important factor to blame for such high fatality rates is the lack of dedicated bike lane and sidewalk infrastructure. One of the easiest and most cost-efficient ways to make space for cyclists and pedestrians is to narrow travel lanes and parking lanes to an optimal width. This adjustment in lane width could offer the opportunity to add dedicated bike lanes and wider sidewalks within the existing infrastructure for as little as $5,000—$30,000 per mile.

Nevertheless, there exists little consensus on the optimal travel lane width and its impacts on traffic crashes and fatalities. Neither existing guidelines nor road design standards are based on data-driven analysis which is likely one of the reasons that the existing travel lanes in many cases are wider than what they should be. Since the modern era in the U.S., all vehicles (except those with special permits) have been required to be operable within 10-foot. lanes. Even the widest bus or truck vehicles cannot exceed a width of 8.5 feet. However, the lane width guideline has remained relatively broad according to ***"A Policy on Geometric Design of Highways and Streets"*** by the American Association of State Highway and Transportation Officials (AASHTO, 2011).

AASHTO's guideline recommends a minimum lane width of 12 feet for high-speed and high-volume roadways and a minimum of 10-feet to 11-feet for urban areas with heavy pedestrian activity. Studies observed that in many cases, state design standards exceed the AASHTO minimum and exceed what is required for driver safety in low-speed environments particularly in urban areas with relatively higher pedestrian activity (Ewing, 2002). Car-oriented U.S. cities have urban (arterial and collector) streets with lanes that are as wide as 16 feet and have a great potential to be narrower and accommodate space for cyclists and pedestrians. Salt Lake City, one of our case studies, is particularly known for its wide streets. Our review of existing guidelines developed by the National Association of City Transportation Officials (NACTO)[1], Institute of Transportation Engineers (ITE)[2], the New Jersey DOT[3], and a few other state DOTs shows that these design guidelines are developed, in most cases, based on expert panel reviews and recommendations rather than rigorous data analysis on road safety and capacity.

This national study investigates the feasibility of narrowing vehicle lanes as the easiest and most cost-effective way to accommodate better sidewalk and bike lane facilities within the existing roadway infrastructure. The study asks whether, and to what extent, we can narrow existing vehicle lanes (for different road classifications) without adversely impacting traffic safety. This study employed a sample of 1,117 street sections (a series of homogeneous road segments) from six different cities and conducted one of the most comprehensive data collections on geometric and street design characteristics of street sections including the bike lane type and width, median type and width, sidewalk type and width, street's sense of visual motion, on-street parking type, width and occupancy rates, number of lanes and number of bus stops, street trees, and the degree of street curvature. We conducted a series of four negative binomial regression analyses to investigate the relationship between lane width and the number of non-intersection crashes, after controlling for the aforementioned confounding factors. This study, to our knowledge, is the largest and most comprehensive study focusing on the impacts of travel lane width on traffic safety outcomes such as occurrence and the number of vehicle accidents.

Overall, this study found no evidence that narrower lanes are associated with higher numbers of crashes and that narrow lanes (9 feet and 10 feet) increase the risk of vehicle accidents, after controlling for cross-sectional street design characteristics and other confounding variables. Quite contrary, our models confirm that in some cases (in the speed class of 30—35 mph), narrowing travel lanes is associated with significantly lower numbers of non-intersection traffic crashes and could actually contribute to improvements in safety. Practical implications and policy recommendations of these findings are further explained in the report.

2. REVIEW OF EXISTING EVIDENCE

2.1 CONVENTIONAL STREET DESIGN PRACTICE IN THE U.S.

The conventional theory of roadway design is that wider, straighter, flatter, and more open is better from the standpoint of traffic safety (Ewing & Dumbaugh, 2009). This viewpoint facilitates fast and convenient driving that is “forgiving” to high-speed drivers The foundation behind this viewpoint is that driver errors, that could lead to an accident, cannot be avoided and so the street design should take into consideration the reasonable worst-case scenarios. If the street is safe for the high-speed users (drivers) in such extreme events, it will be made safe for other low-speed users such as pedestrians and bicyclists. As a result, conventionally traffic engineers have demonstrated preference for high design values in street design standards from speed limit to lane width, shoulder width and other design characteristics that accommodates fast and convenient driving (Dumbaugh & King 2018).

Under the forgiving design practice, streets are designed to accommodate higher driving speeds and in places where higher speeds are not desirable, the posted speed limit can be reduced to slow down traffic. Street lanes are relatively wider and have multiple travel lanes and turn lanes. Building setbacks are as far as possible and their interactions with the street is minimal. Other roadside objects such as sidewalks, street furniture, etc. are designed in a way to give drivers a false sense of safety with little consequences associated with fast driving. The combination of all of these factors makes the posted speed limit somewhat irrelevant (unless there are significant law enforcement programs in place). As a result, the “operating speed” is higher in such roadway setting, regardless of the posted speed (Ewing & Dumbaugh, 2009).

Examples of the forgiving design practice could be seen all over American cities which is largely responsible for the remarkably high rates of traffic crashes and fatalities in the US. Traffic fatalities are also the leading cause of death for those aged 15 to 24 years and are the sixth leading preventable cause of death in this country (Kochanek et al., 2011). The traffic fatality rates in the US are even more striking for pedestrian and cyclists as the most vulnerable street users while pedestrian fatalities have increased more than 40 percent from 2010 to 2018.

During the past couple of decades, there has been a momentous departure from the conventional engineering practice, particularly promoted by transportation planners. Beginning with movements such as the New Urbanism (Duany and Talen 2002), walkable communities (Bicycle Federation of America 1998), smart growth (Smart Growth Network n.d.) and complete streets (National Complete Street Coalition), urban planners have argued for narrower, shorter, more enclosed, and more interconnected streets. The viewpoint of planners is entirely counter to conventional engineering practice (Ewing & Dumbaugh, 2009).

This viewpoint focuses on the safety of the street's most vulnerable users. Similar to the forgiving design practice, this viewpoint is based on minimizing human errors that could cause an accident. But instead of focusing on street design practices that minimize consequences of extreme driving errors, this approach focuses on a street design practice that is safe for its most vulnerable users. The livable street viewpoint argues that if a street is designed to be safe for pedestrians and bicyclists as the most vulnerable users, then it would be also safe for less vulnerable users such as motorists (Dumbaugh & King, 2018). The alternative design approach encourages the use of tools and design concepts that lower vehicle operating speeds including design controls (traffic calming devices) and reallocation of right-of-way to pedestrian and bicyclists (Dumbaugh, 2005, 2013).

In one of the earlier studies, planner/engineer Peter Swift studied approximately 20,000 police accident reports in Longmont, Colorado, to determine which of 13 built environmental characteristics at each accident location (e.g., width, curvature, sidewalk type, etc.) accounts for the number of crashes. Not surprisingly, they found width of the street to be one of the most significant predictors of car accidents. According to this study, a typical 36-foot-wide residential street had 1.21 collisions/mile/year as opposed to 0.32 for a 24-foot-wide street. The safest streets were narrow, slow, 24-foot-wide streets (Swift et al., 2008).

The key question with important practical implications is: Which viewpoint and design practice leads to a safer street? What are the key built environmental determinants of traffic safety? What design characteristics make some streets safer than others in terms of the frequency and severity of traffic accidents? The next section provides a review of traffic safety literature, particularly focusing on lane width and other key street design determinants of traffic safety.

LANE WIDTHS AND SAFETY

Reducing lane width in urban arterials appears to be beneficial for providing more space to include other street features such as bicycle lanes, on-street parking, wider sidewalks, landscaped buffer, and reduced pedestrian crossing distances. However, the impacts of lane width reduction on safety is a critical concern in urban arterial and highway streets. The safety impacts of lane width have been the subject of empirical studies since 1950 and the existing evidence is mixed (Manuel et al., 2014; Potts et al., 2007).

Lane width in urban and rural settings may have different impacts on safety. In rural settings, several studies reported a significant correlation between collision risk and factors associated with road width such as the higher number and width of lanes, shoulders, and medians (if available) (Ahmed et al., 2011; Zhu et al., 2010). A few other studies found that lane width in rural areas does not contribute to crash severity, possibly due to the significant impact of shoulder type on roadway safety that contributes to 30 to 70% in collision reduction (Nowakowska, 2010). In general, the majority of studies focusing on rural highways state that increasing travel lane width up to 12 feet would reduce crashes (Milton & Mannering, 1998; Gross et al., 2009), but beyond 12 feet may be detrimental to safety (Miaou, 1996).

However, there is much less consensus about safety impacts of reducing lane width in urban settings. While some studies of urban arterials found no significant difference in A National Investigation on the Impacts of Lane Width on Traffic Safety 12 safety with respect to lanes narrower than 12 ft. (Strathman et al. 2001; Potts et al., 2007), others have shown that wide lanes adversely impact traffic safety in urban areas likely because drivers tend to adapt to their environment and may feel less safe and drive more cautiously on narrow streets (Manuel et al., 2014; Noland 2003, Noland and Oh 2004, Lee and Mannering 1999).

Another line of research reports that wider lanes and shoulders are associated with lower crash frequencies (Hauer et al. 2004; Yanmaz-Tuzel and Ozbay, 2010; Rista et al., 2018; Lee et al., 2015; Le and Porter 2012). A study of nonfreeway urban arterials in Atlanta, GA found that wider vehicle lanes and narrower paved shoulders are associated with reduction in both roadside and midblock collisions (Dumbaugh, 2006). One particular concern about reducing lane width is the safety impacts on transit vehicles. For example, Dai et al. (2021) reported that narrower lanes below 10 ft. are associated with a higher likelihood of bus involved crashes.

These studies vary substantially in their scope, sample selection and have employed various analytical methods. Manuel et al. (2014) developed negative binomial (NB) safety performance functions to study the effect of road width on urban collector roadways was examined by. The study found that segment length, traffic volume, access-point density, and midblock change were statistically significant and positively related to collisions, while the width was negatively and statistically significant. Other studies have employed quasi-experimental (before-and-after) research design focusing on a single roadway segment or studies of several roadways with various lane widths (Parsons Transportation Group, 2003). Again, these studies are far from consensus on the relationship between lane width, speed and traffic safety.

A MORE COMPREHENSIVE PICTURE OF SAFETY AND STREET DETERMINANT FACTORS

The mixed evidence on safety impacts of narrow lanes could be explained by the fact that not all roads in the same classification are equal and so no standard lane width could fit all roads in the same class. There are several design characteristics associated with the street cross-section that could affect speed and traffic safety. These factors were largely missed in previous studies and could affect the safety of streets with the same lane width.

The roadside is the location for most pedestrian amenities, including sidewalks, street trees, and street lighting. The conventional engineering design practice encourages placement of such features as far away from the roadway as possible, to create a wide “clear zone” in case motorists lose control and leave the roadway (Transportation Research Board 2003, V-43). The concept of clear zones seeks to minimize the likelihood of roadside crashes due to fixed objects such as trees being near the roadway. However, previous empirical studies note that this recommendation might be more applicable to rural areas than urban settings. Dumbaugh (2005) compared the frequency of injurious roadside crashes against the actual percentage of road segments that had clear zones of each offset width in Orlando, Florida, and found that the probability of a roadside-object-related crash was largely independent of the roadway's fixed-object offset.

Design elements such as the presence of trees, building setbacks, and other crosssectional characteristics could actually improve traffic safety by affecting a driver's perceived sense of safety and crash risk and, consequently, could play a key role in slowing down driving speed and make the street safer. Therefore, roadside design features should be factored in the analysis and should be considered in lane width reduction decision making. Safety literature points to some of these key street design (cross-sectional) features as explained below:

Street Tree Coverage

Most studies on the link between tree coverage and traffic safety have focused on small areas due to difficulties of tree data collection at large scales. The findings of these studies have been relatively consistent. Naderi (2003), examined the safety effects of urban streetscape improvements along five arterial roadways in downtown Toronto, and concluded that mid-block crashes dropped between 5 to 20 percent in areas with trees and concrete planters alongside the street. In the same line, Dumbaugh and Gattis (2005) studied two sections of an arterial corridor in Orlando, FL and found that the roadway section with tree coverage and fixed-object offset performed better in terms of both crash frequency and severity indicators.

Two recent studies investigated city wide impacts of tree coverage on traffic safety using remote sensing data. Harvey and Aultman-Hall (2015) developed GIS-based streetscape measures for New York City and found that the risk of crashes is higher in street sections with wider clear zones and less tree coverage. They also found that crashes in this type of street section are 51 percent less likely to result in injury and fatality than their counterparts without tree coverage. Marshall et al. (2018) conducted a similar study in Denver, Colorado and concluded that larger tree canopies are linked to fewer crashed and less likelihood of injury/fatal crashes.

On-street Parking

On-street parking could have a mixed effect on safety. On the one hand, parked cars can act as a buffer between traffic and pedestrians. On the other hand, crash statistics show that on-street parking accounts for a significant portion of crashes in urban areas (Box 2000, 2004; ITE, 2001). Likewise, on-street parking has been linked to an increase in crash risks (Greibe, 2003; Pande & Abdel-Aty, 2009) particularly in crashes that involve children.

In areas where on-street parking is permitted, conflicts with parked cars produce about 40% of total crashes on two-way major streets, 70% on local streets, and a higher percentage on one-way streets (Box, 2000). Lack of visibility due to parked cars is also associated with a high level of pedestrian-automobile conflicts (Loukaitou-Sideris et al., 2007). On-street parking has been identified as one of the key risk factors related to the increase in pedestrian fatalities in Israel (Gitelman et al., 2012). Crash rates are particularly high with angle parking, as compared to parallel parking (Box, 2002). One of a very few before-after A National Investigation on the Impacts of Lane Width on Traffic Safety 14 studies found the non-intersection crash rates reduced by an average 37% after banning on-street parking (Desjardins, 1977).

On-street parking could also significantly affect bicycle safety. One of the main causes of vehicle—bicycle incidents is “dooring”—a vehicle occupant suddenly opening a door into the path of a cyclist which accounts for 12 to 17% of bicycle-motorist crashes in urban streets (Schimek, 2018). Designers have adopted a number of design strategies to create facilities that place bicyclists out of the door zone. However, as Schimek (2018) noted, design guides used in North America permit bike lanes with dimensions such that an open car door can reach the center of the bike lane. Therefore, while parking acts as a buffer for pedestrians and provides “friction” that slows vehicles, it presents serious challenges for cyclists and can “hide” pedestrians, particularly children, from drivers.

Traffic Calming Devices

There exists a general consensus about the effectiveness of traffic calming measures in reducing the operation speed of the street and consequently improving traffic safety. A meta-analysis by Elvik (2001) found that area-wide traffic calming measures significantly reduce the number of injury crashes. In the same line, Ewing (2001) compared collision frequencies before and after traffic-calming measures were installed in the US. For the sample as a whole, collisions declined to a very significant degree after traffic calming installation. Adjusting for changes in traffic volumes and dropping cases for which volume data were not available, collisions still declined significantly at the conventional 0.05 probability level. As for individual traffic-calming measures, all reduced the average number of collisions on treated streets, and twenty-two-foot tables and traffic circles produced differences that were statistically significant.

It is interesting to note that safety impacts of traffic calming in the US is less noticeable than other developed countries particularly European countries. In European and British countries, traffic calming treatments are more intensive and more integrated with their surroundings than U.S. treatments (Juhasz & Koren, 2016). Studies have reported speed reduction (on average) by almost 11 miles per hour or 30 percent in a British example (County Surveyors Society 1994) compared to under seven miles per hour or 20 percent for the U.S. treatments (Ewing 2001).

Pedestrian and Bicyclist Countermeasures

Pedestrian countermeasures are engineering interventions that seek to improve pedestrian safety. Sidewalks are on everyone’s list of pedestrian countermeasures. Pedestrian-motorist crashes are most likely (2.5 times more likely) in street segments without sidewalks. However, not all sidewalks are equal in terms of traffic safety measures. Presence of sidewalk clearances, vertical curbs, and other street objects that buffer pedestrians from traffic, such as trees, concrete planters, other streetscape features, and parked cars, improve the sense of safety for pedestrians.

Likewise, signaled and stopped-controlled intersections increase pedestrians' safety by forcing drivers to stop for pedestrians even in areas without a marked crosswalk. Empirical evidence shows that marked crosswalks in these intersections A National Investigation on the Impacts of Lane Width on Traffic Safety 15 make them even safer as drivers tend to be more cautious and generally more aware of pedestrians. However, the literature on the effectiveness of marked crosswalks alone at an uncontrolled intersection is mixed and inconsistent while the majority of studies found no difference in pedestrian crash rates between marked and unmarked crossings.

The same applies to the bicyclist countermeasures. A comprehensive literature review by DiGioia et al. (2017) summarizes existing evidence on 22 bicycle safety interventions in two categories of bike corridor treatments and intersection treatments. The bike corridor treatments include bike lanes, buffered bike lanes, colored bike lanes, bicycle boulevards, bike tracks, shared lane marking, wide shoulders, and wide curb lanes that could be used by bicyclists.

Surprisingly, only bicycle boulevards and bike tracks have experienced a widely consistent decrease in crash risk (Minikel, 2012; Lusk et al., 2013) whereas the results were mixed for other types of bike lanes. A number of studies pointed to the potential reduction in bike-involved crashes for other types of bike lanes (Metropolitan-Orlando, 2010; Moritz, 1998; Teschke et al., 2012), while a few studies found no significant relationship or in some cases even an increase in bike-involved crashes after the installation of bike lanes (Jensen, 2008). The other category of bike countermeasures covers the intersection treatments for bicyclists such as bike boxes (designated areas ahead of intersections for bicyclists), two-stage turn queue boxes, raised bicycle crossings, traffic circles, and roundabouts.

DiGioia et al. (2017) concludes that while the current body of bicycle safety literature points toward a few conclusive findings on effectiveness of certain bicycle treatments, such as bike lanes and removal of on-street parking, the vast majority of treatments are far from being consistent. These gaps and mixed findings call for future rigorous research with better exposure measures, crash measures, and crash data sources.

Finally, the most compelling countermeasure for pedestrian and bicyclist safety is simply more people out walking and bicycling, which could be the result of dense, mixed use, and connected types of development (Ewing & Dumbaugh, 2009). In other words, there appears to be safety in numbers. When the number of pedestrians and bicyclists increases, the per capita crash rates involving them decrease. According to Jacobsen (2003), for a 100% increase in walking, the associated increase in injuries is only 32%. A recent systematic review and meta-analysis reports highly consistent findings across studies and confirm the theory of safety in numbers (Elvik & Bjørnskau, 2017).

Street Network Design

Extensive literature points to transportation and health benefits of a connected street network which exhibits street grid patterns, smaller block sizes, and higher numbers of intersections. Well connected street networks accommodate shorter trip distances and offer more traveler options with multiple route choices, which in turn, make streets welcoming and more attractive for pedestrians (Ewing and Cervero, 2010).

Research shows that a well connected street network is safer than contemporary suburban street networks with larger blocks, curving streets, and frequent culs-de-sacs. A National Investigation on the Impacts of Lane Width on Traffic Safety 16 Basically, the two network prototypes differ in three safety-related factors including 1) block size, 2) degree of curvature, and 3) degree of interconnectivity. Lovegrove and Sayed (2006) found that areas with more four-way intersections had higher crash rates than those with three-way intersections. Ladron et al. (2004) similarly found a positive relationship between percentage of roadways classified as arterials or collectors and rates of total, injurious, and fatal crashes. Higher intersection densities were associated with fewer total, injurious, and fatal crashes which is largely attributed to lower speeds in interconnected street networks.

In general, previous studies confirm that shorter length of street segments (as a result of the higher number of intersections and higher degree of connectivity) makes the traffic slower and consequently reduces the likelihood of severe crashes. Similarly, short stretches ending in three-way intersections are particularly effective in reducing speed, crash frequency, and crash severity (Ewing & Dumbaugh, 2009).

CONTEXT-SENSITIVE DESIGN

Our review of traffic safety literature identified key determinant factors of pedestrian, bicyclist, and motorist safety. The literature generally shows enhanced safety in urban areas with lower-speed and less “forgiving” design treatments such as traffic calming measures, and street trees close to the roadway. The less-forgiving designs provide drivers with clear information on safe and appropriate operating speeds, thereby preparing drivers to respond to the many vehicle and pedestrian “conflicts” present in highly urbanized areas. Where a roadway consistently informs the driver that caution is warranted, the result is that drivers are more aware of their surroundings, as well as better prepared to respond to the road hazards when they occur (Dumbaugh, 2005).

While transportation planners have been largely the advocates of this theory and the associated design concepts, the engineering profession has been mostly encouraged to make decisions based on the recommendations in engineering design manuals such as the most widely used design manual developed by the American Association of State Highway and Transportation Officials (AASHTO) entitled ***Policy on the Geometric Design of Highways and Streets*** (AASHTO, 2011) and the ***Highway Capacity Manual*** by Transportation Research Board (TRB). In these manuals created and adopted by federal and state transportation departments, there is very little room for departure from the existing roadway design standards. A summary of lane width standards according to these two manuals is presented as following:

AASHTO Green Book: The AASHTO’s ***Policy on Geometric Design of Highways and***

Streets (known as the “Green Book or “The Bible”) has been the most widely used design manual to define lane width and other roadway characteristics for the past several decades. The book is mostly written for the car-oriented roadway design setting with only a handful of pages focusing on pedestrian movement and safety. A summary of lane width guidelines from these two manuals is presented below:

- AASHTO policy suggests 10–12-foot lanes on urban arterials (12-foot lane width reduces costs of shoulder and maintenance and is primarily used in principal arterials. Also, lanes as narrow as 9 feet can be used at local roads).
- Lane widths of 12 feet are most desirable and should be used, where practical, on higher speed, free-flowing, principal arterials.
- Lane widths of 11 feet should be used quite extensively for urban arterial street designs. Under interrupted-flow operating conditions at low speeds (45 mph or less), narrower lane widths are normally adequate and have some advantages such as shorter pedestrian crossing times because of reduced crossing distances. An 11-foot lane width is adequate for through lanes and lanes adjacent to a painted median.
- Lane widths of 10 feet may be used in highly restricted areas with little or no truck traffic. Left-turn and combination lanes used for parking during off-peak hours and for traffic during peak hours may be 10 feet in width.
- Traveled way width must be between 20 and 22 feet; higher speed and design volume picks higher end of design criteria (24 feet is used for areas with a higher percentage of trucks).
- Narrower lanes will help reduce operating speed, increase pedestrian safety, and reduce costs.[1]

Highway Capacity Manual (HCM): According to HCM, lane width reduction significantly impacts the capacity of roadways and signalized intersections. According to HCM, the capacity of a lane at a signalized intersection is reduced by 3.33% for each foot of lane width less than 12 feet. Therefore, the capacity of a 10-foot lane at a signalized intersection is 93% of its counterpart 12-foot lane.

- The HCM requires a lane width adjustment that accounts for the negative impacts of narrow lanes on saturation flow and allows for an increased flow rate on wide lanes.
- Adjusted saturation flow rate is affected by lane width (narrower lane widths require a greater adjustment factor).

---

[1] The Green Book states: “In urban areas, the land use context and presence of nonmotorized users may suggest that an arterial be designed to effectively limit the resultant operating speeds on the facility to best balance the needs of all users. FHWA guidance states that ‘…in urban areas, the design of the street should generally be such that it limits the maximum speed at which drivers can operate comfortably, as needed to balance the needs of all users.’ In those situations, there are several choices in the selection of design elements and criteria for arterials in urban areas that can induce speed reductions and have other operational and crash reduction benefits for all road users. These include reduced lane widths, lane reductions, curb extensions, center islands or medians, on-street parking, and special intersection designs such as roundabouts. All of these speed management design techniques can be implemented on low-speed arterials and some may also be appropriate on high-speed roadways.”

In the past two decades there have been extensive efforts to encourage traffic engineers to adopt a “context-sensitive design” approach and consider “flexibility in highway design” which is based on the need for lower-speed designs in urban contexts (Newman et al., 2002). Several local, state, and national organizations encourage engineers to practice context-sensitive design on a project-by-project basis, and some projects have been implemented in recent years (Committee on Geometric Design, 2004; Congress for the New Urbanism, 2002).

These efforts led to development of the very first manual based on context-sensitive design principles in 2010 in partnership between the Institute of Transportation Engineers (ITE) and the Congress for the New Urbanism (CNU). The manual is titled ***“Designing Walkable Urban Thoroughfares: A Context Sensitive Approach.”*** This manual, for the first time, reconceptualizes street design in terms of the need to accommodate a full range of street users (Dumbaugh & King, 2018). Below is a summary of lane width guidelines from ***Designing Walkable Urban Thoroughfares:***

This is one of the first and still one of the most comprehensive manuals that encourage traffic engineers to reconceptualize urban streets based on their needs to accommodate all users instead of the conventional roadway functional classes that are designed solely for motorists. The manual is transformational in road design practice and incorporates context-sensitive solutions into transportation project development. The specific lane width recommendations in this manual include:

- Lane width is affected by the design vehicle and functional level
- Minimum 10-foot lanes can be accommodated in low-speed areas (25 to 30 mph),
- Adjacent minimums cannot be combined (lane width and parking lane),
- Lane width of 10–12 feet is recommended for arterials (less than 35 mph) and lane width of 10–11 feet is recommended for collectors; the higher the speed limit, the higher end of the design limit should be used,
- The trucks and busses present in roadways and road curves also affect lane width,
- Sufficient bicycle/parking lane width is required for expanding lane width.

In a similar effort to facilitate the adoption of context-sensitive design solutions approach, the National Association of City Transportation Officials (NACTO) developed a blueprint guide to complete streets titled ***Urban Street Design Guide***. The NACTO ***Urban Street Design Guide*** provides a vision for designing a complete street that accommodates all users and offers a road map on how to get there through showcasing successful examples on how to implement these concepts. In 2015, the U.S. Department of Transportation named the ***Urban Street Design Guide*** as one of the standards in the FACT Act that could be used on the local and federal level. A summary of lane width guidelines from ***Urban Street Design Guide*** is presented as follows:

The NACTO Guide offers guidelines related to types of streets; street design elements including lane widths, sidewalks, and curb extensions; types of intersections; intersection design elements such as crosswalks and pedestrian islands; and design controls, the criteria used to measure a street's success. According to the NACTO Urban Street Design Guide, in urban streets:

- Lane widths of 10 feet are the most appropriate in urban areas.
- Lanes greater than 11 feet should not be used as they could cause unintended speeding and assume valuable right of way at the expense of other modes.
- For designated truck or transit routes, one travel lane of 11 feet may be used. In select cases, narrower travel lanes (9–9.5 feet) can be effective as through lanes in conjunction with a turn lane. Lanes greater than 11 feet should not be used as they could cause unintended speeding and assume valuable right of way at the expense of other modes.
- Lanes greater than 11 feet should not be used as they could cause unintended speeding and assume valuable right of way at the expense of other modes.
- Additional lanes are required at tight curves due to more horizontal occupied space in turning movements.

However, according to the literature, there has not been a wide adoption of this manual in the U.S. mostly due to the concerns about liability and the lack of data and empirical evidence to support context-sensitive solutions as compared to the conventional design standards. Again, there exists a big difference between the U.S. and European countries. Unlike in the U.S., where roadways are classified mainly in terms of their access and mobility functions, European design practice begins by examining the developmental context of a roadway, identifying the hazards that are expected to exist in these environments, and then specifying a target design speed to ensure that the driver travels at speeds that are appropriate given these hazards (Lamm et al., 1999). The result is that a roadway's operating speed is consistent with its target speed, contributing to per capita traffic fatalities that are 50 to 75% lower than those in the U.S. (World Health Organization, 2004).

Summary of Findings

The root cause and perhaps the most important risk factors to traffic safety are speed and drivers' "perception of safety." It is suggested that design parameters should be based on "drivers' perception of risk" rather than engineering principles. For instance, on roadways, the perception of safe speed is higher than the posted speed limit. Drivers tend to drive faster than the designated speed. Vehicle operating speeds tend to decline as individual lanes and the street section (as a whole) narrow. Driving behavior seems to be less aggressive on narrow streets as drivers may feel less safe and drive more cautiously (Ewing & Dumbaugh, 2009).

Yet, as Dumbaugh (2005) states, narrow lanes alone do not reduce operating speeds. Once combined with other street design elements as reviewed in this section, they could reinforce the message to drivers to slow down and, therefore, reduce the likelihood and severity of crashes in urban areas.

That may very well be the reason for inconsistent findings of previous studies on the relationship between lane width and traffic safety. The vast majority of previous studies have not accounted or partially accounted for cross-sectional design characteristics of street sections mostly due to the lack of data availability. Microscale data on street A National Investigation on the Impacts of Lane Width on Traffic Safety 20 design elements, traffic calming, pedestrian and bicyclist countermeasures, etc. are not available even to local and state governments and require an extensive data collection process. As a result, there exist very few comprehensive studies focusing on the impact of lane width on safety and almost all of the existing studies have focused on small-scale case studies.

These gaps in the literature and engineering practice call for a comprehensive and large-scale study design which accounts for lane width variations across cities while controlling for the roadside and other street design characteristics. Recent advancements in innovative methods of data collection from crowdsourcing platforms such as Google Maps to collect microscale street-level design data and variables may help pave the way for a more comprehensive and generalizable investigation of the link between lane width and safety.

3. LANE WIDTH AND TRAFFIC SAFETY: A THREE-PART MIXED METHOD INVESTIGATION

This project is one of the most comprehensive investigations on the link between lane width and traffic safety measures in urban streets. We employ a three-part mixed method approach to study safety impacts of lane width both from the quantitative data standpoint as well as the qualitative policy analysis of existing lane width reduction practices by state departments of transportation.

PART 1 of our analysis includes a national survey of committee members of the American Association of State Highway and Transportation Officials (AASHTO) to understand their viewpoint as well as existing lane width reduction practices in the U.S. We asked AASHTO members whether and to what extent they have proposed, approved, and completed lane width reduction projects and, if available, what are their measured/observed transportation impacts of such projects. This analysis will shed a light on the landscape of decision-making regarding the lane width reduction in state transportation agencies.

PART 2 of our analysis takes a deeper investigation into five states' department of transportation current lane width reduction policy and practice to better understand their approach to lane width reduction and to identify best practices that could be applicable to other states in the U.S. The state DOT case studies for this section are selected based on the findings of PART 1 (AASHTO members' responses to our survey). Our research team selected five states–Florida, California, Vermont, Delaware, and Oregon–to represent a diverse range of challenges, solutions, policies and practices regarding the lane width reduction. The findings of this section offer a deeper understanding of challenges that state DOTs face for lane width reduction and innovative solutions to these challenges that could be adopted by other state DOTs in the U.S.

PART 3 of our study conducts one of the most comprehensive data-driven national analyses of lane widths' impact on traffic safety. We employ novel methodologies to A National Investigation on the Impacts of Lane Width on Traffic Safety 21 collect data on microscale street design characteristics for street sections in seven American cities representing a diverse range of street networks and transportation infrastructure. We utilize Google Maps, Google Earth, and Google Street View, as well as local and state agencies' remote sensing data to investigate the link between lane widths and traffic safety measures after controlling for key roadway design determinants of safety including sidewalk, bike lane, on-street parking, traffic calming measures and more. The findings of this section have immediate and direct policy implications, providing data-driven evidence for optimal lane width decision-making as a key component of context-sensitive solutions to street design.

PART 1: SURVEY OF AASHTO COMMITTEE MEMBERS

Our team designed and administered a national survey of the American Association of State Highway and Transportation Officials (AASHTO) committee members. The AASHTO committee is a key national organization that develops standards, specifications, test protocols, and guidelines used in highway design and construction practices throughout the U.S. The survey aimed to explore lane width reduction processes and example projects across the U.S. and their associated impacts, including traffic safety, vehicle speed, and vehicle and pedestrian volumes. While narrowing lane width is often considered a way to reduce vehicle speed and improve traffic safety, comprehensive knowledge is lacking on practices and their impacts. The results of this survey shed a light on current lane width reduction practices and identify exemplary road renovation and lane width reduction projects and lessons learned that can be used by local and state governments throughout the U.S. Appendix A presents the structure and list of questions in the survey.

3.1.1. Summary of AASHTO Survey Responses

Our research team received and analyzed survey responses from 13 individual members of the AASHTO committee (see Appendix B for the name and contact information of these members). The survey questionnaire was structured into three main sections. The first section captures statewide design standards adopted by state transportation agencies, their lane width standards, their exception approval process, and examples.

The second section covers questions about the completed (if any) and ongoing lane width reduction projects within their jurisdiction. If AASTHO members reported a lane width reduction project in their state, then the survey follows up with the observed or measured transportation impacts of the project including traffic safety, traffic volume and speed, pedestrian and bicycle volume, and construction/maintenance costs. The third and final section identifies the committee members' contact information and affiliation for future follow-ups.

All (100%) respondents to the survey indicated that they have statewide roadway design standards, manuals, and policies that regulate travel lane widths and/or limit the reduction of lane widths. Examples of such standards, manuals, and policies include: the Michigan Road Design Manual, Ohio Location and Design Manual, AASHTO Green Book, Highway Safety Manual, ALDOT Performance Based Practical Design, Engineering Instructions for Roadway Design, Highway Design Manual, DIB 79 Design Guidance and Standards for 3R Projects, Highway Preconstruction Manual, Roadway Design Standards and Guidelines, Roadway Design Memorandums, Construction Standard Drawings, Design Executive Summary, and Texas Roadway Design Manual. A detailed list of reference design standards, manuals, and policies for all respondent members is provided in Table 1.

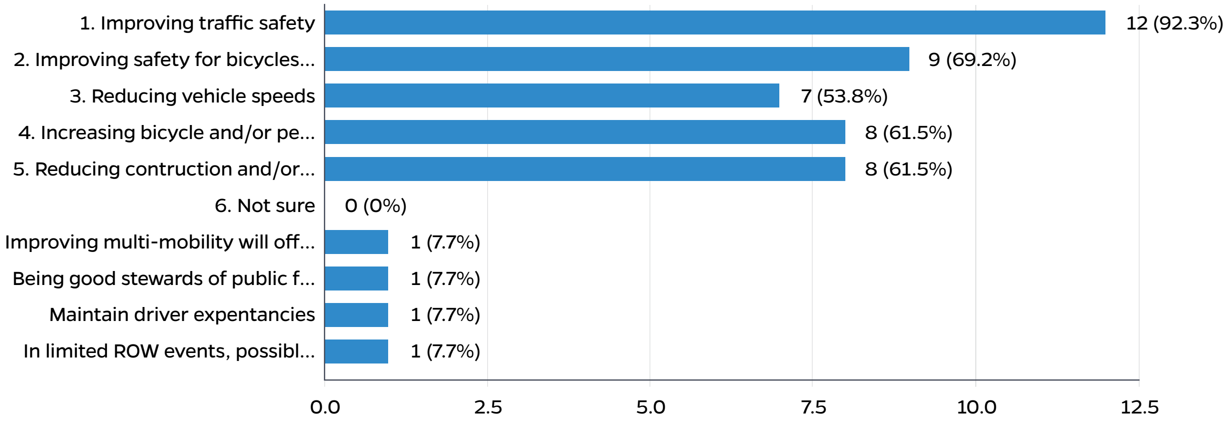
Table 1:
Statewide Roadway Design Standards, Manuals, And Policies Adopted by AASHTO Committee Members

Michigan DOT	• Michigan Road Design Manual	https://mdotjboss.state.mi.us/stdplan/englishroadmanual.htm
Ohio DOT	• Location and Design Manual Volume 1	https://www.transportation.ohio.gov/working/engineering/roadway/manuals-standards/location-design-vol-1/
Alabama DOT	• ALDOT Performance Based Practical Design Guide • AASHTO Green Book • Highway Safety Manual	https://www.dot.state.al.us/publications/Design/pdf/PerformanceBasedPracticalDesignGuide.pdf
Maine DOT	• Engineering Instructions for Roadway Design	https://www.maine.gov/tools/whatsnew/attach.php?id=815852&an=1
California DOT	• Highway Design Manual • DIB 79 Design Guidance and Standards for 3R Projects	https://dot.ca.gov/programs/design/manual-highway-design-manual-hdm https://dot.ca.gov/programs/design/design-information-bulletins-dibs/dib-79-04
Tennessee DOT	• RD11-TS-Series	https://www.tn.gov/content/tn/tdot/roadway-design/standard-drawings-library/standard-roadway-drawings/roadway-design-standards.html
Washington State DOT	• Design Manual M 22-01	https://www.wsdot.wa.gov/publications/manuals/fulltext/M22-01/design.pdf
Minnesota DOT	• MnDOT Road Design Manual • Geometric Design and Layout Development • Bicycle Facility Design Manual	https://roaddesign.dot.state.mn.us/roaddesign.aspx https://roaddesign.dot.state.mn.us/facilitydesign.aspx http://www.dot.state.mn.us/design/geometric/resources.html
Alaska DOT	• Highway Preconstruction Manual • AASHTO Green Book	https://dot.alaska.gov/stwddes/dcsprecon/preconmanual.shtml
Arizona DOT	• Roadway Design Standards and Guidelines • Roadway Design Memorandums • Construction Standard Drawings	https://azdot.gov/business/engineering-and-construction/roadway-engineering/roadway-design/roadway-design-guidelines

Montana DOT	• Road Manual and Guide • Baseline Criteria Practitioners Guide • MDT Geometric Design Criteria and Design Exceptions	https://www.mdt.mt.gov/publications/manuals.aspx#rdm https://www.mdt.mt.gov/business/consulting/design-memos.aspx
Kentucky DOT	• Highway Design Guidance Manual	https://transportation.ky.gov/Organizational-Resources/Policy%20Manuals%20Library/Highway%20Design.pdf
Texas DOT	• Roadway Design Manual	http://onlinemanuals.txdot.gov/txdotmanuals/rdw/index.htm

The survey asks respondent DOTs to specify their agency goals and expectations in having minimum lane width policies and/or lane reduction standards. Improving traffic safety was the top-rated agency goal (92.3%) in having minimum lane width policies and standards, followed by improving safety for pedestrians and bicycles (69.2%). Meanwhile, increasing active transportation use and reducing construction and maintenance costs were the third (i.e., 61.5% apiece) most important agency goals for having minimum lane width standards, followed by reducing operation speed (53.8%). Other agency goals such as improving multi-mobility, connectivity benefits, stewardship of public funds, maintaining driver expectancies, and roadside activity were the least prioritized expectations (7.7% each).

Figure 1:
Agency Goals and Expectations in Having Lane Width Reduction Policies & Standards



According to our survey responses, the most widely used process for lane width reduction projects is through design exceptions. In terms of design exceptions, all (***100%***) respondent DOTs indicated that they have a design exception process where lane width reductions can be proposed, reviewed, and approved. The approval process and criteria vary according to state agencies. Some states don't have specific criteria and review lane width exception projects on a case-by-case based on factors such as funding, impacts on property, impacts to the environment, speed, traffic volume, and modal accommodation. Other states consider lane width reduction projects mostly based on transportation-related criteria such as roadway classification, traffic volume (AADT), and operating speed. The list below presents the most common criteria for lane width reduction exception approval by AASHTO member respondents:

- “Roadway classification, (traffic volume) AADT, Speed”
- “Reduced lane widths are considered on a project-by-project basis and are not based on specific conditions.”
- “We review based on trying to achieve a balance of economics and project needs.”
- “Typically, urban settings, many times where some reduced lanes already exist.”
- “None, however, Caltrans is evaluating and developing guidances to allow for narrower lane widths based on the context type.”
- “In addition to above-listed conditions, public transportation (bus route), turn movements, on-street parking, access management.”
- “We view these as context-sensitive issues unique to each project. Some of the things considered are funding, impacts on property, impacts to the environment, speed, traffic volume, and modal accommodation.”
- “Background information and design guidance for selecting lane widths are identified on pages 25-26 of our PBPD Process and Design Guidance document.”
- “A few conditions (to name a few) that enable reduced lane widths to be considered are design speed, anticipated vehicular traffic, safety, terrain along with other conditions found in our preconstruction manual as well as in the AASHTO Greenbook.”
- “Safety, Capacity, Operational considerations, and needs”
- “Urban or rural context, traffic volume, speed, and functional classification”
- “Mainly good engineering judgment and also a past performance on similar roadway types”
- “The RDM allows the reduction of lane widths to add a TWLTL, add bicycle facilities, and reduce the crossing width for pedestrians at intersections. Additional circumstances may include ROW limitations, area type or context, and functional classification.”

Our next question asks which entity within state DOTs has the authority to approve lane width reduction through design exceptions and what is the corresponding approval process of lane width reduction below the state minimum width. The responses from the AASHTO committee members are provided in Table 2. In some states such as Ohio, Washington, and Tennessee, an individual within the state DOT is responsible for lane width design exception approval. Other states such as Maine have a council or committee that reviews and approves lane width design exception requests.

Table 2:
Lane Width Design Exception and Approval Process Within State DOTs

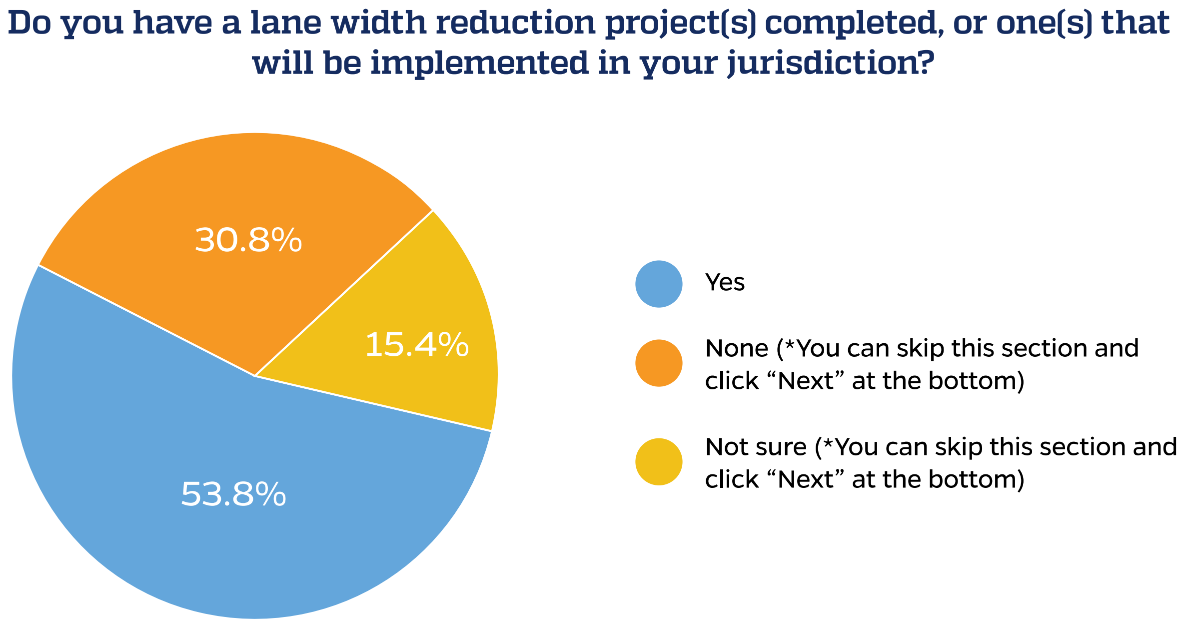
AASHTO COMMITTEE MEMBER	RESPONSE
Michigan DOT	Engineer of Road Design
Ohio DOT	The ODOT Roadway Engineering Administrator (Myself) approves lane width design exceptions. The Designer will submit the exception to one of our Central Office Geometric Subject Matter Experts for review. If the Geometric Subject Matter Expert finds the exception valid, they will forward it to the Roadway Engineering Administrator for approval. We have a website for submitting/reviewing/approving design exceptions.
Alabama DOT	The designer can make the recommendation. A design variance will need to be developed for any narrower width roads, and it will be signed by the Designer, Region Engineer, State Design Engineer & Chief Engineer.
Maine DOT	Maine DOT Engineering Council has the authority to review and approve these requests.
California DOT	Design exceptions are documented in a Design Standard Decision Document (DSDD). For lane widths standards, approval authority is delegated to the District Directors for all highway classifications except for interstate freeways that the Headquarters Project Delivery Coordinators approve.
Tennessee DOT	The Director of the Design Division
Washington State DOT	Assistant State Design Engineers or delegates, depending on route and project type.
Minnesota DOT	N/A
Alaska DOT	The regional preconstruction engineer approves or rejects the proposed design exception request. If approved, an informational copy of all approved design exceptions must be furnished to FHWA. Now, for high-profile projects, FHWA must concur with design exceptions.
Arizona DOT	The Asst. State Engineer - Roadway Engineering Group approves Design Exceptions and Variances associated with AASHTO's controlling criteria and ADOT's Design Standards. This includes lane width reduction. Currently, FHWA provides final approval of Design Exceptions associated with the Controlling Criteria.
Montana DOT	Lane width exceptions are documented and approved by either the State Traffic and Safety Engineer or the Highways Engineer depending on the nature of the project. Urban exceptions are a "variance" documented in a Scope of Work report. Rural or high-speed exceptions are design exceptions. Design Exceptions are a more robust analysis and justification in a standalone report.

Kentucky DOT	The Project Manager makes a recommendation, and the Director makes final approval of the highway design.
Texas DOT	Project types requiring design exceptions to be submitted to the FHWA are first reviewed by TxDOT Design Division and then transmitted to FHWA for approval. The respective TxDOT District approves all other project design exceptions.

In the second section of the survey, we inquired about information about ongoing and completed lane width reduction projects within the DOTs' jurisdiction and their transportation impacts over time. Surprisingly, only a little over half (***53.8%***) of the respondent AASHTO committee members reported at least one completed or ongoing lane reduction project implemented in their jurisdiction while about 30.8% stated no lane reduction projects had been completed or are ongoing in their jurisdiction.

These findings indicate that the majority of state DOTs in our sample prefer to follow the design standards adopted by their DOT and the context-sensitive design approach within their jurisdiction have not been implemented to date. Although in theory there has been a significant departure from conventional lane width design standards to promote flexibility in highway design, in practice we are far from implementation of the context-sensitive design solutions by most state DOTs. The design exception for lane width reduction projects seems to be a rare event in most state DOTs that participated in our survey.

Figure 2:
State DOTs' Existing, Completed, or Ongoing Lane Reduction Projects in Their Jurisdiction



In a follow-up question, survey respondents listed (if any) exemplary lane reduction projects in their jurisdiction with details of their name, location, web sources, and references. Table 3 presents examples of lane width reduction projects in each state DOT in our survey. These projects are excellent case studies for further research to investigate the transportation, economic, and environmental impacts of lane width reduction. Our research team is planning a follow-up study for a deep investigation of these projects and their quality-of-life impacts.

Table 3:

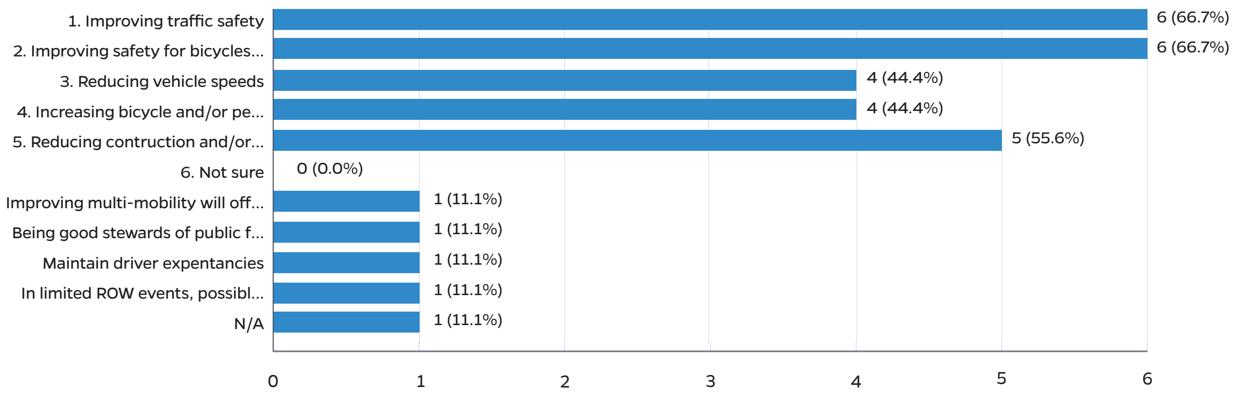
Details of Exemplary Lane Width Reduction Projects in State DOTs' Jurisdiction

AASHTO COMMITTEE MEMBER	RESPONSE
Michigan DOT	Currently under development, so there are no finalized documents; however, we have a lane width reduction project to accommodate wider sidewalks for pedestrians.
Ohio DOT	IR-71 SB north of Columbus - Lane widths were reduced on the interstate to add an additional lane to increase capacity. Please email me for additional details/reports.
Alabama DOT	N/A
Maine DOT	N/A
California DOT	N/A
Tennessee DOT	There are many, in addition to the resurfacing lane reconfiguration or Road Diet requests from locals. Many were reduced from 12 to 11 to accommodate MM. Few reduced to 10’.
Washington State DOT	SR 4 / SKAMOKAWA VIC, TO 0.3 MILES WEST CHIP SEAL
Minnesota DOT	Cases where we utilize narrow through-lanes would include; small-town downtown areas (particularly those with bike lanes or TWLTLs), low-speed areas where speed control is a project goal, and high-speed freeway settings where the narrowed lanes allow the inclusion of additional capacity. Narrow lanes were installed on I-94 to address an emergency need for additional capacity. It was found that narrow lanes combined with increased capacity exhibited better crash performance than the previous condition. A low-speed example would be St. James, where narrow lanes were combined with mini-roundabouts and back-in diagonal parking for excellent results (https://www.youtube.com/watch?v=Elto-q4T5Ag).
Alaska DOT	N/A

Arizona DOT	Conversion of system ramp from one lane to two lanes. This required narrower shoulders and narrower lanes to fit the additional lane within the limits of the existing bridge and bridge barriers—more information upon request.
Montana DOT	N/A
Kentucky DOT	This project is located in Frankfort, KY (Franklin County) - U.S. 60 from Sunset Drive to Laralan Drive, Item 5-526.00
Texas DOT	N/A

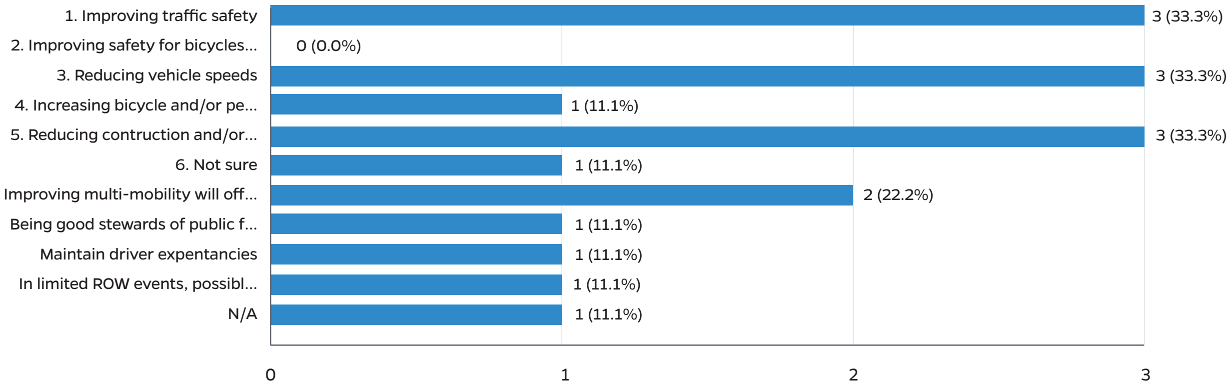
The survey further asked about the primary objectives if considering lane reduction exceptions for a specific site. Improving overall safety, and, more specifically, safety for bicycles and pedestrians, was listed as top primary state DOTs' objective (with 66.7%) followed by the reduction of construction and maintenance costs (***55.6%***). Meanwhile, reducing vehicle speeds and increasing active transportation usage had equal shares of 44.4%. Other key DOT objectives for considering lane width reduction exceptions include providing context-appropriate widths, reducing congestion and utility costs, limiting traffic impacts, and quick turnaround for project delivery (see Figure 3).

Figure 3:
State DOTs' Primary Objectives When Considering Lane Reduction Projects for Specific Sites



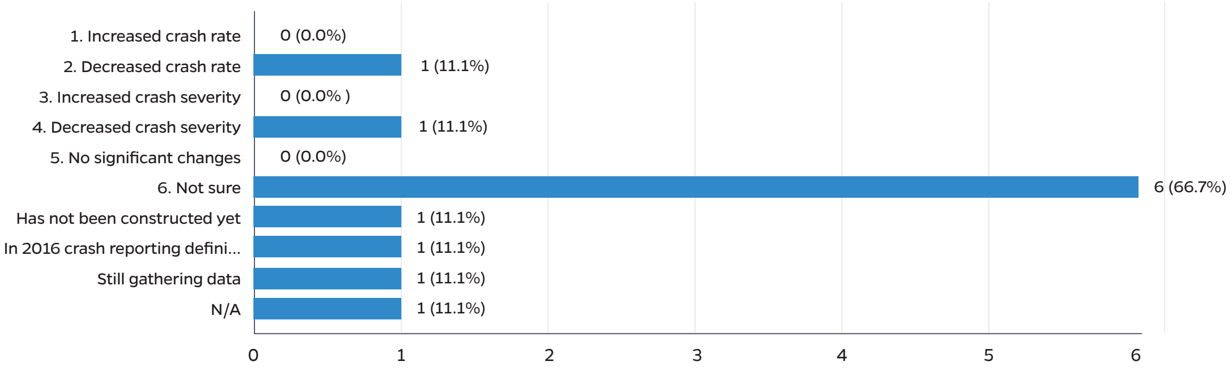
The next series of questions seek to identify the post-implementation impacts of lane width reduction projects. The participant DOTs listed three observed/measured significant changes after the implementation of lane width reduction projects including changes in traffic safety (***33.3%***), changes in vehicle speeds (***33.3%***), and changes in construction and maintenance costs (***33.3%***). Other reported observed or significant measurable changes include bicycle and pedestrian activity changes and reduced congestion (***11.1% each***). About 11.1% of respondents indicated that they have observed no change as a result of the lane width reduction project (see Figure 4).

Figure 4:
State DOTs' Overall Observed/Measured Changes After Reducing Lane Width



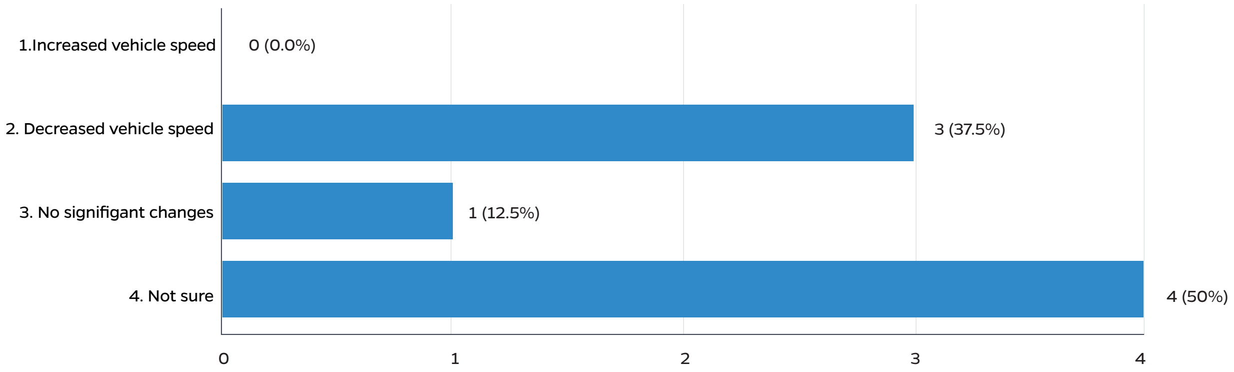
Surprisingly, the majority of respondent DOTs (***66.7%***) stated that they were unsure about the observed/measured safety impacts after reducing lane widths. Another 11.1% of respondent DOTs indicated that they had observed a reduction in rates and crash severity while more than 22% cited inadequate data to show impacts, or the absence of any lane reduction projects in their jurisdiction and/or no significant observed changes (see Figure 5).

Figure 5:
State DOTs' Observed/Measured Safety Changes After Reducing Lane Width



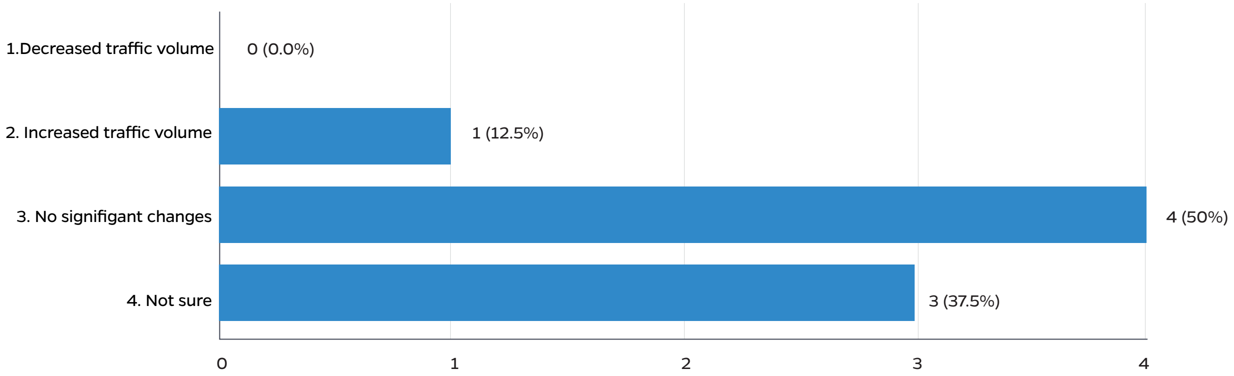
Similarly, about half of the participant state DOTs indicated that they were unsure about the observed/measured changes in vehicle speed after reducing lane widths, whereas a little over a third of respondent DOTs indicated that there had been some observed reductions in vehicle speed. The remaining 12.5% of state DOTs' respondents stated no significant changes either due to non-implementation of any lane width reduction projects, data availability, too early to tell, or a combination of these factors (see Figure 6).

Figure 6:
State DOTs' Observed/Measured Vehicle Speed Changes After Reducing Lane Width



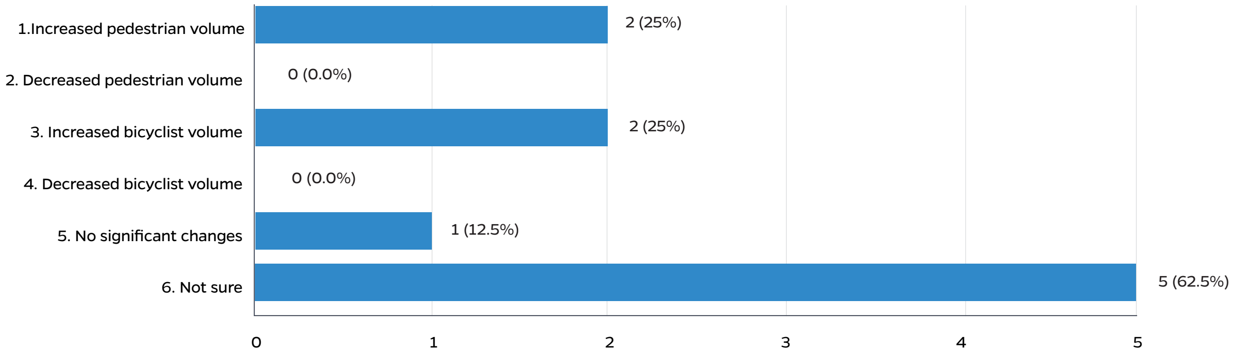
In terms of the observed/measured changes in traffic volume after reducing lane width, half of the survey respondents (***50%***) indicated that no significant changes have been observed, whereas a little over a third of state DOTs' participants were unsure about any observed changes in traffic volume. The remaining 12.5% of respondents indicated that traffic volume has increased after the lane widths reduction implementation (see Figure 7).

Figure 7:
DOTs' Observed/Measured Traffic Volume Changes After Reducing Lane Widths



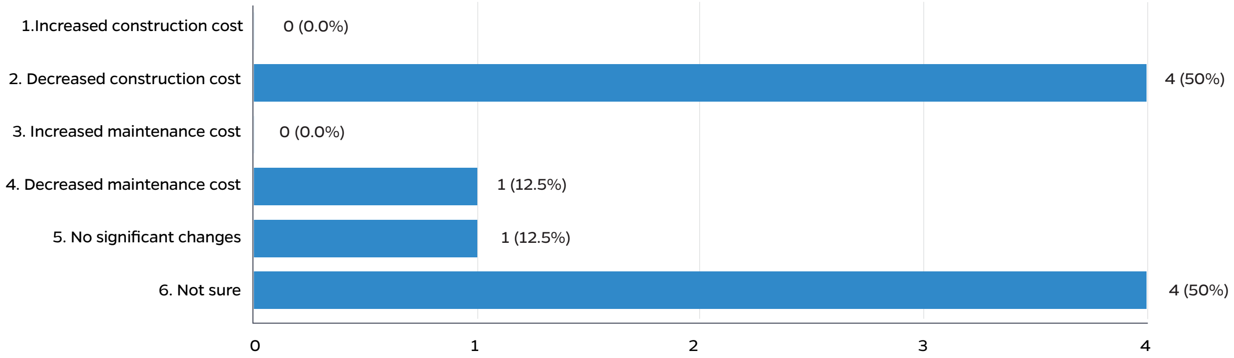
Similarly, over 60% of the survey respondents indicated that they were unsure about any changes in pedestrian and bicyclist volume after reducing lane width, while about 12.5% of respondent state DOTs reported no observed significant changes in pedestrian and bicyclist volume. Finally, about a quarter of respondent state DOTs indicated that they have observed and/or measured an increase in the volume of pedestrians and bicyclists (see Figure 8).

Figure 8:
State DOTs' Observed/Measured Pedestrian and Bicyclist Volume Changes After Reducing Lane Width



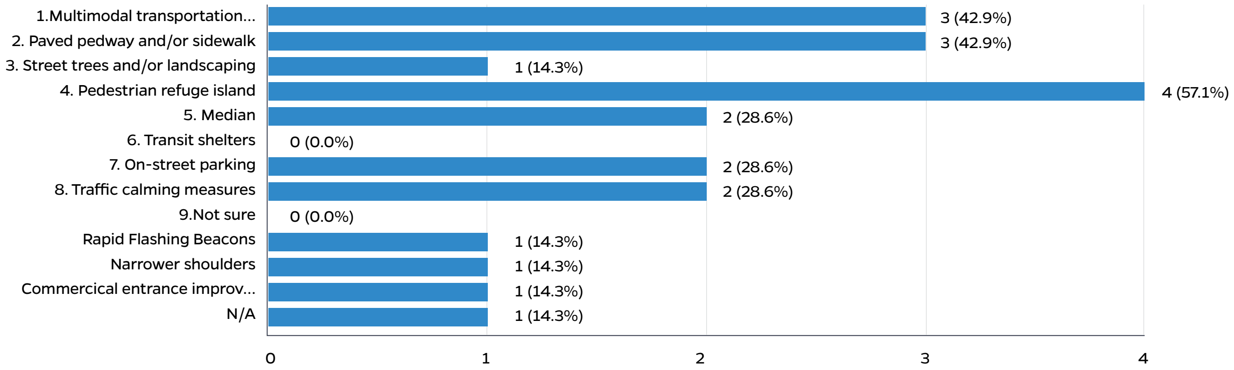
In the same line, about half of the state DOT participants stated they were unsure about observed and/or measured changes in construction and maintenance costs after reducing lane widths. Another half of respondent state DOTs reported a reduction in construction and maintenance costs, while 12.5% of participants suggested no observed and/or measured significant changes in construction and maintenance costs (see Figure 9).

Figure 9:
State DOTs' Observed/Measured Construction/Maintenance Cost Changes After Reducing Lane Width



It is important to note that lane width reduction projects often are not implemented in isolation. Typically, they are executed along with a series of roadway design improvements from widening sidewalks, bike lanes, pedestrian refuge islands, and installation of other traffic calming devices, landscaping, and planting street trees. The combination of these factors would make streets more welcoming for all users and, in turn, could improve safety. The survey questionnaire further asked AASHTO committee members about any other built environmental changes implemented (i.e., cross-sectional road design) while reducing lane widths. Pedestrian refuge islands were on top of the list (***57.1%***) followed by the expansion of pedestrian sidewalks and multi-modal transportation infrastructure (***42.9%***). The next significant physical changes implemented during the lane width reduction projects were on-street parking and traffic calming measures (28.6%). Other observed physical roadways design improvements include street trees, landscaping, rapid flashing beacons, narrower shoulders, and commercial entrance improvements (see Figure 10).

Figure 10:
State DOTs' Observed Physical Changes in Road Cross-Section Design After Reducing Lane Widths



When asked about the overall expected impacts of reducing lane width projects, the state DOT participants noted a range of transportation impacts from improving multi-modal transportation to reducing costs and accommodating higher traffic volumes (AADT). However, responses about the safety impacts were mixed. A summary of expected lane width reduction impacts listed by state DOT respondents are: "Improving overall safety and accommodating ADA sidewalk width."

- "Reducing Lane widths to improve multi-modal accommodation and to reduce cost. In urban areas, 11' is common for freeway lane width to increase capacity and minimize cost"
- "They allow increased widths on adjacent pedestrian facilities and can reduce congestion-related crashes by being able to add lanes at a reduced cost. We do not recommend reduced lane widths to reduce speeds - as this alone is not a proven countermeasure to reduce speeds. Studies have not consistently shown a speed reduction - and sometimes an increase in speed"
- "We believe it is a viable option in some urban settings"
- "Accommodating truck or bus (lateral offset), turn radius, over tracks, vehicles violating bike lanes"
- "Our expectations surrounding reducing lane widths fall in line with the expectations identified in NCHRP 783, in that we can expect similar or improved safety performance while providing elements that improve the safety and functionality for all users, not just motor vehicles"
- "Impact to capacity and speed. Required evaluation of operational and safety impacts must be considered"
- "A balance between cost of project and benefit received, provide an effective project that meets the scope of the project"

The state DOT participants also listed a number of roadway design elements from refuge islands for pedestrians, to speed feedback signs, rapid flashing beacons and adding a right-turn lane that might have contributed to a reduction in crashes, speed, traffic, and pedestrian volumes, in conjunction with the lane width reduction intervention. In general, the participant state DOTs referred to the following roadway design improvements:

- “Refuge islands for pedestrians”
- “A location where only Lane width reduction is proposed without reducing speed limit should be investigated for ADT (***many MM documents limit ADT 6000-10000 range***) however existing major collector or arterial capacity easily pass well above those numbers”
- “Speed feedback signs, rapid flashing beacons”
- “We have found that manipulating one design element is not sufficient to provide a design that is appropriate for the context or to adjust driver/user behavior. We believe, and our efforts have demonstrated, that a holistic approach is necessary, using all available context cues and design elements, to provide a design that matches the context of the roadway segment”
- “Signage and striping enhancements”
- “Right-in Right-out change in access and improved entrance geometrics (added a right-turn lane and improved entrance grade).”

3.1.2. Key Takeaways from the AASHTO Survey

Overall, the results of our AASHTO survey demonstrate the extent of the gap and highlight how little we know about the traffic safety impacts of existing lane width reduction projects due to the lack of data and rigorous quantitative studies. These gaps and shortcomings call for in-depth case study investigations that employ longitudinal research design to measure before-after changes of the completed lane width reduction projects. Quantitative data and empirical evidence are critical for encouraging traffic engineers to adopt context-sensitive solutions rather than the default lane width standards from the design manuals and guidelines.

As noted by one of the state DOT respondents, lane width reduction or any isolated roadway design improvement alone may not be sufficient to provide a design practice that is appropriate for the context or to adjust driver/user behavior. A holistic approach to street design is necessary, using all available context cues and design elements, to provide a design alternative that matches the context of the roadway segment and make it safer for all street users.

PART 2: LANE WIDTH REDUCTION FROM THEORY TO PRACTICE: EVIDENCE FROM FIVE STATES IN THE U.S.

The findings of our AASHTO survey guided us to identify five state departments of transportation for an in-depth case study analysis through semi-structured interviews in order to better understand their lane width decision-making, exception process, and examples of completed lane width reduction projects (if any) as well as the associated transportation impacts. We were able to set up an online interview session with the Vermont Agency of Transportation (VTrans), the Oregon Department of Transportation (ODOT), the California Department of Transportation (Caltrans), the Florida Department of Transportation (FDOT), and the Delaware Department of Transportation (DelDOT). These DOTs represent a diverse range of challenges and innovations related to travel lane width reduction that could be applicable to other state DOTs with similar geographic and transportation characteristics in the U.S.

The interviews aimed to grasp a deep understanding of their road design standards and experience in reducing lane width and their potential outcomes on the transportation network. Generally, the lane width standards in each state depend on their geographical location, available network, and traffic network needs. In addition, the walkability of cities and bike lane requirements appear to play a significant role in the preferred minimum lane width standards.

The interview questions mainly focused on existing lane width standards, design criteria, design exceptions, and completed, ongoing, or future projects on urban and suburban roadways lane width reduction. In the case of available reduced lane width design, we analyzed the project motives and written reports on the before-after analysis of these projects and eventually we summarized key findings as well as obstacles or drawbacks experienced by each state DOT. The summary of design practices and findings are presented in the next sections.

Florida's Practice and Experience with Lane Width Reduction

In 2014, the Florida Department of Transportation (FDOT) modified urban arterial travel lane width in low-speed areas by approving Roadway Design Bulletin 14-17. Specifically, this Bulletin established **11-foot travel lanes for roadways with a divided typical section in or within one mile of an urban area and with a Design Speed of 45 mph or less.** See Appendix C (Part 2) for more detailed information about the Roadway Design Bulletin. This transition was part of the low-speed urban program that FDOT has implemented and offered flexibility in certain contexts. The adjusted space from reducing lane width has been repurposed for a "buffered bike lane." The objective was to dedicate exclusive lanes for bikes and increase the width of bike lanes within the network. However, this lane reduction was not applied to typical suburban areas with higher speed limits (50 mph), as it was found earlier that it might increase the crash rates, and the speed reduction is negligible. The Design Bulletin also established 7-foot Buffered Bicycle Lanes as the standard for marked bike lanes.

According to our interview with FDOT, Florida's Roadway Design Bulletin is "old-news." FDOT adopted a much more comprehensive design manual in 2022 titled the ***"Florida Design Manual (FDM)"*** which sets four geometric and other design criteria and procedures for all new construction, reconstruction, and resurfacing projects on the state and national highway systems. According to the FDM, lane widths are selected based on design speeds. Roads and streets are classified based on the context, which in turn defines target speeds. Context classification is a design control that determines key design criteria elements for arterials and collectors (see Figure 11). Target speed is the highest speed at which vehicles should operate on a thoroughfare in a specific context.

Appropriate street design is chosen to achieve the target speed to attain the desired degree of safety, mobility, and efficiency. In a well implemented project, target speed matches the design speed. Ideally, the target speed, posted speed, and design speed should all be the same where speeds are 45 mph or less. However, design speed and posted speed will often take time and may even need to be changed over several projects. See Appendix C (Part 1) for more detailed information.

Figure 11:

Minimum Travel and Auxiliary Lane Widths for Arterials and Collectors According to the Florida Design Manual (FDM)

Table 210.2.1 – Minimum Travel and Auxiliary Lane Widths

CONTEXT CLASSIFICATION		TRAVEL (feet)			AUXILIARY (feet)			TWO-WAY LEFT TURN (feet)	
		DESIGN SPEED (mph)			DESIGN SPEED (mph)			DESIGN SPEED (mph)	
		25—35	40—45	≥ 50	25—35	40—45	≥ 50	25—35	40
C1	Natural	11	11	12	11	11	12	N/A	
C2	Rural	11	11	12	11	11	12		
C2T	Rural Town	11	11	12	11	11	12	12	12
C3	Suburban	10	11	12	10	11	12	11	12
C4	Urban General	10	11	12	10	11	12	11	12
C5	Urban Center	10	11	12	10	11	12	11	12
C6	Urban Core	10	11	12	10	11	12	11	12

Notes:

Travel Lanes:

(1) Minimum 11-foot travel lanes on designated freight corridors, SIS facilities, or when truck volume exceeds 10% on very low speed roadways (design speed ≤ 35mph) (regardless of context).

(2) Minimum 12-foot travel lanes on all undivided 2-lane, 2-way roadways (for all context classifications and design speeds). However, 11-foot lanes may be used on 2-lane, 2-way curbed roadways that have adjacent buffered bicycle lanes.

(3) 10-foot travel lanes are typically provided on very low speed roadways (design speeds ≤ 35 mph), but should consider wider lanes when transit is present or truck volume exceeds 10%.

(4) Travel lanes should not exceed 14 feet in width.

Auxiliary Lanes:

(1) Auxiliary lanes are typically the same width as the adjacent travel lane.

(2) Table values for right-turn lanes may be reduced by 1 foot when a bicycle keyhole is present.

(3) Median turn lanes should not exceed 15 feet in width.

(4) For high speed curbed roadways, 11-foot minimum lane widths are allowed for the following:
- Dual left-turn lanes
- Single left-turn lanes at directional median openings.

(5) For RRR Projects, 9-foot right-turn lanes on very low speed roadways (design speed ≤ 35 mph) are allowed.

Two-way Left-Turn Lanes:

(1) Two-way left turn lanes are typically 1 foot wider than the adjacent travel lanes.

(2) For RRR Projects, the values in the table may be reduced by 1 foot.

It is worth noting that FDOT has incorporated findings from other studies and outcomes of ongoing projects as a baseline to reduce lane width for controlling speed in urban areas. However, reducing lane width solely without considering other features to lower speed and manage traffic might not be effective. Therefore, narrowing lanes typically is combined with different traffic calming strategies to reach potential outcomes, including horizontal and vertical deflections, which FDOT has implemented extensively. Speed management studies by FDOT have demonstrated a negligible reduction in speed based on lane width being consistent with Highway Capacity Manual. According to our interview with FDOT and based on their experience, reducing lane width by a foot might reduce speed by 1 or 2 mph.

FDOT recommends 10 feet as the minimum design criterion for urban conditions and 11 feet for rural areas. However, other factors, including speed limit, AADT, and truck volume will justify the exact lane width standard value. The corridor's safety is one factor that must be considered when choosing the fitting lane width for a roadway. For instance, 10-foot lanes on 60 mph rural roads will increase crash rates confidently. On the other hand, in urban areas, other road design characteristics might be more significant in controlling safety rather than lane width. Keeping this in mind, FDOT uses a context classification system for road design. The context classification system allows FDOT to look at the area's needs in picking the best road design measurements.

One effective approach that FDOT takes for reducing lane width is through lane repurposing or road diets, which is changing the layout of traffic lanes for more space and reassigning the extra space to other tasks for general purposes. FDOT has employed lane repurposing in various modes, including bus-only lanes, widening sidewalks, multi-use paths, on-street parking, streetcars, bike lanes, and bike facilities. FDOT uses Lane Repurposing Guidebook for road diet, lane reduction, or lane elimination projects, often involving lane width reduction. In most cases, land repurposing is required. Generally, in lane repurposing, a travel lane will be adjusted to accommodate other travel modes or be used for different purposes. Depending on the objective of reducing lane width and the project details, the cost might have increased, but the outcomes and impacts on roadways can justify the financial aspects.

FDOT launched Speed Management Pilot Projects for the first time in 2019. Since speed management has been developed relatively recently as a five-year program, limited before-after analyses have been done on speed management projects. The purpose of speed management (traffic calming) is to establish a "design speed" that is appropriate for the road context. "Design speed" is a design control that sets most of the other elements in a roadway and is context based. On the other hand, "target speed" is the ideal speed that can be fit on a particular project and will be achieved through redesigns in a corridor within time. These redesigns can include adding bulb-outs or adding trees to reduce speed in an area. It should be noted that "target speed" is not necessarily a lower speed; depending on the context, a higher speed might be required to match the context. Using context-based design guidelines has substantially eased the design justification engineers need to apply to roadways. This fact helps designers look at an area's needs and pick the best design standards.

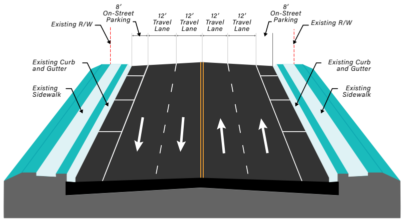
Lane Repurposing Guidebook

Lane repurposing projects involve changes to the roadway cross section and restriping existing travel lanes for either a roadway segment or an entire corridor. The changes may include design modifications such as reduced lane widths, median changes, access management modifications, bicycle lanes, new or wider sidewalks, shared-use paths, on-street parking or transit-only lanes, or loading/transportation network company (TNC) zones.

The Guidebook serves as a resource for local, regional, and statewide transportation agency planners and engineers to analyze potential lane repurposing projects and includes the potential factors to be considered prior to design and implementation. A lane repurposing project done by FDOT is shown in Figure 12.

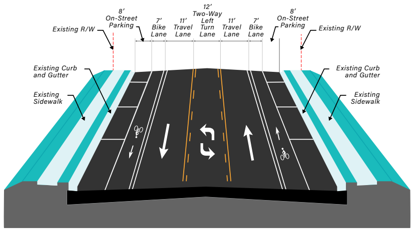
Figure 12:
S.R. 10 (U.S. 90) Monticello, Jefferson County; FDOT Lane Repurposing Guidebook, 2020

FIGURE 5-7 SR 10 (US 90) Existing Typical Section



Source: SR 10 (US 90) Lane Elimination Request FPID 439729-1

FIGURE 5-8 SR 10 (US 90) Proposed Typical Section



Source: SR 10 (US 90) Lane Elimination Request FPID 439729-1

Design Exceptions

Design exceptions are considered when proposed lane width values are outside the acceptable criteria. In case the existing or proposed design element is not compatible with both AASHTO and the FDOT's governing criteria, design exceptions are required while design variations are required in case of incompatibility with the department's standards solely. Before Phase I design submittal, identification approval is necessary to initiate a design exception or variation. Besides, the design exception or variation documents require approval prior to Phase II of design submittal.

FDM recommends using the following mitigation strategies for lane width:

- Optimal combination of shoulder and lane width for optimal safety
- In-advance signing of road lane width changes
- Increased safety by the employment of sensory tools to mark lanes
- Creating safe shoulder and edge for drivers in case of leaving the lane
- Reduce the severity of crashes with a safe design on road shoulders

If the new design value has safety considerations, FDOT requires a benefit and cost analysis. This analysis is based on the reduced number of crashes and aggregated costs during the project's life. The state roadway design engineer will review a request for a design exception. Depending on the project's scope, the chief engineer, state structure engineer, planning office, and FHWA may also be involved. For design variations, only district level approval is required. FDOT requires state roadway design engineer approval only for lane width design exceptions.

Speed Management (Traffic Calming)

FDM has developed speed management practices for arterials and collectors in low-speed areas. The objective of speed management is to reduce the operating speed to a desirable speed safe for context classification. Lane repurposing is used as one of the tools to facilitate speed management strategies by removing travel lanes and creating extra space. FDM suggests that using cognitive senses in drivers by creating roadways that alert users both on-road and roadside will help manage speed. Besides, changes in geometric design, including horizontal and vertical deflection, attract drivers' attention and, correspondingly, can be employed as speed management strategies.

Speed management strategies are applied to reach a "target speed." Target speed is defined as the highest speed in a corridor that will increase mobility and safety for all modes of transportation. FDOT recommends to utilize available sources optimally for speed management purposes. Yet, multiple strategies are suggested by FDM to manage speed that can be applied depending on road classification, user types and needs, access management, and desired speed. These strategies are listed as follows:

- Roundabouts
- On-Street Parking[2]
- Chicanes
- Lane Narrowing
- Horizontal and Vertical[3] Deflections
- Street Trees
- Short Blocks
- Speed Feedback Signs
- Road Posted Speed Marking
- Islands
- Bulb-Outs
- Hybrid Beacons
- Terminated Vistas

FDOT believes that among speed management strategies, narrowing lanes on its own might not be beneficial in reducing speed. However, higher volume roadways show a more significant difference. Combined with other speed management strategies, lane narrowing has been shown to be more effective. Speed management strategies also may be applied in transition zones where roadway classifications change. Application of lane narrowing along with other methods is recommended to reduce speed in perception-reaction areas.

---

[2] Travel lanes must be 11 ft or less.

[3] Mostly recommended for target speeds of 30 mph or less.

Summary

Florida was one of the last states in the Southeast that produced a design manual that is context-sensitive and promotes flexibility in highway design. But it has been one of the most progressive states we interviewed when it comes to implementation.

FDOT Design Manual (2022) was developed based on a comprehensive review of existing evidence and is largely context-sensitive. FDOT recommends in an urban setting to start with a 10-foot lane and try to justify why it should be any bigger and in a rural setting to start with an 11-foot lane and try to justify why it should be any smaller. It is quite innovative to start with 10-foot width and ask traffic engineers to justify for a wider lane. It counters existing practice of lane width design in most states where lane width in the urban core (speed of 35 mph or less) starts with 12 feet and (if any) justification from design engineers aim to narrow it further. The FDOT approach makes the minimum lane width very close to the desirable lane width.

It is important to note that the desirable 10-foot lanes would not fit many urban contexts such as streets that serve as a transit corridor or urban streets with a relatively high volume of trucks (higher than 10%). Other factors, including target speed and traffic volume (AADT), will justify the desired lane width value. The idea is to set an operating (design speed) that is context-appropriate through lane width specification and other countermeasures.

Finally, FDOT has a complementing lane repurposing program which is responsible to get the best use out of the extras space (as a result of reducing lane width and/or the number of lanes). The extra space is typically used to assess a buffered bike lane or a wider sidewalk. FDOT is currently taking six before-after (impact) analysis of such lane width reduction and repurposing.

Perhaps the most important takeaway from our interview with FDOT was their innovative context classification system. According to our interviewees: "If you don’t have that, it’s really scary to the engineers if I just come in and say, 'I’m going to put a 10-foot lane on a road;' they don’t know where that’s going to be, it could be really, really bad to do that. Or it might be okay. And if they don’t know where it’s going to be, then they have reason to be very concerned about that. What we found is that they embraced the context classifications because they love the idea of being able to do 10-foot lanes in a downtown somewhere, and where it was supposed to be low speed. And they love the idea that they could say yes to that project in the downtown but say no to this other 10-foot lane in an urban or rural setting. Before they had no way to justify why they were saying yes to one and no to the other. And so, they said no to everything. So, they love the idea of having that. I think that’s a really important thing to get into place because it helps set and frame the conversation for the decision makers.”

Vermont's Practice and Experience with Lane Width Reduction

Vermont is an interesting case study since it was one of the very first states that developed and adopted its own roadway design standards rather than following the AASHTO Green Book. Vermont's State Design Standards were adopted in 1997 after a long-range planning process required by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). As part of that process, VTrans found that roads built using the AASHTO Green Book guidelines were sometimes out of context and inconsistent with community values; many projects required design exceptions or were scuttled due to community opposition. In response, the Vermont Legislature ordered VTrans to develop standards more appropriate to Vermont. The new standards related to design speed, level-of-service (LOS), travel lane width, clear zone, stopping sight distance, horizontal curvature, and grade. Vermont is the first state to largely rewrite its design standards pursuant to ISTEA. It took five years to get agreement on sub-AASHTO standards (Ewing and King, 2001).

The Vermont State Design Standards manual was pioneering in terms of departure from the AASHTO Green Book in the following aspects. First, it was an intergovernmental agreement with FHWA giving VTrans the power to grant its own design exceptions on all highways except Interstates. Second, it reclassified the definition of urban and rural roadways. The Green Book adopts the census definition of "urban place." Many towns in Vermont have smaller populations but are nonetheless built up. Vermont has taken the position that a road's classification should be based on the surrounding built form, not population or population density. By changing the classification from rural to urban, the agency has greater flexibility with design elements such as roadside clearance, curbs, and shoulder width. Third, the manual allowed a minimum lane width of 9 feet for urban and suburban roadways in special contexts (low volume, low speed) while the AASHTO minimum lane width standards for urban and suburban roadways is 11–12 feet.

The Vermont State Design Standards

Vermont Agency of Transportation (VTrans) roadway design standards aim at providing a safe, reliable, and multimodal transportation system that promotes economic growth and is affordable and socially equitable for all. With this vision, VTrans adopted Vermont State Design Standards almost 25 years ago, a unique and visionary step for a transportation agency fighting the odds of the legislature in establishing flexibility and contextuality in the roadway design process.

Going beyond the standards set for lane widths by the American Association of State Highway and Transportation Officials (AASHTO), otherwise known as the "Green Book," as 11 feet or 12 feet, VTrans standards set the minimum lane width as low as 9 feet which triggers our interest for this case study. While interviewing members from VTrans, we came to know this minimum standard has not been applied for any state routes even though the guidelines permit it.

According to the VTrans, the winter climate of Vermont played a big part here. The primary reason that initiated the formulation of these standards was to ensure a complete street, especially to accommodate the bicyclist. Hence this added flexibility was more helpful for 3R (resurfacing, restoration, and rehabilitation) projects, allowing better utilization of the space to accommodate bicyclists and traffic without any larger scale investment for lane widening.

According to the Vermont State Design Standards, lane widths on urban and village principal arterials may vary from 10 feet to 12 feet and for urban and village collectors is discussed in the next chapter, and it can vary from 9 feet to 11 feet, and there should be appropriate offsets to curb. Further, the document prescribed special cases for adopting narrower lane widths for urban and village arterials. According to the document, “Under interrupted-flow conditions at low speeds (up to 45 mph), the narrower lane widths are normally adequate and have some advantages. Reduced lane widths allow greater numbers of lanes in the restricted right-of-way and facilitate pedestrian crossings because of reduced distance. They are also more economical to construct. On the other hand, 11-foot lane width is adequate for through lanes, continuous two-way left-turn lanes, and a lane adjacent to a painted median. A 10-foot left-turn lane, or a combination lane used for parking, with traffic during peak hours, is also acceptable.” For more detailed information see Appendix D.

Complete Streets: A Guidebook for Vermont Communities

This guidebook was developed by the Vermont Department of Health under its Fit and Healthy Vermonter Program and implemented under Act 34 of 2011, requiring municipalities to adopt a transportation policy that considers all users, including pedestrians, bicyclists, and transit riders. The guidebook suggests resurfacing (3R) as an excellent opportunity to provide complete streets to the community. Especially when 12-foot lane width was considered a “basic” standard, this guidebook states that “VTrans has established a range of acceptable lane widths for the local, collector, and minor arterial streets. They allow for 10-foot to 11-foot lanes under pretty much all urban, downtown, or village conditions (i.e. C3–C6) and will accept 9-foot lanes on local streets. Rural roads typically require 11-foot lanes.”

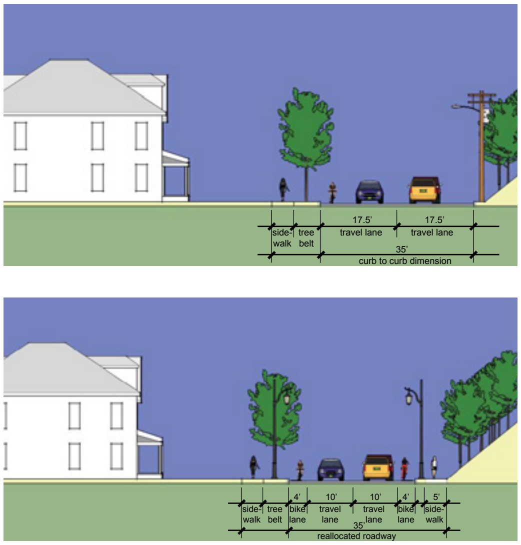
It also mentioned “right-sizing” the major roadways to make room for active modes of transportation known as road diet projects that have been taking place in Vermont. However, VTrans and other transportation agencies in Vermont have been using the concept of the complete street before Act 34 was passed in 2011. Some of the examples are mentioned as follows:

Burlington: Transportation Plan and Street Design Guidelines

Burlington has adopted a complete street design guideline to accommodate all modes through a transportation plan. It proposes redesigning the major corridors, which involved a reduction from a four-lane auto-oriented street to two through lanes and a center turn lane with median refuges, along with left-out space accommodating one bicycle lane in either direction, transit shelters, or streetscape amenities.

Figure 13 shows a redesign of Colchester Avenue into a complete street. On Colchester Avenue, the presence of a steep slope initially prevented the inclusion of a sidewalk on both sides of the road. Converting the road to a complete street reallocates space within the existing roadway zone to make way for two clearly marked bike lanes, two lanes of traffic, and a new sidewalk. Unsightly utilities are placed underground, and the new standard lighting fixture is installed along both sides of the street[4].

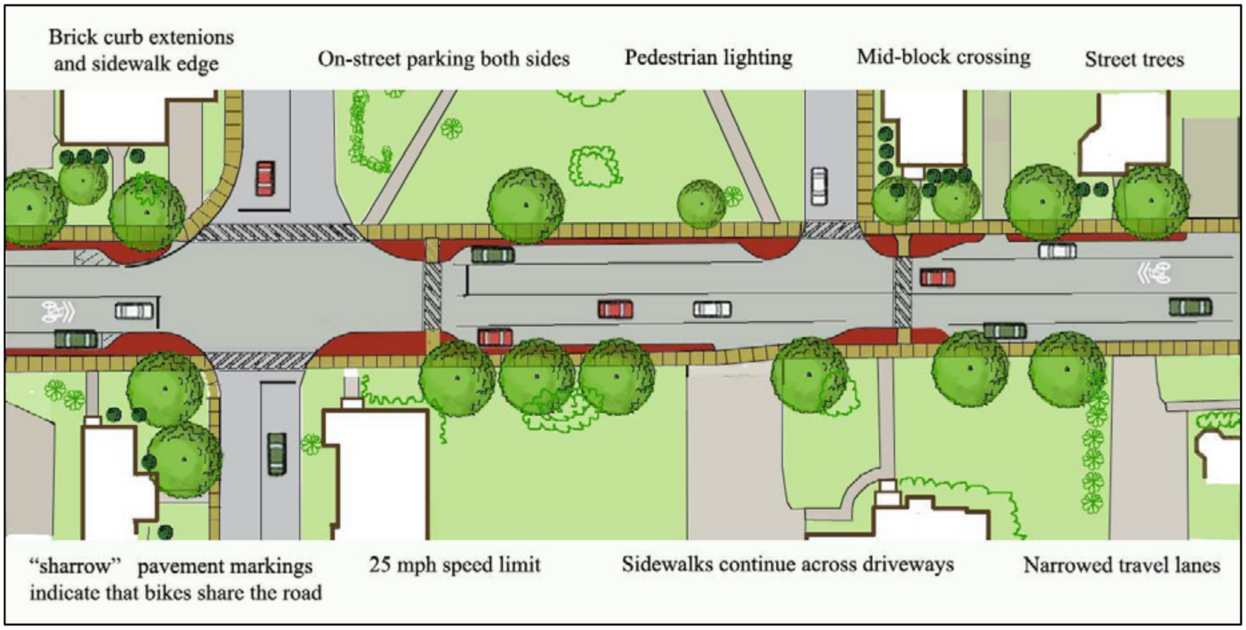
Figure 13:
Conversion for Colchester Avenue; Street Design Guidelines, City of Burlington



Waterbury-Main Street/Route 2: Reconstruction of Street with Streetscape Improvements

Complete street features like wider sidewalks, on-street parking, plantation, pedestrian-scaled lighting, bulb-outs at pedestrian crossings, and shared lanes for bicycles are being added to Waterbury's Main Street (see Figure 14).

Figure 14:
Reconstruction of Waterbury's Main Street; Complete Streets, a Guide for Vermont Communities, 2012



---

[4] www.burlingtonvt.gov/sites/default/files/DPW/TransportationPlan/BTP_Appendix_2_StreetDesign.pdf

Norwich-Route 10A Corridor & Burlington-Riverside Avenue: Reallocation of Right of Way

VTrans reconfigured Route 10A between Hanover and Norwich, converting two eastbound lanes into one vehicular lane and one bicycle lane. The new configuration was tested through temporary restriping before permanent adoption. Another example is Burlington-Riverside Avenue which is a major traffic route connecting northern Burlington with Winooski. Recently, complete street features like a sidewalk, bicycle lane, and a multi-use path have been added through reconstruction to accommodate alternate modes of users.

Vermont Experience with Lane Width Reduction: Dynamic Striping in Four Towns Along Vermont Route 30

Traditional traffic calming measures (horizontal & vertical) often fall short due to wintertime maintenance activities in states with heavy snowfall like Vermont. To overcome this limitation, a psycho-perceptive method was experimented with by VTrans and Windham Regional Commission, known as "dynamic striping." It was intended to reduce driving speed with visual cues like speed humps, using a series of transverse markings with increased widths and decreased distance between them. It is expected to reduce vehicular speeds at the edge of each village (Newfane, Townshend, Jamaica, and Bondville, located along VT Route 30) by drawing drivers' awareness and creating an illusion of increasing speed along with reduced lane width.

After installing the striping layout, traffic speeds were monitored periodically, and necessary data were collected. Analyzing the speed, the dynamic stripes were proven marginally effective in reducing vehicular speeds. Immediately after one week of installation, an average reduction in speed of .01 mph was observed, which improved over time with an average decrease in speed of 1.0 mph after four months. Moreover, evidence suggests that striping has a larger effect on drivers that use this route daily. However, according to the report, ***"Overall, the results from this study are not compelling given the large amounts of variability resulting in standard deviations ranging from 0.5 mph to 3.9 mph. While the effectiveness of the stripes may seem somewhat insignificant, this study proves that it increases over time due to driver awareness and recognition. Feedback from local residents indicates that the dynamic stripes act more as a signal that the village is coming up, and due to the consistency of the stripes in the four villages, the stripes are viewed as a "village approaching" indicator.***"

Summary

Vermont was the first state in the U.S. to adopt its own design standards rather than following the widely used AASHTO Green Book guidelines. The Vermont Design Standards adopted in 1997 reclassified urban vs. rural roads based on the surrounding built forms, not necessarily population of population density. The Vermont Design Standards went even further and changed the minimum lane width from 11 feet to 9 feet in urban areas. It took years for VTrans (Vermont Agency of Transportation) to work on details and justifications of this significant change and get the legislation passed. All these changes and developments were pioneering at that time, which makes the Vermont case study very interesting to see how and to what extent these changes have translated into practice after 25 years.

Our interview with VTrans found that there are so many challenges in the implementation of these changes (relative to the AASHTO guidelines) such as the minimum lane width of 9 feet that makes many of these standards stay in the book with very little success in execution. The VTrans stated that there has not been any case of 9-foot lanes for new or renovation transportation projects. Liability was cited as the main concern for opting for wider than 9-foot lanes, but also weather especially in winter and the maintenance costs associated with snowfalls makes narrower lanes challenging for states such as Vermont. As VTrans stated ***"it is nice from the traffic calming perspective to be able to narrow things down but being able to put pretty big equipment through there and manage snowfall"*** is particularly challenging.

It is worth noting that VTrans considers narrow lanes only in some reconstruction and resurfacing projects, but new projects in most cases follow AASHTO standard of 12-foot width. Our interview and the subsequent review of existing documents could not find any completed or in-progress lane width reduction projects in Vermont.

Oregon's Practice and Experience with Lane Width Reduction

ODOT has adopted two documents to provide roadway-related design guidance: the Highway Design Manual (HDM) and the Blueprint for Urban Design. The ODOT Highway Design Manual (HDM) is the primary document for roadway design on the state highway system and the version currently in use was last updatevd in 2012. The Highway Design Manual 2012 focuses on presenting the appropriate design standards relevant to various project types. The 2023 Highway Design Manual has been fully in effect since January of 2023 and includes the Blueprint for Urban Design which, up until now, has functioned as an independent document.

The Blueprint for Urban Design provides more guidance about how to appropriately apply some of the standards in HDM to get the most out of a corridor and meet the long-term goal of the corridor. The idea behind the BUD was to update a document that was created by the Transportation and Growth Management (TGM) program, a joint program of the ODOT and the Oregon Department of Land Conservation and Development (DLCD), in 1999 - *"Main Street - When a Highway Runs Through It: A Handbook for Oregon Communities."*

The handbook proposed techniques to reduce the perceived lane width in cases where the 12-foot width is required or needed. The BUD builds on the ideas from the handbook but goes much further and provides detailed design guidelines for six urban contexts, which were inspired by the National Cooperative Highway Research Program (NCHRP) Report 855: An Expanded Functional Classification System for Highways and Streets. Each of the six urban contexts has been assigned a set of recommended design elements that include lane widths. The recommended width of travel lanes is between 11feet and 12 feet for all contexts, and in the Traditional Downtown/CBD context, the recommended width is 11 feet.

These lane width standards are based on the 1999's Highway Segment Designations that was authorized by the Oregon Transportation Commission. The highway segment designations of Special Transportation Areas (STAs), Urban Business Areas (UBAs), and Commercial Centers were largely used as tools to implement more compact community development patterns. However, the preferred lane width was reduced to 11 feet in STAs. For the rest of the highway system, the standard length was maintained at 12 feet. Reductions were allowed with design exceptions. Over the years, ODOT has implemented design exceptions as a mean to provide flexibility on projects as needed but did not completely reduce lane width standards from 12 feet except for those designated areas that were STAs. For detailed information on ODOT's Highway Design Manual and the Blueprint for Urban Design, see Appendix E.

When asked about the preferred lane width in urban arterials in Oregon, ODOT staff responded:

> ***"We have suggested cross sections with flexibility in dimensions as opposed to absolute numbers. Our preferred mental calculation is 11 feet, but we have a range of 11 feet to 12 feet in the BUD because of our reduction review route needs in negotiations and discussions with our freight community. We didn't go to 10 ft. as a part of the range at the outset. Our chief engineer is not opposed to 10-ft lanes but doesn't want to have that as a flexibility option to just use. If you want to do a 10-ft lane, we would do that with a design exception based on appropriateness and based on route needs in those locations."***
>
> *(Rich Crossler-Laird, Senior Urban Design Engineer at ODOT)*

Freight Transportation: The Most Critical Barrier for Lane Width (Reduction):

In 2001, the Oregon Legislature formalized the Oregon Freight Advisory Committee, or OFAC, through the passage of House Bill 3364 (now ORS 366.212). This legislation calls for the ODOT Director to "appoint members of a Freight Advisory Committee to advise the Director and Oregon Transportation Commission on issues, policies, and programs that impact multimodal freight mobility in Oregon." Subsequently, ORS 366.215 ("Creation of state highways; reduction in vehicle-carrying capacity") was adopted. It states that the "vehicle-carrying capacity" of an identified freight route (aka Reduction Review Route) may not be permanently reduced unless safety or access considerations require the reduction, or a local government requests an exemption, and the Commission determines it is in the best interest of the state and freight movement is not unreasonably impeded. "It meant that if a vehicle can get through today, that same vehicle needed to get through after the project. So that means anything up to 16–18 feet wide, 245 feet long, depending on what the routes are."

In practice, it limits ODOT's ability to make changes to a roadway cross section that would impact freight and commerce. The term "vehicle-carrying capacity" was insufficiently explained and meant that even a traffic signal could have not been put in place without prior discussions with the freight industry." (Rich Crossler-Laird, Senior Urban Design Engineer at ODOT)

In 2013, an OAR (Oregon Advisory Role) was created to guide the implementation of ORS 366.215. For the purposes of implementing ORS 366.215 and following the OAR guidelines, ODOT established a system of Reduction Review Routes which includes all parts of the state highways that must be traveled to complete the prescribed route and/or connect with other state highways. Another direct outcome of ORS 366.215 was the creation of the Mobility Advisory Committee (MAC), which consists of representatives of widely defined freight interest groups: the trucking industry, mobile home manufacturers, oversize load freight, general contractors, and paving contractors. Any proposed changes to street/road cross sections must be presented to the Mobility Advisory Committee (MAC) group. Even though the group does not hold veto power, ODOT seeks to establish a concurrence to the cross-sectional design and make accommodations for vehicles that are permitted to go through those routes: 18-foot-wide, 245-foot-long, up to million-pound vehicles. These restrictions impact and sometimes impede what ODOT can do, also in relation to travel lane width:

> ***"When we looked at the Blueprint for Urban Design, we wholeheartedly wanted to reduce our lane widths as much as possible, but we don't always find the ability to do that. This depends on what we can do to accommodate those other freight. Even when putting in a six-inch-high raised curb median, we have to discuss it with our freight partners in how that's going to affect their ability to get freight through from a commerce standpoint and economic standpoint."***
>
> *(Rich Crossler-Laird, Senior Urban Design Engineer at ODOT)*

Many other U.S. states are in a similar situation with freight transportation being a major part of their economy and, therefore, it gets priority over everything else. Very little is known on what can be done to implement complete streets in this context. Further research is needed to particularly focus on best practices in lane width reduction and implementation of complete streets in states with relatively heavy freight traffic.

Design Exceptions

Any deviation from lane width design standards (or criteria) outlined by the 2020 Blueprint for Urban Design or the 2023 ODOT Highway Design Manual requires a design exception. This means that projects including travel lane widths of less than 11 feet require additional approvals. Lane width design exceptions are approved by the State

Traffic-Roadway Engineer and require signatures from both the Engineer of Record (EOR) and the State Traffic-Roadway Engineer. In some cases, FHWA approval may also be required (i.e., “High Speed” NHS Roadways). According to ODOT Highway Design Manual, the data required for design exception justification include:

1. Summary of the proposed exception
2. Project description and/or purpose/need statement from the project charter
3. Impact on other standards
4. Cost to build to standard
5. Crash history and potential (specifically as it applies to the requested exception)
6. Reasons (low cost/benefit, relocations, environmental impacts, etc.) for not attaining standard
7. Compatibility with adjacent sections (route continuity)
8. Probable time before reconstruction of the section due to traffic increases or changed conditions
9. Mitigation measures to be used. These can include low cost measures such as lane departure detectable warning devices (rumble strips or profiled pavement markings) or additional signs. Mitigation needs to be appropriate to the site conditions and installed correctly to be effective in reducing crashes.
10. Plans, Cross Sections, Alignment Sheets, Plan Details, and other supporting documents

Summary

With the exception of Special Transportation Areas (STAs), Urban Business Areas, and Commercial Centers where the preferred lane width is 11 feet, for the rest of the highway system, ODOT has maintained the standard length at 12 feet. These standards put Oregon on the list of states with relatively wider travel lanes. This is mostly due to the concerns with freight transportation in state roadways and its potential economic impacts.

However, ODOT has allowed lane width reduction projects through design exceptions. Again, the extent to which design exceptions could get approval from ODOT depends on whether they have any impacts on freight transportation which limits the possibility of requesting and implementing design exceptions. The same applies to traffic calming measurements that would help with speed management. ODOT has not done any before-after (impact) analyses of lane width and traffic calming projects.

Another takeaway from our interview with ODOT is that the agency aims to promote flexibility. ODOT uses design criteria rather than design standards in its design manual to facilitate more flexibility in decisions about lane width and other design elements. In addition, the Blueprint for Urban Design takes into consideration the contexts along the roadway corridor and specifically provides guidance about how to appropriately apply design standards to that specific context. Nevertheless, the range of variation in lane width is 11feet to 12 feet.

California's Practice and Experience with Lane Width Reduction

The California State Design Standards

In 2020, the Highway Design Manual was revised for the California Department of Transportation (Caltrans) by the Division of Design for implementation on the California State highway system. Caltrans defined the minimum lane width on two-lane and multilane highways, ramps, collector, distributor roads, and other appurtenant roadways as 12 feet with few exceptions in their Highway Design Manual (Index 301.1, Caltrans Highway Design Manual, 2020).

One exception to the 12 feet lane width is using 11 feet minimum lane for conventional state highways with posted speeds less than or equal to 40 miles per hour and AADTT (truck volume) of less than 250 vehicles per lane located in urban, city, or town centers, and rural main streets. The city and town centers are designated by a group of experts who are responsible for the design of a road. The idea is to make a balance between road capacity and the needs of local communities. In these conditions the 11-foot lanes are acceptable and, in most cases, desirable. Any design project with proposed lanes narrower than 11-feet is called "non-standard" design and should go through the exception process.

Moreover, the Highway Design Manual states that for right-turn channelization in urban, city, or town centers (and rural main streets) with posted speeds less than 40 miles per hour in severely constrained situations and low truck or bus volume, consideration has been given to reducing the right-turn lane width to 10 feet. So, the lane width is somehow flexible in certain contexts. For more detailed information, see Appendix F.

Compared to other state DOTs we interviewed, Caltrans has relatively wider travel lane standards (mostly 12 feet) and, in some circumstances, it could go down to 11 feet as widely used standards. The main reason is that the majority of roads that are managed by Caltrans are freeways and high-speed highways (40 mph or more). Other road classifications in California such as principal arterial, mirror arterial, and collector streets are typically managed by local jurisdictions (counties and cities) which mostly have their own lane width design standards. Some of them opt for wider lanes and in some others such as the City of Los Angeles, 10-foot lanes have been used in many urban settings.

Caltrans also adopted lane repurposing or road diets where lane width can be reduced, the layout can be changed to create more space, and the extra space can be reassigned for other purposes. In Madera, California, Highway 145, a road diet project, reduced four lanes to two lanes with a center two-way turn lane and created space for other facilities. As the level of service is no longer considered a primary performance measure of the roads, Caltrans started considering compact development, traffic calming, vehicle miles traveled, and roundabouts as performance measures and methods. Caltrans considers bike lanes, on-street parking (preferably reverse angle parking), and a green pit for the buffer area created by the road diet. Some cities also consider buffer areas for sidewalks.

Though the design exceptions are driven by cost savings mostly, place making is also considered in the design exceptions. Caltrans focuses on creating complete streets, and evidence shows that 10-foot or 10.5-foot road lanes have been functioning well without any significant speed reduction or increased crash incidents.

Design Exceptions

Though Caltrans already has 11–12-foot standard lane width, 10-foot is possible with a design exception. For the design features that deviate from the design standards in the Highway Design Manual, Caltrans developed Design Standard Decision Documentation (DSDD) which guides documenting such engineering decisions. The approval authority of the DSDD belongs to the Headquarters Project Delivery Coordinator for some of the nonstandard design features and the District Director for others. The documentation includes a project description, general highway characteristics, the facility's classification, safety improvements, and total project cost. It also includes general information such as the design standard, nonstandard features, and reason for not using the design standard and the added cost to meet the standard, design features with District Delegated Approval Authority, traffic data, collision analysis, future construction, concurrence, and environmental determination documents. Even with the design exception, there is a requirement that in roads with a relatively high volume of trucks, the outside lane does have to be wider.

The design exception request needs a clear justification for slower traffic and most often it comes down to the cost and benefit analysis. The design exception for freeways should be approved at the headquarters level. The design exceptions for conventional highways also used to be approved at the headquarters level which made it a bit more difficult to do all this background research justification. Now the approval process for conventional highways is being done at the district level which makes it easier to go through design exceptions. One major application of 10-foot lane design exceptions is using the extra space to add a buffered bike lane. "What I really want to do is to create not just a minimum bike lane, the five foot very narrow bike lane along the gutter pan, but to be able to create a buffer area. And to do that, many times, you're going to have to squeeze the lanes down to 10 feet." (Caltrans District 6)

However, this lane width reduction may not be applicable everywhere in California, as many cities particularly in sprawling suburban areas disapprove of bicycle lanes on state highways with high-speed traffic because of safety concerns. If there is a certain number of trucks on the highways, the outside lanes may still affect road capacity, speed, and safety and simultaneously create conflicts.

Lane Width Reduction Experience in California

According to our interviews with the Caltrans team, historically, 10-foot lanes have not been very popular in California and there may be few examples of it throughout the state (on state-operated freeways and highways). One of the early but great examples of implementing lane width reduction is Highway 168 by Fresno State. It was a conventional highway with a 40 mph of speed limit. It went through the reconfiguration of lanes and lane width reduction from 12 feet to 10 feet to accommodate a bus lane and turn lane. As a very busy roadway (50,000 vehicles per day), it is a successful example of lane width reduction to 10 feet with no noticeable change in traffic speed, capacity, or safety. The project was completed about 20 years ago and has been in operation with narrow lanes since then.

Another great example of ongoing road diet and lane width reduction projects is the Highway 145. It focused on lane width reduction, but actually coupled it with a series of other traffic calming measures to slow down the operation (design) speed and improve safety. This is a four-lane (two lanes in each direction) conventional highway in a historic district. It was proposed by Caltrans (District 6) to reduce it to two lanes with the addition of two buffered bike lanes and street parking which was somehow controversial due to concerns regarding the short-term and long-term reductions in roadway capacity.

The Caltrans District 6 introduced the idea of recapturing some of that capacity at the intersections by doing compact roundabouts. The project was approved for the road diet and the addition of roundabouts. The cross-section will include 11-foot lanes, a buffered area for bike lanes, a bike facility, and street parking. The proposed design will also include two compact urban roundabouts. In order to maintain some of the parking, the design team is opting for reverse angle parking. Angle parking is known for slowing traffic and was prohibited on state highways in California until recently. But it's been slowly introduced to some of its minor highways.

The lane repurposing, to best use the extra space gained from lane reduction projects, varies from place to place in California. In places such as Los Angeles, San Francisco, or Sacramento and mostly in downtown areas, the emphasis is on widening sidewalks, having a tree canopy, and pedestrian facilities. Other more suburban areas, like Central Valley with its hot summers, typically prioritize bike lanes over widening sidewalks. In most cases it comes down to the preference of local governments and their funding sources since widening sidewalks would be significantly more costly.

State Route 145 Pavement Project and Complete Street

Caltrans considers all types of transport, including walking, biking, transit, and passenger rail, in an integrated way to provide a world-class transportation network. The projects initiated by Caltrans aim to provide comfortable, convenient, and connected complete streets for all.

The State Route 145 pavement project has been initiated to extend the pavement life from Avenue 13 to the East Madera Underpass Bridge, as well as implement the complete street policy of Caltrans (Figures 15–18). The estimated construction cost of this project is around $13.4 million (including $4 million for complete street enhancements), and the construction work is expected to take place from fall 2024.

The scope of this project is to remove and replace about 4 inches of pavement, install or upgrade curb ramps, install bicycle facility, bike parking, and bulb-outs, install transit stops, and upgrade traffic signal components. In 2020, the City Council decided that diversion of traffic, traffic mitigation, potential relinquishment or gateway drive to Lake Street, and parking provision should be part of the project.

Figure 15:
Downtown C Street with Traffic Diversion: Existing Design (left) vs. Proposed Design (right)

Figure 16:
Bike Lanes at Yosemite Ave Between Lyons St & Mace St: Existing Design (left) vs. Proposed Design (right)

Figure 17:
Cross Section of Downtown C Street: Existing Design (left) vs. Proposed Design (right)

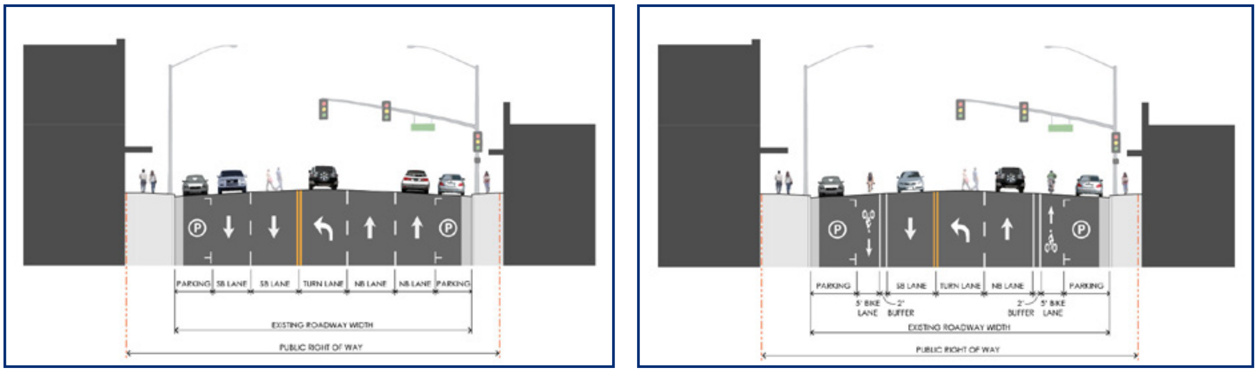


Figure 18:
Narrowing down lane Lake Street to Vineyard Avenue

The proposal would retain a traffic signal in the Lake Street option and provide two through lanes in each direction. The proposal also includes narrowing down lanes to 11 feet to add 5-foot bike lanes. Possible roundabout options have been considered where applicable. The existing speed limit on this road is 45 miles per hour. Caltrans is going to measure the 85th percentile speed after the completion of the project in order to justify a possible reduction in the operating speed before and after the lane width reduction.

State Route 63 (Mooney Blvd, California) Redesign

Caltrans seeks to eliminate fatalities and severe injuries on California's roadways by 2050 and provide safer outcomes for all communities. The State Route 63 project was initiated to meet the requirements of a safe street, especially safe bike lanes.

State Route 63 (SR 63) is a north-south state highway in the Central Valley, starting adjacent to Tulare at Route 137, running north through the city of Visalia and the towns of Cutler and Orosi, and then ending 8 miles (13 km) north of Orange Cove. The main objective of the State Route 63 project is to provide continuously dedicated bike lanes and ensure the safety of bicyclists. Previously this state highway had typical 5-foot bike lanes, green paint placed in conflict areas, and arrows (shared lane markings) placed in right-turn lanes, which were too narrow for a bike lane and unsafe for bike users.

Figure 19 also depicts the project area map where construction starts on a 2.2-mile segment of Mooney Blvd from 0.2 miles south of Caldwell Avenue to SR-198. The construction cost is estimated at $11.8 million and is scheduled for the fall of 2023. In this project, 1.8 inches of asphalt pavement needs to be removed and replaced. Other project components include upgrading traffic signals, installing sign panels, and providing curb ramps. Proposed 5-foot Class II bike lanes will also be added by narrowing travel lanes from 12 feet to 10–11 feet, with green paint in conflict areas.

Figure 19:
SR 63 Mooney Blvd

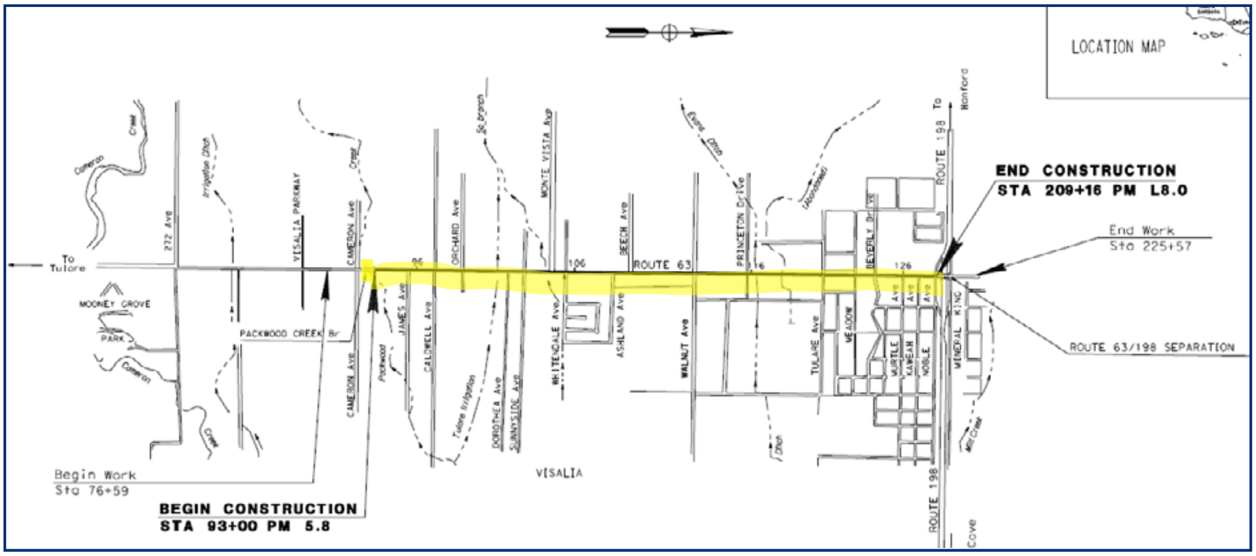


Figure 20:
SR 63 Mooney Blvd Before and After the Project: Existing Design (left) vs. Proposed Design (right)

Figure 21:
SR 63 Mooney Blvd Proposed Design (left); SR 63 N Dinuba Blvd Bike Lanes Proposed Design (right)

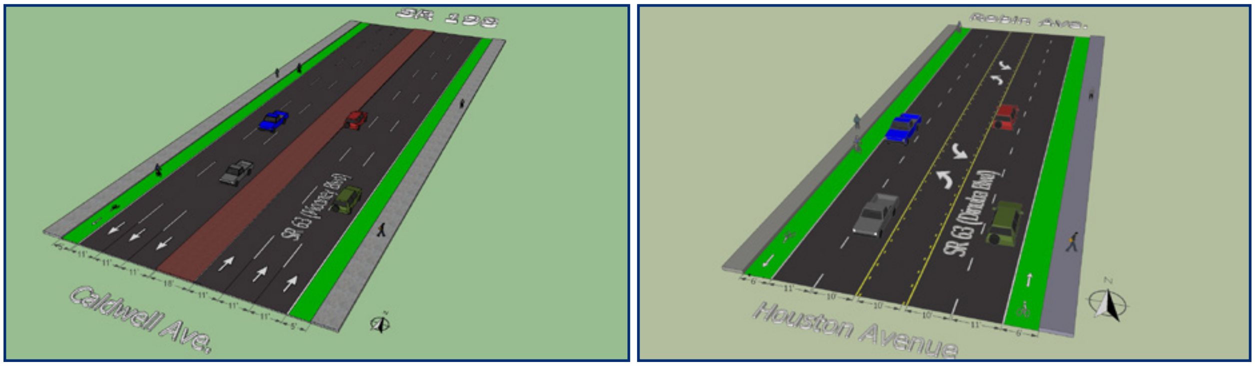


Figure 20 also shows proposed bike lanes for the 0.8-mile segment of N Dinuba Blvd from W Houston Avenue to W Robin Drive. In this road segment, travel lanes will be narrowed from 12 feet to 10 or 11 feet in order to provide 5-foot Class II bike lanes with green paint in conflict areas. The construction work is anticipated to start in spring of 2023.

Summary

Even though Caltrans' lane width standard has largely resulted in 12-foot lanes, perhaps relatively wider than many other states in the U.S., there have not been many cases of lane width reduction to 10 feet. Caltrans has sought innovative interventions on their path to complete streets. First, Caltrans does not use context-sensitive solutions in their design manual and in their street design practice. Rather the agency uses "Complete Street" as their approach and key goal in roadway design which is more comprehensive and representative of street design that facilitates safe mobility for all users.

Second, the Level of Service (LOS) which is a measure of roadway capacity is no longer a performance measure for roadway design projects in California. Likewise, it is not part of the decision-making for lane width standards or design exceptions. This is truly groundbreaking, and California is the first state to implement the shift from using LOS to vehicle miles travelled (VMT) as a performance measure. This paradigm change is the result of the state legislature's, Senate Bill 743, which prohibits the use of LOS as a transportation performance measure because of its direct contribution to adding capacity and encouraging suburban sprawl.

Third and most recently, Caltrans has adopted the Safe System Approach which primarily focuses on serious injuries and fatalities and is relatively less concerned with fender benders. This approach prioritizes pedestrian and bicycle safety and makes it much easier for Caltrans to go through design exception in favor of narrower lanes or to remove travel lanes in order to free up some space for improving pedestrian and bicycle safety.

Delaware’s Practice and Experience with Lane Width Reduction

Delaware and other states in the East Coast are in a unique position compared to other parts of the U.S. due to very tight roadway networks. In other words, due to the geographical nature of Delaware and its intensive transportation network, most of its roadways have narrow passages. The latter raises the need for redesign in some cases to save more space for a new facility or change of utilization purpose.

As a result, reducing lane widths from 12 to 11 feet will significantly change the network to save extra space for other purposes, such as bike lanes. The key point for reducing lane width being feasible in a road design is the “delivery” of the project. "We’ve got very tight constraints we work with, and sometimes it becomes a game of inches.” So “we end up redesigning extensively, trying to save a couple of feet, or even a couple of inches in some places.”

The Delaware State Design Standards

Until recently DelDOT has based its road design regulations on the AASHTO Green Bookand continues to try to maintain their standards. The typical lane width in Delaware is between 10 feet to 12 feet which complies with most standards.

The desired lane width for all new construction and reconstruction is 12 feet. However, on low-speed roadways with low truck volumes and no safety concerns 11-foot lanes can be used. An 11-foot lane width is used particularly in urbanized areas with limited rightof-way and increased pedestrian activity. At higher speeds, a 12-foot lane width is suggested on urban arterials with free flow conditions. On local roads, 11-foot is allowed, although where there are truck and vehicular volumes with low operating speeds, a lane width of 9 or 10 feet can be used.

Design speed is the primary element in picking the best paved lane width. Roadways with higher truck volumes require wider paved lanes as they will perform better for heavier loads. A minimum 12-foot lane width is necessary to keep trucks away from shoulders. Therefore, extra space in wider lanes will be dedicated to the shoulder width. Adequate lane widths on roads with high truck volumes are necessary to ensure sufficient clearance between large vehicles. On the other hand, narrower lanes are permitted on roads where the scope of work and right-of-way is limited. For more detailed information, see Appendix G.

The design guidelines for lane width by DelDOT state that “For new construction and reconstruction projects, 12-foot lanes should be used on roadways with design speeds of 55 mph or greater, and 11-foot travel lanes should be used on roadways with design speeds from 35 mph to 50 mph. Ten-foot travel lanes should be used on roadways with design speeds below 35 mph with consideration for 11-foot lanes that are adjacent to bike lanes. Ten-foot travel lanes should also be avoided along transit routes and roadways with heavy truck traffic.”

Keeping these guidelines in mind, based on the project’s needs, the best lane width varies, and engineering judgment must be used case by case. In new projects, most

A National Investigation on the Impacts of Lane Width on Traffic Safety 57 designs start from a 12-foot lane and adjust the lane width to find the suitable value based on existing conditions. Therefore, reducing to an 11-foot lane would not be considered a design exception and is suggested by DelDOT based on road conditions.

DelDOT is in the process of releasing its new road design manual that, compared to older versions, has not changed in most respects. However, based on design guidelines in the new manual, the default lane width is considered 11 feet. This can be viewed as a remarkable change since, as in previous manuals, an 11-foot lane was considered "acceptable" under specific conditions. On the other hand, the newest guideline specifies the road classifications on which an 11-foot lane can be used. The road design department of DelDOT states that there is a "change of regulation and wording in the new manual." The wording and regulations of the DelDOT manual follow the MUTCD approach. The use of modal verbs in guidelines and their flexibility is based on MUTCD. For instance, the use of "should" and "must" in design rules follows MUTCD rules.

In our interview with DelDOT, a question about the difference between 11-foot and 12-foot lanes on traffic networks was discussed. DelDOT believes that there is no significant difference in traffic operational parameters, including crash and speed, on 11-foot versus 12-foot lanes. Also, from the driver's perspective, there might be no noticeable difference with a 1 foot lane width reduction. It was stated that "No complaints were ever submitted on having 'too narrow' lanes." It was noted that reducing lane width to 10 feet might also show minimal changes in speed. On the other hand, in cases with high truck volume or high-speed corridors, using 12-foot lanes might be a better choice. Nevertheless, showing operational improvements is necessary for road reconfiguration projects. Most 11-foot lanes are in suburban or rural areas with a speed limit of less than 35 mph. The use of 10-foot lanes in Delaware is extremely rare and only in some cases has it been applied to turn lanes when an 11-foot turn lane was not possible. Even in this situation, there is often a 1-foot offset to keep the shy distance. However, 10-foot lanes are rarely implemented in Delaware and are primarily used in rural areas which DelDOT prefers to widen through reconstruction/renovation projects. Based on feedback from transit agencies, 10-foot lanes could restrict moving space for transit vehicles. Besides, auxiliary lanes also are used in higher-speed areas with a speed limit of more than 35 mph. Another reason for not using a 10-foot lane is that DelDOT rarely works on road design projects with the operation (design) speed of less than 35 mph which is the most suitable for 10-foot lanes.

Design Exceptions

The standard offered by the DelDOT Roadway Design Manual is based chiefly on ranges from the AASHTO Green Book; however, in some cases, there might be values lower than recommended by AASHTO, which typically happens on lower functionally classified roads. However, such design exceptions should be determined in the early stages of projects and require documentation and approval by the chief engineer and FHWA. Meanwhile, new construction and reconstruction projects are expected to follow the standard guidelines. Depending on the project type, different types of approvals might be required.

According to DelDOT, there have not been design exceptions for years. There have been a few instances 20 years ago, but they would not go through the design exception process anymore. This mainly is due to the fact that AASHTO and DelDOT Road Design Manual offer sufficient flexibility, so there might not be a need for an exception. Again, for years, the default width in most urban streets was 12 feet and the engineers have not widely justified to go with a narrower lane. However, in the most recent (under development) manual, the default width would be 11 feet.

Lane Width Reduction Experience in Delaware

One of the motives of DelDOT in updating its practices and guidelines is to reduce speed and facilitate a safe and efficient traffic flow in the traffic network. Additionally, DelDOT has implemented multiple "Road Diet" or "Road Reconfiguration" projects. Based on the network performance analysis, the speed and crash rates of the corridor have been reduced due to the new layout of the roadway. Among lane width reduction projects by DelDOT, they have done a pavement rehab project to add extra bike lanes within a corridor. However, the project's before and after study shows that the average speed of the corridor has increased. DelDOT explains this counterintuitive finding in terms of the reduced friction of surfaces due to new pavement used in redesigning the corridor. Therefore, the increase in operating speed may or may not be the result of lane width reduction.

DelDOT has also implemented several roadway configurations (road diet) projects with measured before-after impacts and all of them have shown speed and crash reductions as a result. Engineers at DelDOT proposed this road diet plan by ensuring the improved safety of the corridor while considering the peak hour volume, signal timing, and layout of intersections One of the road diet projects done by DelDOT is on a 4-lane undivided roadway in the city of Newark. The corridor has changed to a 3-lane road with a center turn lane and added bike lanes. The road diet is about 1 mile and despite the roadway's high AADT (28,000 vehicles a day), the corridor's capacity needs are being met. The road diet project included 10 significant improvements and went through a public involvement process with the supervision of a steering committee and city council.

The extra space from lane width reduction can be used for multiple purposes depending on the context of the project. For instance, in pavement rehab projects, the additional space is mainly assigned to broader shoulders or bike lanes. If a road diet is associated with urban areas, the added space might also be used for parking. In addition, reducing right-of-way width has also been affected in some cases.

A great example of lane width reduction is for intersection improvement projects. In many cases, there might be a need for a left- or right-turn lane, where reducing a foot from through travel lane width can help save space and include extra lanes. Adding extra lanes here will improve the roadway's capacity. "An intersection may not currently have all the proper lane configurations that it needs. So, let's say as an example, we need to add in a left-turn lane. Well, so we're trying to squeeze in an entire extra lane without creating a lot of right-of-way impacts. It is very possible that the existing lane widths that are out there are 12-foot lanes. If we're adding a left-turn lane and a rightturn lane on each of the legs, you just went from two lanes at 12 feet, which is 24 feet to four lanes. So, if we go from 12 feet, down to 11-foot lanes, we're saving four feet of impact just right there and that one parameter alone. And sometimes that's a difference of taking out a whole row of parking for a business that may no longer be viable, because they lost all of their frontage parking. That's a huge impact to properties. So, if we can start saving, one foot per lane, times a whole bunch of lanes, including turn lanes, we're saving a lot of properties on both sides."

Speed Management Practices in Delaware

DelDOT has also practiced traffic calming using different measures, including chicanes, diverted intersections, and roundabouts. However, recently, speed humps have been used widely. Speed humps are applied whenever the 85th percentile traffic speed is more than 5 mph over the design speed limit. The dimensions used for speed humps are also based on national guidance. In addition to speed humps, speed radar and signs, despite their limited effects, have been used for traffic calming. Another measurement that is being used for reducing speed in traffic networks is stop signs. Speed humps and stop signs have been more popular due to their low cost. As other tools involve a more complex project and decision-making process, they have been less widely deployed. DelDOT is trying to deploy more vertical traffic calming measures such as speed tables and raised crosswalk outside "subdivisions" as they can reduce vehicular speeds in the network. Speed management is one of DelDOT's strategic safety goals on highways. Using roundabouts also reduces speed efficiently while maintaining traffic movement. Some successful projects include:

Statewide Speed Hump Installation: To address the issue of safety on community roads with high pedestrian volumes, especially children, Delaware has installed numerous speed humps statewide, which have been efficient in controlling speeding at targeted spots.

Kirk Road—Edge narrowing and speed hump: The section of Kirk Road between SR100 and Rockland is bordered by a commercial, historic inn, which generates a lot of pedestrian traffic. To address their safety by slowing traffic, edge islands to narrow the road and a speed hump before a crosswalk were installed on this local one-way road.

Wellington Drive—Realigned intersection: Residents adjacent to the intersection of Wellington Drive and Curlew Drive were experiencing major safety concerns due to speeding traffic along the wide subdivision collector road. As the intersection was on a curve with a high volume of turning traffic, a realignment was implemented with a three-way stop-controlled intersection. It successfully improved safety in the realigned direction by reducing speeds over 10 mph and 5 mph on the opposite side.

Mallard Pointe—Realigned intersection/median islands: To resolve the issue of speeding problems for residents along Mallard Road with a wide subdivision collector road at the intersection with Brandt Drive, DelDOT realigned the intersection and narrowed the road by constructing a median island and pedestrian crosswalks. A significant improvement was observed as the traffic was reduced to approximately 8 mph in both directions.

Delaware Experience with Lane Width Reduction; the Case of Memorial Drive Road Diet Project

Delaware Department of Transportation (DelDOT) undertook a road diet project along Memorial Drive bounded between Delaware Route 9 and U.S. Route 13 in October 2019. Before the road diet, it was a minor arterial roadway passing through residential areas with an AADT of approximately 9,000 vehicles per day and a posted limit of 35 miles per hour. Besides, the studied portion of Memorial Drive included residential uses with five unsignalized intersections (Karlyn Drive (West), Karlyn Drive (East), Lind Avenue, Parma Avenue, and Bizarre Drive). Moreover, DART Bus Route 14 traverses along the corridor with stops in each of the unsignalized intersections, making it unsafe for pedestrians. Through this project, DelDOT **converted the roadway of approximately 1 mile from a four-lane section to a two-lane section and repurposed the rest of the spaces with a 5-foot bike lane and 9-foot curbside parking in each direction to improve safety for pedestrians** (Figure 22).

Figure 22:
Before (left) & After (right) the Condition of the Road Diet Project Along Memorial Drive

DelDOT considered crash history, traffic volumes, transit stop locations, on-street parking, pedestrian crossing distances, turn lane feasibility, utility pole locations, center median, and FHWA Road Diet Informational Guide before implementing this road diet project.

Summary

DelDOT's default lane width standard has been 12 feet for years with "acceptable" 11-foot lanes which has been mostly used for reconstruction and resurfacing purposes. DelDOT experience and observations confirm no noticeable changes in safety, speed, and traffic volume between 11-foot and 12-foot lanes. Even though DelDOT has a design exception option, it has been rarely used because narrowing lanes from 12 feet to 11 feet does not require an exception approval and DelDOT rarely considers 10-foot lanes in the roadway network.

A National Investigation on the Impacts of Lane Width on Traffic Safety 61 DelDOT referred to two reasons for not using 10-foot lanes. First, they rarely have roadway design projects with a design (operating) speed of less than 35 mph which best fits 10-foot lanes. Secondly, the feedback from transit agencies has shown concerns about the operation of transit vehicles in 10-foot lane streets.

Nevertheless, narrowing travel lanes could have huge impacts on property values, business operation alongside the streets, and could even be the difference between the feasibility and successful delivery of a design project. For Delaware and many other states on the East Coast which have very tight street networks with almost fully built-up roadsides, sometimes it becomes a game of inches. Therefore, narrowing lane width is even more critical and much needed evidence-based research could help with planning more often for narrowing lane projects with confidence.

PART 3: A NATIONAL QUANTITATIVE INVESTIGATION OF LANE WIDTH AND SAFETY

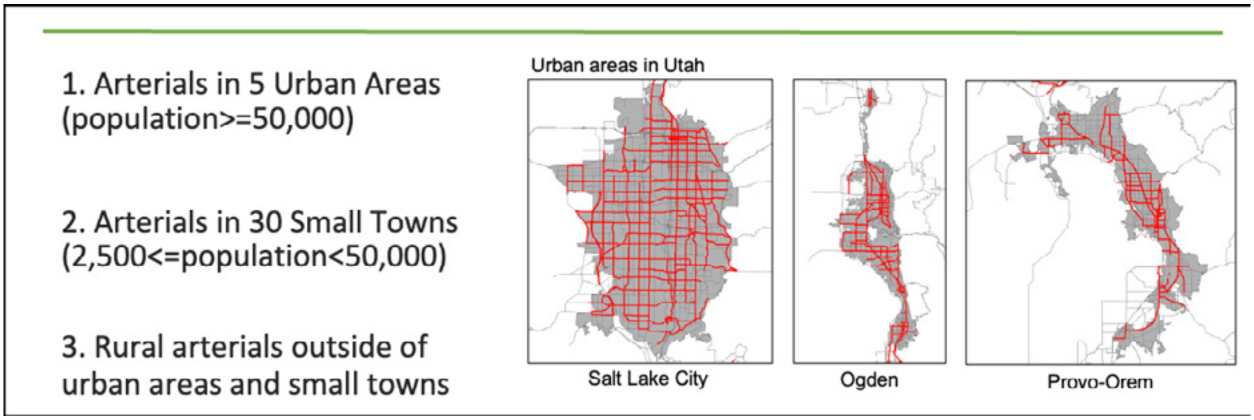
Unit of Analysis

The literature often used two definitions of road units for the purposes of analysis.

The first widely cited approach uses midblock segments as the units of analysis (Liu et al., 2018; Wood et al., 2015; Potts et al., 2007; AASHTO, 2010). According to Highway Safety Manual (AASHTO, 2010), midblock segments “begin at the center of an intersection and end at either the center of the next intersection or where there is a change from one homogeneous roadway segment to another homogeneous segment.” The segments need to be homogeneous with respect to annual average daily traffic volume and key roadway design characteristics (e.g., number of through lanes, presence/type of median, presence/type of on-street parking). The AASHTO manual suggests limiting the segment length to a minimum of 0.10 mile to minimize calculation efforts without affecting results.

Another set of studies employed longer sections of a road as the unit of analysis, which often include in-between access points (Manuel et al., 2014; Park et al., 2016; Chen et al., 2020; TRB, 2010). Highway Capacity Manual (TRB, 2010) defines an urban street facility as “a length of roadway composed of contiguous urban street segments and is typically functionally classified as an urban arterial or collector street.” According to this manual, an urban street facility typically has a length of 1 mile or more in downtown areas and 2 miles or more in other areas with no significant change in one or more facility characteristics, including cross-sectional features (e.g., number of through lanes, shoulder width, curb presence), annual average daily traffic volume, roadside development density and type, and vehicle speed.

Figure 23:
Street Sections in Three Large Urban Areas in Wasatch Front, Utah (as an example)

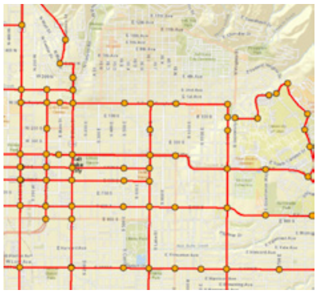
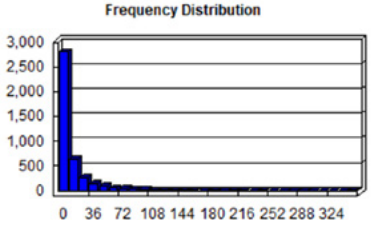
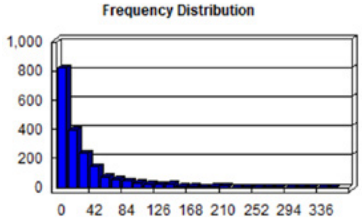


1. Arterials in 5 Urban Areas (population>=50,000)
2. Arterials in 30 Small Towns (2,500<=population<50,000)
3. Rural arterials outside of urban areas and small towns

While both methodologies (street section vs. street segment) are expected to produce units with a certain level of homogeneous characteristics, we found differences that may affect the models' statistical power and practical implications. Figure 23 shows the segmentation results for the arterials of Utah using these two methodologies. Looking at Method 1, as midblock segments with a shorter length likely have uniform design characteristics within the segments, one observation is expected per unit. With a relatively faster data collection for street segments, this approach allows examining a relatively larger sample (e.g., 700 units for urban areas) with little possibility of compromising the homogeneity of the roadway design characteristics in each segment. However, as shown in Figure 23, street segments are significantly shorter than street sections which in turns lead to a large number of zero-crash cases (e.g., 16%), potentially including false zeros occurring due to the short length of the units rather than due to the roadway design features.

On the other hand, road sections (combining multiple homogeneous road segments) can overcome this issue by producing longer units and a smaller number of zero-crash cases (e.g., 5%). However, as road sections are made up of multiple segments, they often require substantially more intensive data collection in a two-step process. The first step would be to identify road sections by manually checking segments within each section one-by-one to ensure their homogeneity in terms of the roadway design features; and secondly, conducting data collection on roadway design features for each road section. Further, with the prolonged data collection time, the sample analyzed can be smaller than the first method, potentially reducing the statistical power. Table 4 compares both methods in terms of the sample size and characteristics of the unit of analysis.

Table 4:
Analysis of Units and Characteristics (in Salt Lake City as an example)

	METHOD 1: MIDBLOCK SEGMENTS	METHOD 2: SECTIONS OF ROAD
Unit Characteristics	- Total number of units in Utah: 4,125 - mean: 0.9 mi. - range: 0.1-35mi. 	- Total number of units in Utah: 1,869 - mean: 2.0 mi. - range: 0.1-49.3 mi. 
Data Collection Time	significantly shorter	longer to examine multiple midblock segments
Number Of Crashes (*based on 5-yr average)	zero-crash cases: 16% (644 out of 4,125) - mean: 14 - range: 0-355  	zero-crash cases: 5% (85 out of 1,869) - mean: 31 - range: 0-355 
References	Liu et al., 2018; Wood et al., 2015; Pott et al., 2007; AASHTO (2010) Highway Safety Manual	Manuel et al., 2014; Park et al., 2016; Chen et al., 2016; TRB (2010) Highway Capacity Manual

In this study, we decided to use sections of roads as our unit of analysis. Although identifying homogeneous roadway sections requires more time, it is expected to produce fewer zero crash cases and more reliable findings since it will remove false zero crash cases occurring due to the short length of the segments rather than due to the roadway design features. Furthermore, road sections covering multiple intersections would be more analogous to sites for local roadway renovation projects and have much more potential for practical implementations by local governments. Our sample covers street segments from seven diverse cities in the U.S., representing different regions and built environmental characteristics. The seven cities in our sample include Dallas, TX, New York City, NY, Philadelphia, PA, Salt Lake City, UT, Miami, FL, Denver, CO, and Washington, DC.

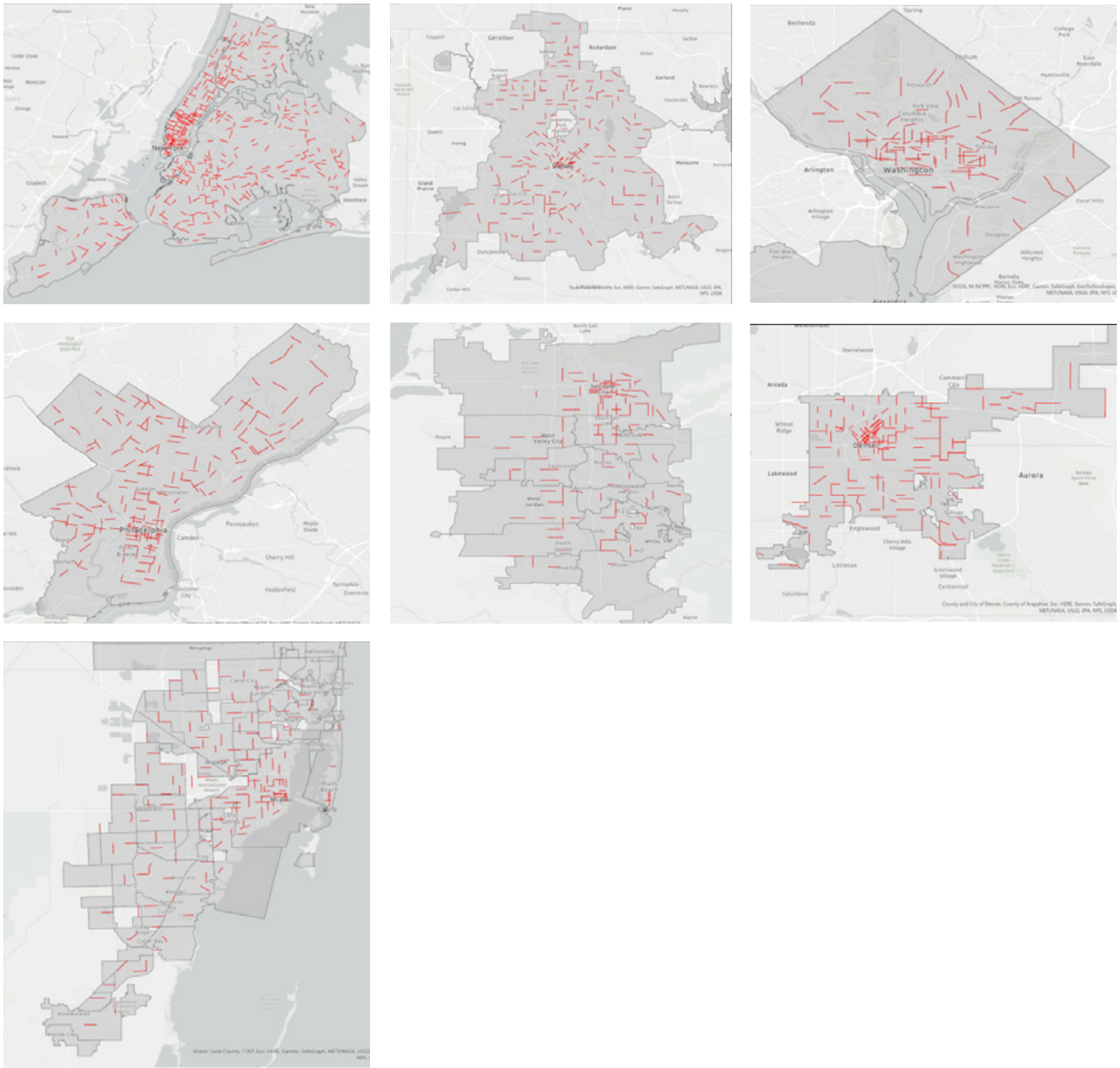
Table 5:
Sample Size and Description of Street Sections in Each City in Our Sample

CITY	SAMPLE SIZE	MEAN SECTION LENGTH	MINIMUM SECTION LENGTH	MAXIMUM SECTION LENGTH
New York City, NY	266	0.571	0.150	1.374
Dallas, TX	184	0.663	0.178	1.68
Washington D.C.	96	0.493	0.179	0.992
Denver, CO	141	0.701	0.325	1.76
Miami, FL	165	0.83	0.163	1.48
Philadelphia, PA	159	0.640	0.346	1.372
Salt Lake City, UT	106	0.881	0.299	1.78

Table 5 shows the sample size and description of street sections in each city. We randomly selected about 15% of street sections as samples in the analysis. The street sections are a) located within the boundary of cities; and b) classified as arterial or major collectors in terms of road functional classification since these two road classes are most likely to be used by pedestrians and cyclists. We focused on urban street streets (both city-owned and state-owned) due to their significantly greater potential to be multi-modal and to be used by pedestrians and cyclists.

We also excluded highway and interstate freeway road classes from the sample since the scope of this study is to focus on the streets that have the most potential to be used by pedestrians and bicyclists, and highways and freeways would not qualify in these criteria due to their relatively higher operation speed. The functional classes included in this study are major arterials, minor arterials, other principal arterials, and major collectors. Figure 24 shows the sample of street sections for each city.

Figure 24:
The Sample of Street Sections for Each City in the Analysis (first row: left-New York City, NY, middle-Dallas, TX, right-Washington, D.C.; Second row: left-Philadelphia, PA, middle-Salt Lake City, UT, right-Dever, CO; third row: Miami, FL



Variables

Table 6 summarizes the list of variables, their descriptions, and data sources. While earlier safety performance studies often rely on AADT (traffic volume) and a fewer number of selected road design variables, we included lane width as our independent variable of greatest interest and also included a comprehensive set of street design features, such as the number of lanes, median width, median type, shoulder width, etc.

Table 6:
Full List of Variables, Description, and Data Sources

VARIABLE NAME	DESCRIPTION	DATA SOURCES
Crash	Total number of all non-intersection crashes	State DOTs (2017-2019 crash data)
Traffic volume (AADT) in 000s	Annual average daily traffic (AADT) in 1000s	State DOTs (2017-2019)
Section length	Length of section (miles)	ArcMap Pro (authors)
Lane width	Lane width at a representative point within a section (ft) 9 = travel lane width of 9 ft or narrower 10 = travel lane width of 10 ft 11 = travel lane width of 11 ft 12 = travel lane width of 12 ft 13 = travel lane width of 13 ft or wider	State DOTs, Google Earth, Google Street View
Number of lanes	Number of alignment-specific travel lanes	
Median width	Width of alignment-specific travel lanes	
Median type	0 = no median 1 = traversable median (e.g., painted (flush)) 2 = non-traversable median (e.g., depressed, raised, curbed, landscaped, guardrail, etc.)	
Shoulder width	Right shoulder width at a representative point within a section (ft)	
Shoulder type	0 = no shoulder 1 = shoulder on one side of roadway 2 = shoulder on both sides of roadway	
Sidewalk	0 = no sidewalk 1 = sidewalk on one side of roadway 2 = sidewalk on both sides of roadway	
Sidewalk width	Sidewalk width at a representative point within a section (ft)	
Bike lane	0 = no bike lane 1 = bike lane on one side of roadway 2 = bike lane on both sides of roadway	
Bike lane width	Bike lane width at a representative point within a section (ft)	
Number of bus stops	Total number of bus stops within the section	
On-street parking	0 = no on-street parking 1 = on-street parking on one side of roadway 2 = on-street parking on both sides of roadway	

On-street parking width	On-street parking width at a representative point within a section (ft)	
Percent parked car	Percentage of parking lanes occupied on both sides of roadway	
Left-turn lane	0 = no left-turn lane 1 = at least one left-turn lane	
Right-turn lane	0 = no right-turn lane 1 = at least one right-turn lane	
Street curvature	The curve length divided by the Euclidean distance between two end points (normalized)	
Sky view	Proportion of the sky ahead view at a representative point within a section of the section	
Visual sense of motion	Level of roadside detail (street objects) that provides drivers with cues for vehicle movements and speeds (binary) 1 = the section is very little surrounded by street objects (e.g., buildings, trees, bus shelters, parked cars, etc.) 2 = the section is surrounded by both static and dynamic objects (trees, shelters, street furniture, etc.), pedestrians, etc.	
Intersection	Number of 3-way and 4-way intersections within a section	
Speed limit	Posted maximum speed limit 25 = posted speed limit of 20-25 mph 35 = posted speed limit of 30-35 mph 40 = posted speed limit of 40-55 mph	
City ID	Unique identifier for cities where a section is located: 8031 = Denver, CO 11001 = Washington, DC 36061 = New York City, NY 42101 = Philadelphia, PA 48113 = Dallas, TX 49035 = Salt Lake City, UT	

Data Collection

While secondary data are available for some road design variables, many other variables require extensive data collection. Thus, we employed Google satellite imagery to measure the majority of data for street design characteristics explained in Table 6. We designed and followed a multi-step procedure to ensure the reliability of the data collected by multiple people. In Step 1, we provided a training session for individual observers and asked them to analyze the same set of samples (e.g., 21 sections of road). After receiving the data collection results, we ran inter-rater reliability tests (e.g., Cronbach's alpha tests) to examine the degree of agreement among the different observers who observed the same set of samples. After individual observers passed the minimum value considered for acceptable reliability (e.g., Cronbach's alpha value > 0.7), they moved to Step 2. In Step 2, each observer was asked to review individual roadway sections and extract sections with a homogeneous cross-sectional design while excluding sections that show a significant change in their design characteristics. In defining a homogeneous section, we considered multiple factors: traffic volume (AADT), posted speed limit, number of lanes, vehicle lane width, median width/type, and presence of sidewalk and bike lanes. Next, in Step 3, for the homogeneous sections, we created a complete roadway design inventory using data sources from state DOTs and observation data from Google satellite imagery.

Step 1: Training Observers & Inter-rater Reliability Tests

In step 1, we conducted Cronbach's alpha tests, a statistical technique widely accepted in assessing the internal consistency or reliability between measurements or ratings. The Cronbach's alpha value ranges on a scale from 0 to 1, where a higher value describes the strong resemblance or internal consistency among the observations and a lower value (near 0) supports the null hypothesis, implying the absence of consistency among the ratings (Bujang et al., 2018; Leontitsis & Pagge, 2007; and Gliem & Gliem, 2003). According to the literature, for varying effect size, a Cronbach's alpha value of 0.7 and greater is considered as an acceptable result showing high consistency for a prespecified alpha value of 0.05, power and effect size of 90%, number of raters as 5, and recommended sample size as 21 (Bujang et al., 2018).

Among the total sample pool, 21 roadway sections were randomly selected, and five researchers from Metropolitan Research Center (MRC) at the University of Utah collected data for these same samples on 18 variables separately to check to which degree their ratings matched following the principles of Cronbach's alpha. After two weeks of in-depth data collection of these 21 cases in the samples (using Google satellite imagery and the Iteris Clear Guide Website), we observed the Cronbach's alpha value of 0.7 and higher for all 18 variables (Table 7), suggesting high consistency and reliability among the ratings. Hence from this stage, raters could confidently proceed to data collection from a subset of the sample size for all cities independently and separately following the data collection protocol.

Table 7:
Cronbach's Alpha Values for Inter-Rater Reliability Tests

VARIABLE	VALUE
Lane width	0.910
Number of lanes	0.972
Median width	0.973
Median type	0.945
Shoulder width	0.809
Shoulder type	0.882
Sidewalk	0.981
Bike lane	0.964
Bus stop	0.956
On-street parking	0.910
Percent parked cars	0.979
Left-turn lane	0.904
Right-turn lane	0.845
Visual sense of motion	0.891
Intersection	0.920

Step 2: Identifying Homogenous Sections of Streets

In Step 2, researchers were asked to identify the homogeneity in the given samples. Each data collector was handed over a subset containing 20%samples of roadways from each city. We only included principal arterials and major collectors in our sample since these street classes have more potential to be used by pedestrians and bicyclists in urban areas. The homogeneity of the road sections was identified by examining the cross-sectional roadway designs through Google satellite imagery and Clear Guide Website based on seven criteria shown in Table 8. The outcomes from students' observations were recorded in the form of a binary variable, 1 meaning inclusion and 0 meaning exclusion of the sample for further data collection.

Table 8:
Observation Protocol for Identifying Homogenous Samples

CRITERIA	OBSERVATION PROTOCOL
Number of lanes	Observed the through lanes in both directions. Ignored flush medians and turning lanes near intersections. If any change (e.g., 4 lanes to 6 lanes) is observed, it's recorded 0.
Posted speed limit	Measured the speed limit from the ClearGuide website. If any change is observed (e.g., 50 mph to 55 mph), it's recorded 0.
Lane width	Measured the lane width at multiple random points within a section. If any difference is over 1 ft (e.g., widened road at a sharp curve), its recorded 0.
Median width/type	If any significant change in the median width (e.g., 12 ft to 3 ft) or median type (e.g., traversable to non-traversable), it's recorded 0.
Shoulderwidth/type	If any significant change in the shoulder width (e.g., 12 ft to 3 ft) or shoulder type (e.g., present in one direction to none), it's recorded 0.
Sidewalk	If any significant change in the presence of sidewalk (e.g., present in one direction to none), it's recorded 0.
Bike lane	If any significant change in the presence of bike lane (e.g., present in one direction to none), it's recorded 0.

Step 3: Collecting the Cross-sectional Street Design Data

In the last stage, a detailed database for 1,117 homogenous roadway sections was created, compiling data for 18 variables collected from Google satellite imagery and Clear Guide Website over the period of four months. To collect information on lane width, median width, sidewalk width, bike lane width, on-street parking width, and shoulder width, we employed the measurement tool of Google Earth Pro software. We collected measurements on three reference points and noted the average number for lane width, median width, and shoulder width. Next, from the aerial view feature of Google Earth Pro, we collected information on the number of lanes, median, and shoulder types, the presence of sidewalks, bike lanes, turn, intersections, and parking lanes.

We closely monitored the satellite images in the areal views and noted each of the variables; minor deviations in the roadway sections are overlooked. Next, we searched for bus stops in the search panel of the software to locate if there were any bus stops on our roadway sections. Lastly, we used the street view feature in Google Earth Pro to assess the roadway environment and rate the sky ahead and nearby objects variables. Apart from Google Earth Pro, we also used ArcGIS software to create shape files of our samples and to collect the total length of each roadway section. By dividing the total length by the Euclidean distance, we obtained the curvature of each roadway section. Moreover, we used the Iteris Clear Guide website and state DOTs' speed limit shapefile to find speed data for each roadway section. We collected all the information for each roadway section and compiled them in one Excel sheet, creating a master database for further quantitative modeling.

Table 9 presents descriptive statistics for the final list of variables after the three-step data collection process. We excluded shoulder type and shoulder width from the original list, since road shoulder is most often applicable to rural areas, and we observed only a handful of street sections with a shoulder in our sample of urban streets. Note that we lost a handful of street sections due to missing values for one or more variables.

Table 9:
Descriptive Statistics for the Dependent and Explanatory Variables

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD. DEVIATION
Crash	952	0	683	43.1	71.76
Traffic volume (AADT) in 000s	936	0.13	153.6	11.83	11.03
Section length	952	0.15	1.89	0.647	0.238
Lane width	952	9	13	10.89	1.029
Number of lanes	947	1	8	3.28	1.56
Median width	952	0	90	5.7	9.36
Median type	952	0	2	0.57	0.795
Sidewalk	952	0	2	1.88	0.43
Sidewalk width	952	0	45	9.51	5.55
Bike lane	952	0	2	0.43	0.78
Bike lane width	951	0	11	1.37	2.38
Number of bus stops	952	0	24	4.54	4.74
On-street parking	952	0	2	1.34	0.88
On-street parking width	817	0	22	5.69	4.11
Percent parked car	947	0	100	41.59	37.21
Left-turn lane	952	0	1	0.45	0.49
Right-turn lane	952	0	1	0.13	0.34
Street curvature	952	-0.0000017	1.02	0.971	0.116
Sky view	951	5	100	67.41	22.84
Visual sense of motion	951	1	2	1.3018	0.46
Intersection	952	0	20	3.57	2.76
Speed limit	946	25	45	30.5074	6.16

Analytical Methods

With a full set of variables in hand, we sought to explain the number of non-intersection crashes on the 952 finalized sampled street sections in seven cities. The nature of dependent variable is a count with many street sections having low or zero crash counts (even the sum of three-year crashes from 2017–2019), few street sections having high crash counts, and no street section having negative counts. Counts range from 0 to 683, with a mean value of 43.1 and a standard deviation of 71.7. The assumptions of ordinary least squares regression are violated in this case. Specifically, the dependent variable is not normally distributed, and the error term will not be homoscedastic nor normally distributed.

Two basic methods of analysis are available when the dependent variable is a non-negative count, with nonnegative integer values, many small values, and few large ones. The methods are Poisson regression and Negative Binomial regression. The models differ in their assumptions about the distribution of the dependent variable. Poisson regression is the appropriate model form if the mean and the variance of the dependent variable are equal. Negative binomial regression is appropriate if the dependent variable is overdispersed, meaning that the variance of counts is greater than the mean. Because the negative binomial distribution contains an extra parameter, it is a robust alternative to the Poisson model. Popular indicators of overdispersion are the Pearson and $\chi 2$ statistics divided by the degrees of freedom, so-called dispersion statistics. If these statistics are greater than 1.0, a model is said to be overdispersed (Hilbe 2011, 88). By these measures, we have overdispersion, and the negative binomial model is more appropriate than the Poisson model. We used the software package SPSS 28 to estimate four negative binomial models of non-intersection counts (see Tables 10–13).

The first model takes the entire sample to test the relationship between lane width and the number of non-intersection crashes while the second, third, and fourth models use a subsample of cases in different speed classes (20–25 mph, 30–35 mph, 40–50 mph, respectively). All four models have highly significant likelihood ratio chi-squares (significant at <0.001 level), indicating a good fit to the data relative to a null model with only intercept terms.

Key Findings

We conducted a series of analyses on the relationship between lane width and the number of crashes that occurred in each road section between 2017–2019. We excluded crashes after 2019 because the COVID-19 pandemic changed travel patterns, traffic volume, and vehicle crashes significantly since early 2020 and we tend to focus on a timeline that best represents the typical transportation, traffic volumes, and safety indicators in street sections in our sample.

The first analysis in these series of regressions investigates the overall impacts of lane width on the number of crashes in all cities in our sample. Table 10 presents the findings of the best fitted negative binomial model for this analysis. The dependent variable is the number of non-intersection crashes between 2017–2019. We only included the non-intersection crashes because the nature of intersection and nonintersection crashes and their determinant factors are very different, and we hypothesize lane width to be a significant predictor of non-intersection crashes.

Our model controls for the fixed effects of cities on the number of crashes. As shown in Table 10, after controlling for all confounding factors, the average number of crashes in street sections in our sample varies significantly among cities. Compared to the reference city (Denver, CO), street sections in New York City have a significantly higher number of crashes. Similarly, street sections in Dallas, TX and Salt Lake City, UT have (on average) significantly higher numbers of non-intersection crashes than their counterparts in Denver, CO. On the other hand, street sections in Philadelphia, PA have a significantly lower number of non-intersection crashes compared to Denver, CO, while we observed no significant difference between Washington, DC and Denver, CO in terms of the number of non-intersection crashes in our sample.

Table 10:
The Best Fit Negative Binomial Model Explaining Determinants of the Number of Non-Intersection Crashes

VARIABLE	B	STD. ERROR	WALD CHI-SQUARE	EXP(B)	SIG.
(Intercept)	0.441	0.4504	0.958	1.554	0.33
[Lane width = 13]	0.135	0.2219	0.368	1.144	0.54
[Lane width = 12]	0.404	0.2071	3.799	1.497	0.049
[Lane width = 11]	0.215	0.1954	1.207	1.240	0.27
[Lane width = 10]	0.182	0.1985	0.837	1.199	0.36
[Lane width = 9] ***reference category***				1	
Traffic volume (AADT) in 000s	0.017	0.0052	11.170	1.017	<0.001
Street curvature	0.495	0.3247	2.328	1.641	0.13
Section length	0.728	0.1990	13.374	2.070	<0.001
Number of bus stops	0.036	0.0097	13.920	1.037	<0.001
Percent parked cars	0.003	0.0015	3.601	1.003	0.05
Number of lanes	0.253	0.0443	32.592	1.288	<0.001
Sky view	-0.003	0.0026	1.702	0.997	0.19
Intersection	0.030	0.0193	2.335	1.030	0.13
Bike lane width	-0.010	0.0175	0.304	0.990	0.58
[Visual sense of motion = 2]	0.207	0.1199	2.983	1.230	0.084
[Visual sense of motion = 1] ***reference category***				1	
[Speed limit = 45]	0.332	0.1935	2.952	1.394	0.086
[Speed limit = 35]	0.178	0.1021	3.050	1.195	0.081
[Speed limit = 25] ***reference category***				1	
[Median type = 2]	-0.354	0.1329	7.103	0.702	0.008

[Median type = 1]	0.217	0.1195	3.304	1.242	0.069
[Median type = 0] ***reference category***				1	
[City ID = 49035]	0.355	0.1770	4.018	1.426	0.045
[City ID = 48113]	0.110	0.1509	0.531	1.116	0.47
[City ID = 42101]	-0.498	0.1515	10.801	0.608	0.001
[City ID = 36061]	1.662	0.1403	140.203	5.268	<0.001
[City ID = 11001]	-0.268	0.1874	2.045	0.765	0.15
[City ID = 8031]	0[a]			1	

At the street level, almost all confounding street design variables have expected signs and the majority of them are statistically significant. Number of lanes, traffic volume (AADT), and number of bus stops are the most significant predictors of nonintersection crashes. Street sections with higher traffic volumes, greater number of lanes, and more bus stops have a higher number of non-intersection crashes. This is expected since higher traffic volumes and higher levels of bus movement increase the number of potential conflicts between vehicles in the section and in turn increase the likelihood and number of crashes. Similarly, a greater number of lanes indicates more likelihood of lane changes and passing other cars by drivers which could lead to a higher number of crashes.

Similarly, streets with a higher percentage of parked cars in on-street parking (in one or both sides of the street) have a significantly higher number of crashes. Extensive research shows that on-street parking accounts for a significant portion of crashes in urban areas (Box, 2000, 2004; ITE, 2001) and increases crash risks particularly crashes that involve children (Greibe, 2003; Pande & Abdel-Aty, 2009).

Bike lane width, however, is linked to a reduced number of non-intersection crashes, although it is significant at 90 confidence intervals. Bike lanes are considered the most critical countermeasure with the intention to increase safety for bicyclists. Previous studies shows that simple or colored bike lanes may not be an efficient intervention for increasing biking safety. Our analysis confirms this statement as our initial analysis included the number of bike lanes in the road section which turned out to be statistically insignificant. However, wider bike lanes, even simple or colored bike lanes, are associated with a reduced number of crashes as wider bike lanes provide more buffer from cars for bicyclists.

Medians are one of the most widely used roadway design features which help with lane separation and management, planting and streetscape, and pedestrian crossing island. They are considered as a traffic calming intervention to make streets safer. Medians could be traversable (e.g., painted flush) which are typically used as a center lane for left turns, etc. or non-traversable (e.g., depressed, raised, curbed, landscaped, guardrail, etc.). Our investigation shows that travelable and non-travelable medians have significant and different impacts on the number of crashes. Street sections with a travelable median (center lane) have significantly higher numbers of crashes than their counterparts without any median. This is likely due to the fact that travelable medians increase the likelihood of traffic conflicts in the street which, in turn, increase the risk of crash. On the other hand, street sections with a non-travelable median (typically a raised median) have significantly lower numbers of crashes compared to streets with no median, possibly because it acts as a pedestrian island for pedestrian crossing which increases pedestrian safety. Non-travelable medians also could contribute to higher traffic safety by reducing the likelihood of traffic conflicts.

Our results also indicate that street sections with a higher posted speed limit have significantly higher numbers of non-intersection crashes, although the relationship is significant at the 90% confidence intervals. Note that the posted speed limit is not equal to the actual driving speed (operation speed) and drivers (based on their perception of safety) could drive faster or slower than the posted speed limit. The street design features such as the visual sense of motion, building setback, tree coverage, presence, and number of traffic calming tools could impact a driver's sense of risk and consequently their driving speed.

We controlled for driver's sense of risk and motion with two variables in our models. The first variable "visual sense of motion" captures the extent to which a street is surrounded by static street objects (buildings, trees, shelters, street furniture, etc.) and dynamic objects (pedestrians, bicyclists, restaurants with patio dining, etc.). Originally, we measured this variable on an ordinal scale of 1 through 4 with 1 for street sections with very little presence of static objects and no dynamic objects and 4 for street sections with the highest level of static and dynamic objects. However, in the final model we opted for including this feature as a dummy variable. Our analysis shows that street sections with a higher visual sense of motion have a significantly higher number of crashes. This finding (although only significant at 90% confidence interval) is unexpected as we hypothesized that visual sense of motion would increase a driver's perception of safety and, in turn, would reduce the likelihood and number of crashes. One possible explanation is that streets with the highest score for this variable are typically located in downtown or other busy neighborhoods in the city and most likely also have a higher traffic volume (AADT) which could cause the interaction between these variables.

Lane width is the variable of greatest interest in this analysis. We included lane width as a categorical variable rather than a continuous variable in this model. The reason behind this specification is that a one-unit change in lane width could differently affect traffic safety for a 9-foot lane compared to 10-, 11-, or 12-foot lanes. In other words, the relationship between lane width and safety is not linear, and treating lane width as a categorical variable allows us to look at each lane width category and their changes in a more precise manner. Our reference lane width category is 9 feet and we compare other lane width categories to 9-foot lanes in all models.

Our analysis shows that there is no significant difference between a 9-foot and 10-foot lanes in terms of the number of non-intersection crashes, after controlling for other confounding factors such as street design features and roadway characteristics. Likewise, we observed no significant difference in terms of the number of crashes between streets with 9-foot lanes and 11-foot lanes.

However, keeping all other variables constant, street sections with 12-foot lanes have a significantly higher number of non-intersection crashes than street sections with 9-foot lanes. In other words, a lane width increase from 9 feet to 10 feet or 11 feet is not often noticeable in terms of the number of crashes, while a lane width increase from 9 feet to 12 feet is significantly associated with an approximately 1.5 times higher number of crashes. Interestingly, street sections with 13-foot or wider lanes again show no significant difference compared to their counterparts with 9-foot lanes in terms of the number of crashes.

Looking at the coefficients of lane width categories, we observe that the effects of lane width on crashes for 10-foot, 11-foot, and 12-foot lanes gradually increases from 1.199 to 1.24, and 1.497 relative to the number of crashes in 9-foot lanes. For 13-foot and wider lanes, the effect of lane width on the number of crashes diminishes to 1.14 times the number of crashes in 9-foot lanes.

While we found statistically significant effects only for the 12-foot lanes relative to 9-foot lanes, the variability that we observe in the effect size is a consequence of relaxing the linear effect assumption by treating lane width as a categorical variable.

The next series of analyses present the best fitted negative binomial mode for street sections in three different posted speed classes. Travel speed is the most widely used indicator for decision-making on lane width policies and standards. For example, Florida DOT, recommends 10-foot lanes for streets with a design speed of 25–35 mph and 11-foot lanes for streets with a design speed of 40–45 mph. Specifying statistical models for each speed class would facilitate the interpretation and practical implications of findings as state and local departments of transportation could incorporate findings tailored for streets on each speed class. Note that we use posted speed in all modeling efforts and classifications due to the lack of data availability on the actual traffic speed. Table 11 presents the best fitted negative binomial model for street sections in speed classes of 20–25 mph, 30–35 mph, 40–50 mph respectively.

Table 11:
The Best Fit Negative Binomial Model Explaining Determinants of the Number of Non-Intersection Crashes for Street Sections in the Speed Class of 20–25 mph

VARIABLE	B	STD. ERROR	WALD CHI-SQUARE	EXP(B)	SIG.
(Intercept)	1.034	0.6482	2.544	2.812	0.11
[Lane width = 13]	0.060	0.2878	0.044	1.062	0.83
[Lane width = 12]	0.295	0.2647	1.239	1.343	0.27
[Lane width = 11]	0.021	0.2389	0.008	1.021	0.93
[Lane width = 10]	-0.057	0.2403	0.057	0.944	0.81
[Lane width = 9] ***reference category***				1	
Traffic volume (AADT) in 000s	0.017	0.0109	2.330	1.017	0.13
Street curvature	0.055	0.4885	0.013	1.057	0.91
Section length	0.582	0.3646	2.551	1.790	0.11
Number of bus stops	0.038	0.0143	7.096	1.039	0.008
Percent parked cars	0.003	0.0022	2.388	1.003	0.12
Number of lanes	0.295	0.0764	14.964	1.344	<0.001
Sky view	-0.003	0.0032	0.865	0.997	0.35
Intersection	0.034	0.0264	1.634	1.034	0.201
Bike lane width	0.024	0.0249	0.949	1.025	0.33
[Visual sense of motion = 2]	0.189	0.1568	1.453	1.208	0.23
[Visual sense of motion = 1] ***reference category***				1	
[Median type = 2]	-0.107	0.2563	0.174	0.899	0.68
[Median type = 1]	0.142	0.1776	0.638	1.152	0.43
[Median type = 0] ***reference category***				1	
[City ID = 49035]	-0.199	0.3835	0.269	0.820	0.604
[City ID = 48113]	-0.206	0.3215	0.412	0.814	0.52
[City ID = 42101]	-0.698	0.2233	9.760	0.498	0.002
[City ID = 36061]	1.545	0.1935	63.773	4.689	<0.001
[City ID = 11001]	-0.424	0.2451	2.989	0.655	0.084
[City ID = 8031] ***reference category***				1	

As shown in Table 11, in street sections with the speed limit of 25 mph or less, there is no significant difference in terms of the number of crashes between 9-foot, 10-foot, 11-foot, 12-foot or even 13-foot lanes. This is possibly due to the fact that such a low speed minimizes the consequences of a driver's error; therefore, even in narrower lanes such as 9 feet or 10 feet the number of crashes is not significantly different than in wider 11-foot or 12-foot lanes, after controlling for cross-sectional and roadway design characteristics.

The most significant predictors of the number of non-intersection crashes in this speed class are the number of lanes and the cities where street sections are located.

Street sections in Dallas, TX and Philadelphia, PA have (on average) a significantly lower number of crashes compared to Denver CO (as the reference group), while street sections in New York City NY have a significantly higher number of crashes than their counterparts in Denver CO.

Again, this study offers a novel finding, indicating that at the speed limit of 25 mph or less, lane width has no significant relationship to the number of crashes. The streets in this category have a high potential to be used by bicyclists and pedestrians due to covering mostly residential areas and districts with relatively lower traffic volumes. Indeed, streets in this speed class could be the best potential candidates for narrowing travel lanes and using the space to add/widen bike lanes and sidewalks.

Table 12:
The Best Fit Negative Binomial Model Explaining Determinants of the Number of Non-Intersection Crashes for Street Sections in the Speed Class of 30–35 mph

VARIABLE	B	STD. ERROR	WALD CHI-SQUARE	EXP(B)	SIG.
(Intercept)	-0.231	0.7740	0.089	0.794	0.77
[Lane width = 13]	0.444	0.4361	1.037	1.559	0.308
[Lane width = 12]	0.850	0.4236	4.024	2.339	0.045
[Lane width = 11]	0.743	0.4060	3.349	2.102	0.067
[Lane width = 10]	0.805	0.4019	4.008	2.236	0.045
[Lane width = 9] ***reference category***				1	
Traffic volume (AADT) in 000s	0.017	0.0068	6.463	1.017	0.011
Street curvature	0.862	0.4734	3.317	2.368	0.069
Section length	0.919	0.2914	9.953	2.507	0.002
Number of bus stops	0.022	0.0154	2.086	1.023	0.15
Percent parked cars	0.002	0.0023	0.689	1.002	0.407
Number of lanes	0.180	0.0645	7.757	1.197	0.005
Sky view	1.085E-05	0.0051	0.000	1.000	0.99
Intersection	0.008	0.0312	0.065	1.008	0.79
Bike lane width	-0.075	0.0277	7.236	0.928	0.007
[Visual sense of motion = 2]	0.204	0.2031	1.011	1.227	0.32
[Visual sense of motion = 1] ***reference category***				1	
[Median type = 2]	-0.491	0.1897	6.696	0.612	0.010
[Median type = 1]	0.231	0.1726	1.792	1.260	0.18
[Median type = 0] ***reference category***				1	
[City ID = 49035]	0.396	0.2367	2.795	1.485	0.095
[City ID = 48113]	0.305	0.2061	2.190	1.357	0.14
[City ID = 42101]	-0.238	0.2287	1.082	0.788	0.29
[City ID = 36061]	1.706	0.2310	54.512	5.505	0.000
[City ID = 11001]	-0.325	0.3843	0.715	0.723	0.39
[City ID = 8031] ***reference category***				1	

Table 12 presents the best fitted negative binomial model for the street sections with the speed limit of 30–35 mph. The speed class has some of the most interesting findings of all speed classes. Our analysis shows that street sections with 10ft lanes have significantly a higher number of non-intersection crashes than their counterparts with 9ft lanes.

This pattern is consistent across other lane width categories. Street sections with 10-foot, 11-foot, and 12-foot lanes have also significantly a higher numbers of nonintersection crashes than their counterparts with 9-foot lanes. Increasing the lane width from 9 feet to 10 feet, 11 feet, and 12 feet increases non-intersection accidents significantly by 2.24, 2.1, and 2.34 times, respectively. An interesting finding is that the effects of lane width on non-intersection accidents in the speed class of 30–35 mph is almost similar, between 2.1 and 2.34, for all three lane width categories (10 feet, 11 feet, and 12 feet).

Similar to the speed class of 25-or-less mph, street sections in this speed class (30–35 mph) have a great potential to be used by pedestrians and bicyclists, and our findings confirm that narrower lanes in this speed class are significantly safer with a fewer number of crashes. There exists a tremendous opportunity to consider narrowing wider travel lanes in this speed class (after controlling for other cross-sectional and street design factors) to improve pedestrian and bicyclists' infrastructure and also potentially reduce the number of non-intersection crashes.

Interestingly, the level of street curvature become important (statistically significant at 90% confidence intervals) in this speed class, indicating that streets with higher levels of curvature have higher numbers of crashes. Another significant variable (specific to this class) is bike lane width. Our analysis show that street sections wider bike lanes have significantly lower number of crashes, perhaps another reason to consider narrowing lane width and using the extra space for wider bike lanes (where appropriate) in this speed class.

Table 13:
The Best Fit Negative Binomial Model Explaining Determinants of the Number of Non-Intersection Crashes for Street Sections in the Speed Class of 40–50 mph

VARIABLE	B	STD. ERROR	WALD CHI-SQUARE	EXP(B)	SIG.
(Intercept)	-3.385	3.1005	1.192	0.034	0.28
[Lane width = 13]	0.846	1.2483	0.459	2.330	0.49
[Lane width = 12]	0.286	1.1604	0.061	1.331	0.81
[Lane width = 11]	0.293	1.1625	0.063	1.340	0.801
[Lane width = 10] ***reference category***				1	
Traffic volume (AADT) in 000s	0.016	0.0132	1.538	1.016	0.22
Street curvature	0.506	1.9030	0.071	1.658	0.79
Section length	0.320	0.5736	0.312	1.378	0.58
Number of bus stops	0.066	0.0359	3.401	1.069	0.065

Percent parked cars	-0.013	0.0505	0.068	0.987	0.79
Number of lanes	0.129	0.1652	0.610	1.138	0.44
Sky view	0.027	0.0284	0.905	1.027	0.34
Intersection	0.279	0.2253	1.533	1.322	0.22
Bike lane width	0.092	0.0740	1.546	1.096	0.21
[Visual sense of motion = 2]	1.489	4.1617	0.128	4.435	0.72
[Visual sense of motion = 1] ***reference category***				1	
[Median type = 2]	0.573	1.0181	0.317	1.773	0.57
[Median type = 1]	0.636	1.1082	0.330	1.890	0.57
[Median type = 0] ***reference category***				1	
[City ID = 49035]	1.932	0.7586	6.484	6.901	0.011
[City ID = 48113]	0.868	0.8526	1.037	2.382	0.31
[City ID = 42101]	-0.859	1.1310	0.576	0.424	0.45
[City ID = 8031] ***reference category***	0[a]			1	

Finally, Table 13 presents the best fitted negative binomial model for street sections with the posted speed limit of 40–50 mph, the highest speed class in our sample. Note that our sample excludes highways and interstate freeways and only focuses on principal arterials (with intersections) and major collectors. As a result, this speed class has a smaller sample compared to the other two speed classes which could be a possible reason for insignificant results for several confounding variables. We ran this model with fewer independent variables to test the robustness of our findings and the results remained generally consistent.

It is also important to note that there is no street section with the lane width of 9 feet in this speed class, which is expected since the higher speed limit of this category requires relatively wider lanes to minimize the risk of vehicles' unsafe confrontations. As a result, the reference category for lane width in this model is 10 feet. As show in Table 13, there is no significant difference between 10-foot and 11-foot or 12-foot lanes in terms of the number of non-intersection crashes. Since we had a few (three) cases with the speed limit of 10 feet in our sample, we reran this analysis specifying 13-foot lanes as the reference category to test the robustness of our findings. All results remined consistent, indicating that street sections with 13-foot lanes are not significantly different than 12-foot, 11-foot, or 10-foot lanes in terms of the number of crashes. Please see Appendix H for the results of the best fitted negative binomial model with 13-foot lanes as the reference category for our lane width variable.

Overall, this study found no evidence that narrower lanes are associated with a higher number of crashes and increase the risk of vehicle accidents. To the contrary, our models confirm that in some cases (in the speed class of 30–35 mph), narrowing travel lanes is associated with significantly lower numbers of non-intersection traffic crashes and could actually contribute to an improvement in safety. The policy recommendations and practical/policy implications of these findings are explained in the next section.

Learning From the Existing Lane Width Reduction Projects (Before-After Studies)

One key objective of our AASHTO survey and interviews with the state DOT officials was to identify and feature successful examples of lane width reduction projects implemented by the state DOTs. This section presents a summary of a few case studies and the observations/studies on the potential before-after impacts of lane width reduction.

Florida DOT has done a before-after analysis of lane width reduction for a couple of their projects and observed that narrowing lanes on its own does not affect average speed significantly. However, applying multiple speed management strategies can improve results and reduce the average speed of corridors. For instance, in S.R. 582, reducing lane width to 11 feet and changing the posted speed limit from 50 to 45 mph successfully reduced the average speed by 3 mph. The same trend was observed on Busch Boulevard with the application of Speed Feedback Signs (SFS), median islands, and reducing lane width from 12 feet to 11 feet. Speed reduction is most significant downstream of the boulevard (4 mph speed reduction) and SFS signs with narrower lanes, indicating the efficiency of multiple practices in traffic speed management.

Oregon DOT was among the state DOTs we interviewed that has not conducted any studies (e.g., before-after studies) regarding lane width reduction, but in 2008 commissioned a study to determine the best roadway design treatments for transitioning from rural areas to urban areas on state highways (Dixon, 2008). The main objective of the study was to identify ways to calm operating speeds as the vehicles transition into developed suburban/urban areas from rural roads. The study evaluated whether either physically or perceptually narrowing the road at these transition locations leads to speed reduction.

The specific transition treatments included (1) layered landscape, (2) gateway with lane narrowing, (3) median treatment only, (4) median with gateway treatment, (5) medians in series with no pedestrian crosswalks, and (6) medians in series with pedestrian crosswalks. The study found that the layered landscape treatment and the gateway with lane narrowing treatment did not result in statistically significant speed reductions. The scenarios with the most effective speed reduction results (although still minimal) included the median treatments (particularly the medians in a series or the treatment combined with a gateway).

The following are examples of before-after studies conducted by state DOTs to capture the effects of lane width reduction on speed and other transportation outcomes.

Powerline Road (Fort Lauderdale, Florida)

The project's primary objective was to provide continuously dedicated bike lanes on both sides of N.W. 19th Street between State Road 7 (SR7) and Powerline Road (Figure 25). Powerline Road is a north-south minor urban arterial that parallels Interstate 95 and Andrews Avenue within the cities of Fort Lauderdale and Wilton Manors. From SR7 to N.W. 29th Avenue and from N.W. 24th Avenue to N.W. 15th Avenue, 4-foot-wide bike lanes were to be provided by **reducing the width of the traffic lanes from 12 feet to 10**

feet via pavement milling, resurfacing, restriping, and isolated widening. From 29th Avenue to N.W. 24th Avenue and from N.W. 15th Avenue to Powerline Road, 5-foot-wide bike lanes with 3-foot-wide buffers were to be provided by converting the outside traffic lane to a buffered bike lane through pavement milling, resurfacing, and restriping. In addition, the project was also to retrofit a number of existing curb ramps to meet current Americans with Disabilities Act (ADA) requirements, upgrade bicycle signing and pavement markings, and install new pedestrian countdown signals at all signalized intersections. The total construction cost was estimated at approximately $3.5 million.

To determine how this project could have affected the roads immediately adjacent to the improvement, FTO identified roads adjacent to the study segment for inclusion in the analyses. Besides Powerline Road, W Sunrise Boulevard and W Oakland Park Boulevard were identified as surrounding corridors.

Figure 25:
Powerline Road, Fort Lauderdale, Florida


(a) Before
(b) After

The construction work on the project started in January 2017 and was completed in June 2017. Thus, the Powerline Road Lane Repurposing Before and After Study used 2014 to 2016 as the before-construction period, 2017 as the construction year, and 2018 to 2019 as the after-construction period. A number of measures were used to evaluate the effectiveness of the lane repurposing project:

- Average annual daily traffic (AADT) and peak counts
- Average travel speed: daily, AM, and PM peaks
- Average speed vs. posted speed
- Planning time index
- Average travel time

- Vehicle delay
- Level of service (LOS)
- Level of traffic stress (LTS) for pedestrians and bicyclists
- The number of fatalities, serious injuries, and nonserious injuries
- The number of bicyclist and pedestrian crashes
- Property values

Traffic volumes (AADT) remained relatively consistent from 2014 through 2019. Powerline Road had an AADT of 22,500 in 2014 and an AADT of 25,000 in 2019. Differences in AADT from 2014 to 2019 represent an 11% increase in volume over the six-year period. Adjacent roadways experienced similar growth in volume ranging from 4% to 17%. In 2014 the AM peak volume was 4,323. In 2019, the AM peak volume was 4,054. This represents a 6% decrease over the six-year time frame. During the same time, W Sunrise Boulevard and W Oakland Park Boulevard witnessed slight gains in traffic, 1% and 2%, respectively. A similar trend was observed in the PM peak period.

Prior to construction in 2014, average daily travel speeds in both directions were 27 mph on Powerline Road. After construction in 2018, the average travel speed increased to a little over 25 mph. In 2019, average travel speeds on the four-lane facility were approximately 26 mph, nearly as high as the speed on the six-lane facility back in 2014. A similar trend was observed on Sunrise Boulevard with a faster speed by 2019. Speeds for Oakland Park Boulevard were not available. **The reduction in capacity had minimal effect on the overall travel speed in the corridor.**

On the other hand, the compliance rate with the posted speed in the study corridor and adjacent roads has decreased by 9%. As travel time is influenced by speed and capacity, the travel time has also increased slightly. Due to higher traffic volumes, the travel time difference during peak hours is more significant in these periods. Besides, more nonrecurring longer traffic times within a month of traffic data were observed on Powerline Road after lane reduction. Based on the number of vehicles that have experienced delays before and after the project, more delayed vehicles are observed after lane repurposing.

Despite more delays in the corridor, the level of service (LOS) has remained at the same level "C." However, a small segment of adjacent roads experienced LOS F after the project. This study also examined the project's impact on bicyclist and pedestrian users' experiences. The travel experience is measured by the level of traffic stress (LTS), which is a function of bike lanes, lane width, bike exclusive facilities availability, auto traffic speed, and AADT. A comparison of LTS for bikes shows that it has reduced from the highest level, being 4, to 1. Lower LTS translates to more comfort for most populations, and a higher value indicates that traveling on the road is uncomfortable even for experienced users. Since this project aimed at bike riders, this outcome was highly expected. However, the LTS has remained unchanged at level 2 with no changes for pedestrians.

Even though the objective of line repurposing in Powerline Road was not the quality of transit ridership, the reduced capacity affected the average ridership after the project. Results were obtained from the average daily transit service of the corridor. The corridor's safety is also viewed as an essential factor in this lane repurposing project. Crash records demonstrate that the project successfully reduced the number of crashes and increased roadway safety. This improvement is significantly observed in crashes with injuries and fatalities. This trend, however, is different for pedestrians and bicyclists. The number of pedestrian injuries tends to decrease through the project process and has an increasing trend. Yet, bicyclists' injuries have decreased since the start of the study period, and a smaller percentage of crashes in corridors involve bicyclists.

One of the interesting findings of this study is that this project has increased the property value in the study area over six years by 65%. Compared to the adjacent area of the study, which shows a 49% increase in property value, results show that the lane repurposing project also had economic benefits. Overall, the project did not affect the mobility of auto traffic or the throughput of the corridor. Nevertheless, the results indicate that non-auto safety and injuries have declined and improved in the corridor. The complete "Powerline Road Lane Repurposing Before and After Study" by FDOT can be found in the Appendix.

Cleveland Street Road Diet Project

Cleveland Avenue is one of the road diets projects done by a collaboration between DelDOT and the city of Newark. Due to the high crash rates observed between 2011 and 2014 on this road, a road diet plan was proposed. The main objective of this project was to increase the safety of the roadway by changing lane layout. Cleveland Avenue is a two-way minor arterial with a 35 mph speed limit and is heavily commercial. Some sections have a 25 mph speed limit and are primarily residential. The road diet was applied to 1.3 miles of road where AADT is 28,800, and LOS at intersections is determined as "F." Even though the traffic volume of the corridor was higher than the threshold of the road diet project, authorities were confident about the outcomes and safety improvement of the road. The proposed road diet project included:

1. Adding bike lanes for both directions of the corridor
2. Adjusting signal timing and using exclusive pedestrian phase scramble
3. Study of options regarding the construction of a northbound right-turn lane on N. College Avenue at Cleveland Avenue
4. Removal of on-street parking on parking on the south side of E. Cleveland Avenue
5. Adding refuge islands for pedestrians on E. Cleveland Avenue, which creates a left-turn pocket for turns onto Wilbur Street
6. Change Margaret Street into a one-way street northbound from E. Cleveland Avenue to Annabelle Street, conditional on the installation of a traffic signal at Paper Mill Road and Creek View Road,

7. Reconfiguration of lanes to two through lanes for east and west directions and one center turn lane; bike lanes will have sharrow marking on the intersection of Paper Mill Road/Cleveland Avenue and Capitol Trail/Cleveland Avenue

8. Creation of a "Florida-T" intersection at Woodlawn Avenue and Capitol Trail with Capitol Trail having a constant green light

9. Installation of a crosswalk on E. Cleveland Avenue, west of McKees Lane, with a central pedestrian refuge island with a "Hawk" (High-intensity Activated Crosswalk) signal[5] for the crosswalk

Since the goal of this project was to reduce crash rates, reducing travel lanes and incorporating other factors are used to improve the safety of corridors with meeting capacity needs. Even though there is no comprehensive before-after study, DelDOT has found that **vehicle speed was reduced by 4 mph**. Besides, it has been shown that **motorists yield to pedestrians 18 times more**. Also, the **corridor has processed 150 vph more traffic** and, **failing intersection, 325 vph more traffic** during the afternoon rush hour after the project. It is worth noting that the initial crash data analysis shows a safety improvement.

4. DISCUSSION AND POLICY RECOMMENDATIONS

This study is one of the first and the most comprehensive efforts to date to address a long overdue built environmental challenge to health: unnecessarily wide travel lanes that are designed to accommodate fast and convenient driving. Previous studies on the relationship between lane width and road safety are inconclusive and report mixed findings, likely because the street design characteristics are largely missed from previous efforts due to the lack of data availability and difficulty of on-site data collection for these variables at a large scale.

This is one of the first studies that includes urban design characteristics in addition to the geometric variables (see Table 6) at a large scale. Previous studies show that urban design features can reduce vehicle operating speeds and, in turn, will minimize unsafe confrontations between motorists and pedestrians. Yet, these features are largely missed in safety studies particularly on travel lane width. This study employed several innovative data sources and data collection methods to measure and include variables related to sidewalks, bike lanes, visual sense of motion, street trees, and other urban design-related variables.

To our knowledge, this is the first multi-city study representing a large sample of 1,117 street sections from a diverse range of cities in the U.S. Almost all previous studies we reviewed are local (only part of a city or county) in their scope and, therefore, may have limited generalizability. This study is the first to make a national comparison of travel lane width and the potential for lane width reduction across states in the sample.

---

[5] This is a signal that would stop traffic when activated by a pedestrian.

This study is also unique in its scope of sample selection, focusing on principal arterials (with intersections) and major collectors as dominant road classes in downtowns, urban subcenters, and residential areas, mostly likely to be used by cyclists and pedestrians. The majority of existing studies on this topic have focused on either interstate highways, freeways, or arterials which are considered high-speed classes of roads and are less likely to be used be pedestrians and bicyclists.

KEY TAKEAWAYS

The most important takeaway from this national study is that in all scenarios we tested, we found no evidence that wider lanes are safer in term of non-intersection crash occurrence. We found that the number of crashes does not significantly change in streets with a lane width of 9 feet compared to streets with lane widths of 10 feet or 11 feet, after controlling for cross-sectional and street design confounding factors such as posted speed limit, traffic volume, on-street parking, median type, number of lanes, bus stops, and similar sense of visual motions, most likely because the difference in lane width is not noticeable to drivers. The difference becomes noticeable once lane width is changed from 9 feet to 12 feet which, in fact, increases the number of crashes. This is most likely due to the fact that in streets with 12-foot lanes, drivers have more space within travel lanes and there is a lesser risk/punishment for driving errors which (in turn) increases the driving speed. In 13-foot and wider travel lanes, again, we observed no significant different compared to 9-foot lanes in terms of the number of crashes, likely because the lanes are wide enough to reduce the likelihood of traffic conflicts even in higher functional driving speeds.

More interestingly, we found that the relationship between lane width and the number of non-intersection crashes varies substantially across different speed classes. In the speed class of 20–25 mph, the driving speed is slow enough that drivers do not notice changes in lane widths. This hypothesis was confirmed by our findings that there is no significant difference in terms of the number of non-intersection crashes between 9-foot, 10-foot, 11-foot, 12-foot or even 13-foot lanes.

However, this is not the case for streets in the speed class of 30–35 mph. Our analyses indicate that that street sections with 10-foot, 11-foot and 12-foot lanes have significantly higher numbers of non-intersection crashes than their counterparts with 9-foot lanes. In other words, in the speed class of 30–35 mph, wider lanes not only are not safer, but exhibit a significantly higher number of crashes than 9-foot lanes, after controlling for geometric and cross-sectional street design characteristics of street sections.

These findings are novel and offer new insights into the dynamics of the relationship between lane width and crash occurrence in urban arterials and major collectors. The scope and coverage of this analysis make our findings more generalizable to other cities with similar characteristics to our sample, as compared to previous efforts.

Similar to the speed class of 20–25 mph, street sections in the speed class of 30–35 mph have a great potential to be utilized by pedestrians and bicyclists, and our findings confirm that narrower lanes in the 30–35 mph speed class are significantly safer with a lower number of crashes. There exists a tremendous opportunity to consider narrowing wider travel lanes in these speed class (after controlling for other cross-sectional and street design factors) to improve pedestrian and bicyclists' infrastructure and also potentially reduce the number of non-intersection crashes.

POLICY RECOMMENDATIONS

This is not to say that 9-foot lanes are appropriate and recommended in different contexts. Road safety is one of the most critical concerns of traffic engineers and practitioners when considering narrowing travel lanes in a specific site, but it is not the only one.

Another key consideration for lane width standards, policies, and lane width reduction projects is freight transportation. In streets with a heavy freight/delivery movement, 9-foot or even 10-foot lanes may not be the best width as freight vehicles are typically larger than passenger vehicles. This concern particularly was brought up in our interview with Oregon DOT as their most important limitation for lane width reduction. Florida DOT, for example, defines a freight-heavy route as a route/street section where truck volume exceeds 10% of total traffic volumes in the street. In such cases, 11-foot lanes would be more appropriate to accommodate oversized trucks.

Likewise, a key concern when considering lane width reduction projects is the potential negative impacts of lane width reduction on bus (public transit movement) in streets that serve as major bus corridors. While the widest buses or truck vehicles do not exceed a width of 8.5 ft, a few existing empirical studies suggest that narrower lanes below 10 feet are associated with a higher likelihood of bus-involved crashes (Dai et al., 2020). Our analysis found the number of bus stops as one of the most significant predictors of the number of crashes overall in all street classes and more specifically in streets in a speed class of 20–25 mph. Our study does not recommend lane widths of 9 feet or 10 feet for streets that are in transit corridors. Lane widths of 11 feet would be a more appropriate option for such streets to accommodates oversized transit vehicles.

In addition, our study does not recommend lane widths of less than 10 feet in the speed class of 20–25 mph and lane widths of less than 11 feet for the speed class of 30–35 mph in areas with harsh and heavily snowing winters. The challenge of wintertime maintenance activities in states with heavy snowfall was highlighted in our interview with Vermont DOT. With the exception of Salt Lake City, UT and Denver, CO, the cities in our sample do not experience heavily snowing winters and our analyses do not account for season-specific crashes. However, according to our interview with state DOT officials, regardless of traffic safety concerns, extra caution should be taken on decisions about lane width reduction in cities with heavy snowfall in winter.

Nevertheless, perhaps the most immediate candidates for lane width reduction projects are street sections with lane widths of 11 feet, 12 feet or 13 feet in urban streets in the class of 20–25 mph and 30–35 mph that do not serve a transit or freight corridor. More specifically, of these candidates, those that have lower traffic volume (AADT), no or a small proportion of on-street parking, low degrees of street curvature, fewer numbers of lanes, and with no travelable (raised) median are the best candidates for the lane width reduction projects, according to our study. These factors influence the perceived sense of risk by drivers and make drivers more precautious of the surrounding environment. As a result, these factors contribute to a lower driving speed (in some areas even lower than the posted speed limit) and substantially reduce the risk of crashes. Streets with such design characteristics and wider lane widths (11 feet–13 feet) have the greatest potentials to be narrowed to improve pedestrian and bicyclist infrastructure and safety and to become truly multimodal and offer safe and inclusive mobility for all users.

Our interviews with state DOTs and best practices review show that the best practice for lane width standards and specification is to set an operating (driving speed) that is context-appropriate and then seek to achieve that through lane width specification and other countermeasures. Perhaps the most important takeaway from our interview with FDOT was their innovative context classification system that helps traffic engineers to differentiate between an arterial (or other road classes) in a low-speed (such as downtown) versus high-speed context. Most often the challenge is that traffic engineers consider roadway design features such as lane width without accounting for the context of a street and its surroundings. Designing and implementing a context classification system would address this gap and help with moving toward more context-sensitive designs which facilitate lane width reduction in low-speed streets in a more systematic way.

However, in practice, justifying, designing, and implementing narrow travel lanes (9 foot–10 foot) are very challenging in most transportation agencies. Vermont, for example, was the first state in the U.S. to adopt its own design standards rather than following the widely used AASHTO Green Book guidelines. The Vermont Design Standards changed the minimum lane width from 11 feet to 9 feet in urban areas. It took years for VTrans (Vermont Agency of Transportation) to work on details and justifications of this significant change and get the legislation passed. Our interview with VTrans found that there are so many challenges in the implementation of the minimum lane width of 9 feet that they make many of these standards stay in the book with very little success in execution. The VTrans stated that there has not been any case of 9-foot lanes in new or renovation transportation projects in the state since the legislation passed.

One effective way to address these challenges is to rethink and redesign the procedure for specifying lane width standards and guidelines. FDOT, for example, recommends in an urban setting to start with a 10-foot lane and try to justify why it should be any bigger and in a rural setting to start with an 11-foot lane and try to justify why it should be any smaller. It is quite innovative to start with 10-foot length and ask traffic engineers to justify for a wider lane. It counters the existing practice of lane width design in most states where lane width in the urban core (speed of 35 mph or less) starts with 12 feet and (if any) justification from design engineers aim to narrow it further.

This concept has been practiced in Europe for years. Unlike in the U.S., where roadways are classified mainly in terms of their access and mobility functions, European design practice begins by examining the developmental context of a roadway, identifying the hazards that are expected to exist in these environments, and then specifying a target design speed to ensure that the driver travels at speeds that are appropriate given these hazards. The result is that a roadway's operating speed is consistent with its target speed, contributing to per capita traffic fatalities that are 50 to 75% lower than those in the U.S. (World Health Organization, 2004).

Another effective way to facilitate the practice of narrower (9-foot–10-foot) lanes is to aim for an inclusive street design rather than prioritizing driving speed and functional class from the very beginning in the process of lane width decision-making. California Department of Transportation (Caltrans), for example, does not use context-sensitive solutions in their design manual and in their street design practice. Rather the agency uses "complete streets" as their approach and key goal in roadway design which is more comprehensive and representative of street design that facilitates safe mobility for all users.

The other key practical question is how to best use the extra space after the implementation of lane width reduction projects. Florida DOT, for example, has a complementing lane repurposing program which is responsible to get the best use out of the extra space (as a result of reducing lane width and/or the number of lanes). The extra space is typically used to add a buffered bike lane or a wider sidewalk.

Nevertheless, narrowing travel lanes could have huge impacts on property values, business operation alongside the streets, and even could be the difference between the feasibility and successful delivery of a design project. For Delaware and many other states on the East Coast which have a very tight street network with almost fully built-up roadsides, sometimes it becomes a game of inches. Therefore, narrowing lane width is even more critical and much needed evidence-based research could help with planning more often for narrowing lane projects with confidence.

The automobile has been the winner of space competition within roadways in American cities. Most often, automobiles get prioritized on streets and sidewalks and bike lanes have been squeezed out from roadway design to accommodate driving. Car dependency, coupled with the lack of walking and biking infrastructure, has led American cities to have significantly lower rates of pedestrian and cyclists, compared to their European counterparts. More than 5,000 studies have linked the lack of walking, biking, and physical activity to the increased rates of obesity, diabetes, high blood pressure, and other associated chronic diseases.

Narrowing travel lanes, in areas that have potential for lane width reduction and are likely to be used by pedestrians and bicyclists, is the easiest and most cost-effective way to accommodate better sidewalk and bike lane facilities within the existing roadway infrastructure. Our findings confirm that it also improves road safety even for drivers. Other benefits of lane width reduction are increasing roadway capacity, promoting walkability, and inclusive use of streets by all travel modes. In addition, lane width reduction contributes to minimizing construction/maintenance costs for urban arterials and collectors. Finally, narrowing lane width would address challenging environmental issues by accommodating more users in less space, using less asphalt pavement, less land consumption and smaller impervious surface areas, and the consequent effects on the occurrence of urban heat islands in cities.

LIST OF REFERENCES

AASHTO (American Association of State Highway and Transportation Officials). (2011). ***A Policy on the Geometric Design of Highways and Streets,*** 6th ed. Washington, DC: AASHTO.

Ahmed, M., Huang, H., Abdel-Aty, M., Guevara, B., 2011. Exploring a Bayesian hierarchical approach for developing safety performance functions for a mountainous freeway. Accid. Anal. Prev. 43, 1581–1589. https://doi.org/10.1016/J.AAP.2011.03.021

Ameli, S. H., Hamidi, S., Garfinkel-Castro, A., & Ewing, R. (2015). Do better urban design qualities lead to more walking in Salt Lake City, Utah?. Journal of Urban Design, 20(3), 393-410.

Bicycle Federation of America. (1998). Creating walkable communities: A guide for local governments. Mid-America Regional Council, Kansas City, MO. http://www.bikewalk.org/pdfs/ncbwpubwalkablecomm.pdf.

Biswas, S., Chandra, S., & Ghosh, I. (2018). Effects of on-street parking in urban context: A critical review. Transportation in developing economies, 3, 1-14.

Box, P. C. (2000). Curb parking findings revisited. Transportation Research E-Circular. Washington, DC: Transportation Research Board.

Box, P. C. (2002). Angle parking issues revisited. ITE Journal 72 (3): 36-47.

Box, P. C. (2004). Curb-parking problems: Overview. Journal of Transportation Engineering 130 (1): 1-5.

Committee on Geometric Design. (2004). Context-sensitive design around the country: Some examples. Washington, DC: Transportation Research Board.

Congress for the New Urbanism. (2002). Civilizing downtown highways: Putting New Urbanism to work on California’s highways. San Francisco, CA.

Dai, B., Hudson, J. G., Ettelman, B., & Park, E. S. (2021). Influence of lane width on bus crashes. ***Transportation research record***, ***2675***(2), 87-97.

Desjardins, R. J. (1977). Effective low-cost traffic engineering. In Compendium of Technical Papers of the 47th Annual Meeting of the Institute of Transportation Engineers at the Fourth World Transportation Engineers Conference, Mexico City, October 2-6, 1977.

DiGioia, J., Watkins, K. E., Xu, Y., Rodgers, M., & Guensler, R. (2017). Safety impacts of bicycle infrastructure: A critical review. Journal of safety research, 61, 105-119.

Duany, A., and E. Talen. (2002). Transect planning. ***Journal of the American Planning Association*** 68 (3): 245-66.

Dumbaugh, E. (2005). ***Safe streets, livable streets.*** Journal of the American Planning Association 71 (3): 283-98.

Dumbaugh, E. (2006). Enhancing the Safety and Operational Performance of Arterial Roadways in the Atlanta Metropolitan Region. Report Submitted to the Atlanta Regional Commission.

Dumbaugh, E., & Gattis, J. L. (2005). Safe streets, livable streets. Journal of the American Planning Association, 71(3), 283-300.

Dumbaugh, E., & King, M. (2018). Engineering livable streets: A thematic review of advancements in urban street design. Journal of Planning Literature, 33(4), 451-465.

Dumbaugh, E. (2013). “A Positive Approach to Urban Road Safety.” In Safety, Sustainability, and Future Urban Transport, 141–61. New Delhi, India: Eicher Goodearth.

Elvik, R. (2001). Area-wide urban traffic calming schemes: a meta-analysis of safety effects. Accident Analysis & Prevention, 33(3), 327-336.

Elvik, R., & Bjørnskau, T. (2017). Safety-in-numbers: a systematic review and meta-analysis of evidence. Safety science, 92, 274-282.

Ewing, R. (2001). Impacts of traffic calming. Transportation Quarterly, 55(1), 33-46.

Ewing, R. (2002). Impediments to context-sensitive main street design. Transportation Quarterly, 56(4), 51-64.

Ewing, R., and R. Cervero. 2010. “Travel and the Built Environment: A Meta-analysis.” Journal of the American Planning Association 76 (3): 265–94.

Ewing, R., King, M., & Center, A. M. V. T. (2001). Flexible Design of New Jersey’s Main Streets. Voorhees Transportation Policy Institute, Rutgers University, New Brunswick, NJ, USA, December.

Ewing, R., & Dumbaugh, E. (2009). The built environment and traffic safety: a review of empirical evidence. Journal of Planning Literature, 23(4), 347-367.

Gitelman, V., Balasha, D., Carmel, R., Hendel, L., & Pesahov, F. (2012). Characterization of pedestrian accidents and an examination of infrastructure measures to improve pedestrian safety in Israel. Accident Analysis & Prevention, 44(1), 63-73.

Greibe, P. (2003). Accident prediction models for urban roads. Accident Analysis & Prevention, 35(2), 273-285.

Gross, F., Jovanis, P., & Eccles, K. (2009). Safety effectiveness of lane and shoulder width combinations on rural, two-lane, undivided roads. Transportation Research Record, 2103, 42–49.

Hamidi, S., & Moazzeni, S. (2019). Examining the relationship between urban design qualities and walking behavior: Empirical evidence from Dallas, TX. Sustainability, 11(10), 2720.

Harvey, C., & Aultman-Hall, L. (2015). Urban streetscape design and crash severity. Transportation Research Record, 2500(1), 1-8.

Hauer, E., Council, F. M., & Mohammedshah, Y. (2004). Safety models for urban four-lane undivided road segments. Transportation Research Record, 1897, pp. 96–105

Hastie, T., & Tibshirani, R. (1990). Generalized additive models. Boca Raton, FL: Chapman and Hall/CRC.

Institute of Transportation Engineers. (2001). A study of angle parking accidents. Traffic Safety Committee, Arizona Section. Washington, DC: Institute of Transportation Engineers.

Institute of Transportation Engineers (2010). ***Design Walkable Urban Thoroughfares: A Context Sensitive Approach***. Washington, USA https://www.ite.org/pub/?id=e1cff43c%2D2354%2Dd714%2D51d9%2Dd82b39d4dbad

Jacobs, J. (1961). ***The Death and Life of Great American Cities***. New York: Random House.

Jacobsen, P. L. (2003). Safety in numbers: More walkers and bicyclists, safer walking and bicycling. Injury Prevention 9:205-09

Jensen, S. U. (2008). Bicycle tracks and lanes: A before–after study. 87th annual meeting of the Transportation Research Board.

Juhász, M., & Koren, C. (2016). Getting an insight into the effects of traffic calming measures on road safety. Transportation research procedia, 14, 3811-3820.

Kochanek, K.D.; Xu, J.; Murphy, S.L.; Miniño, A.M.; Kung, H.C. (2011). National vital statistics reports. Natl. Vital Stat. Rep., 59, 1.

Ladron de Guevara, F., Washington, S. P., & Oh, J. (2004). Forecasting crashes at the planning level: simultaneous negative binomial crash model applied in Tucson, Arizona. Transportation Research Record, 1897(1), 191-199.

Lamm, R., B. Psarianos, and T. Mailender. (1999). Highway design and traffic safety engineering handbook. New York: McGraw Hill.

Lee, J., Nam, B., & Abdel-Aty, M. (2015). Development of crash modification factors for changing lane width on roadway segments using generalized nonlinear models. Accident Analysis and Prevention, 75, 83–91.

Lee, J., and F. Mannering. (1999). Analysis of roadside accident frequency and severity and roadside safety management. Olympia: Washington State Department of Transportation

Le, T., & Porter, R. (2012). Safety effects of cross section design on urban and suburban roads. Paper presented at the 92nd annual meeting of the Transportation Research Board, Washington, DC

Lovegrove, G. R., and T. Sayed. (2006). Macro-level collision prediction models for evaluating neighborhood traffic safety. Canadian Journal of Civil Engineering 33 (5): 609-21.

Loukaitou-Sideris, A., Liggett, R., & Sung, H. G. (2007). Death on the crosswalk: A study of pedestrian-automobile collisions in Los Angeles. Journal of Planning Education and Research, 26(3), 338-351.

Lusk, A. C., Morency, P., Miranda-Moreno, L. F., Willett, W. C., & Dennerlein, J. T. (2013). Bicycle guidelines and crash rates on cycle tracks in the United States. American Journal of Public Health, 103, 1240–1248.

Manuel, A., El-Basyouny, K., & Islam, T. (2014). Investigating the safety effects of road width on urban collector roadways. Safety Science Journal, 62, 305–311.

Marshall W., Coppola, N., & Golombek, Y. (2018). Urban clear zones, street trees, and road safety. Research in Transportation Business & Management, 29, 136-143.

METROPLAN-ORLANDO (2010). Orlando area bicyclist crash study: A role-based approach to crash countermeasures. A study of bicyclist–motorist crashes in the Orlando urban area in 2003 and 2004, tech. rep. Orlando, FL: METROPLAN-ORLANDO.

Miaou, S.P. (1996). Measuring the goodness-of-fit of accident prediction models. Federal Highway Administration, Report No. FHWA-RD-96-040, USA.

Milton, J. C., & F. L. Mannering. (1998). The relationship among highway geometrics, traffic-related elements and motor vehicle accident frequencies. Transportation, 25, 395–413.

Misra, A., Gooze, A., Watkins, K., Asad, M., & LeDantec, C. (2014). Crowdsourcing and its application to transportation data collection and management. Transportation Research Record: Journal of the Transportation Research Board, 2414.

Moritz, W. E. (1998). Adult bicyclists in the United States: Characteristics and riding experience in 1996. Transportation Research Record, 1636, 1–7.

Naderi, J. R. (2003). Landscape design in the clear zone: The effects of landscape variables on pedestrian health and driver safety. In Transportation Research Board, 82nd Annual Conference Proceedings. Washington, DC: Transportation Research Board.

National Association of City Transportation Officials (2013). ***Urban Street Design Guide (3rd Edition); Island Press.* *https://nacto.org/publication/urban-street-design-guide/***

Noland, R. B. (2003). Traffic fatalities and Injuries: The effect of changes in infrastructure and other trends. Accident Analysis and Prevention, 35, 599–611.

Noland, R. B., and L. Oh. (2004). The effect of infrastructure and demographic change on traffic-related fatalities and crashes: A case study of Illinois county-level data. Accident Analysis and Prevention 36:525-32.

Nowakowska, M., (2010). Logistic Models in Crash Severity Classification Based on Road Characteristics. Transp. Res. Rec. J. Transp. Res. Board 2148, 16–26. https://doi.org/10.3141/2148-03

Pande, A., & Abdel-Aty, M. (2009). A novel approach for analyzing severe crash patterns on multilane highways. Accident Analysis and Prevention, 41(5), 985994. doi:10.1016/j. aap.2009.06.003

Potts, I. B., Harwood, D. W., & Richard, K. R. (2007). Relationship of lane width to safety on urban and suburban arterials. Transportation Research Record, 2023, 63–82.

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

Strathman, J. G., Dueker, K. J., Zhang, J., & Williams T. (2001). Analysis of design attributes and crashes on the Oregon highway system (Report No. FHWA-OR-RD-02-01). Salem, OR: Oregon Department of Transportation and Washington, DC: Federal Highway Administration

Swift, P., D. Painter, and M. Goldstein. (2008). Residential Street Typology and Injury Accident Frequency. Swift and Associates. http://www.newurbanengineering.com.

Transportation Research Board. (2003). A guide for addressing run-off-road collisions. NCHRP 500, vol. 6. Washington, DC: National Research Council.

Teschke, K., Harris, M. A., Reynolds, C. C. O., Winters, M., Babul, S., Chipman, M., ... Cripton,P. A. (2012). Route infrastructure and the risk of injuries to bicyclists: A casecrossover study. American Journal of Public Health, 102, 2336–2343.

World Health Organization. 2004. World report on road traffic injury prevention. Geneva: World Health Organization.

Yanmaz-Tuzel, O., & Ozbay, K. (2010). A comparative Full Bayesian before-and-after analysis and application to urban road safety countermeasures in New Jersey. ***Accident Analysis & Prevention***, ***42***(6), 2099-2107.

Zhu, H., Dixon, K.K., Washington, S., Jared, D.M., (2010). Predicting Single-Vehicle Fatal Crashes for Two-Lane Rural Highways in Southeastern United States. ***Transportation Research Record***, 2147(1), 88-96.

APPENDICES

APPENDIX A. AASHTO SURVEY QUESTIONNAIRE

We are a research team in the Metropolitan Research Center at the University of Utah conducting a research project, “Transportation Benefits and Costs of Reducing Lane Widths on Urban and Rural Arterials,” funded by the Utah Department of Transportation. As part of the project, we are surveying DOTs to understand lane width reduction projects, policies, and standards and their associated benefits and costs.

While reducing vehicle lane widths is often considered a way to decrease vehicle speed and increase road safety, comprehensive research is lacking on practices and their impact. The results of this survey are expected to clarify the state of current practices, highlight exemplary road renovation projects, and provide insights for future practice.

The following questionnaire requires 5-15 minutes to complete. The data collected will be used solely for academic purposes and shared with survey participants upon request.

SECTION A. STATEWIDE DESIGN STANDARDS

1. **Do you have statewide roadway design standards, manuals, and policies that regulate vehicle lane widths and/or limit a reduction of vehicle lane widths?**
    1. Yes
    2. No (*You can skip this section and go to the Section B.)
    3. Not Sure (*You can skip this section and go to the Section B.)

2. **Please provide more details about standards, manuals, and policies. Document names, web sources, and links for reference are requested.**

3. **What are your agency’s goals and expectations in having minimum lane width policies and/or lane width reduction standards? Please select all possible answers.**
    1. Improving traffic safety
    2. Improving safety for bicycles and/or pedestrians
    3. Reducing vehicle speeds
    4. Increasing bicycle and/or pedestrian use
    5. Reducing construction and/or maintenance costs
    6. Not sure
    7. Other:

4. Does your DOT have a design exception process where lane width reductions can be proposed, reviewed, and approved?

1. Yes
2. No (*You can skip the following questions and go to the Section B.)

5. Are there specific conditions (e.g., speed, traffic volume, functional class, zoning) that enable reduced lane width to be considered? If so, what are these conditions?

6. Who has the authority to approve lane width reduction requiring design exceptions? Please describe the approval process of lane width reduction below the minimum width of state regulation.

SECTION B. LANE WIDTH REDUCTION PROJECTS

7. Do you have a lane width reduction project(s) completed, or one(s) that will be implemented in your jurisdiction?

1. Yes
2. None (*You can skip this section and go to the last question)
3. Not sure (*You can skip this section and go to the last question)

8. Please select one exemplary project and provide more details about it. Project name, location, web sources, and links for reference are requested.

9. In considering a lane width reduction project for a specific site, what are the primary objectives? Please select all that apply.

1. Improving traffic safety
2. Improving safety for bicycles and/or pedestrians
3. Reducing vehicle speeds
4. Increasing bicycle and/or pedestrian use
5. Reducing construction and/or maintenance costs
6. Not sure
7. Other:

10. If applicable, after reducing lane width, were significant changes observed and/or measured? Please select all possible answers.

1. Change in traffic safety
2. Change in bicycle/pedestrian safety
3. Change in vehicle speeds
4. Change in bicycle/pedestrian volumes
5. Change in construction and/or maintenance costs
6. No significant changes have been observed or measured
7. Not sure
8. Other

11. [Safety] If applicable, after reducing lane width, what changes were observed and/or measured regarding road safety? Please select all possible answers.

1. Increased crash rate
2. Decreased crash rate
3. Increased crash severity
4. Decreased crash severity
5. No significant changes
6. Not sure
7. Other:

12. [Vehicle speed] If applicable, after reducing lane width, what changes were observed and/or measured regarding vehicle speeds?

1. Increased vehicle speed
2. Decreased vehicle speed
3. No significant changes
4. Not sure

13. [Traffic volume] If applicable, after reducing lane width, what changes were observed and/or measured regarding traffic volume? Please select all possible answers.

1. Decreased traffic volume
2. Increased traffic volume
3. No significant changes
4. Not sure

14. [Pedestrian/bicyclist volume] If applicable, after reducing lane width, what changes were observed and/or measured regarding pedestrian and bicyclist volumes? Please select all possible answers.

1. Increased pedestrian volume
2. Decreased pedestrian volume
3. Increased bicyclist volume
4. Decreased bicyclist volume
5. No significant changes
6. Not sure

15. [Construction/maintenance costs] If applicable, after reducing lane width, what changes were observed and/or measured regarding construction and maintenance costs? Please select all possible answers.

1. Increased construction cost (*compared to regular road construction cost with no lane width reduction)
2. Decreased construction cost
3. Increased maintenance cost
4. Decreased maintenance cost
5. No significant changes
6. Not sure

16. [Road cross-sectional design] If applicable, while reducing lane width, were there any other physical changes implemented? Please select all possible answers.

1. Multimodal transportation infrastructure (e.g., bicycle lanes, e-scooter lanes)
2. Paved pedway and/or sidewalk width
3. Street trees and/or landscaping
4. Pedestrian refuge island
5. Median
6. Transit shelters
7. On-street parking
8. Traffic calming measures
9. Not sure
10. Other:

17. [Overall impact] Speaking generally, what are your expectations and/or observations regarding the impacts of reducing lane widths?

18. Were there other elements of the lane width reduction project that might have contributed to a reduction in crashes, speed, traffic, and pedestrian volumes besides lane width reduction?

CONTACT INFORMATION

19. Thank you for your time for completing our survey. Please provide your contact information below. We will e-mail you a link to the online report when it is completed.

APPENDIX B.

Contact Information and Affiliation of Respondent AASHTO Members

AFFILIATION	NAME	POSITION	EMAIL ADDRESS
Michigan DOT	Nathan Miller	Engineer of Road Design	millern13@michigan.gov
Ohio DOT	Adam Koenig	Administrator	adam.koenig@dot.ohio.gov
Alabama DOT	Stan Biddick	State Design Engineer	biddicks@dot.state.al.us
Maine DOT	Steve Bodge	Assistant Highway Program Manager	stephen.bodge@maine.gov
California DOT	Rebecca Mowry	Senior Transportation Engineer	rebecca.mowry@dot.ca.gov
Tennessee DOT	Ali Hangul	Assistant Director of HQ Design Division	ali.hangul@tn.gov
Washington State DOT	Michael Fleming	Deputy State Design Engineer	fleminm@wsdot.wa.gov
Minnesota DOT	Douglas Carter	Design Support Service Director	douglas.carter@state.mn.us
Alaska DOT	Matthew Walker	Statewide Traffic and Safety Engineer	matthew.walker@alaska.gov
Arizona DOT	Michael DenBleyker	Asst. State Engineer - Roadway Engineering Group	mdenbleyker@azdot.gov
Montana DOT	James A. Combs	District Preconstruction Engineer	jcombs@mt.gov
Kentucky DOT	Wendy Southworth	Assistant Director - Highway Design	wendy.southworth@ky.gov
Texas DOT	Kenneth Mora	Roadway Design Section Director (DES)	kenneth.mora@txdot.gov

APPENDIX C. FLORIDA DOT LANE WIDTH GUIDING DOCUMENTS

Part I) FDOT Design Manual

Florida Design Manual (FDM) sets forth geometric and other design criteria and procedures for all new construction, reconstruction, and resurfacing projects **on the state and national highway systems**. The criteria in this manual represent requirements for the State Highway System, which must be met for the design of FDOT projects unless approved Design Exceptions or Design Variations are obtained per the manual's procedures. Its authority is established by Sections 20.23(3)(a) and 334.048(3) of Florida Statutes. In January 2018, the FDM replaced the Plans Preparation Manual (PPM) that had circulated since January 1998. As shown in C1, apart from addressing a wide range of design issues, the FDM also sets standards for lane widths on arterial and collector roads within Florida's state and national highway system. For Interstate, Freeways, and Expressways, minimum 12-foot lane widths are required.

According to the FDOT Design Manual, lane widths are selected based on design speeds. Roads and streets are classified based on context, which in turn defines target speeds. Context classification is a design control that determines key design criteria elements for arterials and collectors. Target speed is the highest speed at which vehicles should operate on a thoroughfare in a specific context. Appropriate street design is chosen to achieve the target speed to attain the desired degree of safety, mobility, and efficiency. In a well implemented project, target speed matches design speed. Ideally, the target speed posted speed, and design speed should all be the same where speeds are 45 mph or less. However, design speed and posted speed will often take time and may even need to be changed over several projects.

Figure C1:
Minimum Travel and Auxiliary Lane Widths for Arterials and Collectors

CONTEXT CLASSIFICATION		TRAVEL (feet)			AUXILIARY (feet)			TWO-WAY LEFT TURN (feet)	
		DESIGN SPEED (mph)			DESIGN SPEED (mph)			DESIGN SPEED (mph)	
		25-35	40-45	≥ 50	25-35	40-45	≥ 50	25-35	40
C1	Natural	11	11	12	11	11	12	N/A	
C2	Rural	11	11	12	11	11	12		
C2T	Rural Town	11	11	12	11	11	12	12	12
C3	Suburban	10	11	12	10	11	12	11	12
C4	Urban General	10	11	12	10	11	12	11	12
C5	Urban Center	10	11	12	10	11	12	11	12
C6	Urban Core	10	11	12	10	11	12	11	12

Notes:

Travel Lanes:

(1) Minimum 11-foot travel lanes on designated freight corridors, SIS facilities, or when truck volume exceeds 10% on very low speed roadways (design speed ≤ 35mph) (regardless of context).

(2) Minimum 12-foot travel lanes on all undivided 2-lane, 2-way roadways (for all context classifications and design speeds). However, 11-foot lanes may be used on 2-lane, 2-way curbed roadways that have adjacent buffered bicycle lanes.

(3) 10-foot travel lanes are typically provided on very low speed roadways (design speeds ≤ 35 mph), but should consider wider lanes when transit is present or truck volume exceeds 10%.

(4) Travel lanes should not exceed 14 feet in width.

Auxiliary Lanes:

(1) Auxiliary lanes are typically the same width as the adjacent travel lane.

(2) Table values for right-turn lanes may be reduced by 1 foot when a bicycle keyhole is present.

(3) Median turn lanes should not exceed 15 feet in width.

(4) For high speed curbed roadways, 11-foot minimum lane widths are allowed for the following:
- Dual left-turn lanes
- Single left-turn lanes at directional median openings.

(5) For RRR Projects, 9-foot right-turn lanes on very low speed roadways (design speed ≤ 35 mph) are allowed.

Two-way Left-Turn Lanes:

(1) Two-way left turns lanes are typically one foot wider than the adjacent travel lanes.

(2) For RRR Projects, the values in the table may be reduced by 1-foot.

Figure C2 shows both context classifications and design speeds for each classification. In contrast, Figure C3 shows a list of strategies or street design elements that can be used to achieve those design speeds.

Figure C2:
Context Classifications and Design Speeds

Table 200.4.1 Context Classifications

CONTEXT CLASSIFICATION		DESCRIPTION OF ADJACENT LAND USE
C1	**Natural**	Lands preserved in a natural or wilderness condition, including land unsuitable for settlement due to natural conditions.
C2	**Rural**	Sparsely settled lands; may include agricultural land, grassland, woodland, and wetlands.
C2T	**Rural Town**	Small concentrations of developed areas immediately surrounded by rural and natural areas; includes many historic towns.
C3R	**Suburban Residential**	Mostly residential uses within large blocks and a disconnected/sparse roadway network.
C3C	**Suburban Commerical**	Mostly non-residential uses with large building footprints and large parking lots. Buildings are within large blocks and a disconnected/sparse roadway network.
C4	**Urban General**	Mix of uses set within small blocks with a well-connected roadway network. May extend long distances. The roadway network usually connects to residential neighborhoods immediately along the corridor or behind the uses fronting the roadway.
C5	**Urban Center**	Mix of uses set within small blocks with a well-connected roadway network. Typically concentrated around a few blocks and identified as part of the community, town, or city of a civic or economic center.
C6	**Urban Core**	Areas with the highest densities and with building heights typically greater than four floors within FDOT classified Large Urbanized Areas (population >1,000,000). Many are regional centers and destinations. Buildings have mixed uses, are built up to the roadway, and are within a well-connected roadway network.

Table 201.5.1 Design Speed

LIMITED ACCESS FACILITIES (INTERSTATES, FREEWAYS, AND EXPRESSWAYS)		
AREA	**ALLOWABLE RANGE (MPH)**	**SIS MINIMUM (MPH)**
Rural and Urban	70	70
Urbanized	50-70	60
ARTERIALS AND COLLECTORS		
CONTEXT CLASSIFICATION	**ALLOWABLE RANGE (MPH)**	**SIS MINIMUM (MPH)**
C1 Natural	55-70	65
C2 Rural	55-70	65
C2T Rural Town	25-45	40
C3 Suburban	35-55	50
C4 Urban General	30-45	45
C5 Urban Center	25-35	35
C6 Urban Core	25-30	30

Notes:

1. SIS Minimum Design Speed may be reduced to 35 mph fpr C2T Context Classification when appropriate design elements are included to support the 35 mph speed, such as on-street parking.
2. SIS Minimum Design Speed may be reduced to 45 mph for curbed roadways within C3 Context Classification.
3. For SIS facilities on the State Highway System, a selected design speed less than the SIS Minimum Design Speed requires a Design Variation as outlines in ***SIS Procedure (Topic No. 525-030-260).***
4. For SIS facilitiles on the State Highway System, a selected design speed less than the SIS Minimum Design Speed may be approved by the District Design Engineer following a review by the District Planning (Intermodal Systems Development) Manager

Figure C3:
Strategies to achieve target speeds

Table 202.3.1 Strategies to Achieve Desired Operating Speed

CONTEXT CLASSIFICATION	TARGET SPEED (MPH)	STRATEGIES
C1	55-70	N/A: Speed Management Strategies are not used on high-speed roadways. See FDM 202.4 for information on transitions from high-speed to low-speed facilities.
C2	55-70	N/A: Speed Management Strategies are not used on high-speed roadways. See FDM 202.4 for information on transitions from high-speed to low-speed facilities.
C2T	40-45	Roundabout, Lane Narrowing, Horizontal Deflection, Speed Feedback Signs, RRFBs and PHBs
	35	Techniques for 40-45 mph, plus On-street Parking, Street Trees, Short Blocks, Islands at Crossings, Road Diet, Bulb-outs, Terminated Vista
	30	Techniques for 35-45 mph, plus Chicanes, Islands in Curve sections
	<25	Techniques for 30-45 mph, plus Vertical Deflection
C3R, C3C	50-55	Project-specific; see FDM 202.4
	40-45	Roundabout, Lane Narrowing, Horizontal Deflection, Speed Feedback Signs, RRFB and PHB
	35	Roundabout, Lane Narrowing, Horizontal Deflection, Speed Feedback Signs, Islands in Crossings, Road Diet, RRFB and PHB, Terminated Vista
C4	40-45	Roundabout, Lane Narrowing, Horizontal Deflection, Speed Feedback Signs, RRFB and PHB
	35	Techniques for 40-45 plus On-Street Parking, Street Trees, Short Blocks, Islands at Crossings, Bulb-outs, Terminated Vista, Road Diet
	30	Techniques for 35 mph plus Chicanes, Islands in Curve Sections

C5	35	Roundabout, On-street Parking, Street Trees, Short Blocks, Speed Feedback Signs, Islands in Crossings, Road Diet, Bulb-outs, RRFB and HAWK, Terminated Vista
	30	Techniques for 35 mph plus Chincanes, Islands in Curve Sections
	25	Techniques for 30-35 mph plus Vertical Deflection
C6	30	Roundabout, On-Street Parking, Horizontal Deflection, Street Trees, Islands in Curve Sections, Road Diet, bulb-outs, Terminated Vista
	25	Techniques for 30 mph plus Vertical Deflection
	35	Roundabout, Lane Narrowing, Horizontal Deflection, Speed Feedback Signs, Islands in Crossings, Road Diet, RRFB and PHB, Terminated Vista

FDOT Design Manual also lists lane narrowing as a speed management strategy: “Use of narrow lanes (less than 12’) alone has limited effect on operating speeds. This effect can, however, enhance engagement as traffic volumes increase. The visible narrowing of travel lanes may be used as a transition device to clearly indicate a change in context. For instance, narrowing two 12-foot lanes to two 11-foot or 10-foot lanes by shifting the lane lines slightly and introducing a hatch in the newly created edge space has been shown to alert drivers of a change in condition or context. **To maximize effectiveness, lane narrowing should be used in conjunction with other low-speed strategies** (e.g., the introduction of parking, the creation of a median, and the beginning of a chicane).

The Manual of Uniform Minimum Standards for Design, Construction and Maintenance (Florida Greenbook)

This manual is intended for all projects, **not on the state and national highway systems**. Its authority is established by Chapters 20.23(3)(a), 334.044(10)(a), and 336.045, Florida Statutes, and Rule 14-15.002, Florida Administrative Code. The Manual provides criteria for public streets, roads, highways, bridges, sidewalks, curbs and curb ramps, crosswalks, bicycle facilities, underpasses, and overpasses used by the public for vehicular and pedestrian travel. Figure A4 shows the minimum lane widths suggested by the Manual.

Figure A4:
Minimum lane widths (Florida Greenbook)

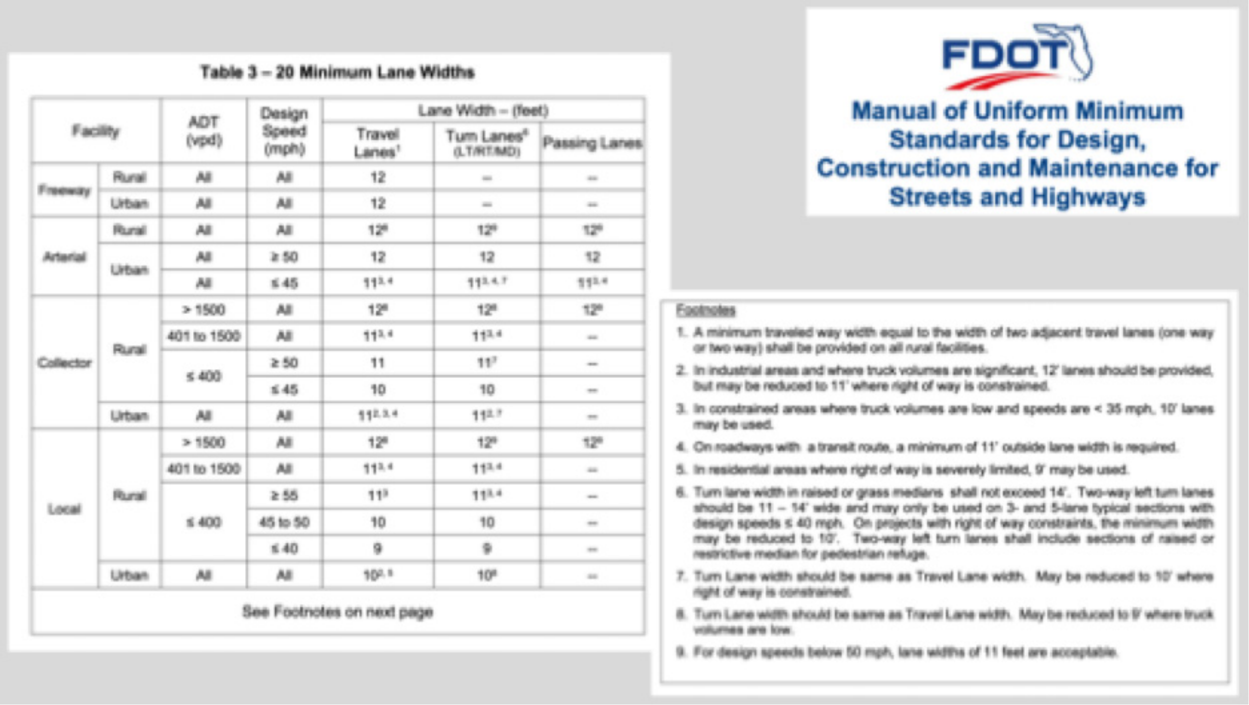


Table 3 – 20 Minimum Lane Widths

Facility		ADT (vpd)	Design Speed (mph)	Lane Width – (feet)		
				Travel Lanes[1]	Turn Lanes[6] (LT/RT/MD)	Passing Lanes
Freeway	Rural	All	All	12	–	–
	Urban	All	All	12	–	–
Arterial	Rural	All	All	12^{9}	12^{9}	12^{9}
	Urban	All	≥ 50	12	12	12
		All	≤ 45	$11^{3,4}$	$11^{3,4,7}$	$11^{3,4}$
Collector	Rural	> 1500	All	12^{8}	12^{8}	12^{8}
		401 to 1500	All	$11^{3,4}$	$11^{3,4}$	–
		≤ 400	≥ 50	11	11^{7}	–
			≤ 45	10	10	–
	Urban	All	All	$11^{2,3,4}$	$11^{2,7}$	–
Local	Rural	> 1500	All	12^{8}	12^{9}	12^{8}
		401 to 1500	All	$11^{3,4}$	$11^{3,4}$	–
		≤ 400	≥ 55	11^{3}	$11^{3,4}$	–
			45 to 50	10	10	–
			≤ 40	9	9	–
	Urban	All	All	$10^{2,5}$	10^{8}	–

See Footnotes on next page

FDOT
Manual of Uniform Minimum Standards for Design, Construction and Maintenance for Streets and Highways

Footnotes

1. A minimum traveled way width equal to the width of two adjacent travel lanes (one way or two way) shall be provided on all rural facilities.
2. In industrial areas and where truck volumes are significant, 12' lanes should be provided, but may be reduced to 11' where right of way is constrained.
3. In constrained areas where truck volumes are low and speeds are < 35 mph, 10' lanes may be used.
4. On roadways with a transit route, a minimum of 11' outside lane width is required.
5. In residential areas where right of way is severely limited, 9' may be used.
6. Turn lane width in raised or grass medians shall not exceed 14'. Two-way left turn lanes should be 11 – 14' wide and may only be used on 3- and 5-lane typical sections with design speeds ≤ 40 mph. On projects with right of way constraints, the minimum width may be reduced to 10'. Two-way left turn lanes shall include sections of raised or restrictive median for pedestrian refuge.
7. Turn Lane width should be same as Travel Lane width. May be reduced to 10' where right of way is constrained.
8. Turn Lane width should be same as Travel Lane width. May be reduced to 9' where truck volumes are low.
9. For design speeds below 50 mph, lane widths of 11 feet are acceptable.

Standard Plans for Road Construction

Standard Plans are intended to support the various engineering processes for construction operations **on the state highway system**. They are established to ensure the application of uniform standards in the preparation of contract plans for the construction of roadways and structures. Standard Plans may be used for maintenance operations or adopted by other authorities for use on projects under their jurisdiction.

Part II) FDOT Roadway Design Bulletin 14-17

FDOT approved Roadway Design Bulletin 14-17 in 2014 to modify the Urban Arterial Travel Lane Width. The Bulletin in its entirety can be found in the Appendix. Commentary included in the Bulletin contains the following statements in support of 11-foot lanes:

> *"Eleven-foot-wide travel lanes on urban arterials are supported by AASHTO Guidance and the Highway Safety Manual. The 2001 AASHTO Greenbook states that for interrupted-flow operating conditions, 11-foot-wide lanes are normally adequate for design speeds of 45 mph or less and even have some advantages over wider lanes. The AASHTO Guide to Bicycle Facilities also cites the Highway Safety Manual. It states that evaluation of the effects of travel lane widths of 10 to 12 feet on crashes for urban arterial roadways has found no general indication that using narrower widths within this range increases crash rates."*

> *"The Highway Safety Manual applies crash modification factors to base conditions, such as lane width, which can be statistically correlated to crash performance. For all roadway types, except Urban and Suburban arterials, lane width is a factor in safety performance. In the case of urban arterials, it was determined, through an expert panel review process, that lane widths between 10 and 12 feet are acceptable and do not cause safety problems. There is no significant correlation between lane width and safety performance for the range of facilities studied. However, neither high truck traffic nor bus traffic was quantified in this research; therefore, it is not known if lanes as narrow as 10 feet have the same safety performance as 11- or 12-feet wide lanes where high truck or bus traffic exists. It has been concluded, though, based on FDOT Central Transit Office research titled "Integrating Transit into Traditional Neighborhood Design Policies – The Influence of Lane Width on Bus Safety," that the minimum acceptable lane widths for transit operations to avoid crashes and perform turning maneuvers safely is 11 feet."*

> *"The practice of using 11-foot-wide travel lanes on urban arterials under interrupted-flow operating conditions has become more accepted nationally. Safety research suggests that there is no safety benefit to using 12-foot-wide lanes over 11-foot-wide lanes and AASHTO publications support the use of 11-foot-wide travel lanes under these conditions."*

APPENDIX D. VERMONT DOT LANE WIDTH GUIDING DOCUMENTS

Vermont State Design Standards

In 1997, the Vermont Agency of Transportation (VTrans) adopted Vermont State Design Standards to allow flexibility in the technical guidelines for designing transportation projects in Vermont so that the transportation projects fit into the social context of the state, minimize the environmental impact, and maximize the public benefits. The standards laid out in this document guide the physical design parameters of roadways and bridges, and in some cases, it augments the standards previously used by VTrans and the American Association of State Highway and Transportation Officials (AASHTO). Speed, traffic volume, and functional classifications of roadways are the determining factors here for setting lane width standards.

Index 3.5 and Index 4.5 of the Design Standard document discussed the recommendations for lane width in urban and village principal arterials and minor arterials, respectively. Because of the large difference in urban and village settings, the manual provided no table of values but provided the following guidelines for both cases:

- Lane widths on urban and village Principal Arterials may vary from 10 to 12 feet, and there should be appropriate offsets to curb.
- For highly restricted areas having little or no truck traffic, 10-foot widths are appropriate.
- The 11-foot lanes are primarily used for urban and village Principal Arterial Street designs.
- The 12-foot widths are applicable for all higher-speed, free-flowing Principal Arterials.

Along with the above-mentioned guidelines, the document prescribed special cases for adopting narrower lane widths for urban and village arterials. According to the document, "***Under interrupted-flow conditions at low speeds (up to 45 mph), the narrower lane widths are normally adequate and have some advantages. Reduced lane widths allow greater numbers of lanes in the restricted right-of-way and facilitate pedestrian crossings because of reduced distance. They are also more economical to construct. 11-foot lane width is adequate for through lanes, continuous two-way left-turn lanes, and a lane adjacent to a painted median. A 10-foot left-turn lane, or a combination lane used for parking, with traffic during peak hours, is also acceptable.***"

Index 3.6 and 4.6 of Vermont State Design Standards provided standards in tabular format for lane width of rural principal arterials and rural minor arterials. It varies from 11–12 feet; details are provided in Figure D1 and Figure D2.

Figure D1:
Minimum Lane Width of Two-Lane Rural Principal Arterials

Table 3.3
Minimum Width of Lanes and Shoulders For Two-Lane Rural Principal Arterials

PROJECTED DESIGN TRAFFIC VOLUME	ADT 0-2000	DHV 200-400	DHV OVER 400
Design Speed (mph)	**Width of Lane/Shoulder (ft)** [a][b]		
35	11/5	11/6	11/8
40	11/6	11/6	11/8
45	11/6	11/6	11/8
50	11/6	11/8	12/8
55	12/6	12/8	12/8

Figure D2:
Minimum Lane Width of Two-Lane Minor Arterials

Table 4.3
Minimum Width of Lanes and Shoulders for Two-Lane Rural Minor Arterials

PROJECTED DESIGN TRAFFIC VOLUME	ADT 0-1500	DHV 1500-2000	DHV 200-400	DHV OVER 400
Design Speed (mph)	**Width of Lane/Shoulder (ft)** [a][b]			
35	11/3	11/3	11/4	11/5
40	11/4	11/4	11/4	11/5
45	11/4	11/4	11/4	11/5
50	11/4	11/4	11/4	11/5
55	11/4	11/4	11/5	12/5[a]

Lane width for urban and village collectors is discussed in the next chapter, and it can vary from 9 to 11 feet according to Index 5.5 of Vermont State Design Standards. According to the manual, "***The 9-foot widths are appropriate in highly restricted areas having little or no truck traffic. The 11-foot lane widths are generally used on all higher speed, free-flowing Collectors.***" Moreover, Figure D3 provided guidance for lane widths of rural collectors.

In the following chapter, the lane width of local streets is mentioned. According to Index 6.4 of this chapter, urban and village local streets can vary from 7 to 11 feet. 7-foot to 8-foot road widths are more appropriate for residential areas with low traffic volumes. However, the manual provided Figure D4 for new construction, lane, and shoulder width in rural local roads.

Figure D3:
Minimum Lane Width of Two-Lane Rural Collectors

Table 5.3
Minimum Width of Lanes and Shoulders for Two-Lane Rural Collectors

PROJECTED DESIGN TRAFFIC VOLUME	ADT 0-400	ADT 400-1500	ADT 1500-2000	ADT OVER 2000
Design Speed (mph)	**Width of Lane/Shoulder (ft)** [(a)(b)]			
25	9/2	9/2	10/3	11/3
30	9/2	9/2	10/3	11/3
35	9/2	9/2	10/3	11/3
45	9/2	9/2	10/3	11/3
50	9/2	10/2	10/3	11/3

Figure D4:
Minimum Lane Width of Rural Local Roads

Table 6.3
Minimum Width of Lanes and Shoulders for Rural Local Roads

DESIGN TRAFFIC VOLUME	ADT[(a)] 0-25	ADT 25-50	ADT 50-100	ADT 100-400	ADT 400-1500	ADT 1500-2000	ADT OVER 2000
Design Speed (mph)	**Width of Lane/Shoulder (ft)**						
25	7/0	8/0	9/0	9/2	9/2	10/3	11/3
30	7/0	8/0	9/0	9/2	9/2	10/3	11/3
35	7/0	8/0	9/0	9/2	9/2	10/3	11/3
40	7/0	8/0	9/2	9/2	9/2	10/3	11/3
45	-	-	9/2	9/2	9/2	10/3	11/3
50	-	-	9/2	9/2	10/2	10/3	11/3

Road Design Manual (VAOT)

Road Design Manual is documentation of guiding principles that are adhered to by VTrans while designing a roadway within the jurisdiction of Vermont. While designing a roadway, VTrans uses Vermont State Design Standards unless a design exception is approved. It also uses VAOT Standard Specifications for Construction, Supplemental Specifications, General Special Provisions, Special Provisions, Standard Drawings, and details, and lastly, it considers A Policy on Geometric Design of Highways and Streets, published by AASHTO (the “Green Book”).

According to Chapter 6 of this manual, traffic lane widths for roadways in Vermont should follow the standards laid down in Vermont State Design Standards. In addition, it is stated that “***The Vermont State Standards provide guidance for lane and shoulder width considerations when bicycles and pedestrians must share the roadway. Refer to the AASHTO Guide for the Development of Bicycle Facilities for additional design criteria.***”

However, lane widths for 3R (resurfacing, restoration, and rehabilitation) projects on rural roadways should be a minimum of 3.6 meters for arterial highways and 3.3 meters for all other state highways. Moreover, the manual states that “***The total width of a two-lane rural roadway, including shoulders and travel lanes, will be not less than the width as originally constructed, will be within 3 meters of the new construction standard per the Vermont State Standards and the AASHTO Green Book.***”

APPENDIX E: OREGON DOT LANE WIDTH GUIDING DOCUMENTS

ODOT has created two documents to provide roadway-related design guidance: the Highway Design Manual (HTM) and the Blueprint for Urban Design which in turn consists of two volumes where Volume One lays out the focus and the performance-based practice design policy and Volume Two provides the background information and key documentation (Figure 12).

Oregon DOT has not conducted any studies (e.g., before-after studies) regarding lane width reduction, but it has used scholarly guidance when establishing its criteria for the Blueprint for Urban Design. Douglas Harwood (Midwest Research Institute or MRIGlobal) was one of the scholars whose work influenced ODOT's approach to lane width standards:

> ***"His research shows that reducing lanes does not increase crash frequency, doesn't affect throughput or capacities necessarily, but once you go below 11 feet, then you potentially have increased sideswipe crashes and some potential slowing of vehicles. It also showed that just reducing lane width by itself doesn't necessarily slow vehicles down. There might be an initial effect, but once people are used to it, the speed goes back up. A combination of things along with the lane narrowing produces better lasting effects—introducing on-street parking, adding some verticality to the cross-section, etc. But just any one of those things by itself doesn't get a noticeable reduction of speed. It's everything together—the whole cross-section."***
>
> *(Rich Crossler-Laird, Senior Urban Design Engineer at Oregon Department of Transportation)*

In 2008, ODOT also commissioned a study by Karen Dixon (Assistant Professor at Oregon State University) to determine the best roadway design treatments for transitioning from rural areas to urban areas on state highways (Dixon, 2008). The main objective of the study was to identify ways to calm operating speeds as the vehicles transition into developed suburban/urban areas from rural roads. The study evaluated whether either physically or perceptually narrowing the road at these transition locations leads to speed reduction.

The specific transition treatments included (1) layered landscape, (2) gateway with lane narrowing, (3) median treatment only, (4) median with gateway treatment, (5) medians in series with no pedestrian crosswalks, and (6) medians in series with pedestrian crosswalks. The study found that the layered landscape treatment and the gateway with lane narrowing treatment did not result in statistically significant speed reductions. The scenarios with the most effective speed reduction results (although still minimal) included the median treatments (particularly the medians in a series or the treatment combined with a gateway). Results are shown in Figure E1 and Figure E2.

Figure E1:
Speed Characteristics at Speed Limit 35 Sign

	WITH DISTRACTER		NO DISTRACTER		ALL			
TREATMENT	MEAN SPEED (mph)	85TH PERCENTILE SPEED (mph)	MEAN SPEED (mph)	85TH PERCENTILE SPEED (mph)	MEAN SPEED (mph)	85TH PERCENTILE SPEED (mph)	SAMPLE SIZE	RANK (LOWEST TO HIGHEST MEAN)
A-Control 2 Lanes (1)	43.8	56.0	42.0	55.7	42.8	57.5	48	1
B-Control 2 Lanes (2)	45.5	59.4	45.1	51.3	45.3	55.7	49	8
C-Layered Landscape	46.4	58.2	44.1	52.7	45.2	55.9	53	7
D-Gateway with Lane Narrowing	46.4	56.4	43.5	49.0	45.0	53.5	51	6
E-Control 2 Lane with Center Lane	47.1	57.1	45.4	51.6	46.3	54.3	51	9
F-Median Only	46.2	56.6	43.4	49.3	44.7	51.4	51	5
G-Median with Gateway	44.6	50.7	42.2	50.5	43.3	50.7	46	2
H-Median in Series No Crosswalks	44.7	56.0	43.3	49.9	44.0	52.1	54	3
I-Median in Series with Crosswalks	45.4	51.6	42.8	45.9	44.1	48.5	50	4

Figure E2:
Speed Characteristics at Speed Limit 55 Sign

TREATMENT	WITH DISTRACTER		NO DISTRACTER		ALL			
	MEAN SPEED (mph)	85TH PERCENTILE SPEED (mph)	MEAN SPEED (mph)	85TH PERCENTILE SPEED (mph)	MEAN SPEED (mph)	85TH PERCENTILE SPEED (mph)	SAMPLE SIZE	RANK (LOWEST TO HIGHEST MEAN)
A-Control 2 Lanes (1)	57.1	63.7	54.1	58.7	55.6	61.6	47	2
B-Control 2 Lanes (2)	55.5	60.1	53.9	58.1	54.7	59.0	53	1
C-Layered Landscape	56.1	59.8	55.8	58.8	56.0	59.5	53	3
D-Gateway with Lane Narrowing	56.6	62.0	55.4	58.3	56.0	60.8	54	3
E-Control 2 Lane with Center Lane	58.4	65.1	57.5	61.5	58.0	63.7	54	9
F-Median Only	57.4	61.5	56.5	59.5	56.9	60.8	51	6
G-Median with Gateway	58.2	63.5	56.3	59.1	57.2	60.9	46	8
H-Median in Series No Crosswalks	57.8	63.9	56.5	60.3	57.1	63.3	54	7
I-Median in Series with Crosswalks	56.7	60.6	56.5	59.7	56.6	60.0	53	5

Figure E3:
ODOT Road Design Guiding Document

Highway Design Manual 2023

The ODOT Highway Design Manual (HDM) is the primary document for roadway design on the state highway system and the version currently in use was last updated in 2012. The Highway Design Manual 2012 focuses on presenting the appropriate design standards relevant to various project types, which are defined to assist the designer in applying the proper standards to the project. In short, it provides roadway-related design guidance. The 2023 Highway Design Manual fully went into effect in January of 2023 and will include the Blueprint for Urban Design which, up until now, has functioned as an independent document.

The new expanded manual will provide uniform standards and procedures for the Oregon Department of Transportation (ODOT). It is intended to provide the standards and guidance for the design of all projects that are located on the state highways: new construction and major reconstruction (4R), resurfacing, restoration, and rehabilitation (3R), and resurfacing (1R) projects. The HDM is to be used in conjunction with Technical Bulletins, Technical Directives, Technical Advisories, and relevant guidance documents. The flexibility contained in the 2023 Highway Design Manual supports the use of Performance-Based Practical Design concepts and Context-Sensitive Design practices (earlier described in the Blueprint for Urban Design)

Blueprint for Urban Design

The Blueprint for Urban Design (BUD) was created in 2020 to incorporate the most current urban design criteria into ODOT designs as the urban design concepts have significantly evolved since the last update of the HDM in 2012. For expediency reasons, the Blueprint was created as a “bridging document” that would establish the revised criteria to be used when designing urban projects on the state system until such time that all Oregon Department of Transportation manuals related to urban design can be updated to include these revised design criteria. This will happen shortly through the implementation of the 2023 Highway Design Manual.

The Blueprint for Urban Design provides more guidance about how to appropriately apply some of the standards in HTM to get the most out of a corridor and meet the long-term goal of the corridor. The use of the Blueprint for Urban Design as the primary design document is required for all urban projects in the planning, scoping, or project initiation stages. Final approval of the Urban Design Concurrence document, which determines project context and defines design criteria and document design decisions, is part of the final Design Acceptance Package process.

The BUD consists of two volumes. Volume One focuses on context and modal integration. It lays out the performance-based practice design policy for projects to follow. Its main purpose is to help project teams to determine a context for the project design. Volume Two contains all the background information and some of the documentation. It’s the design decision part where the cross section for the project is determined—both in terms of performance-based practical design and decision processes. It includes decision sections to document the design decision process that the project team went through to come up with a final cross section. Each project team is required to provide justifications for a specific dimension chosen from the range of dimensions recommended by the BUD.

The idea behind the BUD was to update a document that was created by the Transportation and Growth Management (TGM) program, a joint program of the ODOT and the Oregon Department of Land Conservation and Development (DLCD), in 1999—“Main Street… when a highway runs through it: a handbook for Oregon communities.” The handbook proposed techniques to reduce the perceived lane width in cases where the 12-foot width is required or needed (Figure E4). The BUD builds on the ideas from the handbook but goes much further and provides detailed design guidelines for six urban contexts, which were inspired by the National Cooperative Highway Research Program (NCHRP) Report 855: An Expanded Functional Classification System for Highways and Streets (Figure E5).

Figure E4:
Lane width guidelines from the 1999 “Main Street... when a highway runs through it: a handbook for Oregon communities”

Travel Lane Width

Actual

Narrow cross-sections can effectively reduce speeds, as most drivers adjust their speed to the available lane width. Narrow streets also reduce roadway construction and maintenance costs.

On main streets, truck use is a big consideration. Trucks may be up to 8.5 ft wide and 48 ft long with a single trailer, 75 ft with a double trailer. ODOT standards for lane widths are:

- 12 ft (3.6 m): Designated freight routes or other highways that carry at least 250 4-axle trucks per day.
- 11 ft (3.3 m): May be used on non-freight routes that carry less than 250 4-axle trucks per day at less than 40 mph (60 km/h).

On highways, ODOT prefers the full width of 12 ft unless there is a specific reason to go to a narrower lane. There are many “exception” conditions that require ODOT approval.

The speed reduction achieved from a narrow lane depends on many factors and is best measured in the field. Even when it has little effect by itself, a narrow lane reinforces other speed management measures by sending a consistent message to drivers.

Perceived

Where the 12 ft width is needed but speed reduction is a goal, techniques that change the perceived width can be explored.

Because of the way we see, there are various ways to make drivers believe that the roadway is narrower than it is, which may result in people driving more slowly:

- Street trees can transform the appearance of highways and may complement business uses. The branching pattern of appropriate species of street trees will not block driver’s views of shops and signs of modest height. Their canopies can create a feeling of a street edge, which helps calm traffic.
- By bringing buildings closer to the roadway edge, the highway feels more constricted. Buildings close to the sidewalk also improve the pedestrian environment.
- Where there are shoulders or bike lanes, contrasting colored shoulders create the illusion of a more narrow travel lane. Relatively low-cost ways to accomplish this include paving travel lanes with asphalt and bike lanes with concrete, or the reverse, and incorporating dyes into concrete or asphalt.
- Adding on-street parking, curb extensions, and medians make the travelway feel constricted even when there is ample width.

See also:

Curb Extensions

Transitions

Trees & Landscaping

Reducing lane width can be both real (adding bike lanes and a median) and perceived (planting tall trees).

Reduce Travel Lane Width

Use To: *Slow traffic and reclaim width for other uses.*

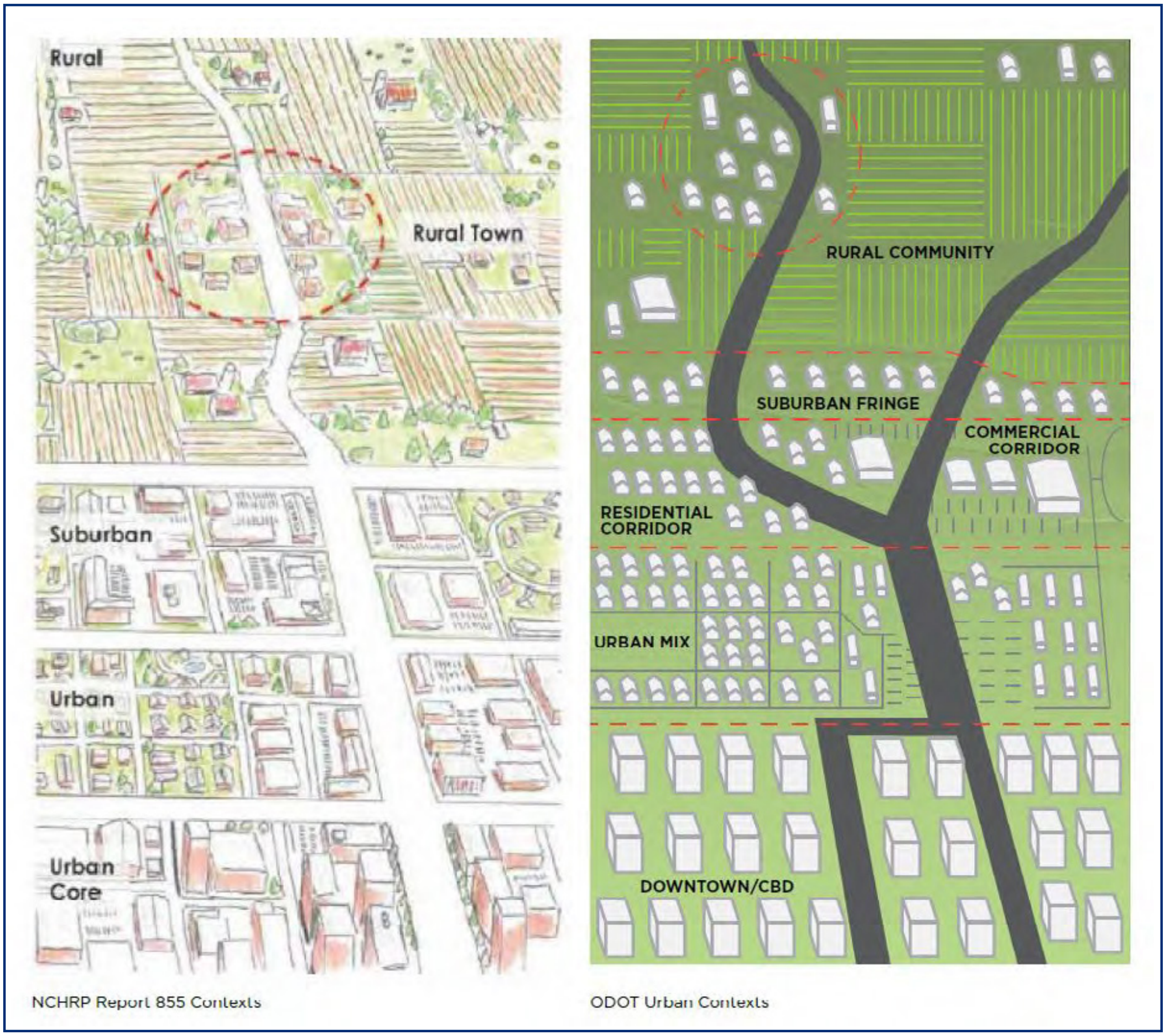
Good News: *Actual narrowing reduces crossing distance and supports other measures. Perceived narrowing can slow speeds somewhat without actually reducing width.*

Bad News: *Actually reducing width is more effective but requires Exceptions from ODOT.*

Figure E5:
ODOT Urban Contexts

ODOT URBAN CONTEXT	NCHRP REPORT 855 CONTEXT
Traditional Downtown/Central Business District (CBD)	Urban Core/Rural Town
Urban Mix	Urban
Commerical Corridor	Urban/Suburban
Residental Corridor	Urban/Suburban
Suburban Fringe	Suburban/Rural
Rural Community	Rural Town

Figure E6:
Lane Use Context



It is worth mentioning that the rural community context is intended for small, mostly unincorporated communities that don't always fit into the federal classification numbers of 5,000 population to be urban but have many urban characteristics in them. Even though the roadways may be classified as rural arterials through such towns, they should not be designed as rural, but instead the urban context should be used (Figure E6).

Each of the six urban contexts has been assigned a set of recommended design elements that include lane widths (Figure E7 and Figure E8). The recommended width of travel lanes is between 11 and 12 feet for all contexts but the Traditional Downtown/CBD context, where the recommended width is 11 feet.

Figure E7:
BUD—Design Element Recommendations

Design Element Recommedations for Traditional Downtown/CBD

DESIGN ELEMENT		GUIDANCE
Pedestrian Realm	Frontage Zone	4' to 2'
	Pedestrian Zone	10' to 8'
	Buffer Zone	6' to 0'
	Curb/Gutter[1]	2' to 0.5'
Transition Relam[6]	Separated Bicycle Lane (curb Constrained Facility)[2]	8' to 7'
	On-Street Bicycle Lane (not including Buffer)[2]	6' to 5'
	Bicycle/Street Buffer [2]	3' to 2'
	Right Side Shoulder (if travel lane directly adjacent to curb)[3,5]	2' to 0'
	On-Street Parking	7' to 8'
Travelway Realm[5]	Travel Lane[4,5]	11'
	Right Turn Lane (including Shy Distances)	11' to 12'
	Left Turn Lane[4]	11'
	Left Side/Right Side Shy Distance	1' to 0'
	Two-Way-Left-Turn Lane	11' to 12'
	Raised Median – No Turn Lane (including Shy Distances)	8' to 11'
	Left-Turn Lane with Raised Curb Median/ separator (includes 16" separator & Shy Distances)	12' to 14'

Design Element Recommedations for Urban Mix

DESIGN ELEMENT		GUIDANCE
Pedestrian Realm	Frontage Zone	1'
	Pedestrian Zone	8' to 5'
	Buffer Zone	6' to 0'
	Curb/Gutter[1]	2' to 0.5'
Transition Relam[6]	Separated Bicycle Lane (curb Constrained Facility)[2]	8' to 7'
	On-Street Bicycle Lane (not including Buffer)[2]	6' to 5'
	Bicycle/Street Buffer [2]	4' to 2'
	Right Side Shoulder (if travel lane directly adjacent to curb)[3,5]	2' to 0'
	On-Street Parking	8'
Travelway Realm[5]	Travel Lane[4,5]	11' to 12'
	Right Turn Lane (including Shy Distances)	11' to 12'
	Left Turn Lane[4]	11' to 12'
	Left Side/Right Side Shy Distance	1' to 0'
	Two-Way-Left-Turn Lane	11' to 12'
	Raised Median – No Turn Lane (including Shy Distances)	8' to 11'
	Left-Turn Lane with Raised Curb Median/ separator (includes 16" separator & Shy Distances)	12' to 14'

Design Element Recommedations for Commerical Corridor

DESIGN ELEMENT		GUIDANCE
Pedestrian Realm	Frontage Zone	1'
	Pedestrian Zone	8' to 5'
	Buffer Zone	5' to 0'
	Curb/Gutter[1]	2' to 0.5'
Transition Relam[6]	Separated Bicycle Lane (curb Constrained Facility)[2]	8' to 7'
	On-Street Bicycle Lane (not including Buffer)[2]	6' to 5'
	Bicycle/Street Buffer [2]	5' to 2'
	Right Side Shoulder (if travel lane directly adjacent to curb)[3,5]	4' to 0'
	On-Street Parking	N/A
Travelway Realm[5]	Travel Lane[4,5]	11' to 12'
	Right Turn Lane (including Shy Distances)	12' to 13
	Left Turn Lane[4]	12' to 14'
	Left Side/Right Side Shy Distance	1' to 0'
	Two-Way-Left-Turn Lane	12' to 14'
	Raised Median – No Turn Lane (including Shy Distances)	8' to 11'
	Left-Turn Lane with Raised Curb Median/ separator (includes 16" separator & Shy Distances)	14' to 16'

Design Element Recommedations for Residential Corridor

DESIGN ELEMENT		GUIDANCE
Pedestrian Realm	Frontage Zone	1'
	Pedestrian Zone	8' to 5'
	Buffer Zone	6' to 0'
	Curb/Gutter[1]	2' to 0.5'
Transition Relam[6]	Separated Bicycle Lane (curb Constrained Facility)[2]	8' to 7'
	On-Street Bicycle Lane (not including Buffer)[2]	6' to 5'
	Bicycle/Street Buffer [2]	5' to 2'
	Right Side Shoulder (if travel lane directly adjacent to curb)[3,5]	4' to 0'
	On-Street Parking	N/A
Travelway Realm[5]	Travel Lane[4,5]	11' to 12'
	Right Turn Lane (including Shy Distances)	12' to 13
	Left Turn Lane[4]	12' to 14'
	Left Side/Right Side Shy Distance	1' to 0'
	Two-Way-Left-Turn Lane	12' to 14'
	Raised Median – No Turn Lane (including Shy Distances)	8' to 11'
	Left-Turn Lane with Raised Curb Median/ separator (includes 16" separator & Shy Distances)	14' to 15'

Figure E8:
BUD—Design Element Recommendations

Design Element Recommedations for Traditional Downtown/CBD

DESIGN ELEMENT		GUIDANCE
Pedestrian Realm	Frontage Zone	4' to 2'
	Pedestrian Zone	10' to 8'
	Buffer Zone	6' to 0'
	Curb/Gutter[1]	2' to 0.5'
Transition Relam[6]	Separated Bicycle Lane (curb Constrained Facility)[2]	8' to 7'
	On-Street Bicycle Lane (not including Buffer)[2]	6' to 5'
	Bicycle/Street Buffer [2]	3' to 2'
	Right Side Shoulder (if travel lane directly adjacent to curb)[3,5]	2' to 0'
	On-Street Parking	7' to 8'
Travelway Realm[5]	Travel Lane[4,5]	11'
	Right Turn Lane (including Shy Distances)	11' to 12'
	Left Turn Lane[4]	11'
	Left Side/Right Side Shy Distance	1' to 0'
	Two-Way-Left-Turn Lane	11' to 12'
	Raised Median – No Turn Lane (including Shy Distances)	8' to 11'
	Left-Turn Lane with Raised Curb Median/ separator (includes 16" separator & Shy Distances)	12' to 14'

Design Element Recommedations for Urban Mix

DESIGN ELEMENT		GUIDANCE
Pedestrian Realm	Frontage Zone	1'
	Pedestrian Zone	8' to 5'
	Buffer Zone	6' to 0'
	Curb/Gutter[1]	2' to 0.5'
Transition Relam[6]	Separated Bicycle Lane (curb Constrained Facility)[2]	8' to 7'
	On-Street Bicycle Lane (not including Buffer)[2]	6' to 5'
	Bicycle/Street Buffer [2]	4' to 2'
	Right Side Shoulder (if travel lane directly adjacent to curb)[3,5]	2' to 0'
	On-Street Parking	8'
Travelway Realm[5]	Travel Lane[4,5]	11' to 12'
	Right Turn Lane (including Shy Distances)	11' to 12'
	Left Turn Lane[4]	11' to 12'
	Left Side/Right Side Shy Distance	1' to 0'
	Two-Way-Left-Turn Lane	11' to 12'
	Raised Median – No Turn Lane (including Shy Distances)	8' to 11'
	Left-Turn Lane with Raised Curb Median/ separator (includes 16" separator & Shy Distances)	12' to 14'

Design Element Recommedations for Commerical Corridor

DESIGN ELEMENT		GUIDANCE
Pedestrian Realm	Frontage Zone	1'
	Pedestrian Zone	8' to 5'
	Buffer Zone	5' to 0'
	Curb/Gutter[1]	2' to 0.5'
Transition Relam[6]	Separated Bicycle Lane (curb Constrained Facility)[2]	8' to 7'
	On-Street Bicycle Lane (not including Buffer)[2]	6' to 5'
	Bicycle/Street Buffer [2]	5' to 2'
	Right Side Shoulder (if travel lane directly adjacent to curb)[3,5]	4' to 0'
	On-Street Parking	N/A
Travelway Realm[5]	Travel Lane[4,5]	11' to 12'
	Right Turn Lane (including Shy Distances)	12' to 13
	Left Turn Lane[4]	12' to 14'
	Left Side/Right Side Shy Distance	1' to 0'
	Two-Way-Left-Turn Lane	12' to 14'
	Raised Median – No Turn Lane (including Shy Distances)	8' to 11'
	Left-Turn Lane with Raised Curb Median/ separator (includes 16" separator & Shy Distances)	14' to 16'

Design Element Recommedations for Residential Corridor

DESIGN ELEMENT		GUIDANCE
Pedestrian Realm	Frontage Zone	1'
	Pedestrian Zone	8' to 5'
	Buffer Zone	6' to 0'
	Curb/Gutter[1]	2' to 0.5'
Transition Relam[6]	Separated Bicycle Lane (curb Constrained Facility)[2]	8' to 7'
	On-Street Bicycle Lane (not including Buffer)[2]	6' to 5'
	Bicycle/Street Buffer [2]	5' to 2'
	Right Side Shoulder (if travel lane directly adjacent to curb)[3,5]	4' to 0'
	On-Street Parking	N/A
Travelway Realm[5]	Travel Lane[4,5]	11' to 12'
	Right Turn Lane (including Shy Distances)	12' to 13
	Left Turn Lane[4]	12' to 14'
	Left Side/Right Side Shy Distance	1' to 0'
	Two-Way-Left-Turn Lane	12' to 14'
	Raised Median – No Turn Lane (including Shy Distances)	8' to 11'
	Left-Turn Lane with Raised Curb Median/ separator (includes 16" separator & Shy Distances)	14' to 15'

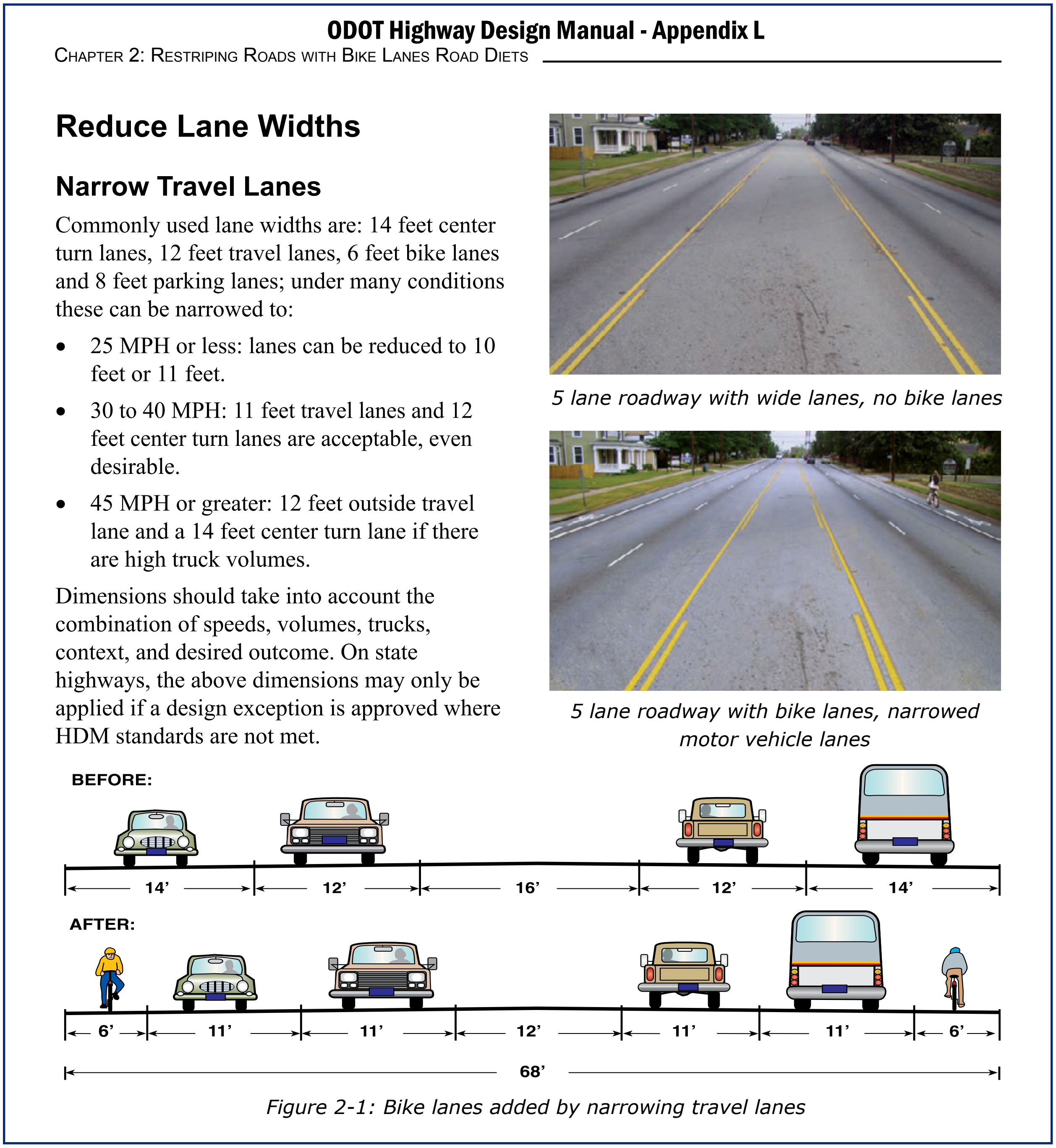
> ***"We have suggested cross sections with flexibility in dimensions as opposed to absolute numbers. Our preferred mental calculation is 11 feet, but we have a range of 11 to 12 in the BUD because of our reduction review route needs in our negotiations and discussions with our freight community. We didn't go to 10 as a part of the range at the outset. Our chief engineer is not opposed to 10-foot lanes but doesn't want to have that as a flexibility option to just use. If you want to do a 10-foot lane, we would do that with a design exception based on appropriateness and based on route needs in those locations."***
>
> *(Rich Crossler-Laird, Senior Urban Design Engineer at Oregon Department of Transportation)*

> ***"The state highway design perspective is a little different from a local jurisdiction perspective where they focus on their grid and their needs. The state has to consider the long term, longer distance mobility as well. We can't just allow 9-foot lanes on roads where 25% traffic is trucks. Decisions are made based on what is appropriate for a specific location. We rely on flexibility in decision-making processes at project levels."***
>
> *(Rich Crossler-Laird, Senior Urban Design Engineer at Oregon Department of Transportation)*

Oregon Bicycle and Pedestrian Design Guide

The Oregon Bicycle and Pedestrian Design Guide is an integral part of the 2023 ODOT Highway Design Manual (Appendix E). The Guide provides guidelines illustrating how a roadway can be restriped for bike lanes without negatively affecting and even enhancing the safety and operation of the roadway. For example, it suggests that with 32 feet available, there are at least three possible ways of restriping to provide a bike lane: 10.5-foot travel lanes with 5.5-foot bike lanes, 11-foot travel lanes with 5-foot bike lanes, or 10-foot travel lanes with 6-foot bike lanes. The choice of width for both travel lanes and bike lanes depends on the context and is project specific. A summary of how to add bike lanes by narrowing travel lanes is provided in Figure E9.

Figure E9:
Adding Bike Lanes by Narrowing Travel Lanes



ODOT Highway Design Manual - Appendix L

CHAPTER 2: RESTRIPING ROADS WITH BIKE LANES ROAD DIETS

Reduce Lane Widths

Narrow Travel Lanes

Commonly used lane widths are: 14 feet center turn lanes, 12 feet travel lanes, 6 feet bike lanes and 8 feet parking lanes; under many conditions these can be narrowed to:

- 25 MPH or less: lanes can be reduced to 10 feet or 11 feet.
- 30 to 40 MPH: 11 feet travel lanes and 12 feet center turn lanes are acceptable, even desirable.
- 45 MPH or greater: 12 feet outside travel lane and a 14 feet center turn lane if there are high truck volumes.

Dimensions should take into account the combination of speeds, volumes, trucks, context, and desired outcome. On state highways, the above dimensions may only be applied if a design exception is approved where HDM standards are not met.

5 lane roadway with wide lanes, no bike lanes

5 lane roadway with bike lanes, narrowed motor vehicle lanes

Figure 2-1: Bike lanes added by narrowing travel lanes

Design Criteria and Concurrence

The 2020 Blueprint for Urban Design and 2023 (combined) Highway Design Manual provide design guidelines (also called criteria) rather than prescriptive design standards. Each design element is assigned a recommended range of values (i.e., widths).

> ***"We're trying to move away from the terms design standard and use the term design criteria. This broadens the spectrum a little bit when you're talking about what's the appropriate thing for this location, taking more things into account as opposed to just looking at the numbers: 12-foot travel lanes, 6-foot shoulders, 6-foot bike lanes, 12-foot median turns. Now we are allowing for a range that you can play within, but you need to justify why you chose a specific number within that range."***
>
> *(Rich Crossler-Laird, Senior Urban Design Engineer at Oregon Department of Transportation)*

As part of ODOT's urban design approval process, projects are required to submit an Urban Design Concurrence Form in which project context is determined, project design criteria are defined, and project design decisions are documented. As mentioned before, the guidance provided in the HDM allows for a diverse range of potential designs. Therefore, for urban projects, the discretionary decisions of project teams must be documented. It is suggested to not only document what the project is accomplishing but also to document what isn't being done or can't be done with the specific project and why. This is particularly encouraged for preservation type projects where the project scope is limited.

The majority of ODOT's projects are two categories of preservation projects—the typical 3R projects and a subcategory of 1R projects (true preservation projects designed simply to preserve the paving). For 3R projects, there is some leeway to install additional safety features (i.e., active transportation features or road diet elements). This opportunity is limited for the 1R project. However, even when only restriping, the number of lanes could be reduced from four to three and a new bike lane put in if that makes an interim improvement to long-term goals and aspirational needs for the location.

Design Exceptions

Any deviation from lane width design standards (or criteria) outlined by the 2020 Blueprint for Urban Design or the 2023 ODOT Highway Design Manual requires a design exception. This means that projects including travel lane widths of less than 11 feet require additional approvals. Lane width design exceptions are approved by the State Traffic-Roadway Engineer and require signatures from both the Engineer of Record (EOR) and the State Traffic-Roadway Engineer. In some cases, FHWA approval may be required (i.e., "High Speed" NHS Roadways). Figure E10 shows the data required for design exception justification.

Figure E10:
Data Required for Design Exceptions

DESIGN EXCEPTION DATA FOR JUSTIFICATION	
1.	Summary of the proposed exception
2.	Project description and/or purpose/need statement from the project charter
3.	Impact on other standards
4.	Cost to build to standard
5.	Crash history and potential (specifically as it applies to the requested exception)
6.	Reasons (low cost/benefit, relocations, environmental impacts, etc.) for not attaining standard
7.	Compatibility with adjacent sections (route continuity)
8.	Probable time before reconstruction of the section due to traffic increases or changed conditions
9.	Mitigation measures to be used. These can include low cost measures such as lane departure detectable warning devices (rumble strips or profiled pavement markings) or additional signs. Mitigation needs to be appropriate to the site conditions and installed correctly to be effective in reducing crashes.
10.	Plans, Cross Sections, Alignment Sheets, Plan Details and other supporting documents.

APPENDIX F. CALTRANS (CALIFORNIA DOT) LANE WIDTH GUIDING DOCUMENTS

Caltrans Highway Design Manual

In 2020, the Highway Design Manual was revised for Caltrans (department) by the Division of Design for use on the California state highway system. Uniform policies and procedures have been established to carry out state highway design functions for the department. According to the Highway Design Manual, during the Project Development process, the project's different effects, such as social, economic, and environmental effects, must be considered fully along with technical issues so those final decisions can be made for the best overall public interest. Special attention is given to providing transportation for all facility users, attainment of community goals, need of low mobility and disadvantaged groups, and costs and benefits of eliminating or minimizing adverse effects on natural resources. Bearing this in mind, the manual also introduces standard lane width with exceptions.

Index 301.1 of the manual discusses the standard of lane width with exceptions. According to the manual (Index 301.1), "The minimum lane width on two-lane and multilane highways, ramps, collector distributor roads, and other appurtenant roadways shall be 12 feet." The exceptions to the rule are as follows:

> *"For conventional State highways with posted speeds less than or equal to 40 miles per hour and AADTT (truck volume) less than 250 per lane that are in urban, city or town centers (rural main streets), the minimum lane width shall be 11 feet. The preferred lane width is 12 feet. Where a 2-lane conventional State highway connects to a freeway within an interchange, the lane width shall be 12 feet. Where a multilane State highway connects to a freeway within an interchange, the outer most lane of the highway in each direction of travel shall be 12 feet.*

> *For highways, ramps, and roads with curve radii of 300 feet or less, widening due to off tracking in order to minimize bicycle and vehicle conflicts must be considered."*

Another exception of lane width for roads under other jurisdictions, such as city streets and county roads, design exceptions has been outlined in Index 308.1.

Moreover, consideration has been given to both left-turn and right-turn channelization. According to Index 405.2 of the Highway Design Manual, in left-turn channelization, "***the lane width for both single and double left-turn lanes on State highways shall be 12 feet. For conventional State highways with posted speeds less than or equal to 40 miles per hour and AADTT (truck volume) less than 250 per lane that are in urban, city or town centers. Rural main streets, the minimum lane width shall be 11 feet***." However, in Index 405.3 of the Highway Design Manual, for "right-turn channelization in urban, city or town centers (rural main streets) with posted speeds less than 40 miles per hour in severely constrained situations, if truck or bus use is low, consideration may be given to reducing the right-turn lane width to 10 feet."

Design Exceptions

For the design features that deviate from the design standards in the Highway Design Manual, Caltrans developed Design Standard Decision Documentation (DSDD) which guides documenting such engineering decisions. The approval authority of the DSDD belongs to the Headquarters Project Delivery Coordinator for some of the nonstandard design features and the District Director for others. The documentation includes a project description, general highway characteristics, the facility's classification, safety improvements, and total project cost. It also includes general information such as the design standard, nonstandard features and reason for not using the design standard and the added cost to meet the standard, design features with District Delegated Approval Authority, traffic data, collision analysis, future construction, concurrence, and environmental determination document.

Traffic Calming Guidance

Caltrans considers all modes of travel essential for providing a world-class transportation network through improved accessibility and connectivity to crucial community destinations, providing livability and safety to all users of the state highway system. Even though the Federal Highway Administration (FHWA) dictates the use of traffic control devices through the Manual on Uniform Traffic Control Devices, and the state acts accordingly, sometimes the goal of orderly and safe movement of traffic is compromised due to excessive speeds by specific drivers. Caltrans employs traffic calming techniques for slowing down speeding vehicles.

According to the FHWA Traffic Calming Primer:

> ***"The primary purpose of traffic calming is to support the livability and vitality of residential and commercial areas through improvements in non-motorist safety, mobility, and comfort. These objectives are typically achieved by reducing vehicle speeds or volumes on a single street or a street network. Traffic calming measures consist of horizontal, vertical, lane narrowing, roadside, and other features that use self-enforcing physical or psycho-perception means to produce desired effects."***

According to Caltrans, conventional highways are the target of traffic calming, and several strategies, such as law enforcement, public education, and temporary and permanent speed calming highway infrastructure, can be considered effective. The need for traffic calming can be determined by several measures, such as existing operating vehicular speeds, volume counts, number of crashes, and adjacent land uses.

APPENDIX G. DELAWARE DOT LANE WIDTH GUIDING DOCUMENTS

DelDOT Road Design Manual

DelDOT has developed the Road Design Manual to ensure safety and effective roadway designs. The manual follows the principal national documents, including AASHTO, HCM, MUTCD, and flexibility in highway design. The objective of road design guidelines is to create roads that are consistent and predictable for drivers. Road functional classification, design controls, design elements, and cross-section elements are required to be determined in the early stages of the project development. Meanwhile, picking the proper design controls relevant to LOS, safety, economics, and context is necessary for each design project. The standard offered by the design manual is based chiefly on ranges from the AASHTO Green Book; however, in some cases, there might be values lower than recommended by AASHTO, which typically happens on lower functionally classified roads. However, such design exceptions should be determined in the early stages of projects and require documentation and approval by the chief engineer and FHWA. Meanwhile, new construction and reconstruction projects are expected to follow the standard guidelines. Depending on the project type, different types of approvals might be required.

The desired lane width for all new construction and reconstruction is 12 feet. However, on low-speed roadways with low truck volumes and no safety concerns an 11-foot lane can be used. Eleven-foot lane widths are used particularly in urbanized areas with limited right-of-way and increased pedestrian activity. At higher speeds, a 12-foot lane width is suggested on urban arterials with free flow conditions. On local roads, 11 feet are allowed, although where there are truck and vehicular volumes with low operating speeds, a lane width of 9 or 10 feet can be used. Design speed is the primary element in picking the best-paved lane width. Roadways with higher truck volumes require wider paved lanes as they will perform better for heavier loads. A minimum 12-foot lane width is necessary to keep trucks away from shoulders. Therefore, extra space in wider lanes will be dedicated to the shoulder width. Adequate lane widths on roads with high truck volumes are necessary to ensure sufficient clearance between large vehicles. On the other hand, narrower lanes are permitted on roads where the scope of work and rightof-way is limited.

Delaware Traffic Calming Design Manual

Delaware's Traffic Calming Design Manual was written by Professor Reid Ewing at U of U and first adopted in 2000. It was later updated in 2011 by DelDOT to provide guidance and set standards for establishing traffic calming measures in Delaware. The applicability of this manual is restricted to local roads and subdivision streets with posted speed limits less than or equal to 35 mph. Major arterials, collectors, and state maintained roads with posted speed limits beyond 35 mph are not eligible for traffic calming measures outlined in this manual. Following the guidelines outlined in the manual, DelDOT undertook several traffic calming projects starting in August 2000.

Traffic calming measures involve spot construction within the scope of existing streets and are implemented within two months or less. The performance can be measured about six months after finishing the project. According to this manual, traffic calming measures are classified into three categories: Non-Road Construction, Vertical, and Horizontal. Most projects need a combination of measures from these categories to address speeding problems. The non-construction measures include yard signs, striping, one-way streets, radar speed signs, and inappropriate signs.

In the manual, striping (a non-construction measure) is described as “***as a means of controlling speed including measures to*** *effectively narrow the travel lanes to encourage lower speeds*, ***to emphasize pedestrian crossings, or to supplement signing regulations (such as existing stop signs). Striping, which can be used in traffic calming, includes centerline stripes, edge line stripes, crosswalks, and stop bars at existing stop signs***.” Striping can be of three types: Centerline Striping, Edge Line Striping, and Crosswalks. Centerline striping is helpful in residential areas with streets that lack existing centerlines to channel traffic, eventually reducing vehicular speeds. The manual describes edge line striping: “Edge line striping is also effective in residential areas **to narrow the lanes and/or provide additional delineation for other uses**. Reducing the lane width can reduce speed by creating a narrower traffic lane. The area between the edge of the road and the lane marking can often be used for parking or as a bike lane, depending on the resulting shoulder width.” Lastly, crosswalks are appropriate to delineate pedestrian movements, but they alone cannot ensure desired safety.

Vertical measures change the elevation (6 inches or less) of a street over short distances so that it causes discomfort to the motorist and forces them to slow down. The vertical measures mentioned in the manual are speed humps, speed cushions, prefabricated speed cushions, raised crosswalks/speed tables, and raised intersections.

Horizontal measures are supposed to “***cause vehicles to alter their direction of travel or*** *reduce the width of the traveled way with the intent of reducing speeds or volumes*. ***Modifications may be made to the overall street width, lane width, and/or lane alignment***.” The horizontal measures included in the manual are chokers, corner extensions, median islands, chicanes, lateral shifts, realigned intersections, roundabouts, partial closures, diagonal diverters, intersection barriers, and forced turn islands. Among the listed horizontal measures, chokers (mid-block narrowing) and median islands (center island narrowing) **narrow the lane width of travel lanes to reduce vehicular speeds.**