2020

Incomplete: Evaluating Current Complete Streets Practice and Presenting a Toolkit for Practitioners

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INCOMPLETE: EVALUATING CURRENT COMPLETE STREETS PRACTICE AND PRESENTING A TOOLKIT FOR PRACTITIONERS

by

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A Dissertation

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy

Major: Civil Engineering

The University of Memphis

December 2020

ABSTRACT

Complete Streets is an urban planning paradigm that seeks to utilize streetscapes as holistic space and not merely as a means for conveyance. This paradigm seeks to provide equitable access for all street users across all modes of transportation, improving urban livability and reducing reliance on car ownership. In the first chapter of this dissertation, we compare the primary benefits of Complete Streets valued by practitioners with the secondary benefits promised by academics and Complete Streets advocates, and suggest a methodology for empirically quantifying spatiotemporal outcomes of infrastructure projects. In the second chapter, we review literature related to Complete Streets outcomes to determine which benefits are well-documented and which rely on logic pathways. We then survey Complete Streets practitioners across the US to find trends in current practice and identify heterogeneities. In the third and final chapter, we develop a Capability Maturity Model for Complete Streets programs. This model identifies seven dimensions of agency practice that are fundamental to robust implementation of Complete Streets policies and guides practitioners through a self-evaluation.

The purpose of the model is to allow agencies to evaluate their current agency capability and evolve to a more mature form of practice. Expected outcomes of this model include improved inter-agency communication and collaboration, identification of useful technologies and best practices, and a culture that values equitable transportation decisions and endures through changes in administration.

TABLE OF CONTENTS

Chapter	Page
List of Tables	vi
List of Figures	vii
Complete Streets: Promises and Proof	1
Abstract	1
Introduction	1
Background	3
Promised Impacts of Complete Streets	6
Approaches for Assessing Impact	9
Challenges to Implementation	11
Case Studies and Best Practices	13
Memphis, TN	14
Somerville, NJ	15
Thunder Bay, Ontario	16
Washington, DC	17
Las Cruces, NM	19
Discussion	20
Conclusions	24
Data Availability Statement	26
Acknowledgements	26

Complete Streets: Theory and Practice 27

    Abstract 27

    Introduction 28

    Overview of Literature 29

        Observations from COVID-19 Lockdowns 41

        Challenges to Empirical Measurement of Outcomes 42

    Examination of Current Practice 45

        Analysis of Survey Responses 46

        Case History: New Face on an Old Broad 51

    Discussion 56

    Conclusions 59

    Data Availability 59

Complete Streets: A New Capability Maturity Model 60

    Abstract 60

    Introduction and Literature Review 61

    Methodology 64

    Results and Discussion 69

        Complete Streets Capability Maturity Model 71

    Conclusions 94

    Data Availability 95

    Acknowledgements 95

Conclusion 96

Recommendations for Future Research 98

References 100

Appendix A: Blank Survey 110

Appendix B: Glossary 112

LIST OF TABLES

Table Page

Sample Studies Showing Benefits of CS Projects 31

Sample of Studies Showing Benefits of CS Project Elements. 34

Methods for Site Selection (N = 29) 47

Relating quiz scoring to agency maturity 75

Complete Streets Capability Maturity Model 88

LIST OF FIGURES

Figure	Page
Illustrative Data Framework for measuring CS project benefits	23
Contradictory logic pathways (82–86)	30
Time period of policy adoption (left) and division by agency type (right)	46
Practitioner Evaluation of Data Management Practices (N = 48)	49
Responses to “My agency has a mature and well-executed Complete Streets Policy”	50
Broad Avenue in 2007 prior to project implementation (left) and in 2011 after completion (right).	55
Process flow for model development	65

PREFACE

Roadway improvement projects have typically been undertaken based on two paradigms: cost/benefit analysis and network improvement problems (the two are not mutually exclusive). The construction of a standard network improvement problem typically takes the existing network as an input and uses an origin-destination demand matrix as a constraint, then asks "What links can be added or expanded to the network to minimize travel time while still meeting demand?" Similarly, cost/benefit analysis seeks to save travel time and fuel consumption (benefits) at a minimum investment (cost), and selects those projects with the highest ratio of benefits to costs. The common factor in these approaches is an emphasis on automobile-centric throughput. In either case, the sole or primary consideration is vehicle travel time. However, these approaches have come at a systemic cost: road networks can encourage urban sprawl, create neighborhood fragmentation, introduce substantial air quality problems, and disadvantage travelers who do not own a vehicle. In short, high traffic speeds and volumes are associated with reduced livability in urban spaces.

In the 1970s, researchers began to associate transportation with public health and quality of life. Since 2003, this association has led to a new paradigm in urban planning: Complete Streets. Under the Complete Streets approach, planners and engineers are encouraged to view streetscapes as *usable community space* rather than solely as a means of *conveyance and throughput*, and to consider the needs of all users across all modes of transportation in lieu of a focus on car travel. As a result, active transportation, multimodality, public transit, and mobility-challenged users are considered alongside other uses for street space like cafés, green spaces, and artwork. By 2020, over 1600 US jurisdictions have formally adopted Complete Streets policies. Advocates of these policies tout a long list of benefits to Complete Streets projects from improved roadway safety and accessibility to lower obesity and cancer rates to equity and impacts on climate change.

This dissertation seeks to explore the observability of some of these predicted Complete Streets outcomes, to evaluate current state of Complete Streets practice, and to provide a means to further evolve future practice. The first chapter provides a look at the development and context for Complete Streets and examines some of the claims made by advocates of the paradigm. It offers an illustrative framework for measuring long-term outcomes within the vicinity of Complete Streets investments and comparing those outcomes with results in communities that received other transportation infrastructure investment or no investment at all, seeking to quantify both the extent and certainty with which a given Complete Streets intervention is likely to yield a particular outcome. The second chapter deals with the challenges inherent to spatiotemporal analysis of community outcomes and offers a more qualitative approach: a literature review, a case study, and a practitioner survey are utilized to determine which Complete Streets benefits can be claimed with confidence, which outcomes are of greatest interest to practitioners, and descriptors of successful Complete Streets programs.

The final chapter of this dissertation has tangible value for practitioners in public agencies. In an iterative process involving literature review, expert input, and practitioner workshops, a qualitative Complete Streets Capability Maturity Model was developed. This model identifies key dimensions for success in Complete Streets practice, and provides a detailed qualitative description of four levels of maturity for each dimension. Practitioners are invited to evaluate their agencies and to identify strategies for incorporating agency structures, cultures, and behaviors that foster mature and robust implementation of Complete Streets policies and programs. This model serves as a guide for goal-setting and program evaluation, allowing agencies to systematically identify strengths and weaknesses along each model dimension and to identify what level of maturity suits their unique context.

Chapter One was submitted for publication with the *Journal of Urban Planning and Development* on 22 January 2020. Chapter Two was submitted for publication with *Cities* on 02 October 2020. Chapter Three was submitted for publication with the *Journal of Urban Planning and Development* on 09 October 2020. At the time of submission of this dissertation, all remain under review.

COMPLETE STREETS: PROMISES AND PROOF

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Abstract

The Complete Streets movement has been steadily gaining attention in the United States over the last 16 years. Adoption of policies that encourage street designers to consider the needs of all users—and not only automobile users—have become more widespread, with over 1,400 US jurisdictions formally embracing Complete Streets policies. The promised benefits of Complete Streets policies are far reaching, but rigorous studies proving these benefits are rare. This paper reviews the state of the practice of Complete Streets and some attempts to catalogue the outputs and outcomes of Complete Streets projects, and analyzes case studies to determine best practices.

Keywords: Complete Streets, Outcomes, Benefits, Analysis

Introduction

The way urban streets are conceived and developed in the United States is changing. In the past, roadway improvement projects were typically undertaken based on cost/benefit analysis; savings in commuter travel time was taken as a primary benefit, and those projects which decrease travel time received heavy investment. This automobile-centric approach to planning and design has, however, changed the nature of cities and communities. In 1972, Donald Appleyard and Mark Lintell published a study correlating increased traffic to decreased quality of life and increased social isolation for nearby residents (*1*). Since then, more and more studies

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have shown what residents intuit to be true: the built environment affects levels of physical activity and quality of life (*2*–*6*), and heavy traffic is bad for communities (*7*–*10*); meta-analysis of existing literature even shows that neighborhood characteristics influence levels of depression in older adults (*11*). Automobile-centric planning and city design increase risk of injury to pedestrians while decreasing community cohesion and limiting safe outdoor spaces for children to play, causing public health risks on several fronts.

In response, a new urban planning paradigm is being developed and adopted under the name Complete Streets (CS). Rather than focusing solely on decreased automobile travel times, CS attempts to reclaim streets as a space for all users across all modes. This includes (but is not limited to) pedestrians, cyclists, transit riders, those with physical disabilities, the elderly, and motorists. The change in focus provided by CS allows adoption of several performance measures for evaluating the worth of streetscape improvement projects: mode shift can decrease automobile demand, decreasing the need for added lanes or higher speeds. Wider sidewalks and creation of plaza space can inspire ongoing economic growth (*12*, *13*) and provide gathering spaces for residents. Curb extensions and median islands can improve pedestrian safety and increase accessibility for mobility-challenged users. In short, CS attempts to shift the calculation away from cost-versus-travel-time-savings mentality and toward quality-of-life improvements for all users.

While the development of CS formally began in 2003 (*14*), an interest in CS-like policies has been growing for much longer. The first CS-like legislation was passed in Oregon in 1971 (*15*)—around the time Appleyard and Lintell were studying the negative correlation between traffic and quality of life (*1*)—and centered on improving cycling infrastructure as a meaningful alternative to driving. As recently as 2010, engineers and planners were often largely unfamiliar with CS practice, preferring instead to deploy automobile-centric designs (*16*). Since that time, adoption of CS policies has become increasingly commonplace: in 2011, the US Surgeon General released a call to action promoting walkable communities as an important way to improve public health (*17*), and in 2013, Memphis, TN became the 500th jurisdiction to formally adopt a CS policy (*18*, *19*). By the end of 2016, over 1400 jurisdictions had established CS policies (*20*, *21*).

The purpose of this paper is to review the state of the practice regarding CS in North America, to identify current best practices through a review of case studies, and to promote the next steps for the CS movement that will lead to a comprehensive framework for evaluating and enhancing local agency capabilities in deploying effective, outcome-oriented CS programs. The next section follows the evolution of the CS concept and identifies the state of the practice. Then, the supposed benefits of CS projects are studied across a variety of settings in order to examine how CS reframes the scope of the cost/benefit paradigm. The authors then identify key performance measures that can be used to assess the impacts of CS projects. Challenges to wider adoption and implementation are discussed next, followed by a review of five case studies in North America to show examples of CS in action. These case studies inform a discussion of CS policy.

Background

The CS movement has grown out of the need to reclaim streets as space. According to 2014 data collected by the Pew research center, 12% of US households do not own a vehicle (*22*). And for many households, vehicle ownership creates undue financial stress—financial experts recommend spending 10-20% of annual household income on vehicle payments, fuel, insurance, and repairs (*23*, *24*), but the average US household spends over $9500 annually on these expenses (*25*). When streets are designed solely for use by drivers, car ownership becomes a necessity. But by allowing access for non-vehicular modes of transportation, the pressure to own a vehicle can diminish; in fact, road diets have been shown to increase cyclist participation (*26*). This can ease financial stress on low-income households while easing traffic congestion in high-demand areas.

It should be noted here that the North American context for CS is fundamentally different than the European context, and brings a separate set of challenges. Automobile-centric development spiked in the US under F.D. Roosevelt's New Deal public works projects immediately following Hoover's apocryphal 'car in every garage', and again with the implementation of the Eisenhower interstate system. Car ownership became a symbol of American independence and prosperity. In Europe, however, cities had a longer history of development without the influence of cars, and had adapted more readily to shared transportation and cycling (*27*). "Most Western European residents live in densely developed communities within reach of public transportation corridors that were established long before widespread use of the automobile, thus providing naturally large markets for transit operators" (*28*).

CS is a policy- and planning-oriented paradigm that has grown alongside two similar yet distinct processes: Context-Sensitive Solutions (CSS) and Context Sensitive Design (CSD). Per the FHWA, CSS is defined as "a collaborative, interdisciplinary approach that involves all stakeholders in providing a transportation facility that fits its setting. It is an approach that leads to preserving and enhancing scenic, aesthetic, historic, community, and environmental resources, while improving or maintaining safety, mobility, and infrastructure conditions" (*29*). The core of the CSS process is focused on stakeholder inclusion and communication, and the flexible application of transportation solutions. Meanwhile, CSD focuses on safe, resource-efficient projects tailored to the context of the surrounding community. "The use of CSS to achieve CSD outcomes is referred to as CSS/D" (*27*). Complete Streets adds to these processes an emphasis on all users and all modes. All three processes are attempts to avoid one-size-fits-all transportation projects in favor of projects specially designed to enhance the community under investment. Though these three approaches are not equivalent, they are compatible (*30*); CS projects often utilize part or all of the CSS/D approach as planning projects move into the design phase.

Recent trends in pedestrian and cyclist fatalities in the US have been unsettling; the number of pedestrians killed in traffic crashes increased 35% from 2008-2017 (the most recent year for data)—accounting for nearly 15% of all traffic fatalities (*8*). In 2015, 818 cyclists were killed in vehicle/cyclist collisions, a 12% increase over the previous year (*31*). While total motorist fatalities have been slightly decreasing, fatalities among pedestrians and cyclists has been increasing (*32*, *33*) These trends have led the National Complete Streets Coalition to endorse Vision Zero (*34*), a "strategy to eliminate all traffic fatalities and severe injuries, while increasing safe, healthy, equitable mobility for all" (*35*). A 2014 report released by Smart Growth America details trends in pedestrian fatalities, identifying children, the elderly, and people of color as the most threatened populations. The report states that "the only acceptable number of pedestrian fatalities is zero" (*8*), harmonizing with the core motivation for Vision Zero. In response to the increase in cyclist fatalities, 'A Right to the Road' outlines the 'US policy on Bicycle and Pedestrian Accommodation' approach to reducing vehicle/cyclist crashes (*31*, *36*, *37*):

1) Take a CS approach to infrastructure improvements
2) Identify and address barriers to making streets safer and more convenient for all users
3) Gather and track bike/ped data

4) Use designs that are appropriate to the context of the street and its users (integrating Context-Sensitive Solutions with CS)
5) Capture opportunities to build on-road bike networks during routine resurfacing
6) Improve safe biking and walking laws and regulations
7) Educate and enforce proper road use behavior by all

There is also a push to collect more and better data. Lack of strong data is a major limiting factor in the delivery of effective CS projects; providing better information would allow future CS projects to improve upon current designs (*38*). Additionally, there is a concern that many CS policies need more robust integration of public transit access, and a broader consideration of impacts at the network level (*39*, *40*)

Promised Impacts of Complete Streets

The promised benefits of complete streets are myriad. Because implementation of CS projects is adaptive to the scenario and goals of the planning team, almost any goal can be touted as a direct or indirect benefit of CS. The following list provides a sampling of the supposed benefits of CS projects with brief explanations of the rationale behind these promises:

- Complete streets create livable communities (*4*)
    - CS prioritize all users and all modes, allowing safer interactions for pedestrians and reduced traffic noise and intensity.
- Complete streets improve public transit (*41*, *42*)
    - Creating complete streets allows for safer and more comfortable first- and last-mile commutes for transit riders
- Complete streets promote good health (*5*, *43*)

  - By creating safer spaces for physical activity, CS encourage more active transportation. Increased physical activity reduces obesity and risk of chronic diseases.
- Complete streets fight climate change (*44*)
  - CS allow alternative means of transportation, effectively removing cars from the road and decreasing the carbon load from traffic. This alleviates one source of greenhouse gasses.
- Complete streets help keep kids safe (*45*, *46*)
  - CS emphasize pedestrian safety, shortening crossing distances and slowing traffic. The result is a safer environment for children walking or biking to school.
  - When more people use active transportation, street crime diminishes and traffic collisions occur less often—the "safety in numbers" effect.
- Complete streets stimulate the local economy (*12*, *47*, *48*)

When traffic slows down, motorists are more likely to notice and patronize local businesses: "All of a sudden, people were noticing your business that had never noticed it before because they were speeding by at 45 or greater" (*19*). Creating new foot and bike traffic also increases the potential customer base for local businesses.

The benefits of CS extend into areas of public health, community severance and isolation, blighted urban properties, equity, public transit ridership, and economic benefits. There are even claims that CS can reduce racism (*49*) and help treat or prevent some types of cancer (*14*). For simplicity, six main areas of benefit are listed here.

1) Safety
    a. Reduction in severity and frequency of vehicle collisions

    b. Reduce vehicle/pedestrian or vehicle/cyclist conflict points
    c. Public Health
        i. Increase participation in active transportation
        ii. Increase social participation
2) Mobility
    a. Increase bike/ped trips
    b. Improve access to transit stops
        i. Create bus pull-outs
        ii. Remove barriers to accessing transit stops (see Washington, DC case study below)
3) Equity
    a. Reduction in need for vehicle ownership helps equalize opportunity across class and racial lines
    b. Increasing the number of accessible jobs allows more choices for workers and decreases monopsony
4) Environmental
    a. Energy conservation
    b. Reduced runoff
    c. Reduced air/noise pollution
    d. Increased vegetation
5) Livability
    a. Reclamation of streets as space
    b. Traffic calming reduces traffic noise and stress

6) Economic
    a. Increased awareness of local businesses
    b. CS areas are desirable for residents, driving up land values and tax roles

These lists make CS look like a modern panacea for struggling urban areas, but also suggest a healthy skepticism. The need to measure these outcomes and provide supporting evidence for these claims is clear (*12*).

Approaches for Assessing Impact

Smart Growth America and the National Complete Streets Coalition (NCSC) draw a distinction between measuring the outcomes and outputs of a project. Outputs tend to be easily observable and imminently measurable; in regards to CS projects, outputs may include added miles of bike lanes or number of obstacles removed from sidewalks. Outcomes, on the other hand, "are the ultimate results of a project as it contributes to the larger environment. Outcomes include measures such as rates of chronic disease, rates of fatal or injurious crashes, and changes in economic activity" (*50*). This distinction proves especially valuable in evaluating the benefits provided by CS projects because, as discussed previously, the CS movement promises benefits in terms of outcomes.In 2004, the FHWA released a report advocating the use of performance measures to evaluate systems-level outcomes for major projects (*39*). Since that time, each major surface transportation funding bill has encouraged or required the use of performance measures (*51–53*). Performance measures allow snapshot information to act as an indicator of overall system health, and tend to encourage the measurement of outcomes over outputs. For each goal of a project or series of project, (an) appropriate performance measure(s) can be selected.

The NCSC provides recommendations for dozens of potential performance measures at the project and network levels (*50*). Each recommendation is associated with one of seven major goals:

- Access (quantifying safe and reliable connections of users to destinations)
- Economy (increased local revenue or land value, or improved access to jobs)
- Environment (reduction in pollutants or improvements in energy efficiency)
- Place (reduced property blight, improved aesthetics, or increased user satisfaction)
- Safety (reduced accidents, fatalities, or crimes)
- Equity (measuring how opportunities are distributed across gender, age, income, race, etc.)
- Public Health (increases in active transportation, reduction in illnesses)

For example, one measure of safety could be the number and severity of automobile crashes in the project area, or security in terms of the number of violent crimes in the area. A measure of environment could be the air quality in terms of particulate matter or levels of toxic chemicals. And a measure of access could relate to the number of transit trips as a portion of total trips along the project, measured by demographic characteristic. In any case, pairing the proper performance measure with each project goal can help to demonstrate how effectively those goals are being achieved. Some approaches to assessing the impacts of CS-oriented changes can be qualitative, avoiding an over-reliance on data: researchers in Kraków, Poland surveyed business owners a decade after the introduction of local car and parking restrictions to determine impacts on business revenues (*54*).

It should be noted here that although CS projects have rarely received thorough evaluation, some elements common to CS projects *have* been studied. Road diets—a form of traffic calming that sacrifices capacity in favor of multimodal access and reduced conflict points—have received attention (*55*, *56*), with studies showing increased cyclist usage (*26*), reduction in the number and severity of crashes (*57*, *58*), and economic benefit for nearby homes (*13*). However, these studies often focus on the particular tool—road diets—and related traffic safety outcomes without expanding more broadly to CS projects and the myriad forms of benefit claimed by CS advocates.

Challenges to Implementation

Currently, CS policies are adopted and implemented by each jurisdiction independently of all others; a state can adopt a CS policy while its constituent counties and cities do not, and in theory all cities and counties in a state could adopt CS policies without the state having to do so as well. In part, this is because CS has become a partisan issue (*59*). In 2009, legislation to create a CS policy at the federal level passed the house of representatives, but stalled in the senate (*60*); a newly-introduced 2019 measure will require bipartisan support to succeed (*61*). This partisanship may be due to the apparent conflict between traditional, cost/benefit-based project prioritization and the CS paradigm, which prizes intangible and unamortizable benefits. In short, CS has promised much and proven little. With all the promised benefits listed previously, CS seem too good to be true—fiscal conservatives may want additional proof that investment in CS projects has a similar or preferable return on investment as compared with traditional projects.

There are several barriers to proving the efficacy of CS. Adoption of a CS policy within a jurisdiction may not lead to on-the-ground implementation of CS projects, and CS projects can exist even without a formal CS policy in place. Where CS policies exist, some jurisdictions have single-page ordinances while others have rich, comprehensive guidelines. As a result, drawing comparisons between CS jurisdictions and non-CS jurisdictions is rarely straightforward. Overlapping jurisdictions further complicate this issue: while there is no unified federal policy on CS, the USDOT has endorsed CS (*36*) leaving states, counties, and cities the freedom to opt in or out.

Even if good control groups can be found and reasonable comparisons made, proving benefit of CS projects can be challenging or impossible. A cursory review of the performance measures recommended by the National Complete Streets Coalitions reveals two fundamental flaws: the first is that showing a before/after improvement—and causally attributing that improvement to nearby CS initiatives—requires robust before and after data sets which most cities lack the incentives and resources to collect. Instead, hard data is replaced with anecdotal observations about general improvements or increases in active transportation rates (*12*). Without clean, well-collected panel data relating to each intended project goal, demonstrating outcomes proves elusive. Secondly, even where careful data collection exists before and after project implementation, it may be difficult or impossible to analyze that data with the level of granularity assumed by the NSCS performance measures: to evaluate performance with the goal of providing improved and equitable bicycle access at the project level, the NCSC recommends tracking "bicycle trips as portion of total trips along project; measured by gender, age, income, race, ethnicity, and disability status" (*50*). Few organizations have the means to track this level of information. Finding simple, objective, quantitative data regarding these metrics can be difficult (*62*).

If such data were available, the conversation could shift from whether or not CS is effective to how to value and monetize these long-term outcomes and how to balance tradeoffs:

how much travel time savings is it worth to improve air quality, to decrease social isolation, or to reduce blighted urban properties? This sort of calculation appeals to a broader engineering desire to optimize these systems, but there is not yet any real agreement on *what* should be optimized or *how* it should be measured (*63*). There is also the problem of isolated cost and diffuse benefit—local or regional planning offices have limited budgets for project implementation, but the benefits promised by CS advocates are often dispersed among all users and never directly monetized by those planning offices.

This points to the fundamental challenge to broadscale implementation of CS policies and projects: skeptics require proof that CS policies can provide better outcomes than traditional projects, but the data that could validate claims of improvement is unavailable (*64*) or prohibitively expensive.

Case Studies and Best Practices

Best practices can often be gleaned from reviewing prior implementation case studies to determine what approaches have led to success in the past. To that end, five case studies are presented here, each embodying a different goal associated with CS. Improvements in bike infrastructure in Memphis, TN focused on public health; upgrades to a downtown corridor in Somerville, NJ demonstrate partnership between local and state agencies to stimulate economic growth; a re-worked project in Thunder Bay, Ontario demonstrates the importance of data collection to achieve the desired effects; improvements to Americans with Disabilities Act (ADA)-compliant transit access in Washington, DC demonstrates a focus on intermodality and *all* users; and a project in Las Cruces, NM illustrates the advantages of open dialogue between planners and community members.

Memphis, TN

In 2010, Memphis was named one of the worst cities for cycling in the US (*65*). There were no bike lanes in the city, and requests from bike clubs and shops went unanswered. By 2018, the city had undergone a complete shift in regards to its bike policies: there were over 60 miles of trails and dedicated bike lanes (*66*), city employees have traveled to Europe to learn from their bike initiatives and infrastructure (*67*), and Memphis has been named one of the "Best Bike Cities in America" (*68*). How did such a drastic change happen in such a short time? The change in attitude can be attributed to one thing: public health. According to then-Mayor A C Wharton, "At that time, a large number of our children suffered from [lung disease] COPD and asthma….You can do something about that without taking a pill every day." (*69*). In addition, Memphis had been called both America's most sedentary and most obese city in 2007 (*70*). By focusing the conversation about bike lanes and complete streets on public health, the city was able to sidestep approaches that treated bike lanes as recreational and embrace approaches that addressed connectivity, mobility, and encouraging physical activity (*17*).

Progress started with a 2010 restriping project called *New Face for an Old Broad* which sought to calm traffic on Broad Avenue. 13,000 community volunteers participated in a 2-day event to reconfigure and restripe the corridor, slowing traffic and creating buffered bike lanes (*19*, *71*). *New Face* took advantage of an existing need—restriping Broad Ave—and utilized grass roots involvement to make changes at marginal cost. The resulting decrease in traffic speed and improved bike/ped facilities improved safety in the area and inspired economic growth, helping to attract $20 million in new investments over the next three years (*19*). This success helped to ease the worries of city officials, who were more willing to back CS projects in the future. In 2013, Wharton issued an executive order establishing Memphis as the 500th jurisdiction adopting CS policy.

In summary, three main facets helped ensure Memphis' success in becoming a bike-friendly city: first, taking advantage of low-cost opportunities for improvement made CS projects fiscally painless; second, early success supported implementation of additional projects; and finally, an emphasis on public health allowed the city to generate sustained investment in CS projects, avoiding implementation as recreation-focused investments.

Somerville, NJ

The small borough of Somerville, NJ is home to around 12,400 residents, and was a fairly late adopter of CS policy. Though the state of NJ had adopted a CS plan in 2009, Somerville did not adopt a plan until September of 2015 (*72*). Somerville is small and densely populated, allowing a culture of walking—before CS implementation, 7% of residents walked to work. The borough wanted to improve transit ridership and bolster economic activity along its downtown Division St. There were three distinct challenges for this goal: residents were averse to major changes, finding funding was difficult for such a small community, and Somerville did not have jurisdiction over Division Street, which doubles as New Jersey route 28 under the control of the State. To overcome these challenges, Somerville relied on strong partnerships across jurisdictional lines, working closely "with Somerset County, the Somerset County Business Partnership, Ridewise TMA, NJ Transit, and NJTPA" (*72*).

To secure funding, Somerville worked with the state of New Jersey to gain a designation as a Transit Village, granting them access to technical assistance and priority funding. They immediately applied for $1.75 million in state grants to improve pedestrian access to the transit station, effectively eliminating the financial obstacle. Partnership with the state and county also helped Somerville to overcome jurisdictional issues: developing relationships within those offices provided not only technical expertise, but avenues for communication and trust. Gaining buy-in from residents actually happened more through luck than anything else: the original intent of the development was to widen sidewalks and calm traffic, but after construction, the concrete needed time to cure. So, for 60 days, the area was open to pedestrians, but not to vehicles. The new accidental pedestrian mall was so popular, Somerville decided to keep it. Movable bollards were erected so that the road was accessible to vehicles on typical days but could be closed into pedestrian-only space for special events.

Since construction, the site has become a town gathering place, and has seen economic growth and new investment. Retail vacancies dropped from 50% to 0% within a year, and now the space is rarely opened to vehicles. Success in this project is attributed entirely to communication between the Somerville planners and the county and state offices, as well as local businesses.

Thunder Bay, Ontario

Thunder Bay has had significant challenges implementing CS policies. The city of some 100,000 residents includes both a dense urban core and sprawling rural space, making context-sensitivity an important aspect of design. Though the city adopted an Active Transportation Plan in 2008 (*73*), weak wording left loopholes from past legislation that prevented bike lanes from crossing provincial roads, making it difficult to establish a comprehensive and well-connected bike network (*74*). As a result, some CS projects have been fraught with problems. For example, the city had a hard learning experience through an improvement project on Hudson Avenue in 2012, where development of new biking facilities actually led to a *decline* in usage. The city found that the provided bike lanes did not match residents' needs, and that paint delineating bike space from vehicle space had been worn away by vehicle tires, implying diminished safety for users.

Rather than scrapping the Hudson Ave. project, designers collected additional data and modified the design. Where the original plan had created a one-directional bike lane on either side of the street and a two-way pedestrian lane on one side of the street, separated only by paint, the new design merged pedestrian and bike lanes together and created a physical barrier between active transportation users and motorists. Meanwhile, the city has been working to strengthen CS legislation and take a more unified and pro-active stance regarding active transportation, and has seen a citywide increase in cycling (*73*).

The Thunder Bay case study provides a few key takeaways for best practices. Strong policies are important to the implementation of CS projects, especially large-area projects like bike networks. A properly functioning network must be accessible and well-connected, and that requires supportive legislation that encourages addition of well-planned lane mileage. Secondly, as the Hudson Ave project shows, CS projects cannot be undertaken within a one-size-fits-all mindset. Because of the rural context of the site, motorists were accustomed to driving quickly and using the whole roadway; adding bike lanes to that context required more than just paint. Finally, this case study demonstrates the need for data collection and, at times, iteration. Planners in Thunder Bay had the exceptional challenge of integrating active transportation alongside motorists in a fast-moving rural context, but were able to succeed after observing the site, communicating with users, and revising the initial design.

Washington, DC

While many CS plans and projects focus on active transportation projects such as widening sidewalks or improving bike networks, CS applies more generally to *all* users across *all* modes of transportation. Washington, DC demonstrated this broader application when it sought to improve accessibility of transit stops for mobility-challenged users. While ADA-compliance requires that an "accessible" bus stop "1) have a firm landing surface; 2) be at least five feet wide and eight feet long; and 3) connect to the curb" (*75*), the Washington Metropolitan Area Transit Authority (WMATA) adopted a fourth criterion in 2014: "A curb cut at the corner nearest to the bus stop with a matching curb cut at (at least) one adjacent corner" (*76*). This additional criterion was intended to allow safer and easier access to transit stops, making traditional public transit services more viable for mobility-challenged users. In many areas, lack of curb cuts made it difficult or impossible for some residents to access the transit stops they needed, or to safely transfer between transit lines—the change in the criteria for ADA-compliance adopted by WMATA would necessitate work on an estimated 10,006 bus stops (*75*, *76*). How could WMATA justify that expense and effort to benefit such a small percentage of the population?

WMATA garnered support for this change by focusing on the elimination of some paratransit trips. Each paratransit trips comes at a cost to the District of some $50, while traditional transit costs between $4-$8 per trip. WMATA estimated that improving accessibility at the first 57 eligible transit stops could have as much as $600,000 return on investment in paratransit cost avoidance, in addition to hard-to-measure factors like improved independence and increased safety.

The improvements made to WMATA transit stops yield two key takeaways for practitioners. The first is a reminder that CS applies to all modes of transportation and not just to active transportation. Extension of considered users beyond bike/ped/motorist traffic allows for a more inclusive environment that may make better use of a city's existing resources, such as DC's robust public transit network. The second is that just because CS projects may not fit a traditional cost/benefit paradigm they are not necessarily incompatible with one; finding sources of benefit outside of motorist travel time reduction can be both valid and synergetic.

Las Cruces, NM

The city of Las Cruces faces a unique set of challenges. As a bilingual border town, nearly 25% of its 100,000 residents lives below the poverty level (*77*), and the mix of cultures and languages present can make community outreach and communication difficult. Though the city and local Metropolitan Planning Organization (MPO) adopted CS policies in 2008, no CS project was implemented until 2015 (highlighting the distinction between adoption of policy and tangible change in procedure discussed earlier). One major cause of this delay was lack of community engagement. To foster engagement and communication, the MPO partnered with an existing nonprofit representing underserved populations, the Empowerment Congress. This partnership allowed the MPO to demonstrate an interest in engaging with residents while giving them access to the relationships the Empowerment Congress had already established. Soon, the planning process was modified to be more inclusive, with meetings scheduled at times and places more residents would be able to attend, interpreters present for the Spanish-speaking population, and meetings advertised across a variety of platforms rather than isolated on a local government website. The content of the meetings changed too—problems were presented "in an open-ended way, without providing options for how the problem may be solved at the outset" (*77*)—allowing more engagement with the public and giving the group space to come to a solution together.

The new approach paid off in 2015, when the MPO proposed a new roadway project. In discussion with residents, the MPO discovered that residents would be better served by a bike boulevard than a road—community engagement allowed a substantial financial savings to the MPO while meeting the needs of residents.

The key takeaway from the Las Cruces case study is that communication and community engagement start in the planning process. By creating (in this case, using existing) inroads into the community, Las Cruces was able to build trust with an underserved group and to provide the improvements that were needed without driving up costs. The purpose of corridor improvement is not to increase traffic capacity, but to make life better and easier for corridor users; community engagement allows planners to correctly identify the best ways to provide those improvements.

Discussion

Each of these case studies is lacking one common feature: a detailed and rigorous before and after study to show that the initial goals of the projects were met. This is due to the inherent challenge and expense involved in collecting and analyzing this data before projects are implemented. The sum of these case studies is still anecdata—causality has not been established, and only the general perception that quality of life has improved has been established. For example, while Memphis, TN has undoubtedly become a more bike-friendly place, the initial justification for CS adoption by Wharton focused on high rates of childhood lung disease, but there is no study showing that more children are using bike infrastructure, or that use of that infrastructure is impacting rates of lung disease. This lack of proof emphasizes the need for long-term, well-controlled before and after studies to support the promises of benefit made by CS advocates. Information on public opinion, opposition to proposed or implemented changes, and public response to completed projects is also unavailable. Because public participation and public opinion play such an important role in the success of CS projects, the lack of documentation on public discussion or perceptions creates a significant gap in any analysis of outcomes.

Integration of sensing technology and smart cities can help fill in the data needs that justify some CS projects, and finding inexpensive ways to tweak planned improvements already on the books (such as adding restriping to a repaving process) can create opportunities to phase new technology into key corridors, allowing cities to prepare for the arrival of connected and autonomous vehicles one project area at a time. Similarly, policy makers must be prepared to legislate defensively regarding new technologies like dockless bikeshare or drones. Cities that prepare for these innovations ahead of time will be able to incorporate them into existing plans, diminishing the disruption often caused by new technologies.

One avenue for future research involves the identification and application of publicly available data sources for the measurement of CS project impacts. Geospatial panel data could be used to demonstrate changes in trends within the areas receiving CS investments in order to measure the tangible benefits of CS projects across a variety of metrics. An illustrative data framework presented in Figure *1* shows a possible flow for linking information from panel data to related performance measures at each site in a study area. In this example, a framework is developed that demonstrates how each site in a jurisdiction could be studied more comprehensively so that measurable outcome results can be tied back to performance of the CS design. For example, the location of each capital project in a network would be added to a GIS map with a list of the CS treatments included in that project (if any). A buffer would be drawn around each site. For each desired performance measure in the right-hand column, relevant geospatial panel data would be sampled to determine whether particular CS treatments can be correlated to improved outcomes, and whether the rate of those improvements outpaces the rate of change in control areas. The figure outlines possible panel data and how these data can be used to assess particular areas of impact and potential performance measures that could be used to document outcomes. Selection of a context-sensitive set of performance measures would allow different study areas to be evaluated according to local values, needs, and context; some data (such as AADT) may influence several performance measures. Use of a model similar to the framework in Figure 1 would allow further validation of the CS paradigm, and could provide a basis for a more bipartisan support of CS policies. If these outcomes can be linked to levels of investment and CS project descriptors, future research may show what elements of projects bear the strongest positive impacts on surrounding communities to further inform priorities for policy makers and developers.

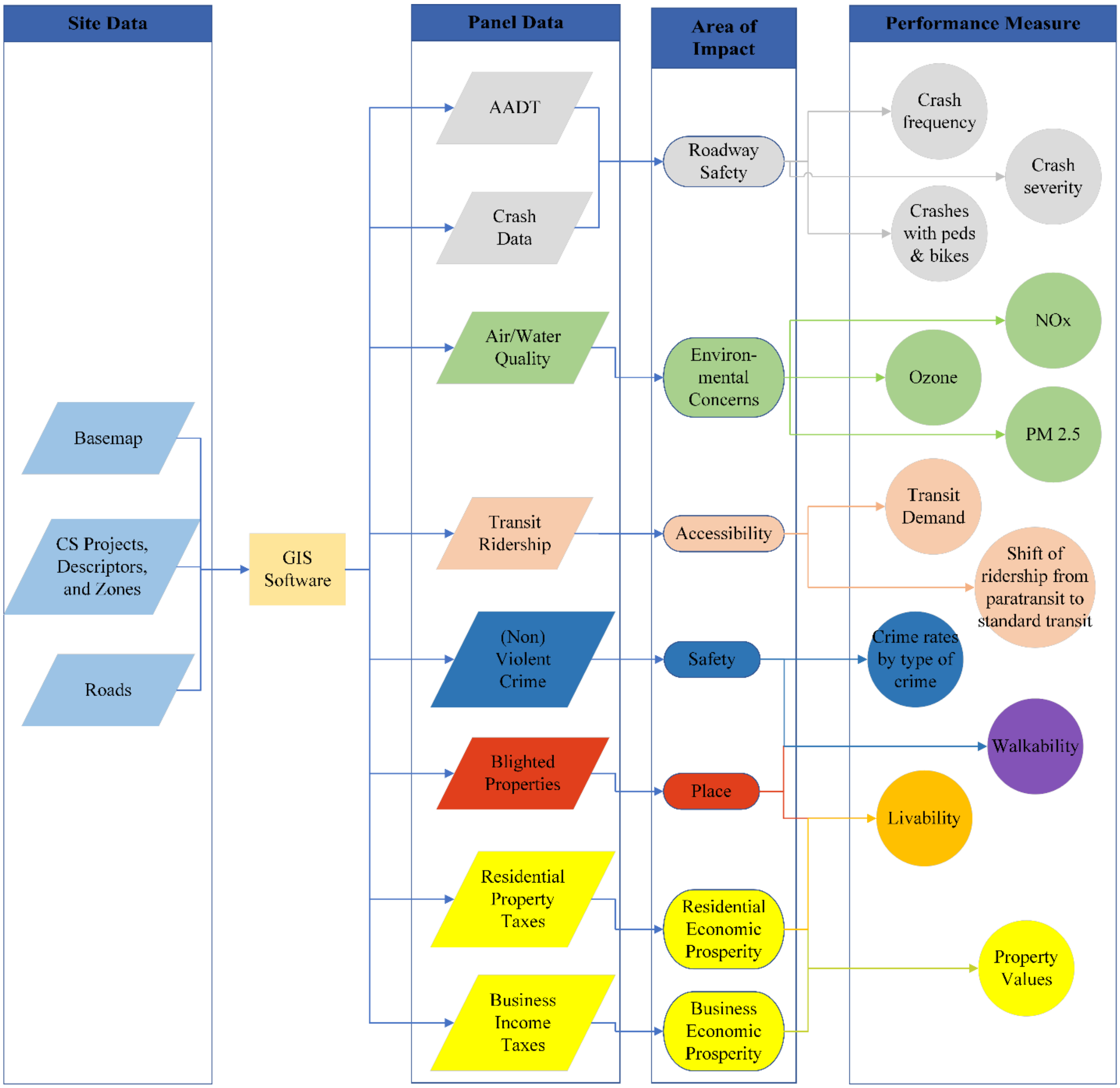

Figure 1. Illustrative Data Framework for measuring CS project benefits

Another avenue for future research is a further reconciliation of common practice with academic literature. In-depth consideration of practical approaches and the constrained resource set found in public agencies including constrained capital, constrained space, and often limited access to active transportation specialists is needed for development of research-based tools that will be successful in supporting Complete Streets programs at the local level. Similarly, if current challenges to data collection and project outcome monitoring are to be overcome, additional research is needed into accurate and cost-effective ways of obtaining those data including an expanded application of Smart Cities, Intelligent Transportation Systems, and the incentivization of new travel behaviors using such tools as Active Demand Management, rideshare programs, and parking management.

Conclusions

The definition of a successful CS project will depend on its context and goals. And although providing solid proof that a project has met its intended outcomes can be elusive, many communities find that, broadly, quality of life and social participation increase when CS projects are implemented. In practice, four key elements emerge as strong predictors of success across the board, regardless of the desired outcomes. One indicator of success is a strong local champion fighting for CS policy and processes. In the case of Memphis, it was Mayor Wharton's insistence that CS policies could affect public health that led to success; in Washington DC, it was WMATA finding creative ways to redirect costs that led allowed expansion of ADA compliance. Corridor improvement processes take time, especially when planning teams are using new or unfamiliar processes. A persistent, connected, long-term local champion can be the difference between a first successful CS implementation and a token policy document.

Another indicator of success is advocacy. When planning organizations work on behalf of marginalized or disenfranchised communities, new ideas and new synergies are brought to the forefront of discussions. In Las Cruces, advocacy meant adjusting town hall meeting times and providing interpreters. In Memphis, advocacy meant creating a cycling network designed to connect low-income residents with opportunities and foster participation in active transportation.

Regardless of the setting, clearly defining the primary beneficiaries of a project—and working to enfranchise them—tends to lead to successful projects.

Community buy-in is a natural result of advocacy coupled with communication. When planners not only work on behalf of a community but also include them in the planning process, residents and users can share their needs and take ownership in local projects. When residents are included early in the planning process, they feel listened to and valued; skepticism and aversion to change can be replaced with trust and mutual understanding. In Somerville, partnerships across jurisdictions and communication with the business community led to economic growth and valuable shared space; in Las Cruces, community outreach resulted in completely redefining the scope and scale of the proposed project, better meeting the needs of residents at reduced cost.

Finally, as demonstrated in Thunder Bay, iteration is a key element of successful CS projects. Solutions that work well in one context cannot always be copied into another, and building successful projects will take trial and error on the part of planning teams. However, iteration is a precarious step—it trades on the banked goodwill of stakeholders. When those stakeholders have been involved in the process and trust is high, there is room for iteration and improvement. The need to iterate highlights the need for the other elements discussed here—a local champion, advocacy, and community buy-in.

The next step for the CS movement is clear. Advocates of CS policies must work to bridge the gap between cost/benefit analysis and CS. Demonstrating tangible capital benefits to CS projects could help to garner bipartisan support and improve funding opportunities for new projects. Bridging this gap will require collection and dissemination of panel data across study areas, and communicating successes. Sharing outputs with stakeholders in the short term can provide a sense of instant accomplishment, while tracking and sharing progress in outcomes can help to build long-term support of CS projects and policies.

Data Availability Statement

No data, models, or code were generated or used during this study.

Acknowledgements

This research was made possible with support from the Intermodal Freight Transportation Institute at the University of Memphis, and from the Dwight D. Eisenhower Transportation Fellowship Program. Any opinions, findings, conclusions, or recommendations are those of the authors and do not necessarily reflect the views of the Federal Highway Administration or the University of Memphis. The author would like to thank Drs. Stephanie Ivey and Sabyasachee Mishra for their guidance and support on this project.

COMPLETE STREETS: THEORY AND PRACTICE

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Abstract

As the Complete Streets movement grows into maturity, there is a broad focus on empirically cataloging both primary and secondary benefits of Complete Streets projects. With over 1,400 US jurisdictions formally adopting Complete Streets policies, gaps are emerging between academic approaches to Complete Streets analysis and the heterogeneous approaches utilized by practitioners and public agencies. This paper reviews attempts to analyze the benefits of Complete Streets projects and uses a practitioner survey to identify current state of the practice. Contrasting academic approaches to Complete Streets with current practice provides recommendations for further research and identifies opportunities for growth in Complete Streets practice.

Keywords: Complete Streets, Outcomes, Practice, Theory, Benefits, Analysis

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Introduction

There is a gap between academic literature regarding Complete Streets (CS) and the application of CS theory in professional practice. This gap exists at every step of the project planning process from site selection and valuation of perceived benefits, to context awareness and even feature design. In academic literature, CS advocates tout the supposed secondary benefits of CS projects pertaining to improved public health, reduced pollution, and social justice (among other areas of benefit). Advocates use those secondary benefits as the basis for recommending CS approaches to project design; there is an underlying expectation that Metropolitan Planning Organizations (MPOs) and city Departments of Transportation (DOTs) will first identify a potential locus of livability challenges, then use CS projects to treat those challenges. This expectation, however, is question-begging: does this realistically represent the approach taken by public agencies in deciding whether, when, and where to implement CS elements in transportation projects?

In this paper, we use survey data collected from current MPO and city DOT practitioners specializing in active transportation initiatives to compare common real-world approaches to CS projects and policies with academic literature, and to better describe the gap between CS theory and practice. We collect and summarize attempts to catalogue both the primary and secondary benefits of CS practices, and compare those with project outcome evaluation as performed by practitioners. Finally, we offer a case history of one jurisdiction's early experience with CS project implementation, and utilize the lessons learned in conjunction with the survey results to recommend development of new tools that will benefit CS practitioners and help to close the gap between CS theory and practice.

Overview of Literature

CS advocates promise an array of benefits from CS projects. Broadly, these benefits can be split into two categories: primary outcomes are those directly intended and achieved through project implementation; secondary outcomes result from behavioral changes resulting from CS projects. For example, improving traffic safety or increasing active transportation participation rates are often the direct objectives of project planners and designers and are therefore considered primary project outcomes. However, improving traffic safety may be achieved through a road diet, which in turn may reduce total traffic volumes in the project area, which in turn may reduce emissions and improve air quality (*78*). Increased participation in active transportation may help to reduce occurrences of obesity and heart disease in the community (*79*, *80*). Improved air quality and public health, then, are secondary benefits of CS projects. Primary outcomes can typically be directly analyzed using before-and-after studies around project locations, while secondary outcomes often rely on logic pathways to infer results that are difficult to measure (*81*). In fact, the logic pathways resulting in secondary benefit claims can be contradictory, as shown in *Figure 2*. As a result, a great deal of academic effort has gone into attempting to empirically measure and catalogue the benefits of CS projects; a sample of these efforts is presented in **Error! Reference source not found.**. **Error! Reference source not found.** shows the category of outcome studied, the method applied, and the summary result of the study. Table cells indicate the more specific metric studied within each category of outcome. Studies that indicated a need for more data are noted in the ‘Data’ column; N/A in ‘Data’ column indicates a theoretical model that required no empirical input data. Some studies do not indicate a need for more data, but have limited generalizability; these are noted as No*.

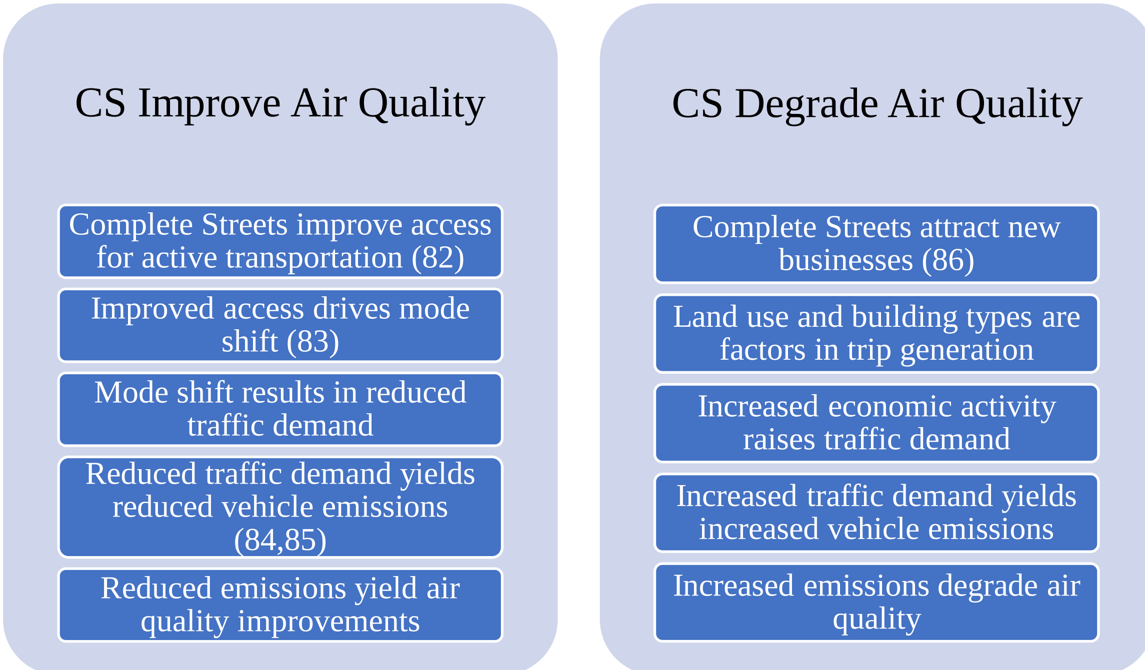

Figure 2. Contradictory logic pathways (*82–86*)

Table 1. Sample Studies Showing Benefits of CS Projects

Short Title	**Year**	**Econ-omics**	**Safety**	**Environ-ment**	**Equity**	**Multimodal**	**Method**	**Results**	**Data**
Improving Cyclist and Pedestrian Environment (*87*)	2013		Non-motorized vehicle safety			Non-motorized traffic volumes	Before-and-after; single site	Increased bike/ped volumes with no significant changes to vehicular traffic	No
Lessons Learned from Adopting the HSM (*88*)	2014		Crash Modifi-cation Factors				Theoretical	CMFs provided in HSM may not be applicable to multimodal CS projects	N/A
CS Design: Emission Impact (*89*)	2014			Emissions			EPA emission model	CS may increase congestion, increasing emissions.[7]	N/A
Double Benefit from Green Street Design (*91*)	2014			Life cycle energy and greenhouse gasses			Theoretical life cycle analysis	CS yields lower life cycle emissions & GHG than traditional design	N/A
Changes of Street Use (*92*)	2014			Air quality		Ped participation	Before-and-after; single site	Improved air quality and increased ped participation rates	No*

[7] Results are based on a hypothetic road diet; it is generally considered poor practice to implement a road diet when demand is high (*90*)

Table 1 Continued. Sample Studies Showing Benefits of CS Projects

Short Title	**Year**	**Econ-omics**	**Safety**	**Environ-ment**	**Equity**	**Multimodal**	**Method**	**Results**	**Data**
Capturing the Benefits of CS (*86*)	2015	Property values & job growth					Three case studies; interviews and data from LEHD and County Property Assessor	Correlation between Complete Streets projects and increased property value, job growth	Yes
Safer Streets, Stronger Economies (*93*)	2015	Averted costs	Reduction in crashes & injuries			Mode split	Varied before/after studies at 37 sites	CS are safer than traditional projects. They encourage economic growth and diversify mode split.	Yes
Walkability, Complete Streets, and Gender (*94*)	2017				Gender equity		Comparison of four sites	Greater walkability correlates to increased ped usage and gender parity	Yes

Table 1 Continued. Sample Studies Showing Benefits of CS Projects

Short Title	**Year**	**Econ-omics**	**Safety**	**Environ-ment**	**Equity**	**Multimodal**	**Method**	**Results**	**Data**
Effect of BRT on Physical Activity (*95*)	2017				Improved access for women with low education	Ped participation	International Physical Activity Questionnaire, before and after site intervention	Increased ped participation, users willing to walk farther to access transit services	No
Assessing the Economic Benefits of CS (*96*)	2018	Home values					Single-site. Changes in single-family property value during boom (2000-2007) and price resilience during recession (2007-2011)	Home value and value resilience increase with proximity to CS.	Yes

Table 2. Sample of Studies Showing Benefits of CS Project Elements.

Short Title	**Year**	**Element**	**Economics**	**Safety**	**Environ-ment**	**Multimodal**	**Livability**	**Oper-ations**	**Method**	**Results**	**Data**
Safe Streets, Livable Streets (*97*)	2005	Traffic calming		Reduction in crashes and injuries					Theoretical, with anecdotal example	Narrower roads are safer in urban contexts	Yes
A Field Evaluation Case Study (*98*)	2009	Traffic calming			Emissions & fuel use				GPS data and emissions modeling	Sudden acceler-ations around traffic calming devices may increase emissions and fuel use	Yes

Table 2 Continued. Sample of Studies Showing Benefits of CS Project Elements.

Short Title	**Year**	**Element**	**Economics**	**Safety**	**Environ-ment**	**Multimodal**	**Livability**	**Oper-ations**	**Method**	**Results**	**Data**
Protected Bike Lanes in NYC (*99*)	2014	Bike lanes	Retail sales	Injury crashes, ped injuries, bike injuries		Bike/ped participation rates			Before-and-after analysis	Bike lanes increase bike volumes and decrease injury crashes. Also increase in nearby retail sales.	No
Road Diet Info Guide (*100*)	2014	Road diets		Conflict points, crash rates			Delays, speed harmonies		Literature synthesis	Road diets lead to rash reduction (19-47%); speed reduction s and improved speed harmony; reduced delays	No

Table 2 Continued. Sample of Studies Showing Benefits of CS Project Elements.

Short Title	**Year**	**Element**	**Economics**	**Safety**	**Environ-ment**	**Multimodal**	**Livability**	**Oper-ations**	**Method**	**Results**	**Data**
4th Avenue, Sunset Park (*101*)	2014	Traffic calming		Crash rate, ped injuries		Bike/ped participation rates			Before and after, single site	Crash reduction (12%), ped injury reduction (29%), speeding reduction (38%). Increased ped volumes.	No
Road Diet Case Studies	2015	Road diets		Yes			Yes	Yes	Synthesis of 24 case studies	Improve safety, operation, and quality of life; non-specific.	N/A
Does Walkability Matter? (*102*)	2015	Walk-ability	Housing values, foreclosures	Crime rates					Correlate Walkscore ™ with sustain-ability	Walkability improves economic health and decreases crime	No

Table 2 Continued. Sample of Studies Showing Benefits of CS Project Elements.

Short Title	**Year**	**Element**	**Economics**	**Safety**	**Environ-ment**	**Multimodal**	**Livability**	**Oper-ations**	**Method**	**Results**	**Data**
When a Diet Prompts a Gain (*103*)	2016	Road diets				Bike counts, gender parity of cyclists		Auto-mobile travel times	Single site, bike/ped counts before/after constr-uction	Significa ntly higher bike counts and gender parity after constr-uction	Yes

Table 2 Continued. Sample of Studies Showing Benefits of CS Project Elements.

Short Title	**Year**	**Element**	**Economics**	**Safety**	**Environ-ment**	**Multimodal**	**Livability**	**Oper-ations**	**Method**	**Results**	**Data**
Traffic Calming and Obesity (*81*)	2017	Traffic calming		Public health					Literature review	Active transport leads to better health; insufficient evidence that traffic calming yields sufficient increases in active transport to affect public health	Yes

Table 2 Continued. Sample of Studies Showing Benefits of CS Project Elements.

Short Title	**Year**	**Element**	**Economics**	**Safety**	**Environ-ment**	**Multimodal**	**Livability**	**Oper-ations**	**Method**	**Results**	**Data**
How's that Diet Working? (*90*)	2020	Road diets	Retail sales, home value	Crash rates		Bike/ped participation, reduced pedestrian injury crashes	Reduced speeding	Delay	Literature review	Crash reductions, improved connectivity for nonmotorized modes, improved livability, economic benefits	Yes

Direct measurement of the benefits of CS has been a particular challenge for advocates and researchers alike. While a traditional approach to design can utilize benefit cost analysis, the benefits of CS projects are often diffuse and difficult to monetize (*83, 104*). Additionally, CS projects may have different goals and elements based on context. Defining a CS project as one that *considers* all users and all modes of transportation does not imply that every CS project should carve out physical space for every mode or every activity; not every CS project will provide grade-separated bike lanes, bus bulb outs, and pedestrian refuges. As a result of the variety of shapes and contexts for CS projects, many studies have focused on measuring the outcomes of one aspect or element of CS.

Table 2 provides a sample of these studies and their results. Of those elements of CS studied, road diets and traffic calming are most common. A comprehensive study of the effects of road diets through 2014 can be found in the *Road Diet Informational Guide* (*100*); an equally comprehensive study from 2014-2019 can be found in the work of Ohlms et al (*90*).

One common claim made by CS proponents is that CS projects have beneficial impacts on public health measures like obesity and cancer rates. The abbreviated logic pathway is as follows: the built environment can encourage participation in active transportation which influences level of physical activity, which in turn affects overall physical health (*79, 84*, *105*, *106*). In a 2017 review, Brown et al explore this logic pathway in relation to traffic calming[8] (*81*), though without conclusive results. The lack of conclusive evidence found by Brown, et al encapsulates the challenge faced by CS advocates looking to empirically prove secondary benefits for CS projects: while many studies show that CS projects and the elements that compose them meet the *primary* objective of improving traffic safety in the immediate project vicinity, little or no data are collected on the supposed *secondary* benefits of these projects. While a feasible logic path exists for many of these claims (*104*), empirical studies are lacking. Instead, heavy emphasis is placed on anecdotal accounts or perceived improvement from stakeholders (*108*).

Observations from COVID-19 Lockdowns

While no substantive research has been completed on the long-term effect of CS projects on local air quality, the global experience with the COVID-19 pandemic provides evidence that

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[8] The US DOT defines traffic calming as "the combination of measures that reduce the negative effects of motor vehicle use, alter driver behavior, and improve conditions for non-motorized street users" (*107*). The presence of traffic calming, while neither necessary nor sufficient to identify a CS project, is often an element of CS projects whether in terms of network design (ie, restriction of traffic movements) or in terms of physical interventions like speed humps, chicanes, or roadway narrowing.

CS projects may in fact yield a substantial decrease in air pollution. CS projects encourage behavioral change at the consumer level. During lockdowns following the COVID outbreak, vehicular traffic was reduced drastically (*109*, *110*) due to restrictions related to the pandemic. At the same time, surface-level concentrations of $PM_{2.5}$ dropped 35% in northern China and concentrations of NO_2 diminished by 20-40% in Western Europe, the US, and China (*111–113*). Together, these two studies provide strong evidence[9] that a major reduction in vehicle traffic at the consumer level will in fact cause substantive reduction in air pollution. While this correlation may seem obvious in theory, COVID-19 lockdowns have provided the first widespread test. Whether successful CS projects can remove sufficiently many vehicles from the roadway, however, remains an untested hypothesis.

In many parts of the US, the COVID-19 lockdowns have drawn similar attention to roadway fatalities. Nationally, March 2020 saw an 18.6% decrease in VMT compared to March 2019. While the total number of roadway deaths decreased in that time period, the death rate per VMT increased around 14% (*114*, *115*). Some of this increase can be attributed to an increase in street racing and other reckless driving behavior (*114*, *116*). Straight, wide streets with capacity that greatly exceeds traffic volume seem to invite reckless behavior; this observation directly confirms the theories provided by Dumbaugh in 2005 (*97*). This trend has special implications for Complete Streets: the presence of higher traffic volumes on the roadway serves as an important traffic calming measure. Because Complete Streets typically (though not exclusively) supply additional traffic calming measures within CS project spaces, the expansion of CS practices may help to curb reckless driving in other areas even when traffic volumes are low.

[9] At the time of manuscript submission, it is far too early to claim that this evidence constitutes *proof*, merely evidence through inductive reasoning. Tangible proof will require carefully controlled long-term study, in addition to final peer review of (*113*).

Areas where roadway capacity greatly exceeds demand may reap safety benefits from the application of CS treatments.

Challenges to Empirical Measurement of Outcomes

While using ground-level data to empirically analyze outcomes for CS projects is in the zeitgeist in academic literature, attempts to perform this analysis face several challenges. As shown in Tables 1 and 2 above, 10 out of the 16 discussed empirical studies mentioned a lack of data as a barrier to analysis or generalizability. In general, the kind of dense, granular, longitudinal data necessary to make strong claims about outcomes—secondary outcomes in particular—are often not collected or not readily accessible (*93*) or may rely on subjective perceptions (*117*). A distinction between publicly available data and publicly accessible data is pertinent to this discussion: publicly accessible data can be freely used by anyone, without restriction or proprietary access. Most of the data of interest to CS researchers—such as crime statistics, crash rates, or usage counts—are publicly accessible *in theory*. In fact, however, much of those data are not publicly available: the organizations that collect and house the data are under no obligation to share it with the public, and may not have the data housed in a format that is readily searchable. Researchers cannot access these data without significant networking, effort, and/or expense.

A second hurdle for researchers attempting to empirically measure outcomes of CS projects is that causation is significantly more difficult to show than correlation. Given the right spatiotemporal dataset, researchers may be able to show that CS investments do correlate to desired primary and secondary outcomes: CS projects may lead to improved roadway safety and increased participation in active transportation (primary outcomes), and may show the associated improvements to public health and air pollution levels (secondary outcomes). However, demonstrating causality in these areas would necessitate controlling for underlying factors: what changes have been made to emission regulations or nearby manufacturers that could have a more direct effect on pollution levels? What improvements to other local public health initiatives might better explain lower rates of obesity or heart disease? Proving causality requires a significantly more robust dataset than proving correlation, and proving causality may be necessary before attempting to optimize outcomes of capital projects in general, or CS projects in particular. Similarly, attempts to optimize outcomes require not only an empirical measurement of CS project outcomes but also empirical measurement of alternative types of capital projects. Budgets and space are both finite resources, and CS projects (like any other capital investment) come with opportunity costs (though of course these may be mitigated by good project prioritization tools (*118*)). Researchers attempting to optimize project outcomes must treat those outcomes as a function of the time, capital, and space spent on those projects; they cannot be meaningfully analyzed in a vacuum.

The Complete Streets concept is closely related to context sensitivity; in fact, context sensitivity is a necessary (though not sufficient) condition of Complete Streets (*119*). Because of this connection, it is helpful to discuss Context Sensitive Solutions and Design (CSS/D). According to the FHWA, CSS/D "is a collaborative, interdisciplinary decision-making process and design approach that involves all stakeholders to develop a transportation facility that fits its physical setting" (*120*). In short, context sensitivity means taking into consideration the *entire context* of a project or plan: the community's needs and history, the local environment and climate, equity, network connectivity, political forces, and more. Unfortunately, context sensitivity in CS projects can introduce circularity into the models of researchers seeking to catalogue CS benefits. When planners and designers select sites for CS projects and incorporate the individual features for a project, those practitioners are (ideally) considering much more than the surrounding streetscape. So when a model *is* able to show that, for example, "Complete Streets encourage more walking and bicycling" (*78*), interpretation of that finding must be taken with care and nuance. The key takeaway of this finding is not 'bike lanes should be added to all projects', but rather 'practitioners are using good judgment in deciding where and how to include bike lanes in projects.' In other words, due to the circularity that context sensitivity can introduce into benefit analysis models, the findings of these models must often be used descriptively rather than prescriptively.

The final challenge in measuring the benefits of CS projects is a philosophical one. The main point of benefit analysis is to say "Neighborhoods with Complete Streets are better off than those without" according to some set of metrics such as livability, safety, or accessibility. This can be demonstrated using geospatial models and panel data: areas within a given radius of CS projects are tested before and after project implementation to see whether the metric of interest has improved. However, the most basic input for this model is the set of CS project locations which may require a binary distinction between what *is* and what is *not* a CS project. A more accurate estimation of CS projects will not ask "Is this a CS project?" but rather "How 'Complete' is this project?" This question necessarily increases the complexity and subjectivity of any model.

Examination of Current Practice

While documenting current academic perceptions of and approaches to CS policies and projects can be handled through literature reviews, determining how the public sector deals with CS can be more challenging. Neither formation nor implementation of CS policies is standardized, and approaches vary between jurisdictions. In order to examine how different agencies define and approach CS practice, two tactics are adopted in this paper. First, a survey (see Appendix A) was sent to CS practitioners across the United States. Second, interviews were conducted to provide a case study regarding one seminal CS project in Memphis, TN. The purpose of the surveys is to gather cross-sectional data across the US to show common practices and to compare motivations for CS practices between organizations and jurisdictions. The interviews provide an in-depth look at the genesis of one city's CS experience and help to show a more nuanced approach. The survey was presented online and distributed via email to MPO directors and city active transportation managers. Contact information for the MPOs was taken from a national database (*121*). Contact information for city DOTs was searched manually: a list of cities was curated from NACTO members and medium to large cities in more than 20 states. Each city's website was searched for a CS liaison, active transportation director, bike/ped office, or similar title. In all, the survey was sent to 401 MPOs (47 of which returned with address errors) and 90 city DOTs. Out of those 491 surveys, 50 responses were returned for a 10.2% participation rate. Because each question in the survey was optional, the number of responses for each survey question is included in the survey analysis in the next section of this paper.

Of the 50 respondents, 11 came from city DOTs and 39 came from MPOs. Of these, 31 respondents (all 11 cities and 20 MPOs) had formally adopted CS policies; 19 had not. *Figure 3*a shows the year each respondent's agency adopted their CS policy and demonstrates the wide range in CS policy age. *Figure 3*b shows the breakdown of respondents by agency type. Respondents represent agencies from 32 different states.

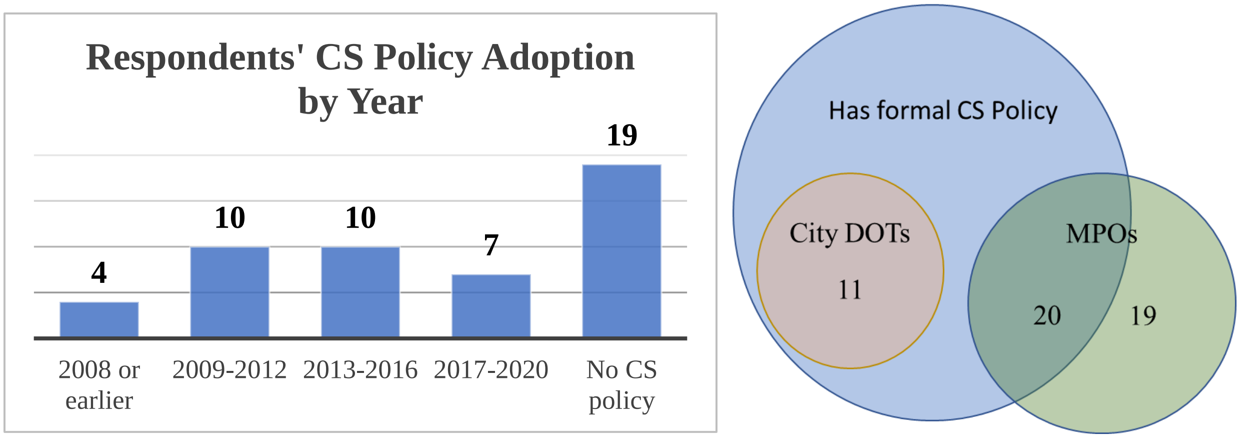

Figure 3. Time period of policy adoption (left) and division by agency type (right)

Analysis of Survey Responses

The survey included the question "How does your agency select Complete Streets project locations?" in order to better assess what motivates each jurisdiction to apply Complete Streets elements. Twenty-nine (29) practitioners responded to this question, and their answers fit into the following six categories (with some responses fitting multiple categories; totals do not add to 100%). Table 3 shows the frequency of each type of response, and quotes a response that typifies the category. "Top-down" methodologies emphasize long-range planning or Transportation Improvement Plans (TIPs). "Bike/Ped" approaches seek to apply CS elements where active transportation use is already high. "Crash reduction" strategies use CS projects to mitigate hot spots for crashes. "CS Lens" approaches seek to eliminate the binary distinction between what is and is not considered a CS project by viewing all projects as candidates for CS elements. "Ad Hoc" approaches lack a formalized strategy and rely on suggestions from staff and citizens, or seek to leverage grant funding as it becomes available. Around 10% of respondents stated that site selection is handled by a different agency.

Table 3. Methods for Site Selection (N = 29)

Method	Example Quote	Number	Percent
Top-down	"MPO plan references thoroughfare plan, non-motorized plan for typical cross sections, etc."	9	31%
CS Lens	"All transportation improvements should follow complete streets guidance. We are trying to get away from differentiating complete streets projects from other projects."	6	21%
Bike/Ped	"where ped traffic is high"	4	14%
Ad Hoc	"Staff recommends projects in our Long-Range Plan and TIP, which are approved by Executive Board"	4	14%
Crash Reduction	"Crash rates"	4	14%
Not handled at respondent level	"MPO Member Entities select projects."	3	10%

The survey also included the question "How does your agency decide which projects should be "complete", or how "complete" a project should be?" Responses followed a similar pattern to that shown in Table 3: 21% indicated that all streets should be complete, while 17% referenced a master planning document. 14% rely on input from the design team, and another 14% rely on context sensitivity. The specific CS elements included or mode(s) considered varied, with emphasis placed on context and general network health.

The survey included a total of eight questions related to data collection, data storage, data sharing, and data usage: two free response questions and six five-point Likert questions. A summary of responses to the Likert questions is shown in Figure 4; note that due to the limited number of respondents, the five-point Likert scale has been aggregated to a three-point scale.

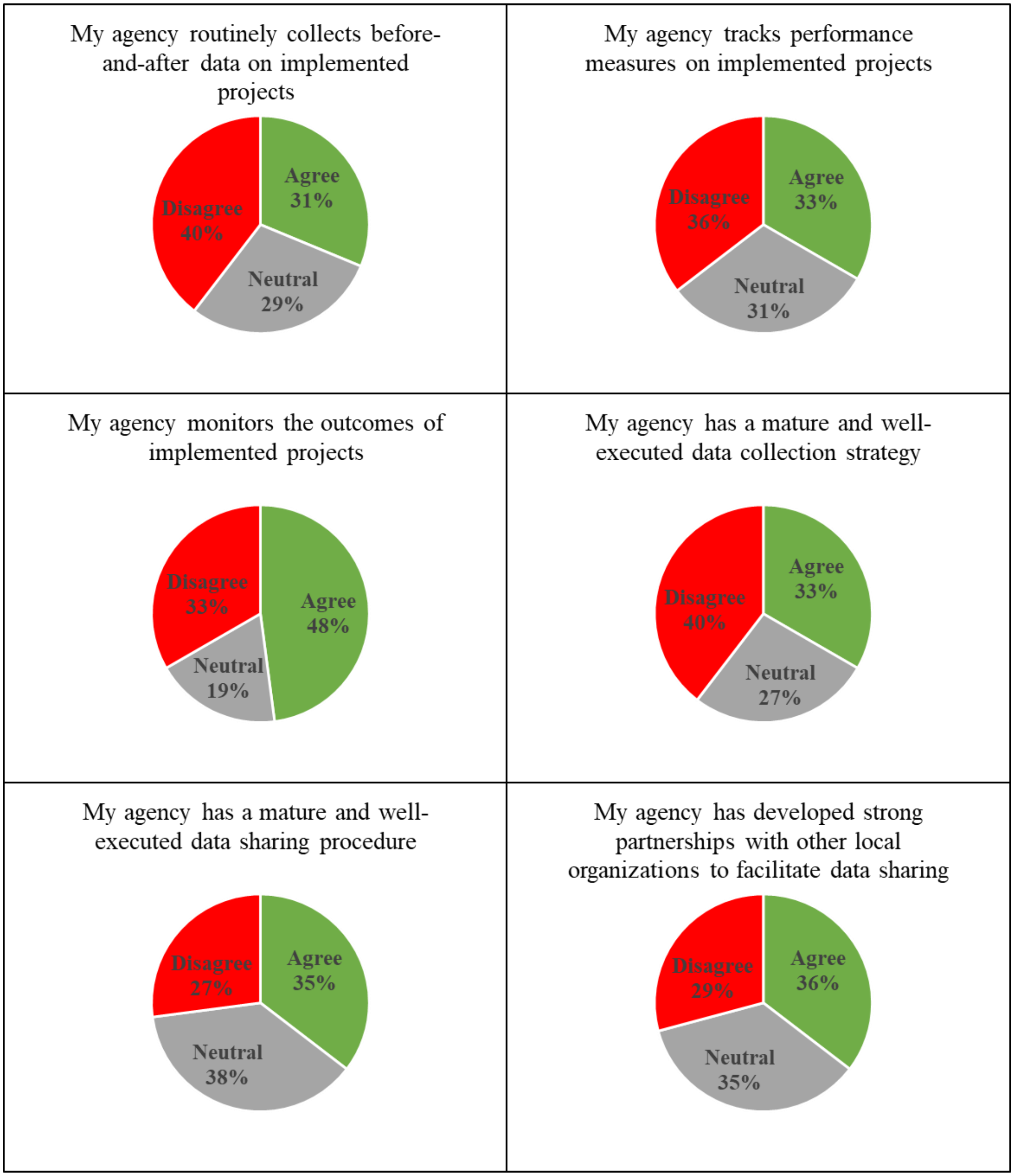

Figure 4. Practitioner Evaluation of Data Management Practices (N = 48)

There is a disparity between the respondents' answers to questions about outcome monitoring. 48% agree that their agency "monitors the outcomes of implemented projects", but only 31%

agree that their agency "routinely collects before-and-after data on implemented projects". In fact, practitioners feel more confident in the ability of their agency to *share* data than to *collect* that same data. This contrast suggests that outcome monitoring may be driven by impression and user sentiment, rather than by hard data. The lack of hard data is further shown by the free response section (N = 39 respondents) of the survey: 38% of respondents say monitoring of project outcomes is either not performed by their agency or not performed at all; 25% stated that outcome monitoring is either ad hoc or uses public feedback as a proxy; the remaining 37% use a combination of crash data, bike/ped usage counts, and performance measures.

Perhaps the most important question included in the survey was a 5-point Likert scale question that stated "My agency has a mature and well-executed Complete Streets Policy". All 19 of the MPOs that do not have a CS policy gave neutral or 'disagree' responses. The remaining responses are shown in *Figure 5*.

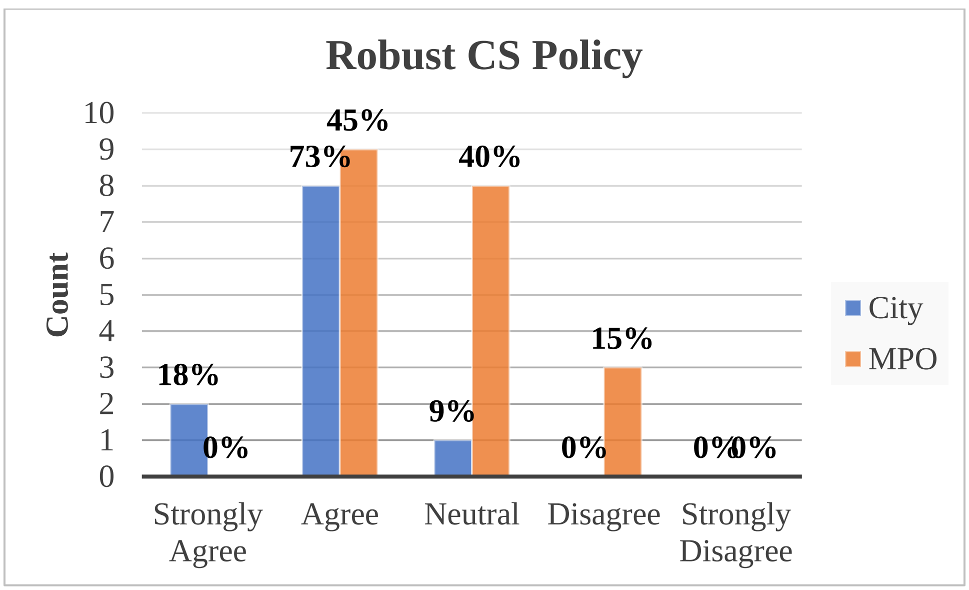

Figure 5. Responses to "My agency has a mature and well-executed Complete Streets Policy"

Overall, city DOTs generally feel positively about their CS policies, while MPOs do not. However, this is where statistically significant analysis of these responses ends. There was no correlation between practitioners' general sentiments toward their CS policy and any other investigated question. The age of the policy, collection of data, and method of site selection had no significant bearing on whether practitioners felt their policy is robust and well-executed.

Only one agency submitted multiple survey responses. An MPO in the Southeast region submitted a response from the MPO coordinator and another from a Transportation Program Manager. These two responses were in agreement on free response questions: both gave similar responses when asked to define a Complete Street or asked how project locations are selected. However, responses to Likert scale questions varied widely. Of the 10 Likert questions, these two respondents answered differently on 7 questions, indicating a difference in how each practitioner perceived its agency's success with particular aspects of its policy.

Case History: New Face on an Old Broad

A brief case history offers additional insight into how fledgling CS policies can be developed, how sites can be selected, and how benefits can be measured and used to promote future CS polices and projects. Interviews were conducted with two CS practitioners in Memphis, TN. The first (*122*) is a Transportation Planning and Design Engineer working with Capital Improvement Projects for the City of Memphis. The second (*123*) is the Executive Director for a non-profit NGO that "supports the revitalization of Memphis neighborhoods through public policy development and advocacy, organizational capacity building, and community education" (*124*). The NGO official worked to implement Memphis' first CS project in 2010; the success of this project led to the adoption of a formal CS policy by the City of Memphis (under executive order by then-mayor AC Wharton (*125*)). Both the city engineer and the NGO official assisted in the development of the Complete Streets Project Delivery Manual (CSPDM) (*126*), and the city engineer now ensures conformance of city Capital Improvement Projects with the CSPDM. Interviews with these two practitioners provide a unique long-term view of the evolution of CS policy and practice in Memphis, TN, as well as how a flagship project helped to kickstart the city's CS approach.

In 2010, Wharton pledged the construction of over 50 miles of bike lanes in Memphis (*127*) At the time, there was no CS policy on the books; the stated intent of this broad infrastructure investment was to improve public health by providing safe areas for active transit: "At that time, a large number of our children suffered from [lung disease] COPD and asthma….You can do something about that without taking a pill every day." (*128*). The move would make use of the Federal Highway Safety Improvement Program (HSIP) fund. Generally, however, awareness of the CS paradigm was low and support from many city officials was unenthusiastic. Because of this lack of awareness and enthusiasm at the political level, the drive for a CS project was not mandated through any official, top-down channel but rather came as a grass roots response to community interest. Cycling advocates and NGOs were looking for an over-built and under-utilized space where bike lanes would make sense, and found that space along Broad Avenue. "[We] had pushed for protected bike lanes [at another location]…, but had very vocal opposition from a large owner of properties along the street, and he got it shut down fairly quickly…[Broad Avenue business owners] all said 'We want something to happen here, and we're willing to take a risk'."

Broad Avenue was a four-lane street one block north of a major thoroughfare—Sam Cooper Blvd—which handled the majority of thru-traffic conveyance. Broad Ave consisted primarily of retail space and had a high vacancy rate (*122*). With sidewalks crumbling and businesses struggling, landowners and retail tenants were pushing for change. “That’s really been the most important piece in this process: when the business owners, the residents, the people who are on that street day-to-day want something to be done about high-speed, low-ish volume traffic” (*123*).

The layout of the street made it ripe for a road diet. Broad Avenue was a high capacity, low demand street in a retail area, and existing curbside had few breaks for driveways which allowed low conflict with a new bike lane. However, while the context of the physical infrastructure and network in the area had some influence over site selection, the much larger attraction for this location was the socio-political context. With the community pushing for change and a promise from the Mayor, the NGO was able to raise awareness and volunteers to put in a temporary restriping at the tactical urbanism level. In late 2010, the project was publicized under the name “New Face on an Old Broad”, emphasizing the reclamation of space for users and consumers. Because the plan was for a temporary restriping, the NGO created a weekend-long event to showcase how the re-imagined area would function. The event introduced the public to how the new space would be used, emphasizing bike/ped traffic on a slower corridor. The date was set to coincide with another major bike project in the area: the opening of the Shelby Farms Greenline—an unused rail line converted into a trail—and took advantage of an overlap in promoting the two events.

Another important piece of the socio-political context was the investment landscape in the area. “There were a few new businesses, mainly the art galleries, and a couple of new bars and restaurants that were getting ready to start”(*123*). These, in addition to a few businesses that had been in the area for years, showed that Broad Ave. was ready for revitalization. The New Face project, then, was able to catalyze new investment in the area rather than trying to start from scratch. “I think that’s true of these events kind of across the board. We always want it to be adjacent to some new area of investment. We want it to be a place with some kind of inertia or momentum” (*123*).

The event itself drew tremendous grass roots support. There were over 200 volunteers working behind the scenes to promote the project and to conduct the work. The NGO official cites the amount and diversity of supporting talent as a major factor in the event’s overall success: “With New Face, we had artists, craftspeople, business owners, community leaders, we had designers on hand. Even if they weren’t architects or [landscape architects] or something like that, they had design sensibilities…We had planners and students of transportation, so I feel like for that particular event, we had just about all the parts you could ask for. We had folks who could do the advertising and designing, we had folks who could do the streetscape planning and make sure it was to code and things like that.” Where many community events utilize a handful of people and ask them to work outside of their expertise, New Face was able to let volunteers act within their areas of strength.

Another main feature of the event was to show how the corridor would feel with fewer vacant storefronts; business owners recognized the need to bring a critical mass of foot traffic in order for their businesses to be sustainable. To that end, artists and entrepreneurs were invited to set up short-term pop-up shops during the event using vacant spaces. This was of major benefit to property owners: it cost little or nothing for them to allow use of their spaces for a weekend, while serving as a connection point between property owners and entrepreneurs. For a weekend, previously vacant retail spaces were filled with bookstores, art galleries, and even a bike shop with a quarterpipe for skateboarding. As a result, streetscape went from empty to vibrant and bustling; an estimated 13,000 people attended the event.

Outcomes from New Face were far-reaching. Within five years, the area featured 29 property build/renovations with 25 new businesses and over $15 Million in new investments (*123*). Occupancy and rents had both increased, and 17 blighted properties had been reclaimed (*123*). Business owners were seeing increased revenues: “All of a sudden, people were noticing your business that had never noticed it before because they were speeding by at 45 [mph] or greater” (*108*). Some of these changes are evident in *Figure 6*, taken before and after project implementation.

Figure 6. Broad Avenue in 2007 prior to project implementation (left) and in 2011 after completion (right).

The success of New Face created a starting point for the Memphis CS policy. Residents and local business owners now had a positive perception of CS initiatives, and experience with how they could be used to reinvigorate a corridor. City transportation officials now had a tangible experience with what had previously only been an abstract concept. This flagship project was needed to refine the city’s policy from a promise to provide additional bike lanes to a formally adopted CS policy, and later to the development and adoption of the Memphis Complete Streets Project Delivery Manual. By 2019, the City’s approach to CS projects was philosophical and multimodal, focusing on the holistic design of public spaces. “We try to view all public works projects through a Complete Streets lens, and to add the elements of Complete

Streets that fit the context for each project" (*122*). There is still room for growth with the Memphis CS practice: "We have vital pieces of the system that are essentially public rights of way on private properties, so there is still a disconnect between the land development process and the infrastructure right of way process" (*123*). Further development of CS practice in Memphis will hinge on improving coordination between city agencies and inclusive planning processes.

The central lesson illustrated by New Face and the evolution of Memphis' CS practice is that 'context' includes much more than just the physical layout of the surrounding streetscape. Residential attitudes toward redevelopment of spaces, political will, and available investment capital all contribute to successful project planning and implementation. In addition, CS projects must be more meaningful than just the addition of bike lanes. Modern CS projects include consideration for stormwater and power management, freight access planning, and incorporation of public transit and micromobility (where consideration does not necessarily imply delivery of infrastructure).

Discussion

There is a disparity between how academics and practitioners view CS projects. In terms of site selection, secondary benefits dominate the discussion in academic literature. A focus is often placed on benefits that are intangible or causal impacts are difficult to measure: streets become more inviting, more accessible, and more equitable; air and surface water are cleaner; contributions to global warming are reduced. In practice, transportation agencies are not expressing an interest in these metrics. Only 28% of respondents indicated using CS projects to address specific problems in the community, and all of those respondents were focused on bike/ped usage and traffic safety. In fact, the data that could be used to support secondary benefit claims are rarely collected by these agencies. Discussions on the effects of CS on vacant or blighted properties, crime rates, obesity, and the natural environment are limited to opinion and philosophy rather than forming an integral part of agency policy.

Academic literature often assumes a binary nature in CS: a project *is* or *is not* a CS project, and a particular streetscape *is* or *is not* ‘complete’. In practice, a view of CS evolves over time: “In this context and in this time period, *this* is defined as a complete street” (*122*). How ‘complete’ a project can be is often determined by available grant money and public approval. And because many jurisdictions (21% of survey respondents) seek to implement some elements of CS wherever possible, the question ‘Is this a CS capital improvement project?’ is often difficult to answer. Furthermore, the term ‘Complete Streets’ has become politically charged (*104, 129–131*) which can make CS difficult to address. Instead, agencies may default to CSS/D, road diets, and other elements of CS projects without formally embracing CS policies. As a result, projects that are intended to be complete may not be, and projects that are not labeled as CS may in fact be complete.

A central result from the survey is that assessment of the quality of CS policies and practice is deeply subjective. Policies are rarely measured against an ideal; there is no Bureau of Weights and Measures for Complete Streets. The inability to correlate site selection techniques or statements like “My agency tracks performance measures on implemented projects” with an overall estimation of CS policy fitness reveals the subjectivity of the CS paradigm as a whole. While organizations like Smart Growth America have provided excellent guidance on the elements of successful CS policies (*132*), these guidelines are not a part of the vernacular for most CS practitioners. Additional tools are needed to help agencies adapt and mature their CS policies as new information and techniques become available.

Perhaps the most useful information from the survey responses came in a free response section. The following quotes are all pulled from responses to the question “Would you like to share any other thoughts on Complete Streets in your community?” Responses in general showed an enthusiasm for CS projects, but some disillusionment with unclear guidelines or leadership: “We have no policy on the MPO or City level; Complete streets do nevertheless get performed, but this procedure is not codified. It is my opinion that is in not a good long-term strategy, even if outcomes are good in the present”. From a separate response: “Elected [officials] support Complete Streets in general, but sometimes waffle in implementation when faced with constituent pressure. Staff can be guilty of the same.” Formal policy adoption is an important step in creating continuity within a CS program, but if leadership lacks enthusiasm for CS, project delivery can suffer. Other responses highlight a need for interdepartmental collaboration throughout the planning and design process; as one city DOT respondent said, “We need to start the design conversation earlier internally and with the public. Project locations and budgets are set by Engineering staff through a pavement management lens, so when other requests are made budget issues arise. I am working to push for earlier scoping before project budgets are set.” An MPO official holds a similar view: “It can be a challenge as an MPO to promote Complete Streets since we work with multiple municipalities and do not have jurisdiction of the roads. Some municipalities are more on-board than others, or have better staff capability than others. We are working with the Health Dept. to coordinate with municipalities to each adopt their own Complete Street Policies. The MPO will assist in implementing them.” Finally, one respondent illustrates the fact that implementing a new CS policy requires a commitment and takes time: “Progress is slow [and] incremental due to the large number of pipelined projects.”

Conclusions

Measuring, monetizing, and optimizing the long-term benefits of CS projects are more challenging than they may appear at first glance. Challenges in data collection, project classification, and model circularity are common in attempts to empirically catalogue outcomes. Measuring the secondary benefits of these projects can be even more daunting, as data needs are intensive and producing statistically significant results will require study of a wide range of project typologies and contexts. Future data collection efforts can be significantly facilitated through implementation of Smart Cities initiatives; inclusion of data collection devices in current project design can be seen as an investment in future capital projects and right-of-way initiatives.

Public agencies are focused on primary outcomes: reduction of crash frequency and severity, provision of multimodal access, and creation of livable communities. Researchers have shown that the elements of CS projects often produce their desired primary outcomes: road diets improve safety and reduce speeds, separated bike lanes encourage cycling and improve safety, and improving access improves economic opportunity. In order for CS practice to move from its current form into a more mature and robust methodology, organizations need to be able to assess the health of their CS practices and attain guidance on improving those practices. A major opportunity for additional research in this area is the provision of a multidimensional tool that assesses the maturity of a CS policy and protocol and guides growth in terms of data management, establishing and tracking useful PMs, and interagency collaboration.

Data Availability

The survey sent to MPO and city DOT officials is attached in Appendix A. No other data, models, or code were generated or used during the study.

COMPLETE STREETS: A NEW CAPABILITY MATURITY MODEL

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Abstract

Complete Streets practice in the United States is heterogeneous. While organizations like the National Complete Streets Coalition have offered guidance on formation of a robust Complete Streets policy, the maturity of public programs for Complete Streets practice is ill-defined. This research adapts existing transportation-focused Capability Maturity Frameworks to propose a new Capability Maturity Model for Complete Streets that is designed to help organizations evaluate current program maturity and identify next steps for evolving practice. The model includes a self-assessment tool and a set of qualitative descriptions of incrementally increasing maturity across seven program dimensions determined to be fundamental to the success of Complete Streets programs. The proposed model is designed to assist in strategic planning and organizational capacity building.

Keywords: Complete Streets, Professional Practice, Tools, Capability Maturity Model, Workshops

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Introduction and Literature Review

Complete Streets (CS) is an urban planning and development concept centered around the application of context-sensitive approaches that seek to treat streets and streetscapes as useful, livable community space rather than solely as a means of automobile-centric conveyance (*104*, *133*). CS place emphasis on consideration of all users across all modes of transportation. CS applications commonly address active transportation including cycling and pedestrian usage, but can also include public transit, accessibility solutions for mobility-challenged groups, freight considerations, and shared micromobility. Cities in the United States have historically been planned around car travel; interstates, wide street layouts, annexation, and land use policies including minimum parking requirements have contributed to urban sprawl in ways that are often not mirrored in older European cities and other parts of the world. As a result, this research focused on CS applications in the United States.

Local DOTs tend to apply CS treatments in order to take advantage of the primary benefits of these treatments: improved mode split and decreased crash rates and severity (*87*, *88*, *93*, *97*, *99*, *100*, *133*, *134*). In an estimated 14% of jurisdictions, CS implementation is used primarily as a tool to mitigate hot spots for crashes, with another 14% implementing CS projects in areas where bike/ped traffic is already high (*133*). These primary benefits of CS projects are well-documented (*104*). However, significant academic effort has focused on the secondary benefits of CS projects, often justified using logic pathways rather than empirical methods (*133*). These secondary benefits include improved public health outcomes (*79–81*), improved outcomes in the natural environment (*91*, *92*, *98*, *135*, *136*), and sustainable economic growth (*86*, *137*, *138*). These potential benefits are often ignored by practitioners, whose focus is on transportation-specific challenges and outcomes. In order to leverage the secondary benefits offered by CS projects—and to provide empirical measurement of these benefits—public agencies need additional guidance and tools to further evolve the practice of CS. With these tools, practitioners will be more able to advance CS theory by utilizing new and valuable datasets cross-applied to the empirical measurement of CS benefits and accessing a broader set of interdisciplinary outcomes The broad set of potential benefits encourages a reconsideration of what data are relevant to CS: traditionally, CS data collection efforts focus on usage counts and crash statistics, but discussion of secondary benefits suggests the inclusion of other panel data may be advantageous. Relevant data sets may include tax rolls and land assessor values, public health indicators, air and water quality metrics, and statistics on crime, equity, and security.

There is a growing awareness of structural inequalities in urban contexts in the United States. In 2014, an estimated 12% of US households did not own a vehicle—a lack that creates substantial barriers to the access of goods, services, and opportunities in many cities (*22*, *139*). By creating space for alternate modes of transportation, Complete Streets can reduce the need for a vehicle and reduce travel times in non-motorized modes, facilitating equitable access (*84*, *90, 92*, *94*, *135*, *140*, *141*). This intersection of transportation-specific solutions to quality-of-life challenges highlights the need for a maturation of Complete Streets practice to address the needs of modern transportation system users.

Capability Maturity Modeling draws its roots from a 1973 publication on the Stages of Growth model for computer resource management (*142*). This model recommended planning the mid-to-long-term maturation in business organizations of emerging computational technologies. The model phased computer resource management in four stages: acquisition, intense system development, proliferation of controls, and user/service orientation (*142*). In the 1980's, problems arose within the US Department of Defense regarding project failure due to lack of capability in software development organizations. As a result, the Institute of Electrical and Electronics Engineers (IEEE) published a 1988 software process maturity framework (*143*). The intent of the software process maturity framework was to "be used by any software organizations to assess its own capabilities and identify the most important areas for improvement" (*143*). These ideas were further expanded and clarified by Carnegie Mellon University's Software Engineering Institute (SEI) (*144*, *145*). The capability maturity model frameworks (CMFs) published by the SEI tie the model itself to three companion questionnaires, and describe software process maturity in five levels: "A *maturity level* is a well-defined evolutionary plateau on the path toward becoming a mature software organization. Each maturity level provides a layer in the foundation for continuous process improvement."

As usage of Capability Maturity Models (CMMs) and Capability Maturity Frameworks (CMFs) proliferated, the concepts behind these models were adapted for other areas of business practice. The CMM was adapted for workforce management in 1995 (*146*) and for the process of innovation in 2009 (*147*). Under the Transportation Research Board's second Strategic Highway Research Program (SHRP2), Capability Maturity Modeling was adapted for use in the transportation sector in conjunction with Transportation Systems Management and Operations (TSMO). Through SHRP2, six TSMO-related applications were studied and each received a tailored CMF. Unlike the early CMFs developed by the SEI, these CMFs identified key dimensions of importance within TSMO, and evaluate the maturity level for each dimension rather than for the organization as a whole. Five of these CMFS (*148–152*) utilize the same six dimensions, each evaluated at four levels of maturity; the last (*153*) identifies nine dimensions evaluated at three levels of maturity.

The transportation agencies responsible for implementation of CS projects are diverse in scope, in scale, and in expertise. In many small US cities, a few non-specialized city engineers may handle projects ranging from roadway design to stormwater management to structural applications, while larger cities may have adequate staffing to split responsibilities by discipline. Some cities are able to leverage funding and expertise from county governments or Metropolitan Planning Organizations (MPOs), and some are able to dedicate experts not only to transportation but to active transportation or other specialized programs. Because the agency context for CS is so diverse, the size, scope, and health of CS programs is also inconsistent between agencies. As evidenced through practitioner survey results (*133*), there is little agreement on what characteristics define a robust CS program. A CMM dedicated to CS practice can help this diverse set of agencies to assess their CS capabilities and to identify important opportunities for improving those capabilities. When applied to the strategic planning process, the proposed CS CMM will aid in the long-term success of CS programs and initiatives in US transportation agencies.

Methodology

The process used to develop the model is shown in *Figure 7,* and consists of three main phases: literature review, long-form interviews, and model beta testing.

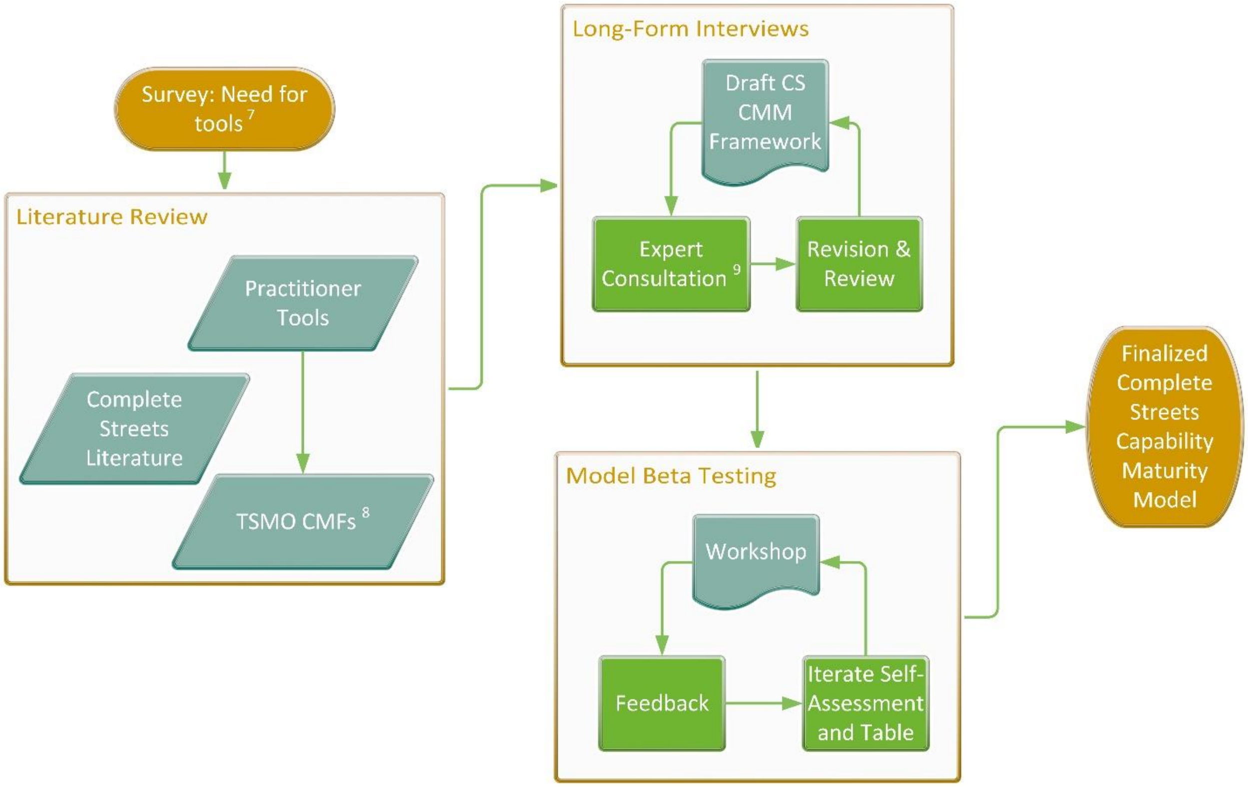

Figure 7. Process flow for model development [7, 8, 9]

The proposed CMF model structure and content for CS was heavily informed by TSMO CMFs developed as a part of the Strategic Highway Research Program 2 (SHRP2) by the American Association of State Highway and Transportation Officials (AASHTO) (*148–155*). The TSMO CMFs all follow a common structure in three parts. TMSO researchers identified key program dimensions at the root of overall project maturity for each associated TMSO field. Organizations utilizing a CMF are directed to start with a self-assessment quiz that seeks to identify that organization's current level of maturity in each of the identified program dimensions. Results of the self-assessment quiz place the organization on a qualitative table

[7] (*133*)
[8] (*148–155*)
[9] (*156–161*)

which describes levels of increasing maturity for each dimension related to the TSMO field. Finally, the CMF offers a list of available actions to help the organization to evolve practice to the next level for each dimension. A more detailed discussion of the TSMO CMFs is provided in the Federal Highway Administration's (FHWA) 2017 report (*162*).

The proposed CS CMM follows a similar structure. Extensive research related to CS potential and practice was conducted (*104*, *133*) to develop appropriate adaptations to these existing, well regarded TSMO models (*148–155*) that allowed translation of the frameworks to the CS context. Results of this research (that included literature review, case study analysis, and a national survey of practitioners) (*104*, *133*) informed development of the proposed CS CMM. Key dimensions for CS program health were identified and described by an associated qualitative set of maturity levels. A self-assessment quiz was developed to guide organizations in identifying their current level of maturity for each dimension using the same scoring techniques presented by the TSMO CMFs. Then, a panel of subject matter experts (*156–161*) reviewed the initial version of the self-assessment quiz and CMM table. Long-form interviews were conducted with each of the panel experts in order to determine the following:

1) Do the dimensions selected represent the most important aspects in CS practice?
2) Does the self-assessment quiz ask questions that are relevant?
3) Do answers to self-assessment quiz questions adequately describe the levels of maturity in real-world organizations?
4) Does the self-assessment quiz accurately place organization on the CS CMM table?
5) Do the levels described in the CS CMM table reflect incremental improvements for real-world agencies?

6) How can the self-assessment quiz and CMM table be modified to better reflect real-world practice within a modern CS context?

The panel of experts was cultivated to create a diverse set of perspectives: one panelist was selected based on prior experience in developing the TSMO CMFS (*156*); another was selected based on expertise in modern Smart Cities and ITS technologies (*157*); a third was selected based on affiliation with the National Complete Streets Coalition (*158*); and the remainder were selected to represent transportation officials at city DOTs (*159*), county government (*160*), and MPOs (*161*). After each interview, the quiz and model were revised to incorporate the advice of each subject matter expert. This process was important for ensuring that the model presented here is reflective of the goals and practices of modern transportation agencies and practitioners.

While the TSMO CMFs were initially comprised of three parts—self-assessment quiz, the CMM table, and 'Next Steps' guidance—implementation of those CMFs resulted in the developers simplifying the framework. One simplification that evolved from the TSMO CMFs implementation was to provide direct access to the CMM tables without need for the self-assessment quiz, ensuring that each matrix cell was described clearly enough that users could quickly locate their agency's maturity level for each dimension.

> "Our second – and more fundamental step – was to focus on self-evaluation – without externally-provided guidance at all. Our belief (subsequently verified in over 50 workshops) was that the strength/validity of the matrix row and column logic was such that users (typically workshops of key state DOT TSMO staff)—prompted by the appropriate row and column definitions—would "discover" their own guidance; that is, identify the obvious steps to get from one defined level to another, given their own agency context –without external guidance.

> In effect, CMM users essentially re-created the guidance that we had embedded in the website, but in terms, language and context specifics appropriate to their own agency context. Equally important, the evaluation and discussion of appropriate actions to get from one level to the next was done by group consensus involving the key players. This supported substantial buy-in (*156*)."

Focusing on this insight, the 'Next Steps' guidance was dropped from the CS CMM. The self-assessment quiz is still included in order to provide users with the option to utilize it if desired. In order to see how organizations used the CS CMM without the 'Next Steps' guidance, a series of workshops were hosted for practitioners. In these workshops, practitioners were given an abbreviated selection from the CS CMM and encouraged to discuss its applicability.

To test the model, three 90-minute virtual workshops were offered to CS professionals (workshops were offered online due to COVID-19 measures). Invitations were sent to MPOs across the country (*121*) as well as city DOTs. All participants in the 2019 Complete Streets survey performed by the University of Memphis (*133*) were included in the invitation, and additional outreach was performed using contacts within the National Complete Streets Coalition and the Institute of Transportation Engineers. Over 60 practitioners signed up for the workshops across three days in August of 2020 representing more than 25 organizations including some from local, county, and state DOTs, MPOs, one state department of health, and the private sector. Participants were split into breakout groups based on stated interest in the model's seven dimensions. Each group was given one dimension of the model and tasked with completing the Self-Assessment Quiz for that section and placing their agency on the CS CMM table. Participants where then asked the following:

- Do I agree that my agency is at the level shown? What additional nuance needs to be added to better describe our current maturity?
- Is my agency interested in moving to the next maturity level?
- If so, what are some concrete action items my agency can take to move forward?
- Who should be responsible for those steps, and on what time scale?
- Discussion of the first question was used to revise the quiz and the model table to better depict current practice. The remaining questions allowed participants to engage in the CMM process for a single dimension of practice. In a full-scale implementation, care would be taken to include several participants from each organization and the entire model would be used in order to allow discussion of the interconnected nature of various model dimensions; however, due to the time constraints inherent to the workshop format, discussion within each group was limited to a single model dimension.

Results and Discussion

Overall, workshop participants found the CS CMM to be a helpful tool in fostering discussion and reframing agency growth, but struggled to identify specific and actionable steps to take for agency growth. While this may be due to the limited scope of the offered workshops—many participants were the sole representative of their agency, and were working with only a subset of the model—general discussion also indicated a sense that practitioners felt they had a limited capacity to foster agency change. "The will [to improve our Complete Streets practice] is there, but trying to make it a priority is like herding cats" said one MPO practitioner. "Nobody really knows whose job this is" said an engineer from a city DOT.

However, some agencies were able to identify useful action items for future growth. One MPO planner described their agency's struggle to implement useful performance measures for

CS projects: the agency had *identified* target PMs and relevant data sources, but had not assigned responsibility for calculating and monitoring those PMs to any particular individual. Through the workshop, the MPO planner identified the need to identify not only the target PM, but also the responsible party and time frame for evaluating and using each PM. Similarly, a county transportation engineer in the "Culture" breakout group focused on the qualitative description for Culture Level 3: "…successes are identified and shared internally and externally." This engineer identified the need to improve collection of data in order to improve performance measurement as the barriers to sharing information about successful projects and the rationale behind some design decisions: "If we can get better data and measure how much things are improving, we can share that out at town meetings and head off some public objections."

The "Technology & Implementation Approaches" breakout group was largely comprised of state DOT officials. In this breakout group, discussion centered around ITS and Congestion Mitigation and Air Quality (CMAQ) grant funding. They realized that while the DOT had an active multimodal office and an active ITS office, those two offices had little interface with each other. Workshop participants identified two specific action items: first, the need to investigate new technologies for getting multimodal usage counts and other technological applications to facilitate multimodal trip making, and second, the need to connect the ITS work group with the multimodal work group to reduce intra-office siloing.

Participants gave positive feedback about the CS CMM's validity and about the workshop experience. One participant noted that "You can't go from a [maturity level] one to a four. I think some people want to jump straight into a very mature practice, but the table helps to show the incremental steps along the way. Growth is a process." Another participant added "I think the discussion [the CMM process] generates is really the important thing, getting everyone talking and on the same page." While participants felt the workshops were valuable, some expressed concern over the time required to bring stakeholders together to implement the full model; practitioners already find their time in high demand, and carving out time for organizational strategy can be a challenge. "It just sounds hard to get everyone together for long enough to go over it all." However, participants indicated that finding the time to invest in agency capability is likely to yield substantial long-term rewards.

Complete Streets Capability Maturity Model

Researchers and panelists identified seven key dimensions for CS maturity in public agencies at the local, county, and MPO levels. While the presented model may be useful for private agencies, NGOs, or public agencies at larger spatial scales, adjustments to the model may be necessary to more closely mirror these diverse contexts. The seven dimensions can be sorted as follows (again, following the structure of the TSMO CMFs (*148–155*)):

- Process-Oriented Dimensions
    - Business Processes
    - Technology and Implementation Approaches
    - Performance Measurement
- Institutional Dimensions
    - Organization & Workforce
    - Culture
- Network Integration Dimensions
    - Inter- and Intra-Agency Communication and Collaboration Capabilities
    - Focus on Traveler Choices

Each dimension is described at four levels of maturity based, identical to those found in (*162*) and reproduced here for the reader's convenience:

1) **Level 1—"Performed."** Activities and relationships are largely ad hoc, informal, and champion driven, substantially outside the mainstream of other DOT activities.
2) **Level 2—"Managed."** Basic strategies and applications are understood; key processes support the requirements for effective implementation; key technologies and core capacities are under development, but limited internal accountability and uneven alignment of accountability with external partners.
3) **Level 3—"Integrated."** Standardized strategies and applications implemented in a prioritized manner and managed for performance; Technical and business processes developed, documented, and integrated in DOT activities; partnerships aligned.
4) **Level 4—"Optimizing."** [Complete Streets] is considered a full, sustainable core DOT program priority, established on the basis of continuous improvement with top-level management support and formal partnerships.

It should be noted here that model dimensions are illustrative. While an agency may find that a single level perfectly encapsulates their current set of activities and approaches, more commonly agencies will often find that some activities within a given dimension are better described by a variety of levels: for instance, an agency may find that its Business Processes are solidly at Level 2, while its Organization & Workforce is somewhere between Level 1 and Level 3. A fundamental part of implementing the CS CMM involves generating discussion between agency stakeholders and practitioners in order to clearly identify current agency practices and to discover necessary action items to further mature those practices. Additionally, Level 4 (Optimizing) is an idealized set; for many agencies, attaining a Level 4 across all seven model dimensions would be too costly. Agencies must select their own target level for each dimension according to agency context, including available funding, population density, coverage area, and other local factors.

Model dimensions are often interrelated; agencies may find that advancing practice in one dimension requires or causes advancement in a related dimension. For example, improving Performance Measurement (PM) (especially for PMs more traditionally related to public health, security, or economics) may require acquisition and mastery of new Technology & Implementation Approaches for data acquisition as well as partnering with other agencies in the region using Inter- and Intra-Agency Communication and Collaboration Capabilities. For this reason, it is recommended that the CS CMM implementation process be viewed as holistic and collaborative and not partitioned into discrete, non-overlapping sections. Inclusion of voices and perspectives from all levels and departments of the transportation agency's workforce is likely to yield a more robust analysis of current agency performance and a clearer identification of concrete action items to move forward.

Ideally, implementation of the CS CMM would begin with identifying key players within the agency at all levels of the workforce. Including input from planners, design engineers, technicians, managers, and specialists allows a more detailed analysis of the actions taken at all levels of the organization. These key players would work through the self-assessment quiz together, using the questions as prompts to allow nuanced discussion as it arises. Once the assessment is complete, the team would turn to the CS CMM table and discuss how accurately the table describes the agency's current maturity for each dimension. Next, team members would discuss exactly what ‘regional’ means in their context: for some communities, ‘regional’ may be synonymous with their county boundary; for others, it may mean only adjacent jurisdictions; for MPOs, it may mean the extent of their jurisdiction or include nearby non-member entities. In any case, robust application of the model will require addition of context and nuance specific to the participating agency or agencies. Similarly, the participating agency will need to identify its long-term CS goals: for each dimension, what level of maturity is desired? Finally, the team should discuss concrete action items to help them to evolve their practice to the next level. These action items should be assigned to specific personnel and be in service to SMART goals[10]—goals which are Specific, Measurable, Attainable, Realistic, and Time-Bound (*163*). Creating group consensus on the agency’s current maturity and on the strategy for evolution can generate a sense of ownership and buy-in among key personnel that is more likely to yield sustainable growth within the organization than a top-down strategy might yield (*156*).

The Self-Assessment quiz is presented here. Participants should be fully aware of which model dimension each question pertains to. Each section of the quiz is preceded by a brief definition of the dimension at question, as well as a few sample outcomes that could be gained by improving along this dimension. Scoring for the quiz is identical to the approach used in the TSMO CMFs: for each model dimension, the average is taken from answered questions. Questions that do not apply to the participant agency are marked ‘N/A’ and omitted from scoring. Agency maturity for each dimension is shown in *Table 4*. To provide additional clarity, a glossary is included in Appendix B.

[10] SMART goals are one way to frame agency objectives, but not the only way. The term is used here to emphasize the importance of actionable steps for growth; agencies can of course substitute any number of strategies in place of SMART goals.

Table 4. Relating quiz scoring to agency maturity

Level 1	Level 2	Level 3	Level 4
$1 \leq score < 2$	$2 \leq score < 3$	$3 \leq score < 4$	$score = 4$

Business Processes	Business processes, in the context of Complete Streets, refers to the practice of good governance in activities such as planning, programming, agency project development processes, and those organizational aspects that govern various technical or administrative functions such as training, human resource management, contracting and procurement, information technology, or agreements. In many cases, the business process elements go beyond the day-to-day operational activities and require broader institutional support and involvement to address. All of these processes are fundamental to the success of multimodal initiatives. Without the right procurement processes, partnering commitments, sustainable funding, internal awareness, and support, there could be a limited capacity to be able to implement more complex programs and activities. Some sample outcomes for this area include: • Codified business practices that endure through administration changes • Stable partnerships with related agencies • Improved governance and use of resources

Business Processes 1: How is planning for CS projects undertaken?

1	The agency does not formally address CS in its projects or planning.
2	CS projects are typically implemented at the tactical urbanism level or the flagship level, but not both. CS elements are primarily utilized to address safety concerns.
3	The agency makes use of approaches at both the level of tactical urbanism and the level of flagship projects. Low-cost additions such as bike lanes or curb extensions are utilized alongside high-profile treatments like pedestrian malls or park-front retail spaces. CS elements are utilized to address equity and access, as well as safety concerns.
4	In-house CS specialists view all projects through a CS lens and from a systems approach. While flagship projects often draw much of the community's attention, CS principles and

	elements are applied as appropriate within all projects to encourage a culture of safe, active, and mixed-modal transportation across the transportation system as a whole.
-	N/A

Business Processes 2: How are funds procured or budgeted to ensure CS programs are sufficiently resourced?

1	Funded through community donations and volunteer labor.
2	Funds are sought through grant applications. Little or no recurring funding for CS programs is budgeted by the agency.
3	Budgeting processes consider CS programs, but resources are often a significant limitation. Some supplemental grant funding is sought, but no formal program exists to find and pursue these grants.
4	Budgeting processes always consider CS programs, and these programs receive significant funding. A structured and collaborative program to pursue external funding is in place. Funding allows for complex, multi-year or multi-stage projects, and includes interagency collaboration.
-	N/A

Business Processes 3: How is the CS program implemented?

1	Ad-hoc implementation of some CS elements in projects, with no system-level approach.
2	CS elements are limited to bike/ped projects. Some guidebooks and templates are used to implement predefined elements. Implementation is handled with limited consideration of the overall community system context.
3	CS programs are supported by local politicians and implemented by champions within the agency. CS projects are viewed as distinct from traditional projects, but are considered more holistically for the system.
4	Data from past projects and community input are used to inform an idealized set of elements for use with each project or program. CS specialists utilize this information to design context-sensitive CS applications for each project. Each project is viewed within the context of the entire system to ensure connectivity, consistency, and fidelity to overall goals.
-	N/A

Technology & Implementation Approaches	Use of the appropriate processes for design and implementation of systems will ensure that the needs of the jurisdiction are appropriately addressed, that best practices are implemented in an efficient manner, and that interoperability with other systems is achieved. Some sample outcomes for this area include: • Encouragement of innovation • Mainstreaming of best practices in design • Ability to demo new technologies • Integration with ITS and Smart Cities applications

Technology & Implementation 1: How well does your agency assess, adopt, and procure best practices and new technologies for CS projects?

1	No new technologies are explored beyond traditional bike/ped signage and systems.
2	Innovative technologies and strategies are used sporadically, as funding allows and when a project 'champion' expresses an interest in them.
3	Willingness to try new technologies and to update best practices are institutional norms. Planners and designers have established relationships with ITS specialists and vendors, and pursue continuing education on current best practice.
4	Technologies and best practices are regularly reviewed for effectiveness and performance. This review process creates an atmosphere of continuous improvement. New technologies are routinely tested in tactical urbanism settings, then considered for more widespread rollout.
-	N/A

Technology & Implementation 2: Is CS-related data captured?

1	No CS-related data is routinely captured.
2	Some data is regularly captured at some project sites. Data collection is largely manual, and primarily focused on usage counts.

3	CS-related data collection is scheduled and routinely performed, and explores a variety of information in support of the agency's preferred CS performance measures.
4	CS-related data is captured in real time using ITS or Smart Cities technologies. Captured data is multi-dimensional and includes traffic counts across a variety of modes, safety and crash information, environmental measurements, and any other data desired by the agency.
-	N/A

Technology & Implementation 3: Does a standardized system (or playbook) exist for CS technologies?

1	No standardized systems for CS technologies is in place. Applied technologies are selected and deployed based on the experience of a few key personnel.
2	New technologies are often reviewed and utilized, but consistency between projects is lacking. There is no generalized, institutional knowledge of best practices regarding CS technologies.
3	Specific protocols and guidelines for CS projects exist, but are underutilized or inconsistently applied. Interoperability between project areas or jurisdictions remains a challenge.
4	Specific protocols and guidelines exist for CS technology applications and are consistently applied across the network area. Such protocols are consistent with the MUTCD and are regularly reviewed and updated using best industry practices as well as locally collected data, and maintain interoperability with nearby jurisdictions where applicable.
-	N/A

Performance Measurement	Performance measurement is essential as the means of determining program effectiveness, determining how changes are affecting performance, and guiding decision-making. In addition, operational performance measures demonstrate the extent of transportation problems and can be used to 'make the case' for operations within an agency and for decision-makers and the traveling public, as well as to demonstrate to them what is being accomplished with public funds on the transportation system. Some sample outcomes for this area include:

	• Data-driven decision making • Outputs easily communicated to internal and external constituents • Use of consistent, concrete metrics in grant funding applications

Performance Measurement 1: How does your agency measure multimodal/CS performance?

1	No measurement of multimodal performance is performed.
2	Multimodal performance is measured, but is strictly qualitative and not well documented.
3	Multimodal performance is measured qualitatively and quantitatively by some entities. Awareness of performance tracking among stakeholder entities is limited and reporting is inconsistent.
4	Measurement and reporting of multimodal performance are routinely conducted and tied to system- and/or region-wide goals for safety, accessibility, equity, and other outcomes. All stakeholder entities are fully informed and engaged in performance tracking.
-	N/A

Performance Measurement 2: How are data for CS performance measures collected?

1	No data are collected.
2	Qualitative data are collected ad hoc, or passively from perceptions of a limited number of stakeholders.
3	Quantitative data are routinely collected using legacy systems. Qualitative data are sometimes actively sought from a variety of stakeholders.
4	Robust, integrated data collection systems with automated reporting are in place. Qualitative data are routinely and systematically collected by gathering user & stakeholder input.
-	N/A

Performance Measurement 3: Is CS performance used to influence/improve future CS planning and management?

1	CS performance is not measured, so future planning is not influenced.
2	CS planning and management is loosely based on the qualitative recollections of key personnel.
3	Comprehensive performance measures (including multimodal usage, safety, economic and environmental impact, and others deemed relevant by the agency) are used for considering future improvement options, but inconsistently and not by all entities.
4	Comprehensive data and corresponding performance measures are used by all entities to support decision making in a structured and consistent manner. These performance measures influence not only project design, but new iterations of the Transportation Improvement Plan and other master planning documents. Performance outcomes are shared between entities and with the general public.
-	N/A

Organization & Workforce	Efficient execution of processes supporting effective programs requires appropriate combination of coordinated organizational functions and technical qualified staff with clear management authority and accountability. Some sample outcomes for this area include: • Improved sharing of institutional knowledge • Encouragement of innovation

Organization & Workforce 1: How is staffing allocated for CS?

1	No CS specialists are employed by the agency.
2	Staffing for CS specialists is minimal; CS is seen as a separate effort and is not integrated into daily operations.
3	CS staff is diverse and well-trained. These staff members are viewed as an important part of the daily operation of the agency.

4	In addition to a diverse and well-trained staff, all agency staff has some cross-training in CS approaches. All agency members are familiar with the jargon and concerns of mixed modal projects.
-	N/A

Organization & Workforce 2: How are CS knowledge, skills, and abilities developed among agency staff?

1	CS training is ad hoc, typically initiated by interested individuals.
2	CS specialists are systematically trained, but other divisions of the agency are not included.
3	CS training is comprehensive and applied strategically throughout the agency. Techs are trained on integrated, smart systems.
4	CS training includes partnership with outside agencies. Best practices are shared between agencies, and official training is regularly reviewed and improved to keep pace with changing techniques and technologies.
-	N/A

Culture	Culture is the combination of values, assumptions, knowledge, and expectations of the agency in the context of its institutional and operating context, and as expressed in its accepted mission and related activities. Some sample outcomes for this area include: • Reduced reliance on ‘champions’ to execute projects • Improved professional capacity building • Enhanced public engagement

Culture 1: How is CS valued within the agency?

1	Perceived value of CS efforts is uneven across the agency. A core staff insists on doing things ‘the old way’.

2	CS projects are champion-driven; a small and vocal core of staff is passionate about CS and active transportation.
3	Use of streets as space (and not merely as conveyance) is understood and embraced by all levels of the agency.
4	CS is a core value across the agency. Throughout the planning and design process, practitioners look for opportunities to deploy CS technologies and to encourage safety, equity, user friendliness, and mixed modality.
-	N/A

Culture 2: What public outreach activities are in place regarding CS?

1	No strategic public outreach is performed. Public input is taken in the form of public complaints or concerns.
2	Public engagement takes place only for flagship projects.
3	Community stakeholders are typically engaged in outreach during the project design phase. Stable channels for public feedback are open, and feedback is systematically documented and reviewed.
4	Public outreach before, during, and after implementation of CS projects is a part of a proactive, comprehensive communications program. Public feedback on planned and past projects is assessed and systematically incorporated into the planning and design process.
-	N/A

Culture 3: Are efforts being made to inform community perception of the value of CS?

1	No efforts are made to influence public perception.
2	Public officials express support for CS initiatives in town hall meetings and other public forums.
3	Local and regional agencies share information on how innovation is taking place in the transportation community, with spotlights on important projects and key players. This information is typically housed in agency websites or as op-eds in local newspapers and publications.

4	Public perception of CS projects is tracked and documented as an important agency Performance Measure. Local (and some regional) agencies have a social media presence that allows them to engage public perception, share future plans, and advertise agency objectives using performance measures and infographics. Through a variety of media, the public is educated on why new systems are important and how to use them properly.
-	N/A

Inter- and Intra-Agency Communication and Collaboration Capabilities	Creating new opportunities for Complete Streets professionals to work closely with other transportation professions requires the establishment of inter- and intra-agency communication and collaboration capabilities that enable greater awareness of community- and region-wide Complete Streets practices. These capabilities may include the ability of CS and other transportation professionals to create joint processes and playbooks geared towards shared learning, shared data, and standardized practice. This area includes the development and use of information exchanges and data environments which provide a view of planned and current conditions within local and adjacent jurisdictions to a wide variety of audiences. Some sample outcomes in this area include: • Guidelines that help choose or prioritize project coordination activities for construction • Improved coordination with local and regional agencies around network connectivity • Improved processes for information sharing around traffic management plans to transit and TDM professionals • Gathering and sharing of multi-dimensional data between agencies in and out of the transportation sector

Communication & Collaboration 1: What level of regular communication exists between CS stakeholders within the jurisdiction?

1	Communication between CS specialists and outside agencies is limited.
2	CS specialists communicate with other stakeholders in the area for certain projects and programs.

3	Best practices are regularly shared between agencies. Practitioners have a shared forum for communication and collaboration.
4	Locally, all stakeholders have an integrated structure for interagency engagement. Managers and practitioners have effective, ongoing communications and forums. Regionally, interagency communication and collaboration is available and commonly utilized.
-	N/A

Communication & Collaboration 2: What processes exist to homogenize layouts, signage, and wayfinding throughout the area?

1	Interagency collaboration is reserved for special circumstances.
2	Interagency communications include periodic scheduled meetings between managers and practitioners, but attempts to homogenize layouts, signage, and wayfinding throughout the region are inconsistent and limited.
3	Interagency communication occurs on a regularly scheduled basis. Best practices are shared, and there is effort to consistently construct and mark intrajurisdictional routes.
4	Interagency collaboration is ongoing and clearly defined, and a shared playbook is utilized by all relevant entities. Intrajurisdictional routes are seamless, with common layouts and signage.
-	N/A

Communication & Collaboration 3: Is CS-related data shared between all stakeholders in the area?

1	CS-related data is not shared outside the agency that collects it.
2	CS-related data is shared via special requests. Fulfilling requests is seen as time consuming and costly.
3	CS-related data is shared seamlessly with all stakeholders in the transportation community within the jurisdiction.

4	CS-related data is shared in real time with all stakeholders in the region, even those working outside the traditional sphere of the transportation community including public health, police and emergency services, and the general public.
-	N/A

Focus on Traveler Choices	This capability area supports strategies and tactics focused on providing and enabling choices to travelers for their trip. Included in this area are approaches to facilitate travel needs through a variety of modes and support for travel throughout the trip chain. Sample Outcomes: • Support for parking pricing and cordon pricing to encourage mode shift • Ability to leverage public-private partnerships to provide first/last-mile connections to transit • Improved wayfinding for inter- and multi-modal travelers • Approaches to overcome or eliminate barriers to travel for vulnerable populations requiring special assistance

Traveler Choices 1: How supportive are programs and policies toward encouraging mode shift using CS?

1	Transportation agencies focus on single-occupant vehicles, with some enabling of public transit.
2	Efforts to consolidate travelers are focused on long-distance commuters, utilizing commuter trains, HOV lanes, or ride sharing programs along key corridors.
3	Long-term plans recognize that capacity expansion alone may be insufficient to meet future demand, and attempts to provide parallel pathways to relieve pressure on arterials. Land use and land development policies have been reworked to accommodate mode shift.
4	Planning across the entire jurisdiction as well as relevant adjacent jurisdictions incorporate mode shift as a fundamental element. Emphasis is placed on such programs as park & ride and bike share, and first-and-last-mile commuting is a major priority.
-	N/A

Traveler Choices 2: What are the regional capabilities to communicate information about travel choices?

1	No public outreach activities focus on informing mode choice for travelers.
2	Communication of alternative travel options is utilized by a few entities and at low priority. Focus is largely or completely on public transit.
3	Mode shift via CS is communicated in strategic locations to improve safety or relieve pressure on the road network.
4	Local and regional agencies see communication of mode choice for travelers as beneficial to meeting diverse goals include environmental quality, social justice, and public health. Mode shift via CS is a cornerstone of public outreach in the community.
-	N/A

Traveler Choices 3: Are travelers able to change modes at key locations across the region as part of a region-wide CS approach?

1	No hubs for mode shift are identified.
2	Mode shift is largely unidirectional: focus is placed on shifting commuters to mass transit modes, but the suite of available traveler options is limited.
3	Strategic hubs are identified across the region, and used to encourage mode shift across a variety of travel choices. CS efforts typically include connectivity to multimodal hubs. Public-private partnerships may play a key role in first and last mile travel.
4	Agency directors prioritize mode shift across the region. This priority translates to collaboration at all agency levels to facilitate multimodal travel. Key hubs for mode shift are identified, and rebalancing of resources across jurisdictional lines is performed as needed. CS efforts consistently and seamlessly include connections to multimodal hubs. Public-private partnerships are used to fill any gaps in network coverage. Approaches to encourage mode shift are regularly reviewed and updated.
-	N/A

The following table provides the core of the Complete Streets Capability Maturity Model. Agencies can use the long-form Self-Assessment Quiz shown above to help evaluate their current maturity, or can simply refer to this table to self-evaluate without the assistance of the quiz. Each of the seven model dimensions are shown here with qualitative descriptions of each maturity level. Users are expected to modify the illustrative maturity levels shown here to better represent each agency's context and goals. Reading through the levels of maturity shown here may help to guide users in forming Next Steps for their agency, as discussed above in the 'Results and Discussion' section of this article.

Table 5. Complete Streets Capability Maturity Model

Class	Dimension	Level 1 (Performed)	Level 2 (Managed)	Level 3 (Integrated)	Level 4 (Optimized)
Process-Oriented	Business Processes	Planning for CS is informal, reactive, and ad-hoc. If business processes address CS, they do so on a superficial level. Agencies are constrained by funding limitations and inability to make long-term capital improvements.	Business process encourage some CS elements on flagship projects, but application is sporadic and champion-driven. Funding is variable and prone to reallocation to other priorities.	A formal planning process for CS has been established, but institutional barriers that prohibit addressing all needs are evident. Funding for CS is an integrated part of the local and regional planning process, and resource sharing enables multi-year projects and programs.	Business processes focus on continuous improvement of institutionalized CS efforts. A formal, documented planning process for CS is in place, and budgeting always considers CS approaches and elements. Decisions are data-driven and prioritize access and equity.

Table 5 Continued. Complete Streets Capability Maturity Model

Class	**Dimension**	**Level 1 (Performed)**	**Level 2 (Managed)**	**Level 3 (Integrated)**	**Level 4 (Optimized)**
	Technology & Implementation Approaches	No standarized systems or protocol for CS. Use of special technologies or systems typically does not occur.	Focus on CS best practices and technologies is growing. Agencies have identified tools of interest, and are likely to have a patchy and underutilized network of implemented technologies. While a greater degree of CS data is collected, data quality and interpretation vary widely from one application to another.	Technology allows data collection and monitoring in real time, but with limited automation. Systems are integrated with local ITS infrastructure. Functional usage of data streams is a priority, as is interoperability with other systems.	Use of systems and technology to enhance user experience, safety, and operations are regularly evaluated and optimized. Agencies are likely to invest in controlled deployment of technologies and best practices in test beds for research purposes. Interoperability across local and regional systems is the norm.

Table 5 Continued. Complete Streets Capability Maturity Model

Class	Dimension	Level 1 (Performed)	Level 2 (Managed)	Level 3 (Integrated)	Level 4 (Optimized)
	Performance Measurement	Use of PMs for CS non-existent or irregular. Existing PMs are output-based and single-modal, and may not be specific to CS projects.	PMs are largely qualitative; PMs are occasionally computed and largely used for public relations.	Desired outcomes are clearly identified, and performance is measured at project and programmatic levels. PMs are used to make strategic improvements in CS policies and procedures.	Agency CS objectives are mapped to PMs, and used to inform pipelined projects. Analyses of PMs results are distributed internally and externally, and are archived for later use.
Institutional	Organization and Workforce	CS approaches are not an assigned responsibility of any staff. Efforts to identify, develop, retain, and enhance CS workforce skills are limited or non-existent.	Agency staffing needs are clearly identified and positions are being developed, but roles and responsibilities remain unclear. Some KSA development and retention occur, but implementation is uneven across the agency.	Responsibility for CS approaches are assigned to specific staff. Skill development and retention is institutionalized across the agency.	Cross-training is commonplace in the agency, and workforce development practices are regularly reviewed and improved as needed.

Table 5 Continued. Complete Streets Capability Maturity Model

Class	Dimension	Level 1 (Performed)	Level 2 (Managed)	Level 3 (Integrated)	Level 4 (Optimized)
	Culture	Perception of value of CS policies, programs, and projects is limited. Evolution of CS practice is not viewed as a priority, and efforts to innovate are not highly regarded.	Value of CS is a stated agency emphasis (possibly through adoption of a fomal CS policy), but adoption and support is uneven across the agency. Public outreach is limited, and CS efforts are largely champion-driven.	Equity is a core value across the agency, and the importance of CS initiatives is well understood. Public input is valued, and successes are documented and shared internally and externally.	A CS approach is an integral part of the project planning process. The impact CS have on the transportation system is recognized by all stakeholder entities, and processes are in place to encourage CS innovation and public outreach. These processes are routinely reviewed and improved as needed.

Network Integratio n	Inter- and intra- agency communicati on and collaboration capabilities	Stakeholder organizations are largely siloed. Relations between stakeholders are informal; collaboration is non-existent or ad-hoc. Data is not shared outside the agency that collects that data. Data collection efforts may be duplicated between agencies. Multi-dimensional metrics are disused due to difficulty in collection of multivariate data.	Collaboration with stakeholders is viewed as important, but processes to ensure and facilitate interagency collaboration are informal and unevenly adopted. Traffic data is shared across transportation agencies, but sharing with external partners like police or public health officials is rare. Challenges to data sharing include incompatible filing systems, heavy reliance on paper documents, or unclear direction on which parties or staff members are responsible for data sharing.	Many agencies routinely collaborate on CS projects and strategies, but not all entities are represented. Data availability is a stated area of importance at the local or regional level, but not all member entities are on board. Data sharing is still largely handled by request, rather than open-platform sharing.	Agencies and entities approach CS projects at a regional level. Data sharing is streamlined across agencies. Agencies are on a common platform and use compatible filetypes. Agencies have access to shared databases, and the processes for updating datasets are established and automated. Processes that encourage good data management and the coordination and collaboration of CS efforts are regularly reviewed and optimized.

Table 5 Continued. Complete Streets Capability Maturity Model

Class	Dimension	Level 1 (Performed)	Level 2 (Managed)	Level 3 (Integrated)	Level 4 (Optimized)
	Focus on traveler choices	Limited network connectivity for non-vehicle modes. Weak interconnectivity between modes.	Complete routes are planned between key community attractors. Interactions between freight movements and active transportation creates a substantial barrier to safe routing.	A multimodal network is taking shape, but substantial gaps in coverage exist. Major thoroughfares create neighborhood fragmentation, but efforts are being made to improve seamless routing of alternative modes.	Connectivity of each mode is considered at the network level. Changing modes at key network nodes is seamless; bike racks and bike shares, park and ride, and ridesharing allow multimodal transfer. Freight and active transportation are routed to minimize conflict points. Care is taken to ensure that vulnerable or mobility-challenged populations have full access to the transportation network.

3

Conclusions

Proving the claims made by CS advocates—especially claims of secondary benefits—will require the collection, distribution, and analysis of a diverse and multidimensional set of panel data; much of that data falls under the purview of non-transportation agencies. Data on public health, safety and security, economic sustainability, and environmental health all describe the overall health of public spaces in urban settings and therefore relate to CS projects, but utilizing these data will require partnerships with local and regional agencies outside the transportation sphere. Systematic performance measurement for CS project areas, then, will rely on advanced business practices in the formation and management of interagency collaboration.

Implementation of the CS CMM can help public agencies to identify opportunities for these interagency partnerships, as well as encouraging robust agency growth strategies in other areas. Good governance of public programs like (but not limited to) CS programs is a complex and multifaceted task, and requires time, effort, and practical tools to aid in long-term agency growth. The CS CMM proposed through this research is designed to push practice forward by encouraging collaboration of key agency players and enabling discussion of specific program elements at the strategic planning level through the developed tools.

Avenues for future research on this topic are diverse. First, the identification of multimodal and multi-objective PMs for Complete Streets projects would be useful for identifying which data and partnerships would offer the most immediate benefits for transportation agencies. While substantial research has gone into Multimodal Level of Service (*164*), few dashboard-ready PMs are widely accepted for monitoring secondary outcomes of CS projects or their long-term impacts on urban quality of life. Another avenue for research is in the area of multimodal active demand management. Study of programs that incentivize active or shared transit modes could increase the perceived value of CS project spaces while alleviating some need for short-term parking. A third avenue for future research is the creation of a site selection optimization tool for Complete Streets. While many agencies have tools that help to prioritize roadway projects, a review of existing practice did not reveal any such tools for identifying or prioritizing sites for CS treatments.

The proposed CS CMM helps to identify key elements of mature CS policies and programs, creating the opportunity for agency practitioners to discuss the strengths and weaknesses of their current approaches with an eye toward sustainable program growth. Inclusion of a strategy to develop agency capabilities in regards to CS policies and programs as a part of the long-range planning process may yield long-term benefits to the organization and give key agency practitioners a sense of control over agency development. Allotting time to host a conversation about agency trajectory and maturity is critical to the success of Complete Streets programming.

Data Availability

No data, models, or code were generated or used during the study.

Acknowledgements

This research was made possible with support from the Intermodal Freight Transportation Institute at the University of Memphis, the Herff College of Engineering, and from the Dwight D. Eisenhower Transportation Fellowship Program. Any opinions, findings, conclusions, or recommendations are those of the authors and do not necessarily reflect the views of the Federal Highway Administration or the University of Memphis.

CONCLUSION

This dissertation has advanced the Complete Streets urban planning paradigm. While the first chapter proposes use of empirical, data-intensive mathematical modeling to show definitive proof of disparate primary and secondary benefit outcomes, experience in the research process showed that these data are rare, incomplete, and often inaccessible even where extant. Further exploration of empirical measurement of Complete Streets project outcomes must wait until cities develop more extensive means of acquiring, tracking, and presenting data to the public. Some forward-facing cities are making strides toward better data management: smart cities and intelligent transportation systems are making transportation-related data streams more available, and local governments are creating data hubs that allow unrestricted access to these data streams. If properly maintained, these hubs may be useful in future attempts to catalogue project outcomes and to provide comparison between areas of the city receiving Complete Streets investment and control areas that receive no funding or other types of infrastructure projects. Some of the challenges to empirical benefits measurement discussed in Chapter 1 of this dissertation are likely to remain, but the existence and accessibility of transportation-related data is a problem that is currently being solved. As public data hubs mature, opportunity may arise to expand the types of data included in these hubs to incorporate security and safety data, economic data, and pollutant levels, creating the type of robust longitudinal dataset required for advanced interdisciplinary academic research.

In recognition of current data limitations, Chapter 2 of this dissertation pivots to focus on current Complete Streets practice. Evidence presented is both anecdotal (in the form of a case study on Broad Avenue in Memphis, TN and the genesis of the Complete Streets program in that city) and statistical (in the form of a survey of practitioners at Metropolitan Planning

Organizations and local Departments of Transportation across the United States), in addition to a review of relevant academic literature on past attempts to measure outcomes for implementation cases related to Complete Streets. The implications of these research are the identification of a set of descriptors of successful Complete Streets programs and a general sense that in many jurisdictions, Complete Streets programs are ad hoc or opportunistic rather than structured, systematic, and optimized.

Chapter 2 also identifies an academic over-reliance on proof through inductive reasoning. Secondary benefits of Complete Streets projects are often identified through logic pathways: a series of steps, each known with a degree of uncertainty, presents a reasonable conclusion that Complete Streets projects improve quality of life in a variety of ways. However, this chapter demonstrates that these logic pathways can be contradictory; they can be used to make whichever point the author wishes. In reality, these outcomes will depend on the size of one effect versus another: whether a particular implementation case results in more or less total vehicle miles traveled in the area will depend on whether improved intermodality removes more vehicles from the road than are generated by improved economic activity in the area.

Lessons learned in Chapter 2 of this dissertation form the basis for the most valuable output of this research in Chapter 3. In Chapter 3, information from the preceding chapters is synthesized to create a Capability Maturity Model for Complete Streets projects, intended for use by practitioners at Metropolitan Planning Organizations and local Departments of Transportation (though the tool can be adapted for use by many types of agencies at all network scales). The model identifies seven interrelated dimensions of agency practice, each described by four incrementally increasing levels of maturity: performed, managed, integrated, and optimizing.

Care was taken to ensure that this model accurately reflect current agency structure and practice, grounded in reality and providing accessible metrics of program health.

Transportation networks are entwined with national security, urban livability, equitable access to opportunities, and community cohesion. They affect public health, environmental quality, and economic prosperity. As such, transportation network planning and decision making is inherently an interdisciplinary endeavor. Plans must be feasible and economically viable. Roads must be designed for safe travel by all users, balancing the competing needs of throughput and accessibility. The purpose of this dissertation is to provide public agencies with tools to address these interdisciplinary challenges and to encourage safe, healthy communities.

RECOMMENDATIONS FOR FUTURE RESEARCH

Recommended future research stemming from this dissertation falls into two broad categories: observations on empirical outcomes of Complete Streets projects and new tools for advancing practice. The former category may result in more widespread adoption of Complete Streets strategies for planning and a more optimized approach for the deployment of Complete Streets treatments within project implementation, while the latter will help to homogenize practice across the United States and allow practitioners to 'fail forward' as a united whole rather than having to re-learn practical lessons one agency at a time.

- Outcome Studies
    - Congestion mitigation at project locations and adjacent streets
    - Environmental impacts
    - Changes in neighborhood cohesion/fragmentation
    - Public health impacts of Complete Streets implementation

- Tools for Advancing Practice
    - Site selection tool for Complete Streets projects
    - Complete Streets treatment optimization package
    - Performance Measures tailored to intermodal projects, with guidance on obtaining and applying relevant datasets
    - Incorporation of Smart Cities / Intelligent Transportation Systems to collect multimodal data at Complete Streets project locations

REFERENCES

1. Appleyard, D., and M. Lintell. THE ENVIRONMENTAL QUALITY OF CITY STREETS: THE RESIDENTS' VIEWPOINT. *Journal of the American Institute of Planners*, Vol. 38, 1972, p. 19.
2. Srinivasan, S., L. R. O'Fallon, and A. Dearry. Creating Healthy Communities, Healthy Homes, Healthy People: Initiating a Research Agenda on the Built Environment and Public Health. *American Journal of Public Health*, Vol. 93, No. 9, 2003, pp. 1446–1450. https://doi.org/10.2105/AJPH.93.9.1446.
3. Appleyard, D. *Livable Streets*. University of California Press, Los Angeles, CA, 1981.
4. Complete Streets Help Create Livable Communities. *Smart Growth America*. https://www.smartgrowthamerica.org/app/legacy/documents/cs/factsheets/cs-livable.pdf. Accessed Jan. 3, 2019.
5. Arroyo, V. A., M. F. Ableson, C. Braceras, G. Evans, N. I. Fernandez, N. P. Ford, A. S. Fotheringham, R. Batory, and M. Berube. Advancing Obesity Solutions Through Investments in the Built Environment. *TR News*, No. 319, 2019, pp. 11–17.
6. Mahmoudi, J., and L. Zhang. Impact of County-Level Built Environment and Regional Accessibility on Walking: A Washington, DC–Baltimore Case Study. *Journal of Urban Planning and Development*, Vol. 144, No. 3, 2018, p. 04018020. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000452.
7. Anciaes, P. R., S. Boniface, A. Dhanani, J. S. Mindell, and N. Groce. Urban Transport and Community Severance: Linking Research and Policy to Link People and Places. *Journal of Transport & Health*, Vol. 3, No. 3, 2016, pp. 268–277. https://doi.org/10.1016/j.jth.2016.07.006.
8. Anderson, G., C. Chester, K. Davis, S. Davis, A. Dodds, and D. Eder. *Dangerous by Design 2014*. National Complete Streets Coalition, 2014, p. 48.
9. Miller, H., F. Witlox, and C. Tribby. Developing Context-Sensitive Livability Indicators for Transportation Planning: A Measurement Framework. *Journal of Transport Geography*, Vol. 26, 2013, pp. 51–64.
10. Rápalo, V. A. W., S. S. Ivey, M. V. Hart, K. Schroeckenthaler, and T. Adams. An Evaluation of Factors Affecting Livability in Freight-Centric Community in Memphis, Tennessee. Presented at the Transportation Research Board 95th Annual MeetingTransportation Research Board, 2016.
11. Barnett, A., C. J. P. Zhang, J. M. Johnston, and E. Cerin. Relationships between the Neighborhood Environment and Depression in Older Adults: A Systematic Review and Meta-Analysis. *International Psychogeriatrics*, Vol. 30, No. 8, 2018, pp. 1153–1176. https://doi.org/10.1017/S104161021700271X.
12. Perk, V., M. Catala, M. Mantius, and K. Corcoran. *Capturing the Benefits of Complete Streets*. University of South Florida, Tampa, FL, 2015, p. 74.
13. Yu, C.-Y., M. Xu, S. D. Towne, and S. Iman. Assessing the Economic Benefits and Resilience of Complete Streets in Orlando, FL: A Natural Experimental Design Approach. *Journal of Transport & Health*, Vol. 8, 2018, pp. 169–178. https://doi.org/10.1016/j.jth.2017.11.005.
14. Zehngebot, C., and R. Peiser. Complete Streets Come of Age. *American Planning Association*. https://www.planning.org/planning/2014/may/completestreets.htm. Accessed Jan. 3, 2019.

15. Oregon Revised Statute 366.514. 1971.
16. Johnson, B. J., and S. S. White. Promoting Sustainability through Transportation Infrastructure? Innovation and Inertia in the Kansas City Metropolitan Area. *Journal of Urban Planning and Development*, Vol. 136, No. 4, 2010, pp. 303–313. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000027.
17. Step It Up! The Surgeon General's Call to Action to Promote Walking and Walkable Communities | SurgeonGeneral.Gov. *U.S. Department of Health and Human Services*. https://www.surgeongeneral.gov/library/calls/walking-and-walkable-communities/exec-summary.html. Accessed Jan. 3, 2019.
18. Murphy, C. Memphis Adopts the 500th Complete Streets Policy in the U.S. *Smart Growth America*. https://smartgrowthamerica.org/memphis-adopts-the-500th-complete-streets-policy-in-the-u-s/. Accessed Jan. 3, 2019.
19. Complete Streets in Practice: Memphis, Tennessee. *Smart Growth America*. https://www.smartgrowthamerica.org/app/legacy/documents/cs/resources/cs-brief-memphis.pdf. Accessed Jan. 3, 2019.
20. *Complete Streets Policy Adoption*. 2019.
21. Complete Streets Policies Nationwide. *Smart Growth America*. https://smartgrowthamerica.org/program/national-complete-streets-coalition/publications/policy-development/policy-atlas/. Accessed Feb. 9, 2019.
22. Poushter, J. Car, Bike or Motorcycle? Depends on Where You Live. Pew Research Center, Apr, 2015.
23. Deaton, J. P. How Much Should You Spend on a Car? *U.S. News & World Report*. https://cars.usnews.com/cars-trucks/best-cars-blog/2015/07/how-much-should-you-spend-on-a-car. Accessed Feb. 9, 2019.
24. How Much Can You Afford to Spend on a Car? *Consumer Reports*. https://www.consumerreports.org/buying-a-car/how-much-can-you-afford-to-spend-on-a-car/. Accessed Feb. 9, 2019.
25. CONSUMER EXPENDITURES--2017. *Bureau of Labor Statistics*. https://www.bls.gov/news.release/cesan.nr0.htm. Accessed Feb. 9, 2019.
26. Gudz, E. M., K. Fang, and S. L. Handy. When a Diet Prompts a Gain: Impact of a Road Diet on Bicycling in Davis, California. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2587, No. 1, 2016, pp. 61–67. https://doi.org/10.3141/2587-08.
27. Knoflacher, H. Success and Failures in Urban Transport Planning in Europe—Understanding the Transport System. *Sadhana*, Vol. 32, No. 4, 2007, pp. 293–307. https://doi.org/10.1007/s12046-007-0026-6.
28. Sterman, L., D. Armijo, D. Bayliss, S. Giudice, H. Gault, G. Giuliano, C. Lave, H. Levinson, J. Pucher, J. Reilly, B. Scott, J. Tarr, and J. Zupan. *Making Transit Work: Insight from Western Europe, Canada, and the United States*. Publication Special Report 257. Transportation Research Board, Committee for an International Comparison of National Policies and Expectations Affecting Public Transit, Washington, D.C., 2001.
29. What Is CSS - Context Sensitive Solutions and Design. *Federal Highway Administration*. https://www.fhwa.dot.gov/planning/css/what_is_css/. Accessed Jan. 10, 2020.
30. How Is Complete Streets Different from Context Sensitive Solutions. http://completestreetsforcanada.ca/faq/how-complete-streets-different-context-sensitive-solutions. Accessed Jan. 3, 2019.

31. Fischer, P. *A Right to the Road: Understanding and Addressing Bicyclist Safety*. Governors Highway Safety Association, 2017.
32. Fatality Analysis Reporting System (FARS) Encyclopedia. *FARS Data Tables*. https://www-fars.nhtsa.dot.gov/Main/index.aspx. Accessed Jul. 30, 2019.
33. Retting, R. *Pedestrian Traffic Fatalities by State: 2018 Preliminary Data*. Governors Highway Safety Association, 2019.
34. Hanzlik, M. Complete Streets and Vision Zero: Engineering for Safe Streets. *Smart Growth America*. https://smartgrowthamerica.org/complete-streets-vision-zero-engineering-safe-streets/. Accessed Jan. 3, 2019.
35. What Is Vision Zero? *Vision Zero*. https://visionzeronetwork.org/about/what-is-vision-zero/. Accessed Feb. 11, 2019.
36. United States Department of Transportation Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations - Guidance - Bicycle and Pedestrian Program - Environment - FHWA. https://www.fhwa.dot.gov/environment/bicycle_pedestrian/guidance/policy_accom.cfm. Accessed Jan. 3, 2019.
37. USDOT Announces Mayors' Challenge Pedestrian and Bicycle Awards at 2016 Safer People, Safer Streets Summit. *US Department of Transportation*. https://www.transportation.gov/briefing-room/usdot-announces-mayors-challenge-pedestrian-and-bicycle-awards-2016-safer-people-safer. Accessed Jan. 3, 2019.
38. Grossman, A., M. O. Rodgers, Y. Xu, R. Guensler, and K. Watkins. If Safety Matters, Let's Measure It: Nationwide Survey Results for Bicycle and Pedestrian Treatment Prioritization. *Journal of Transportation Engineering, Part A: Systems*, Vol. 145, No. 1, 2019, p. 04018081. https://doi.org/10.1061/JTEPBS.0000205.
39. MacDonald, D., C. P. Yew, R. Arnold, J. R. Baxter, R. K. Halvorson, H. Kassoff, M. Meyer, and K. Philmus. *Transportation Performance Measures in Australia, Canada, Japan, and New Zealand*. Publication FHWA-PL-05-001. Federal Highway Administration, 2004, p. 108.
40. Babb, A., and K. E. Watkins. Complete Streets Policies and Public Transit. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2543, No. 1, 2016, pp. 14–24. https://doi.org/10.3141/2543-02.
41. Jones, F., and J. Sloboden. Jacksonville, Florida, Transportation Authority's Mobility Corridors: Improving Transit System Performance Through Enhanced Safety and Urban Design. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2651, No. 1, 2017, pp. 118–126. https://doi.org/10.3141/2651-13.
42. Ibrahim, H., A. Salama, F. Wiedmann, B. Aboukalloub, and R. Awwaad. Identification and Analysis of Land Use Change in Doha Downtown Neighborhoods. *Journal of Urban Planning and Development*, Vol. 146, No. 1, 2020, p. 04019028. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000544.
43. Complete Streets Promote Good Health. *Smart Growth America*. https://www.smartgrowthamerica.org/app/legacy/documents/cs/factsheets/cs-health.pdf. Accessed Jan. 11, 2019.
44. Climate: Benefits of Complete Streets. *Smart Growth America*. https://smartgrowthamerica.org/resources/clmate-benefits-of-complete-streets/. Accessed Feb. 11, 2019.

45. Complete Streets Help Keep Kids Safe. *Smart Growth America*. https://www.smartgrowthamerica.org/app/legacy/documents/cs/factsheets/cs-children.pdf. Accessed Feb. 11, 2019.
46. Gilderbloom, J. I., W. W. Riggs, and W. L. Meares. Does Walkability Matter? An Examination of Walkability's Impact on Housing Values, Foreclosures and Crime. *Cities*, Vol. 42, 2015, pp. 13–24. https://doi.org/10.1016/j.cities.2014.08.001.
47. Economic Revitalization: Benefits of Complete Streets. *Smart Growth America*. https://smartgrowthamerica.org/resources/economic-revitalization-benefits-of-complete-streets/. Accessed Feb. 11, 2019.
48. Norcross, A. » The Benefits of Complete Streets. *Plan4Health*. http://plan4health.us/the-benefits-of-complete-streets/. Accessed Feb. 11, 2019.
49. Lefkowitz, M. City Hopes Complete Streets Address Structural Racism of Infrastructure. Green City Blue Lake: Cleveland Museum of Natural History, Mar 21, 2018.
50. Seskin, S., H. Kite, and L. Searfoss. *Evaluating Complete Streets Projects: A Guide for Practitioners*. American Association of Retired Persons and Smart Growth America, 2015, p. 49.
51. Program Analysis Team. SAFETEA-LU - Summary Information. *Federal Highway Administration*. https://www.fhwa.dot.gov/safetealu/summary.htm. Accessed Feb. 11, 2019.
52. Office of Policy and Governmental Affairs. A Summary of Highway Provisions - MAP-21 - Moving Ahead for Progress in the 21st Century | Federal Highway Administration. *Federal Highway Administration*. https://www.fhwa.dot.gov/map21/summaryinfo.cfm. Accessed Feb. 11, 2019.
53. Office of Policy and Governmental Affairs. A Summary of Highway Provisions - FAST Act | Federal Highway Administration. *Federal Highway Administration*. https://www.fhwa.dot.gov/fastact/summary.cfm. Accessed Feb. 11, 2019.
54. Szarata, A., K. Nosal, U. Duda-Wiertel, and L. Franek. The Impact of the Car Restrictions Implemented in the City Centre on the Public Space Quality. *Transportation Research Procedia*, Vol. 27, 2017, pp. 752–759. https://doi.org/10.1016/j.trpro.2017.12.018.
55. Knapp, K., B. Chandler, J. Atkinson, T. Welch, H. Rigdon, R. Retting, S. Meekins, E. Widstrand, and R. J. Porter. *Road Diet Informational Guide*. Publication FHWA-SA-14-028. Federal Highway Administration, 2014.
56. Ohlms, P., and L. Dougald. How's That Diet Working? A Synthesis of Studies Since the Road Diet Information Guide. Washington, D.C, Jan 14, 2020.
57. *4th Avenue, Sunset Park Traffic Calming*. New York City Department of Transportation, New York City, NY, 2014.
58. *Protected Bicycle Lanes in NYC*. New York City Department of Transportation, New York City, NY, 2014.
59. Transportation For America – Once a Critic, Now a Supporter, Ohio Rep. Helps Make Complete Streets Bill Bipartisan. Sep, 2010.
60. Harkin, T. S.584 - 111th Congress (2009-2010): Complete Streets Act of 2009. 2009.
61. Markey, E. J. S.2077 - 116th Congress (2019-2020): Complete Streets Act of 2019. 2019.
62. Harvey, J. T., A. Kendall, A. Saboori, M. Ostovar, A. A. Butt, J. Hernandez, and B. Haynes. *Framework for Life Cycle Assessment of Complete Streets Projects*. Publication NCST-UCD-RR-18-39. National Center for Sustainable Transportation, 2018.

63. Hui, N., S. Saxe, M. Roorda, P. Hess, and E. J. Miller. Measuring the Completeness of Complete Streets. *Transport Reviews*, Vol. 38, No. 1, 2018, pp. 73–95. https://doi.org/10.1080/01441647.2017.1299815.
64. Polanski, N. Reimagining the Right-of-Way: Designing Streets as Environmental and Economic Assets for Active Living and Healthy Environments. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2521, No. 1, 2015, pp. 139–148. https://doi.org/10.3141/2521-15.
65. Mattheis, C. Worst Cities For Cycling. *Bicycling*. https://www.bicycling.com/rides/a20013366/worst-cities-for-cycling/. Accessed Jan. 3, 2019.
66. Bicycle Map | Memphis Bike Trails. https://www.memphistravel.com/memphis-bike-map. Accessed Jan. 3, 2019.
67. Perry, E. Bike and Community Projects Proposed for South Memphis Inspired by the Netherlands. *The Daily Memphian*. https://www.dailymemphian.com/article/175/Bike-and-community-projects-proposed-for-South-Memphis-inspired-by-the-Netherlands. Accessed Feb. 10, 2019.
68. Shilton, A. C., and the B. M. Editors. The Best Bike Cities in America. *Bicycling*. https://www.bicycling.com/culture/a23676188/best-bike-cities-2018/. Accessed Feb. 10, 2019.
69. Bike Lanes Can Save Cities. Here's Proof. *Bicycling*. https://www.bicycling.com/rides/a24065432/bike-lanes-can-save-cities-heres-proof/. Accessed Jan. 3, 2019.
70. Ruiz, R. In Pictures: America's Most Obese Cities. *Forbes*. https://www.forbes.com/2007/11/14/health-obesity-cities-forbeslife-cx_rr_1114obese_slide_2.html?thisspeed=20000#5e0603984fc0. Accessed Feb. 10, 2019.
71. Cowan, K. A New Face for an Old Broad. *Federal Reserve Bank of St Louis*. https://www.stlouisfed.org/publications/bridges/winter-20102011/a-new-face-for-an-old-broad. Accessed Feb. 10, 2019.
72. Brown, C., J. Sinclair, and L. Cintron. *Complete Streets Case Study: Somerville, New Jersey*. The New Jersey Bicycle and Pedestrian Resource Center at Rutgers, The State University of New Jersey, New Brunswick, NJ, 2016.
73. Whitney, R. A. Complete Streets Gap Analysis: Opportunities and Barriers in Ontario. 2012, p. 60.
74. Thunder Bay. *Complete Streets for Canada*. https://www.completestreetsforcanada.ca/locations/thunder-bay/. Accessed Feb. 10, 2019.
75. Seskin, S. All Aboard for More Accessible Bus Stops in Greater Washington, DC. *Smart Growth America*. https://smartgrowthamerica.org/all-aboard-for-more-accessible-bus-stops-in-greater-washington-dc/. Accessed Jan. 3, 2019.
76. WMATA. *Improving Accessibility of Regional Bus Stops and Pathways*. Publication Customer Service and Operations Committee, Board Information Item III-A. 2014.
77. *Case Study: Las Cruces, NM: Engaging Underserved Communities to Focus on Building More Complete Streets*. American Public Health Association, 2016.
78. Benefits of Complete Streets | Smart Growth America. *National Complete Streets Coalition*. http://old.smartgrowthamerica.org/complete-streets/complete-streets-fundamentals/benefits-of-complete-streets/. Accessed Jun. 17, 2020.

79. Arroyo, V. A., M. F. Ableson, C. Braceras, G. Evans, N. I. Fernandez, N. P. Ford, A. S. Fotheringham, R. Batory, and M. Berube. Advancing Obesity Solutions Through Investments in the Built Environment. *TR News*, No. 319, 2019, pp. 11–17.
80. Complete Streets Promote Good Health. *Smart Growth America*. https://www.smartgrowthamerica.org/app/legacy/documents/cs/factsheets/cs-health.pdf. Accessed Jan. 11, 2019.
81. Brown, V., M. Moodie, and R. Carter. Evidence for Associations between Traffic Calming and Safety and Active Transport or Obesity: A Scoping Review. *Journal of Transport & Health*, Vol. 7, 2017, pp. 23–37. https://doi.org/10.1016/j.jth.2017.02.011.
82. Complete Streets Policies | US Department of Transportation. *Complete Streets Policies*. https://www.transportation.gov/mission/health/complete-streets-policies. Accessed Jun. 19, 2020.
83. Litman, T. The Value of Designing Roads For Diverse Modes, Users and Activities. *Victoria Transport Policy Institute*, 2015, p. 29.
84. Mahmoudi, J., and L. Zhang. Impact of County-Level Built Environment and Regional Accessibility on Walking: A Washington, DC–Baltimore Case Study. *Journal of Urban Planning and Development*, Vol. 144, No. 3, 2018, p. 04018020. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000452.
85. Su, J. G., M. Winters, M. Nunes, and M. Brauer. Designing a Route Planner to Facilitate and Promote Cycling in Metro Vancouver, Canada. *Transportation Research Part A: Policy and Practice*, Vol. 44, No. 7, 2010, pp. 495–505. https://doi.org/10.1016/j.tra.2010.03.015.
86. Perk, V. *Capturing the Benefits of Complete Streets*. University of South Florida, Tampa, FL, 2015.
87. Barnes, E., and M. Schlossberg. Improving Cyclist and Pedestrian Environment While Maintaining Vehicle Throughput: Before- and After-Construction Analysis. *Transportation Research Record*, Vol. 2393, No. 1, 2013, pp. 85–94. https://doi.org/10.3141/2393-10.
88. Barua, S., K. El-Basyouny, T. Islam, and S. Gargoum. Lessons Learned from Adopting the Highway Safety Manual to Assess the Safety Performance of Alternative Urban Complete Streets Designs. *Conference Proceedings of the Transportation Association of Canada*, 2014, p. 19.
89. Peiravian, F., and S. Derrible. Complete Streets Designs: A Comparative Emission Impact Analysis. Presented at the Transportation Research Board 93rd Annual MeetingTransportation Research Board, Washington, DC, 2014.
90. Ohlms, P., L. Dougald, and H. MacKnight. *How's That Diet Working: Performance of Virginia Road Diets*. Publication FHWA/VTRC 20-R19. Virginia Transportation Research Council, 2020.
91. Rodriguez-Valencia, A. Double Benefit from Green Street Design: A Life Cycle Perspective. Presented at the Transportation Research Board 93rd Annual MeetingTransportation Research Board, 2014.
92. Shu, S., D. C. Quiros, R. Wang, and Y. Zhu. Changes of Street Use and On-Road Air Quality before and after Complete Street Retrofit: An Exploratory Case Study in Santa Monica, California. *Transportation Research Part D: Transport and Environment*, Vol. 32, 2014, pp. 387–396. https://doi.org/10.1016/j.trd.2014.08.024.
93. Anderson, G., L. Searfoss, A. Cox, A. Dodds, K. Masumi, H. Kite, R. Millar, C. Murphy, E. Schilling, S. Seksin, S. Warlick, and C. Zimmerman. *Safer Streets, Stronger Economies: Complete Streets Project Outcomes from across the Country*. Smart Growth America, 2015.

94. Jensen, W., T. Stump, B. Brown, C. Werner, and K. Smith. Walkability, Complete Streets, and Gender: Who Benefits Most? *Health & Place*, Vol. 48, 2017, pp. 80–89. https://doi.org/10.1016/j.healthplace.2017.09.007.
95. Chang, A., L. Miranda-Moreno, J. Cao, and B. Welle. The Effect of BRT Implementation and Streetscape Redesign on Physical Activity: A Case Study of Mexico City. *Transportation Research Part A: Policy and Practice*, Vol. 100, 2017, pp. 337–347. https://doi.org/10.1016/j.tra.2017.04.032.
96. Yu, C.-Y., M. Xu, S. D. Towne, and S. Iman. Assessing the Economic Benefits and Resilience of Complete Streets in Orlando, FL: A Natural Experimental Design Approach. *Journal of Transport & Health,* Vol. 8, 2018, pp. 169–178. https://doi.org/10.1016/j.jth.2017.11.005.
97. Dumbaugh, E. Safe Streets, Livable Streets. *Journal of the American Planning Association*, Vol. 71, No. 3, 2005, pp. 283–298. https://doi.org/10.1080/01944360508976699.
98. Ahn, K., and H. Rakha. A Field Evaluation Case Study of the Environmental and Energy Impacts of Traffic Calming. *Transportation Research Part D: Transport and Environment*, Vol. 14, No. 6, 2009, pp. 411–424. https://doi.org/10.1016/j.trd.2009.01.007.
99. *Protected Bicycle Lanes in NYC*. New York City Department of Transportation, New York City, NY, 2014.
100. Knapp, K., B. Chandler, J. Atkinson, T. Welch, H. Rigdon, R. Retting, S. Meekins, E. Widstrand, and R. J. Porter. *Road Diet Informational Guide*. Publication FHWA-SA-14-028. Federal Highway Administration, 2014.
101. *4th Avenue, Sunset Park Traffic Calming*. New York City Department of Transportation, New York City, NY, 2014.
102. Gilderbloom, J. I., W. W. Riggs, and W. L. Meares. Does Walkability Matter? An Examination of Walkability’s Impact on Housing Values, Foreclosures and Crime. *Cities*, Vol. 42, 2015, pp. 13–24. https://doi.org/10.1016/j.cities.2014.08.001.
103. Gudz, E. M., K. Fang, and S. L. Handy. When a Diet Prompts a Gain: Impact of a Road Diet on Bicycling in Davis, California. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2587, No. 1, 2016, pp. 61–67. https://doi.org/10.3141/2587-08.
104. Jordan, S., and S. S. Ivey. Complete Streets: Promises and Proof. *Journal of Urban Planning and Development*, Vol. Under Review, 2020.
105. Appleyard, D. *Livable Streets*. University of California Press, Los Angeles, CA, 1981.
106. Sallis, J. F., L. D. Frank, B. E. Saelens, and M. K. Kraft. Active Transportation and Physical Activity: Opportunities for Collaboration on Transportation and Public Health Research. *Transportation Research Part A: Policy and Practice*, Vol. 38, No. 4, 2004, pp. 249–268. https://doi.org/10.1016/j.tra.2003.11.003.
107. Traffic Calming to Slow Vehicle Speeds. *U.S. Department of Transportation*. Accessed May 28, 2020.
108. Complete Streets in Practice: Memphis, Tennessee. *Smart Growth America*. https://www.smartgrowthamerica.org/app/legacy/documents/cs/resources/cs-brief-memphis.pdf. Accessed Jan. 3, 2019.
109. Here’s How Oregon’s Traffic Has Changed since COVID Response | KOIN.Com. https://www.koin.com/news/heres-how-oregons-traffic-has-changed-since-covid-response/. Accessed May 19, 2020.
110. Near-Real-Time Daily VMT for 3,000+ U.S. Counties. StreetLight Data.

111. Bauwens, M., S. Compernolle, T. Stavrakou, J. -F. Müller, J. Gent, H. Eskes, P. F. Levelt, R. A, J. P. Veefkind, J. Vlietinck, H. Yu, and C. Zehner. Impact of Coronavirus Outbreak on NO2 Pollution Assessed Using TROPOMI and OMI Observations. *Geophysical Research Letters*, 2020. https://doi.org/10.1029/2020GL087978.
112. COVID-19 Lockdowns Significantly Impacting Global Air Quality. *AGU Newsroom*. https://news.agu.org/press-release/covid-19-lockdowns-significantly-impacting-global-air-quality/. Accessed May 19, 2020.
113. Shi, X., and G. Brasseur. The Response in Air Quality to the Reduction of Chinese Economic Activities during the COVID-19 Outbreak. *Geophysical Research Letters*, 2020.
114. Chadra, K. Motor Vehicle Fatality Rates Jump 14% in March Despite Quarantines. *National Safety Council*. https://www.nsc.org/in-the-newsroom/motor-vehicle-fatality-rates-jump-14-in-march-despite-quarantines. Accessed May 21, 2020.
115. Metro, L. L. closeLuz L. reporter covering W. U.S. Roadways More Lethal during Pandemic, Safety Group Says. *Washington Post*. https://www.washingtonpost.com/transportation/2020/05/20/us-roadways-more-lethal-during-pandemic-lockdown-national-safety-council-data-shows/. Accessed May 21, 2020.
116. Memphis Police See Increase in Street Racing since Safer-at-Home Orders Relaxed, Several Suspects Arrested. *https://www.wmcactionnews5.com*. https://www.wmcactionnews5.com/2020/05/11/memphis-police-see-increase-street-racing-since-safer-at-home-orders-relaxed-several-suspects-arrested/. Accessed May 21, 2020.
117. Páez, A., and K. Whalen. Enjoyment of Commute: A Comparison of Different Transportation Modes. *Transportation Research Part A: Policy and Practice*, Vol. 44, No. 7, 2010, pp. 537–549. https://doi.org/10.1016/j.tra.2010.04.003.
118. Marleau Donais, F., I. Abi-Zeid, E. O. D. Waygood, and R. Lavoie. Assessing and Ranking the Potential of a Street to Be Redesigned as a Complete Street: A Multi-Criteria Decision Aiding Approach. *Transportation Research Part A: Policy and Practice*, Vol. 124, 2019, pp. 1–19. https://doi.org/10.1016/j.tra.2019.02.006.
119. Complete Streets. *Institute of Transportation Engineers*. https://www.ite.org/technical-resources/topics/complete-streets/. Accessed Jun. 17, 2020.
120. Context Sensitive Solutions and Design - Planning - FHWA. *Federal Highway Administration*. https://www.fhwa.dot.gov/planning/css/. Accessed Jun. 17, 2020.
121. MPO Database - Transportation Planning Capacity Building Program. *U.S. Department of Transportation*. https://www.planning.dot.gov/mpo/. Accessed Jun. 12, 2020.
122. Edwards, S. Complete Streets in Memphis. Oct 16, 2019.
123. Shaffer, J. History: New Face on an Old Broad. Apr 07, 2020.
124. BLDG Memphis. *BLDG Memphis*. https://www.bldgmemphis.org/about. Accessed Apr. 5, 2020.
125. Wharton, A. An Order Establishing a Complete Streets Policy for the City of Memphis. 01-2013, 2013.
126. *City of Memphis Complete Streets Project Delivery Manual*. City of Memphis, Memphis, TN, 2015.
127. Wharton, A. Giving Memphis the Bike-Friendly City You Deserve. From the Mayor's Desk, Jul 15, 2010.

128. Bike Lanes Can Save Cities. Here's Proof. *Bicycling*. https://www.bicycling.com/rides/a24065432/bike-lanes-can-save-cities-heres-proof/. Accessed Jan. 3, 2019.
129. Harkin, T. S.584 - 111th Congress (2009-2010): Complete Streets Act of 2009. 2009.
130. Transportation For America – Once a Critic, Now a Supporter, Ohio Rep. Helps Make Complete Streets Bill Bipartisan. Sep, 2010.
131. Markey, E. J. S.2077 - 116th Congress (2019-2020): Complete Streets Act of 2019. 2019.
132. The Ten Elements of a Complete Streets Policy. *Smart Growth America*. https://smartgrowthamerica.org/resources/the-ten-elements-of-a-complete-streets-policy/. Accessed Jun. 4, 2020.
133. Jordan, S., S. S. Ivey, M. Levy, M. Lipinski, P. Palazolo, and B. Waldron. Complete Streets: Theory and Practice. *Cities*, Vol. Under Review, 2020.
134. *Road Diet Case Studies*. Publication FHWA-SA-15-052. Federal Highway Administration, 2015.
135. Seskin, S., H. Kite, and L. Searfoss. *Evaluating Complete Streets Projects: A Guide for Practitioners*. American Association of Retired Persons and Smart Growth America, 2015, p. 49.
136. Climate: Benefits of Complete Streets. *Smart Growth America*. https://smartgrowthamerica.org/resources/clmate-benefits-of-complete-streets/. Accessed Feb. 11, 2019.
137. Economic Revitalization: Benefits of Complete Streets. *Smart Growth America*. https://smartgrowthamerica.org/resources/economic-revitalization-benefits-of-complete-streets/. Accessed Feb. 11, 2019.
138. Norcross, A. » The Benefits of Complete Streets. *Plan4Health*. http://plan4health.us/the-benefits-of-complete-streets/. Accessed Feb. 11, 2019.
139. McCann, B., and S. Rynne. *Complete Streets: Best Policy and Implementation Practices*. Publication 559. American Planning Association, Planning Advisory Service, 2010, p. 148.
140. Johnson, B. J., and S. S. White. Promoting Sustainability through Transportation Infrastructure? Innovation and Inertia in the Kansas City Metropolitan Area. *Journal of Urban Planning and Development*, Vol. 136, No. 4, 2010, pp. 303–313. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000027.
141. Ibrahim, H., A. Salama, F. Wiedmann, B. Aboukalloub, and R. Awwaad. Identification and Analysis of Land Use Change in Doha Downtown Neighborhoods. *Journal of Urban Planning and Development*, Vol. 146, No. 1, 2020, p. 04019028. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000544.
142. Nolan, R. L. Managing the Computer Resource: A Stage Hypothesis. *Communications of the ACM*, Vol. 16, No. 7, 1973, pp. 399–405. https://doi.org/10.1145/362280.362284.
143. Humphrey, W. S. Characterizing the Software Process: A Maturity Framework. *IEEE Software*, Vol. 5, No. 2, 1988, pp. 73–79. https://doi.org/10.1109/52.2014.
144. Paulk, M. Capability Maturity Model for Software. In *Encyclopedia of Software Engineering* (J. J. Marciniak, ed.), John Wiley & Sons, Inc., Hoboken, NJ, USA.
145. Paulk, M. C., B. Curtis, M. B. Chrissis, and C. V. Weber. *Capability Maturity Model for Software, Version 1.1:* Defense Technical Information Center, Fort Belvoir, VA, 1993.
146. Curtis, B., W. Hefley, and S. Miller. *People Capability Maturity Model*. Defense Technical Information Center, Fort Belvoir, VA, 1995.

147. Essmann, H., and N. Du Preez. An Innovation Capability Maturity Model – Development and Initial Application. *Proceedings of World Academy of Science: Engineering and Technology*, Vol. 53, 2009, p. 11.
148. Planned Special Event CMF. https://ops.fhwa.dot.gov/tsmoframeworktool/tool/pse/index.htm. Accessed Jul. 30, 2020.
149. Road Weather Management CMF. https://ops.fhwa.dot.gov/tsmoframeworktool/tool/rwm/index.htm. Accessed Jul. 30, 2020.
150. Traffic Management CMF. https://ops.fhwa.dot.gov/tsmoframeworktool/tool/traffic_mgmt/index.htm. Accessed Jul. 30, 2020.
151. Traffic Signal Systems CMF. https://ops.fhwa.dot.gov/tsmoframeworktool/tool/tssc/index.htm. Accessed Jul. 30, 2020.
152. Work Zone Management CMF. https://ops.fhwa.dot.gov/tsmoframeworktool/tool/wzm/index.htm. Accessed Jul. 30, 2020.
153. Active Demand Management CMF. https://ops.fhwa.dot.gov/tsmoframeworktool/tool/adm/index.htm. Accessed Jul. 30, 2020.
154. AASHTO: Transportation Systems Management & Operations Guidance. *AASHTO TSMO Guidance*. http://www.aashtotsmoguidance.org/. Accessed Aug. 25, 2020.
155. Capability Maturity Frameworks Overview: Business Process Frameworks for Transportation Operations - FHWA Operations. https://ops.fhwa.dot.gov/tsmoframeworktool/cmf_overview.htm. Accessed Jul. 30, 2020.
156. Lockwood, S. Interview with Stephen Lockwood, TSMO Capability Maturity Model Specialist. Jul 10, 2020.
157. Comstock, K. Interview with Kevin Comstock, Smart Cities Director for City of Chattanooga. Jul 20, 2020.
158. Jelen, M. Interview with Michael Jelen, Steering Committee, National Complete Streets Coalition. Jul 23, 2020.
159. Oyler, N. Interview with Nicholas Oyler, Bikeway and Pedestrian Program Manager, City of Memphis TN. Jul 24, 2020.
160. Crook, J. Interview with James Crook, Engineering Department, Shelby County TN Government. Aug 19, 2020.
161. Zavisca, E. Interview with Ellen Zavisca, Principal Transportation Planner, Knoxville Regional Transportation Planning Organization. Jul 24, 2020.
162. Gettman, D., L. Burgess, D. Haase, E. Flanigan, and S. Lockwood. *Guidelines for Applying Capability Maturity Model Analysis to Connected and Automated Vehicle Deployment*. Publication FHWA-JPO-18-629. Kimley Horn and Associates, 2017, p. 92.
163. Doran, G. T. There’s a S.M.A.R.T. Way to Write Management’s Goals and Objectives. *Management Review*, Vol. 70, No. 11, 1981, pp. 35–36.
164. Dowling, R. G., National Research Council (U.S.), and National Cooperative Highway Research Program, Eds. *Multimodal Level of Service Analysis for Urban Streets*. Transportation Research Board, Washington, D.C, 2008.
165. Hufty, M. *Investigating Policy Processes: The Governance Analytical Frame-Work (GAF)*. Geographica Bernensia, Bern, Switzerland, 2011.

APPENDIX A: BLANK SURVEY

Describe your agency and position.

Agency type (MPO, City DOT, etc.)	[Free response]
State	[Free response]
County (if applicable)	[Free response]
City (if applicable)	[Free response]
Job Title	[Free response]
When did your agency adopt a Complete Streets policy?	[Drop-down]: 2005 or earlier; years {2006-2019}; "My agency does not have a complete streets policy.

Please rate your level of agreement with the following statements: *6-point Likert scale: Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree, Not Applicable to my agency.*

My agency has a mature and well-executed Complete Streets policy.	[Likert]
My agency routinely collects before-and-after data on implemented project.	[Likert]
My agency tracks performance measures on implemented projects.	[Likert]
My agency monitors the outcomes of implemented projects.	[Likert]
My agency has a mature and well-executed data storage procedure.	[Likert]
My agency has a mature and well-executed data sharing procedure.	[Likert]
My agency has developed strong partnerships with other local organizations to facilitate data sharing.	[Likert]
It is important to measure the impacts of Complete Streets projects.	[Likert]
A framework for measuring impacts of Complete Streets projects would be valuable to my agency.	[Likert]

How do YOU define a Complete Street?	[Free response]
Who are the users your agency considers when planning a Complete Streets project?	[Select all that apply]: Drivers; Pedestrians; Cyclists; Transit Riders; Rideshare users (Uber, Lyft, etc.); Shared micromobility users

	(bike share, e-scooters, etc.); Other (please explain) [Free response if ‘other’ selected].
How does your agency decide which projects should be “complete”, or how “complete” a project should be?	[Free response]
How does your agency collect, store, and share data?	[Free response]
Would you like to share any other thoughts on Complete Streets in your community?	[Free response]
Would you like to hear back from our research team?	[Select all that apply]: No thanks; I would like to participate in follow-up discussions; I would like a copy of the completed study
If you’d like to hear back from our research team, please provide your email (optional)	[Free response]

APPENDIX B: GLOSSARY

Many terms are used differently by different agencies or in different parts of the world. The following provides a quick guide for how these terms are used within the Complete Streets Capability Maturity Model.

Agency: An organization working to provide a particular service. While Complete Streets may be the responsibility of a local DOT, other agencies such as public works or zoning commissions play important related roles.

Capability Maturity Model (CMM): A qualitative model designed to help agencies to identify and evolve existing practices across a set of relevant program dimensions. In short, a CMM helps an agency to ask "What does 'good' look like? How do we measure up? And how can we improve?"

Complete Streets (CS): Complete Streets is a planning and design perspective that seeks to treat streets as a **space**, and not only as a means of **conveyance**. This perspective considers **all users across all modes** of transportation. For the purposes of this module, any planning paradigm that fits this description is referred to as a Complete Streets initiative whether or not relevant agencies are using this term. Related terms include context-sensitive solutions, CSS/D, and active transportation.

Complete Streets elements: Treatments applied to a space with the purpose of making the street more "Complete". One project may utilize several treatments within a space.

Flagship project: A flagship Complete Streets project is easily recognizable by the general public, and has all the bells and whistles of a Complete Street. These may include creation of pedestrian malls and café spaces, rails-to-trails initiatives, and bikeshare hubs. A flagship project typically requires considerable space, expense, and construction.

Governance: "the processes of interaction and decision-making among the actors involved in a collective problem that lead to the creation, reinforcement, or reproduction of social norms and institutions" (*165*). Good governance requires the efficient use of available resources to create the best available outcomes for the community and stakeholders.

Intelligent Transportation Systems (ITS): Use of sensors, computers, and communications systems to make travel faster, safer, and easier. ITS is commonly used in active demand management and traffic incident management.

Interoperability: Function of a set of technologies as a whole. Interoperability is achieved when new technologies "play well" with older technologies and existing systems, and information is exchanged freely between systems. Interjuristictional interoperability is of special importance in relation to connected/autonomous vehicles (CAVs), infrastructure-to-vehicle and vehicle-to-infrastructure (i2v or v2i) communications, and regional/inter-regional collaboration.

Outputs/Outcomes: Outputs are the immediate and easily measurable results of a project or program, while outcomes are the long-term effects those projects or programs have on the surrounding society. Outputs include miles of added bike lanes, installed park benches, and other physical items. Outcomes include changes in public health, participation in active transportation, and safety or security.

Policy: A formally adopted set of agency goals and values. A policy is usually adopted by a political body.

Program: A set of related measures or activities with a particular long-term aim. A program is usually maintained by an agency.

Project: A temporary endeavor undertaken to provide a particular service or result. In the case of Complete Streets, a project is typically one construction project at a single site.

Smart Cities: Smart Cities use sensors and computers as with ITS, but applications are not limited to transportation. Examples include sensor-based stormwater management, air quality monitoring, irrigation, and Chicago's Array of Things.

Tactical Urbanism: Low-cost, temporary changes to urban environments such as restriping projects or guerrilla gardening.