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# City of Emeryville

INCORPORATED 1896

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## ECONOMIC DEVELOPMENT ADVISORY COMMITTEE

Regular Meeting
Emeryville City Hall, Garden Level
1333 Park Avenue Emeryville, CA 94608
**May 20, 2026 – 11:30 AM**

## AGENDA

1. Call to Order
2. Roll Call
3. Public Comment
4. Approval of March 18, 2026, Regular Meeting Action Minutes
5. Action Items
6. Information Items
   - 6.1 Business License Tax Reform
   - 6.2 Economic Evaluation of Active Transportation Projects, Part II
   - 6.3 Emeryville Commerce Connection Updates
   - 6.4 2025 Q4 Sales Tax Report
7. Future Agenda Items
   - 7.1 BIPOC Small Business Support Program Update
8. Announcements / Member Comments
9. Adjournment

Public comment for agenda items can be submitted online via our online speaker card at www.emeryville.org/advisorybodies. Written comments can also be submitted by email to the Committee Secretary. If you would like to support, oppose, or otherwise comment on an upcoming agenda item, please send in your comments prior to the meeting.

**FURTHER INFORMATION** may be obtained by contacting Chadrick Smalley, Committee Secretary, at 510-596-4355 or csmalley@emeryville.org / edac@emeryville.org. The next regular meeting is scheduled for July 15, 2026, at 11:30 AM.

**DATED: MAY 13, 2026**

Post On: MAY 15, 2026
Post Until: MAY 21, 2026

Lorrayne Leong, Deputy City Clerk

City of Emeryville
INCORPORATED 1896
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**Emeryville Economic Development Advisory Committee**
Chair Mary Lou Thiercof
Vice Chair Fran Quittel
Member Javier Contreras
Member Scott Donahue
Member Rob Fong
Member Marchelle Huggins
Member David Kritzberg
Member Michael Reed
Member Kyle Weddington

**Action Minutes**
**Emeryville Economic Development Advisory Committee**
**Regular Meeting**
Wednesday, March 18, 2026, 11:30 AM

## I. Call to Order

The meeting was called to order at 11:44 am.

## II. Roll Call

Members Present: Chair Mary Lou Thiercof, Vice Chair Fran Quittel, Scott Donahue, Marchelle Huggins (arrived 11:44), David Kritzberg, Michael Reed, Kyle Weddington

Members Absent: Javier Contreras, Rob Fong

Staff Present: Chadrick Smalley, Community Development Director; Valerie Bernardo, Economic Development and Housing (EDH) Manager; Niwonna Jones, EDH Management Analyst

## III. Public Comment

Joyce Cunningham made comment regarding the 40th Streetscape Project, noting retailers were not notified.

Director Smalley confirmed the 40th Street project is not on the EDAC's agenda for this meeting.

Vice Chair Quittel expressed concern about the 40th Street project, and stated an economic study should have been conducted for the project.

## IV. January 21, 2026 Action Minutes

**Motion by Vice Chair Quittel approve the January 21, 2026 Regular Meeting Action Minutes. Member Weddington seconded. Motion passes (6-0).**

## V. Action Items

### Item 5.1 – Consideration of Support for Emeryville Commerce Connection Restaurant Week Event

Chair Thiercof recused herself from the meeting for this item, noting her role as CEO of Emeryville Commerce Connection (ECC) and departed the meeting room.

Director Smalley presented an outline of the staff report for this item and introduced Christa Williams, Chair of the ECC Board of Directors. The EDAC discussed print vs. electronic media outreach methods, the role of the City funding the ECC's activities, the unique status of ECC as a small business-oriented association, and the need for the collection of data from restauranteurs and customers as part of evaluating the effectiveness of Restaurant Week.

**Motion by Member Donahue recommending the City Council approve funding support for the ECC's production of Restaurant Week. Member Weddington seconded. Motion passes with Chair Thiercof recused (6-0).**

Chair Thiercof rejoined the meeting.

## VI. Information Items

### Item 6.1 – BIPOC Small Business Support Program

Director Smalley introduced Management Analyst Niwonna Jones. Ms. Jones provided an overview of program activities through the first quarter of the year.

Joyce Cunninham provided public comment, inquiring about the definition of small business.

The EDAC discussed promotion platforms such as bluedot, yifty, and the potential of utilizing the City's local cable channel. The committee also discussed the City's minimum wage, Dmall Business Development Center workshops and regional partnerships.

### Item 6.2 – Rotten City Cultural District Programs Update

Director Smalley provided an update on Rotten City Cultural District programs, noting the Emeryville Film Festival is scheduled for March 21st.

### Item 6.3 – Emeryville Commerce Connection Update

Chair Thiercof provided an update on the Emeryville Commerce Connection ("ECC"), noting membership is growing and the next event is the two-year anniversary of ECC to be held on March 25th at Flores restaurant.

### Item 6.4 – 2025 Q2 Sales Tax Report

Director Smalley referred members to the report, which shows receipts up 6.5% year over year for the quarter. Business to business transactions are down, while liquor sales are up. The committee noted a number of the top 25 sales tax generators are located on the 40th Street corridor.

## VII. Future Agenda Items

Future agenda items were noted on the agenda.

Stella Santillan urged the committee to pay attention to issues faced by the businesses along 40th Street.

## VIII. Announcements / Member Comments

Chair Thiercof noted she presented the committee's annual report to the City Council on March 17th, and read her concluding remarks to the committee.

The committee requested an update on the Arts Center project.

## IX. Adjournment

The meeting was adjourned at 1:08 PM.

Prepared by: Approved by Committee:

______________________________________ May 20, 2026

Chadrick Smalley, Community Development Director

City of Emeryville
CALIFORNIA

**MEMORANDUM**

**DATE**: May 20, 2026

**TO**: City of Emeryville Economic Development Advisory Committee

**FROM**: Chadrick Smalley, Community Development Director

**SUBJECT: Business License Tax Reform**

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## DISCUSSION

On November 4, 2025, the City Council held a study session to evaluate potential revenue measures that could be included on the election ballot in 2026. The City Council reviewed options including 1) modernizing the business license tax, 2) a Citywide parcel tax, 3) a ¼ cent sales tax, 4) increasing the transient occupancy tax ("TOT"), and 5) update and expansion of the utility users tax ("UUT").

The City Council directed staff to further explore modernizing the business license tax and a Citywide parcel tax, but not to pursue the other revenue methods at this time.

On November 19, 2025, Finance Director Sharon Friedrichsen provided the EDAC with an overview of the business license tax modernization analysis.

On May 19, 2026, the City Council is scheduled to hold a study session to review the results from a public opinion survey and provide direction to staff. Ms. Friedrichsen will provide the EDAC with an update on the City Council's action. For reference, the staff report to the City Council is attached.

## ATTACHMENTS

1) City Council Staff Report, May 19, 2026

City of Emeryville
CALIFORNIA

**MEMORANDUM**

**DATE:** May 19, 2026

**TO:** Mayor and City Council Members

**FROM:** LaTanya Bellow, City Manager

**SUBMITTED BY:** Sharon Friedrichsen, Finance Director

**SUBJECT:** REVENUE MEASURES UPDATE STUDY SESSION

## RECOMMENDATION

Staff recommends that the City Council hold a study session to receive an update on potential revenue measure(s) that could be included on the November ballot and provide direction to staff to proceed with drafting the required documents to place a business license tax reform measure on the ballot for the November 2026 general election.

## BACKGROUND

The City Council held its annual Strategic Planning Session on March 21, 2025, where Council discussed and agreed on four multi-year broad goals and four top priorities for the coming year, including researching possible revenue measures for the 2026 ballot to address the City's General Fund budget challenges. This timeframe coincided with the development of the City's biennial budget for fiscal years 2025-2027.

The five-year General Fund forecast depicts a structural deficit whereby expenditures outpace revenues resulting in a projected shortfall of $9.7 million in fiscal year 2025-26 increasing upwards to $14.6 million in fiscal year 2029-30 absent either additional transfers from reserves, significantly reduced expenditures, and/or enhanced revenues. As part of the budget deliberation process, the Budget Advisory Committee (BAC) met on May 8, 2025, to review the proposed biennial budget and long-term financial forecast. At that meeting, the BAC recommended that Council explore revenue measures that could be placed on the November 2026 general election ballot. Since that time, staff developed revenue measure options, which were then presented to the BAC and the Budget and Governance Committee in September 2025 for recommendations. Subsequently, on November 4, 2025, City Council held a study session to review, discuss, and provide direction on potential revenue measure(s) that could be included on the November 2026 ballot.

The City Council considered several potential revenue enhancement measures including:

- Business License Tax Reform
- Citywide Parcel Tax
- Local ¼ Cent Transactions & Use (Sales) Tax
- Increase in Transient Occupancy (Hotel) Tax
- Utility Users Tax Increase & Expansion

The City's current business license tax ordinance was last modified in 1984. Under the City's current business license tax structure, most businesses are taxed at $1 per $1,000 in gross receipts. The Finance Department estimates that the Business License Tax will generate $6.6 million, or 14% of the General Fund revenue, in FY 2025-26. As part of the research of potential revenue measures, the City contracted with HdL Companies to prepare a business tax study that included a comparison with other comparable cities and modeled two revisions to the tax structure: (1) a single gross receipts tax with rates at $1.5 and $2.0 per $1,000 of gross receipts and (2) a variable gross receipts tax with different rates based on business type or category as illustrated in the table below.

| Categories* | Minimum Rate | Option 1 | Option 2 |
|---|---|---|---|
| Contractor | $25 Flat Rate (Up to $25,000 Gross Receipts) | 0.002 X Gross | 0.003 X Gross |
| General/Retail | | 0.00075 X Gross | 0.001 X Gross |
| Property Rental | | 0.0035 X Gross | 0.004 X Gross |
| Services | | 0.002 X Gross | 0.003 X Gross |
| Professional | | 0.003 X Gross | 0.004 X Gross |
| Exempt | $0 | $0 | $0 |

In addition, the City contracted with NBS to research options related to forming a Citywide Community Facilities District or levying a Citywide Parcel Tax. Options included assessing a single rate per parcel or per square foot, based on land use as illustrated in the table below. Under this scenario, generating $5 million in annual revenue would require assessing a flat rate of $125 per year for residential parcels and $0.34 per square foot for commercial parcels.

| Tax Rate by Land Use | | | | |
|---|---|---|---|---|
| **Residential Per Unit** | **$3.5M Revenue** | **$4M Revenue** | **$4.5M Revenue** | **$5M Revenue** |
| 7,872 | $50 | $75 | $100 | $125 |
| **Non-Residential per Building Square Feet** | | | | |
| 11,692,206 | $0.27 | $0.29 | $0.32 | $0.34 |

During the November 2025 study session, Council provided direction for staff to explore the feasibility of business license tax reform and a citywide parcel tax. In particular, Council supported the variable gross receipts (option 2) model for business license tax reform and the parcel tax by land use with a cap of $100 per residential parcel.

Staff contracted with Godbe Research and the Lew Edwards Group to conduct a revenue measure feasibility analysis and public opinion survey on the viability of these two revenue measures. The purpose of this study session is to provide an update on these measures and to receive Council direction to staff to proceed with moving forward in placing a business license tax reform measure on the November 2026 ballot.

## DISCUSSION

Godbe Research surveyed a sample of 306 likely voters during the period of March 30-April 10, 2026, on the feasibility of a business license tax reform measure and a parcel tax. Data was gathered through surveys completed though voice (landlines and mobile phones) and text and email for online interviewing. The margin of error is ± 5.4%.

The objectives of the survey included (1) to gauge the public's perception of the job the City is doing to provide City services and effectively manage taxpayer funds; (2) assess potential voter support for a business license tax reform measure; (3) prioritize projects and programs to be funded with such a measure and (4) assess support for a parcel tax.

Key findings of the survey indicated the following:

- 81.0% of participants have a favorable rating of the job the City is doing in providing City services;
- 76.4% support a potential business license tax reform measure;
- 51.8% support a parcel tax of $98 per residential parcel. The survey also assessed the viability of a parcel tax with reduced amounts of $78 and $58 per residential parcel respectively and neither alternative garnered support close to 67%. (A parcel tax is a special tax and requires 2/3 approval by the voters).

Based upon the results of the public opinion survey, staff recommend Council provide direction to staff to draft the necessary documents to place a business license tax reform measure on the November 2026 ballot. Staff does not recommend moving forward with a parcel tax at this time. An alternative parcel tax rate of $58 per residential parcel received 57.9% support. It is unlikely that the voters would approve a parcel tax with a 2/3 majority. In addition, under this alternative, the City would either receive less revenue or need to increase the square footage rate on commercial parcels to offset the reduced residential parcel rate to generate $5 million in revenue.

## STRATEGIC PLAN CONNECTION

The City Council's strategic plan priorities for 2025-2026 included researching revenue measures for 2026. As part of the 2026 - 2028 strategic planning session, Council identified continuing work on revenue measures as a top priority for the upcoming year.

## FISCAL IMPACT

There is no fiscal impact associated with holding the study session. A business license reform measure has the potential to generate an additional $6.8 million in revenue over the existing projected business license tax revenue for a total revenue of approximately $13.4 million each fiscal year.

## STAFF COMMUNICATION WITH THE PUBLIC

While a sample of registered voters were contacted to participate in the survey, there has not been any general communication with the public on the results of the survey.

## CONFLICT OF INTEREST

There are no known conflicts.

## CONCLUSION

Based upon the results of the public opinion survey, staff recommends Council provide direction to staff to draft the necessary documents to place a business license tax reform measure on the November 2026 ballot. Staff does not recommend moving forward with a parcel tax at this time.

**PREPARED BY:** Sharon Friedrichsen, Finance Director

City of Emeryville
CALIFORNIA

**MEMORANDUM**

**DATE**: May 20, 2026

**TO**: City of Emeryville Economic Development Advisory Committee

**FROM**: Chadrick Smalley, Community Development Director

**SUBJECT: Economic Evaluation of Active Transportation Projects, Part II**

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## DISCUSSION

On January 21, 2026, the EDAC held a discussion on the economic evaluation of Active Transportation Plan projects (see Attachment 1). Since then, Chair Thiercof and Vice Chair Quittel requested additional discussion on this topic. Because the EDAC's May 2026 agenda is relatively short, staff has agendized this "Part II" discussion.

Of note, the EDAC's interest in this topic originated from the 40th Street Multimodal Project. On March 19, 2026, the City Council approved the design of this project. There is no further City Council action anticipated on this project until award of the construction contract, and the City Council has not requested the EDAC's input on its design. The EDAC is advisory to the City Council, accordingly, the EDAC's role as regards this specific project is limited to providing the City Council with advice on potential programs to mitigate construction impacts.

Staff urges the EDAC to think broadly about the City's planned transportation projects and the relationship of these projects to the City's economic development goals. To assist the EDAC in its continued discussion, staff has attached a selection of relevant studies.

## ATTACHMENTS

1. EDAC Memo, January 21, 2026
2. Daniel Arancibia, Steven Farber, Beth Savan, Yvonne Verlinden, Nancy Smith Lea, Jeff Allen & Lee Vernich (2019) Measuring the Local Economic Impacts of Replacing On-Street Parking With Bike Lanes, Journal of the American Planning Association, 85:4, 463-481

3. James Gillespie, Isiah Batman & Katya Benham (2026) Business Impacts of Access Changes, Virginia Transportation Research Council, VTRC 26-R38
4. Todd Litman (2025) Economic Value of Walkability, Victoria Transport Policy Institute
5. Jamey Volker & Susan Handy (2021) Economic Impacts on Local Businesses of Investments in Bicycle and Pedestrian Infrastructure: A Review of the Evidence, Transport Reviews Vol 41 No. 4 401-431

City of Emeryville
CALIFORNIA

# MEMORANDUM

**DATE**: January 21, 2026

**TO**: City of Emeryville Economic Development Advisory Committee

**FROM**: Chadrick Smalley, Director of Community Development

**SUBJECT: Economic Evaluation of Active Transportation Plan Projects**

Background

On October 17, 2023, the City Council adopted Emeryville's first Active Transportation Plan ("ATP"). The ATP's stated purpose is to serve as "…a guide for improving the quality of life for every resident, worker, and visitor by providing not just safe, but joyful experiences on its streets, sidewalks, and trails." It is a blueprint for improving active transportation (i.e. walking and bicycling) infrastructure and programs over the next ten years. Chapter Four of the ATP consists of a set of policies, programs and projects (Attachment 1).

The projects and programs outlined in the ATP take their first step toward becoming a reality when the City's Transportation and Sustainability Committee recommends projects to advance. Recommendations for projects then move through the Capital Improvement Program (CIP) budget process. Once the City secures funding for the recommendation, and staff capacity is available, it will move through the project delivery process (preliminary planning and engineering, conceptual design, detailed design, and construction).

The City is in the process of implementing the ATP through the design and construction of street improvements in various locations across the City. Some ATP projects entail substantive changes to roadway design (e.g. removal of parking, travel lanes, addition of bike lanes and/or wider sidewalks). The most visible manifestation of this is currently the Sustainable Streetscapes Project on Hollis Street, which is nearing completion.

The 40th Street Multimodal Improvements Project is also included in the ATP, though this project's origins predate the ATP. While advancing this project through the design phase, some community members have raised concerns regarding the impact of the project on area businesses. In light of these concerns, EDAC and business owners have inquired as to the EDAC's role regarding the project.

The EDAC's purpose is to "provide input and recommendations regarding City policies and priorities related to the City's economic development priorities and strategies." Historically, the EDAC's involvement in CIP projects has been limited to providing input on the CIP prior to its adoption by the City Council, as the planning of infrastructure (of all types) is related to economic development.

The community discussion related to the 40th Street Multimodal Improvements Project has highlighted a more specific aspect of the CIP's relationship to economic development, that is, the desirability of evaluating the economic effects of transportation projects. Most of the transportation projects in the CIP are derived from the ATP, and the ATP's ten-year timeframe extends beyond the CIP's typical five-year cycle. Consequently, staff has agendized this topic to discuss whether and how to evaluate the economic effects of ATP projects.

<u>Discussion</u>

Under this broad discussion topic, there are several considerations to weigh, as follows:

*Whether to Evaluate*
Firstly, it should be established whether or not to evaluate the economic effects of these types of projects. The ATP's stated purpose is to improve quality of life for residents, workers and visitors, and is the adopted policy of the City. As such, the economic effects of these projects must be weighed against the other policy goals of quality of life and sustainability. To the extent measuring economic performance of these projects is not a consideration in the policy calculus, the City's resources may be better used elsewhere.

Additionally, as will become evident in the following discussion, evaluating economic effects of transportation projects is not straightforward, subject to many confounding variables, and causality is difficult to establish. If the analysis that can be feasibly accomplished within the City's limited resources is of questionable validity, it may be of limited utility at best and counterproductive at worst.

*Types of Projects*
Presuming economic analysis of ATP projects is a worthwhile endeavor, it should be determined which types of projects should be evaluated. The ATP contains a wide variety of transportation improvements – some are quite minor interventions, while others are more substantial. A decision on what level of modifications should be evaluated is required to manage limited resources.

*Geographic and Time Extent of Impacts*
Related to the scope of projects considered, the geographic and time extents of effects needs to be established for each project. Some projects may cause localized impacts at the single property level but have offsetting benefits (or negative impacts) that involve a larger area. Establishing this is not always

straightforward. Similarly, the timing of impacts is a consideration: construction impacts can be measured and will primarily affect businesses in the immediate area of the project. Longer-term impacts relating to the project's completion are more difficult to assess and attribute to the project.

*Metrics*

Lastly, the metrics to be measured should be quantifiable data points that are easily accessible to staff and do not require significant effort to analyze. Examples of these are gross receipts (since these are collected from most business types as part of business licenses), sales tax receipts, land use, and vacancy rates. Economic indicators that would be more difficult to obtain include employment, wages, and lease rates/land value.

It should be noted that considering the metrics to analyze pre- and post-project highlights the complexity introduced by confounding factors. For example, measuring gross receipts of all businesses in a corridor before and after a theoretical project that removed lanes of traffic and parking might show a decline in economic activity for those businesses – but causality cannot necessarily be attributed to the project if there were other factors not controlled for. It is also difficult to establish a control group for these types of analyses.

These complicating factors raise the issue of resource constraints. The more complex an analysis has to be to have utility for decision making, the more costly it is to complete.

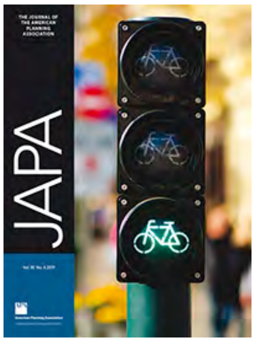
## Conclusion

The City's ATP envisions a wide variety of transportation improvement projects on nearly every roadway in the City. Each project will individually proceed through project delivery phases, including community outreach, as funds are identified and in accordance with City Council priorities.

The business community and the City alike may have an interest in understanding how these projects affect the City's economic performance, and the City could undertake research projects to attempt to evaluate these projects accordingly. In deciding whether to undertake such analyses, the City needs to consider resource and data constraints, competing policy objectives, and the utility of the analyses.

Attachment:

1) ATP Chapter 4 – Policies, Programs and Projects




Journal of the American Planning Association

Routledge
Taylor & Francis Group

ISSN: 0194-4363 (Print) 1939-0130 (Online) Journal homepage: https://www.tandfonline.com/loi/rjpa20

# Measuring the Local Economic Impacts of Replacing On-Street Parking With Bike Lanes

## A Toronto (Canada) Case Study

**Daniel Arancibia, Steven Farber, Beth Savan, Yvonne Verlinden, Nancy Smith Lea, Jeff Allen & Lee Vernich**

**To cite this article:** Daniel Arancibia, Steven Farber, Beth Savan, Yvonne Verlinden, Nancy Smith Lea, Jeff Allen & Lee Vernich (2019) Measuring the Local Economic Impacts of Replacing On-Street Parking With Bike Lanes, Journal of the American Planning Association, 85:4, 463-481, DOI: 10.1080/01944363.2019.1638816

**To link to this article:** https://doi.org/10.1080/01944363.2019.1638816

# Measuring the Local Economic Impacts of Replacing On-Street Parking With Bike Lanes

## A Toronto (Canada) Case Study

Daniel Arancibia Steven Farber Beth Savan Yvonne Verlinden Nancy Smith Lea Jeff Allen Lee Vernich

**ABSTRACT**

**Problem, research strategy, and findings:** Bike lane projects on retail streets have proved contentious among merchant associations in North America, especially when they reduce on-street parking. A limited but growing number of studies, however, detect neutral to positive consequences for merchants following bike lane implementation. In 2016, the City of Toronto (Canada) removed 136 on-street parking spots and installed a pilot bike lane on a stretch of Bloor Street, a downtown retail corridor. Using a case–control and pre–post design, we surveyed merchants and shoppers to understand the impacts of the bike lanes on economic activities. We find no negative economic impacts associated with the bike lanes: Monthly customer spending and number of customers served by merchants both increased on Bloor Street during the pilot.

**Takeaway for practice:** Our findings are consistent with an improving economic environment at the intervention site. Downtown retail strips may therefore be suited to tolerate bike lanes and even benefit from increased retail activity. Pre and post surveys can provide valuable insights into local economic impacts of streetscape changes affecting merchants along city streets, especially where access to sales data is limited.

**Keywords:** bike lanes, local economic impact, on-street parking

With a surge in the number of bike lane projects across North America, some local merchants on affected streets have expressed concerns about potential reductions in customers because of associated on-street parking losses. As a result, planners and politicians have sometimes shown reluctance to support or recommend bike lanes in commercial streets at the cost of on-street parking.

A unique opportunity to explore the local economic impacts of bike lanes materialized when the City of Toronto (Canada) identified a segment of Bloor Street, a vibrant commercial street, as a major cycling corridor in the city's Ten Year Cycling Network Plan (City of Toronto, 2016). In August 2016 the city installed bike lanes on a 2.4-km (1.5-mile) stretch of Bloor Street as a pilot project. Determining local economic impact was originally outside of the scope for the city's study. In this context, a team of University of Toronto and The Centre for Active Transportation researchers collaborated with the City of Toronto and business improvement areas (BIAs) to survey merchants and shoppers to understand economic activities before and after the installation of the bike lanes.

A project report intended for Toronto's stakeholders and decision makers is available online (Smith Lea et al., 2017). In this study, we provide a substantially different, more technical account of the research and its implications geared toward the academic planning community and planning practitioners.

We first examine eight prior studies that investigate bike lanes' effects on local businesses. We then outline how we investigated these effects in Bloor Street using a case–control study. We use four indicators to assess economic activity: estimated customer counts from merchant surveys, estimated spending and visit frequency from visitor surveys, and vacancy counts. We find all indicators point to increased economic activity

DOI: 10.1080/01944363.2019.1638816 

on Bloor Street following the installation of the bike lane. We conclude by demonstrating how the study contributes to a growing body of empirical research aimed at understanding the impacts of bike lanes on local retailers and service providers. Though we advise against extrapolating our results to other streets with markedly different consumer behaviors and urban forms, our results suggest bike lanes can be added to vibrant, downtown retail streets without negative impacts. Bike lanes on Bloor Street were made permanent in November 2017.

## Studying the Impacts of Cycling Infrastructure on Local Economies and Customer Mode Share in North American Cities

### *Local Economic Impacts of Bicycling Infrastructure in North America*

Urban interventions affect local economies at many different scales. A large and growing body of research reflects a diverse set of approaches to conceptualizing and calculating economic impacts, from cost–benefit and investment return analyses to tracking changes in employment, vacancies, retail sales, or property values (Hicks, Keil, & Spector, 2012; Krizec, 2007; Pivo & Fisher, 2011). We are primarily concerned here with impacts affecting local merchants in an urban North American context. Early works addressing this include Edminster and Koffman's (1979) "moderately positive" evaluation of three North American transit malls and Weisbrod and Pollakowski's (1984) mixed-results assessment of eight downtown improvement projects. Edminster and Koffman (1979) use customer and merchant surveys, retail sales, and vacancy rates in their evaluation, whereas Weisbrod and Pollakowski (1984) track the number of retailers and employment in the study areas. Contemporary examples include the use of citywide consumer surveys to assess the opening of a big box store in Davis (CA) by Sciara, Lovejoy, and Handy (2018), who find that "experiential" aspects of shopping downtown likely protected urban businesses from negative impacts.

Focusing on the impacts of bike lanes specifically, we looked for North American studies addressing bike lanes' effects on urban merchants. Despite the importance of economic impacts on cycling infrastructure decision making, we found only eight studies—six quantitative and two qualitative—that measure this. Because most of these studies have not been described previously in the academic literature, we describe them in some detail here. Results from the six quantitative studies are presented in Table 1.

Two New York City (NY) Department of Transportation (NYC DOT) studies published in 2012 and 2013 are landmark evaluations of sustainable street improvements' economic impacts. They both find associations between bike lanes and improved retail sales. The first study notes a substantial rise (177%) in cyclists accompanied retail growth along Manhattan's controversial 1st and 2nd Avenue bike lanes, for example (Kramer, 2011; NYC DOT, 2012). The second study uses up to 7 years of sales data (2005–2011) to evaluate interventions. Use of taxable sales data, multiple controls, and multiyear evaluations make these studies' results reliable indicators of bike lanes' potential economic benefits. Unfortunately, maintenance of on-street parking at most interventions means these reports do not address the potential trade-offs of losing on-street parking.

Similarly, McCormick (2012) finds no adverse economic impacts by using merchant and customer surveys, retail sales data, and property values to evaluate bike lanes' effects on York Boulevard in Los Angeles (CA). On-street parking also coexisted with painted bike lanes. The author relies on tax and property value data sets from 2000 to 2005 (pre–bike lanes) and 2006 to 2011 (post–bike lanes) for his comparison. Merchant and customer surveys collected in 2011 provide the valuable insight that merchants overestimated the number of customers who arrived by car, a finding consistent with a series of other studies that could help explain merchant opposition to traffic and parking lane removal for bike lane installations (Chan et al., 2016; Forkes & Smith Lea, 2010; McCormick, 2012; Stantec, 2011; Sztabinski, 2009).

Rowe's (2013) evaluation of bike lanes in two Seattle (WA) neighborhoods considers a site where on-street parking was replaced with a bike lane in 2011. Sales at this site increased drastically in 2012 compared with sales in 2010, whereas sales at a control site and neighborhood-wide remained steady. Sales were also stable between 2009 and 2012 at another site where bike lanes were installed in 2010 and at its control site. The author concludes concerns about significant detrimental impacts on local merchants prove unjustified.

The City of Calgary (2016b) also carried out a comprehensive study of a downtown cycle track network pilot project involving on-street parking removal. This survey-based study finds a drop in monthly customer per capita spending and a drop in average number of customers per day as reported by merchants between 2014 and 2016. Because no controls were used, it is difficult to ascertain whether reduced spending and

Color version available at **tandfonline.com/rjpa**

**Table 1**

**Quantitative North American studies measuring the economic impact of bike lanes on commercial streets.**

| Study | Location | Context | Methods | Findings |
|---|---|---|---|---|
| NYC DOT (2012) | New York (NY) | The study looked at economic impacts of recently implemented protected bike lanes:<br>• 9th Avenue<br>• Manhattan's 1st and 2nd Avenues (bus lanes were also added to these streets)<br>• Union Square North (pedestrian realm was also improved at this location) | Taxable sales data and retail vacancy data were used to estimate economic impacts over a period of 2–3 years from the completion of each project, comparing the data at each site with borough-wide metrics as control. | • 9th Avenue saw a 49% increase in retail sales (compared with 3% borough-wide)<br>• Manhattan's 1st and 2nd Avenues saw a drop of 47% in commercial vacancies (compared with a 2% increase borough-wide)<br>• Union Square North vacancies decreased by 49% (compared to a 5% increase borough-wide) |
| McCormick (2012) | Los Angeles (CA) | A portion of York Boulevard, a commercial street, received a road diet treatment including a painted bicycle lane, whereas another portion did not. Bike lanes installed were intermittent and separated from the sidewalk by on-street parking. This study looks at the economic impacts of that intervention. | Merchant surveys ($n = 115$), customer surveys ($n = 50$), retail sales data, and property values were examined to evaluate bike lanes' impact. A case–control and before–after comparison of each of these areas was conducted. | • The study found a neutral result with no adverse economic impacts<br>• Survey results suggest merchants overestimated the number of customers who arrived by car |
| NYC DOT (2013) | New York | The study looked at economic impacts around recently implemented protected bike lanes:<br>• Vanderbilt Avenue (traffic calming measures were also implemented)<br>• Columbus Avenue (this was a parking-protected bike lane)<br>• Bronx Hub<br>• St. Nicholas and Amsterdam Avenues (intersection) | Taxable sales data were used to estimate economic impacts over a period of 2–3 years from the completion of each project, comparing the data at each site with borough-wide metrics and specific comparison sites with similar characteristics. | • Vanderbilt Avenue saw an increase in retail sales of 102% (compared with 64% at comparison sites)<br>• Columbus Avenue saw a 20% increase in sales (compared with 11% in comparison sites)<br>• Bronx Hub saw an increase of 50% in sales (compared with 18% borough-wide)<br>• St. Nicholas and Amsterdam Avenues saw an increase in sales of 48% (compared with 7% at comparison sites) |

(*Continued*)

**Table 1** *(Continued)*

| Study | Location | Context | Methods | Findings |
|---|---|---|---|---|
| Rowe (2013) | Seattle (WA) | The study looked at economic impacts on commercial nodes adjacent to two painted bike lanes in Seattle over 3 years (including a year prior to implementation):<br>• Latona and 65th Neighborhood Business District (where bike lanes replaced on-street parking)<br>• Greenwood neighborhood | Aggregated before–after retail sales data for the commercial nodes were examined over time and compared against comparison sites. | • Increase in sales of up to 400% in Latona and 65th Neighborhood Business District compared with steady sales at a comparison site<br>• Sales remained steady in the Greenwood neighborhood<br>• Positive outcomes may not be due to bike lanes, but concerns about significant detrimental impacts on local merchants were not justified |
| City of Calgary (2016b) | Calgary (AB, Canada) | Study of a cycle track network pilot project consisting of 6.5 km of protected bike lanes in downtown streets. The pilot's duration was 18 months. Economic vitality was one of nine themes examined in this study. Approximately 370 parking spots were removed to accommodate the bike lanes, but 500 new parking stalls were created nearby to offset this loss. | Economic vitality was measured with before–after customer surveys inquiring about spending and visit frequency ($n = 380$) and merchant surveys inquiring about the number of customers served ($n = 251$). No controls were used. | • Drop in monthly customer per capita spending from 153 CAD to 131 CAD, but average number of weekly visits by each customer remained constant at 3.5<br>• Drop in average number of customers per day as reported by merchants from 112 to 92<br>• **Note:** Alberta was experiencing a severe recession at the time of this study |
| Poirier (2018) | San Francisco (CA) | This study examines the performance of businesses abutting the following painted bike lanes over a period of 5 years:<br>• Valencia Street<br>• Polk Avenue<br>Columbus Avenue (where sharrows were painted) was also studied and questionably described as a bike lane | Longitudinal firm-level data from the National Establishment Time-Series data set were used to track before–after sales along the bike lanes, using non-abutting businesses in the vicinity for comparison. | • No catastrophic negative impacts were detected<br>• Both sites with bike lanes experienced a marked increase in sales following implementation; Columbus Avenue saw a decrease in sales compared with non-abutting businesses<br>• Bike lanes positively affected local-serving businesses more than other types |

Note: CAD = Canadian dollars.

customers resulted from the pilot or from unrelated economic trends. At the time, the Province of Alberta was undergoing a severe economic recession. The city acknowledges this in their final report, stating, "The influence of the cycle tracks is difficult to extract from the overall economic downturn" (City of Calgary, 2016a; Gibson, 2016). Interpretation of these results is further complicated by the city's addition of more than 500 parking stalls intended to offset parking losses, which produced a net gain of 130 parking spots before the pilot's end (City of Calgary, 2016a).

Poirier's (2018) study is unique both in its use of longitudinal firm-level data from the National Establishment Time-Series data set to track sales along two bike lanes in San Francisco (CA) and in its chosen control. The performance of businesses abutting the bike lanes was compared over 5 years with businesses in the vicinity but not abutting the bike lane. This atypical approach toward selecting a control means that many "non-abutting" businesses used for comparison are a few meters away from the bike lanes, whereas others are up to 1 km away. Businesses at both Valencia Street and Polk Street experienced a marked increase in sales following implementation of bike lanes between 1999 and 2001 and 2004 and 2006, respectively (Poirier, 2018). On-street parking was maintained at both sites but was marginally affected at Valencia Street.

One of the two qualitative studies we found also centers on Valencia Street's bike lanes, using merchant surveys to study perceptions (Drennen, 2003). Four years after the bike lane's 1999 implementation, merchants' responses were overwhelmingly positive, with 65.4% reporting that the bike lanes had a positive impact on business and sales and only 3.8% suggesting a negative impact. These findings match those of Poirier (2018), who identifies a positive economic impact for all business types.

Stantec (2011) prepared the second qualitative study for the City of Vancouver (Canada). Its aim is to study the economic impacts of upgrading bicycle facilities on two streets from unidirectional unprotected bike lanes to bidirectional protected cycle tracks. Stantec (2011) uses merchant surveys, collected during a single sampling event in 2011, to inquire about sales. The Downtown Vancouver Business Improvement Association vocally opposed the cycle tracks, and the Canadian Federation of Independent Businesses produced a report showing virtually no support for improved cycling infrastructure (CTV News BC, 2010; Smith, 2010). Only 32% of merchants responded to the Stantec survey. At the time of the survey, one cycling facility (Dunsmuir) was 1 year old, and the other (Hornby) had been completed 4 months prior. Merchants reported a 2% decrease in sales in Dunsmuir and 11% in Hornby. Businesses in comparator streets reported a 2% increase and a 1% decrease, respectively. The study authors warn that due to low response rates and the limited time the new infrastructure had been in place, it is difficult to assess the extent to which sales were affected. A sidewalk customer survey also reveals that merchants who responded to the merchant surveys overestimated people driving into the neighborhood (40% estimated versus 20% measured) and underestimated people arriving by bicycle (4% estimated versus 8% measured). In the 6 years following the implementation of the cycle tracks, the Downtown Vancouver Business Improvement Association gradually shifted their stance and now champion the cycle tracks, with their president saying they provide "a competitive edge" (Lovgreen, 2017).

### *Customer Modes of Transportation and Spending*

Numerous studies investigate how spending relates to customer mode choices. Four different studies suggest cyclists are higher per capita monthly spenders than customers arriving by car (Chan et al., 2016; Clifton et al., 2013; Sztabinski, 2009; Transportation Alternatives, 2012). A fifth study, which uses an online survey rather than customer intercept surveys to obtain data, concludes that cyclists' and drivers' spending behaviors in downtown Davis (CA) were equivalent (Popovich & Handy, 2014). This suggests increases in cycling traffic may have positive economic impacts despite an associated loss of parking. Clifton et al. (2012, 2013) and Poirier (2018) suggest cyclists might be particularly inclined to spend money on "local-serving" businesses like restaurants and neighborhood shops.

In eight studies investigating traditional retail strips and dense urban areas, only two studies show automobile mode shares in excess of 21% (Bent & Singa, 2008; Chan et al., 2016; Clifton et al., 2012; Forkes & Smith Lea, 2010; McCormick, 2012; Stantec, 2011; Sztabinski, 2009; Transportation Alternatives, 2012). The lowest measured shares were in New York's East Village (4%) and Toronto's Queen Street West (4%), and the highest were in Portland's (OR) central business district (34%) and Los Angeles' York Boulevard (28%; Chan et al., 2016; Clifton et al., 2013; McCormick, 2012; Transportation Alternatives, 2012). This is in stark contrast with suburban North American regions, where automobile-related mode share can climb to 78% even in transit-friendly cities like Portland (Clifton et al., 2012).

Overall, the existing literature suggests bike lanes have a neutral to positive impact on commercial activity, even when some on-street parking is lost. This is consistent with the notion that only a small portion of customers arrive by car in North America's dense urban areas and traditional shopping strips. Furthermore, the spending behaviors of cyclists compare favorably to those arriving by other modes. We explore these relationships within the Bloor Street pilot study, which elicited strong parking-related opposition from some merchants while receiving broad community support.

## Toronto's Bloor Street: Bike Lanes Added to One of Canada's Iconic Commercial Strips

### *Study Context*

In Toronto, Bloor Street is home to a vibrant mix of retailers, restaurants, bars, and service providers. Since 2007, civil society organizations had been requesting through yearly demonstrations that bike lanes be added to Bloor Street, but concerns about traffic impacts and loss of on-street parking turned the issue contentious (Bells on Bloor, 2015). Nearly 20 km of Bloor Street was identified as a major cycling corridor in the City of Toronto's (2016) Ten Year Cycling Network Plan. It represents a priority east–west route, with important linkages to existing cycling facilities and to many neighborhoods with high cycling mode shares.

In August 2016, the city installed bike lanes along 2.4 km of Bloor Street as a 1-year pilot, stretching from Avenue Road in the east to Shaw Street in the west. Figures 1A and 1B show these areas. BIAs were supportive of the pilot provided that its economic impacts were measured and included among the variables to determine its permanence.

The street, which ranges in width from 12.2 to 16.2 m over this stretch, consisted of two traffic lanes in each direction prior to bike lane installation. Parking was allowed during off-peak hours as shown in Figure 1D. This was reconfigured into one traffic lane in each direction with turning lanes at intersections, one lane of curbside parking (alternating sides), and a curbside bike lane in each direction protected by flexi-post bollards, as shown in Figure 1E. A total of 136 on-street parking spots were removed, constituting nearly half of the on-street parking in this section. When nearby public and privately run parking lots are considered, however, this reduction only amounts to 10% of convenient customer parking (City of Toronto, 2017).

### *Study Area*

Our study area consists of a 1.5-km section of Bloor Street, bounded by the east and west borders of the Bloor Annex and Korea Town BIAs, respectively, and falls within the 2.4-km bike lane pilot area as shown in Figure 1A. This stretch contains two- and three-story buildings with shops, services, and restaurants on the ground floor. We selected Danforth Avenue from Broadview Avenue to Chester Avenue as a control site without bike lanes. Danforth Avenue is the continuation of Bloor Street 3 km east of the study location, and it is a suitable control site because of its similarity in scale, business composition, and subway access. The Yorkville neighborhood and the Prince Edward Viaduct (a 500-m-long bridge that marks the end of Bloor Street and the beginning of Danforth Avenue) act as buffers between the study area and the control site, shown in Figure 1C.

The City of Toronto's (2015) employment survey shows the business composition of Korea Town and Bloor Annex as just more than one-third bar and restaurant establishments and just less than one-third each retail and service establishments. The chosen control site is similar but offers more retail and fewer restaurants. The two sites are also similar demographically, as shown in Table 2, with the caveat that Bloor Street is closer to the University of Toronto St. George campus. Students may be more strongly represented among customers and traffic because of this proximity.

## Evaluating Local Economic Impacts of Bike Lanes in Toronto's Bloor Street

### *Approach and Study Design*

We preferred a survey-based approach for assessing economic impacts and used Sztabinski's (2009), Forkes and Smith Lea's (2010), and the National Bicycle and Pedestrian Documentation Project's (2010) instructions to inform our survey design. We used a combination of merchant and visitor surveys for various reasons: They allowed our research team to determine shifts in mode share, detect changes in customer spending patterns and consumer behavior, identify travel patterns, and measure perceptions of safety. These tools also provided valuable insights into attitudes through open-ended questions, including support of or opposition to the project.

The University of Toronto research team proposed four economic impact indicators, which all study partners agreed upon (including partner BIAs):

1. Estimated customer counts (merchant surveys).
2. Estimated monthly customer spending (visitor surveys).

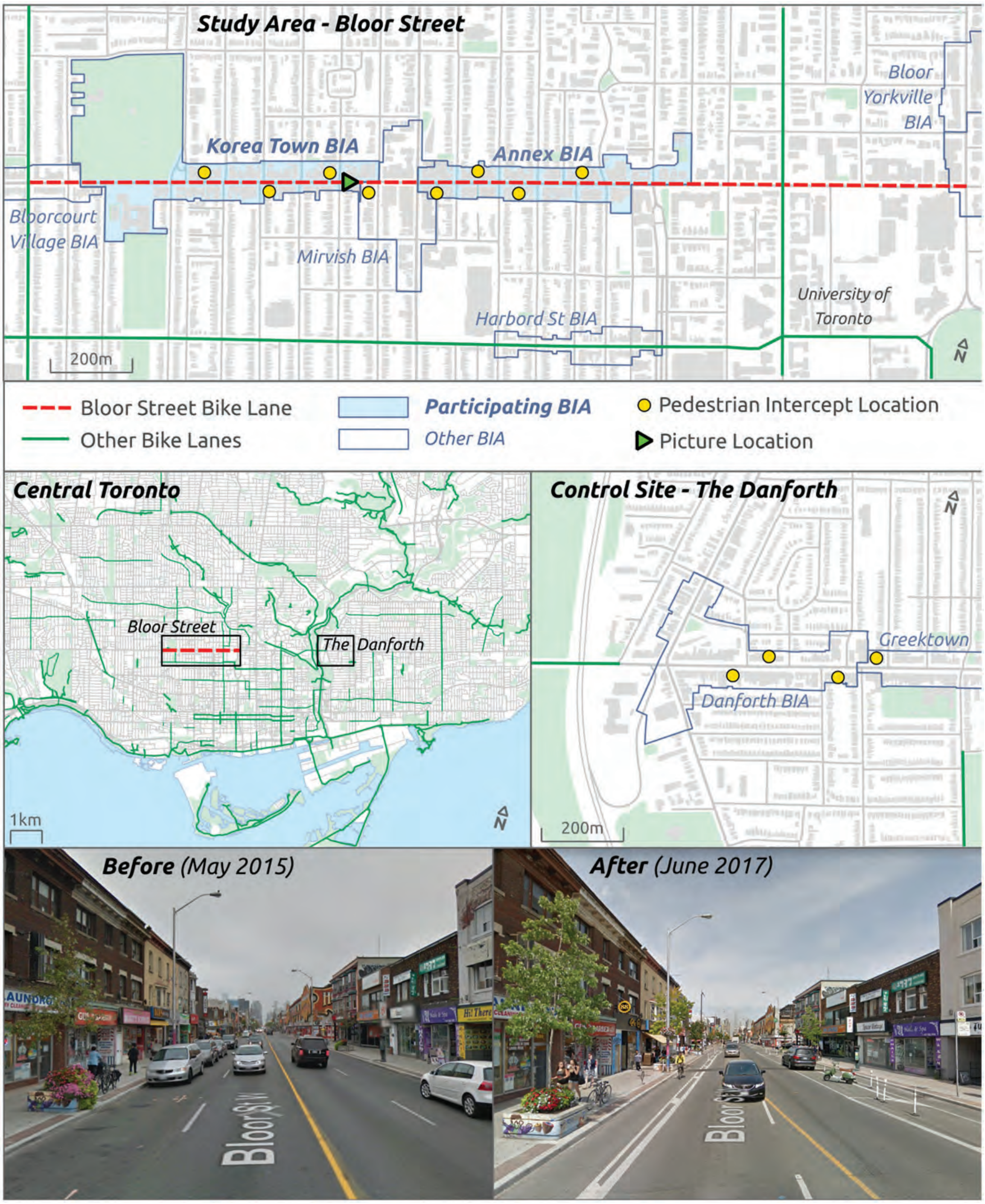



*Figure 1. (A) The study area and its features. (B) View of the study and control areas in relation to the rest of the city. (C) The control area. (D) Before and (E) after photographs of the street configuration.*
*Data sources: City of Toronto, 2017, Google, 2015, 2017.*

3. Estimated visit frequency (visitor surveys).
4. Business vacancy counts (street-level fieldwork).

We decided to study the change in indicator values through a pre–post study with a case–control design. Data were collected before and after the bike lane's installation on Bloor Street and along the control site on Danforth Avenue. Data collection began in October 2015, approximately 1 year prior to installation of the bike lane, with follow-up

Table 2

**Select demographic indicators from the latest Canadian census (Statistics Canada, 2018) comparing the Bloor Corridor (intervention site) with Danforth Avenue (control site).**

| | Bloor Street (intervention site) | Danforth Avenue (control site) |
|---|---|---|
| Population density per $km^2$ | 8,634 | 8,221 |
| Average age, years | 40.53 | 41.3 |
| Median household income after tax, CAD | $60,102 | $69,304 |
| Recent immigrant (2001–2016) | 8.09% | 5.90% |
| Visible minority | 25.67% | 19.22% |
| Unemployed | 5.13% | 4.31% |
| Residential mobility (moved in past year) | 20.37% | 11.20% |
| Commute by bike | 15.84% | 7.76% |

Note: Data were obtained by combining census tracts abutting each site. CAD = Canadian dollars.

collection occurring in October 2016 and again in May 2017.

A demographically diverse team of trained University of Toronto students administered the merchant and visitor surveys at the Bloor Street and Danforth Avenue study sites. Surveyors used a paper version of the surveys to record respondents' answers for the 2015 sampling period. Tablets were used to record responses for all surveys in the 2016 and 2017 sampling periods. A dedicated Korean translator was on hand for all merchant and visitor surveys conducted in Korea Town.

We designed the merchant survey primarily to gather perceptions of customer counts. We also collected data about travel patterns. Surveyors approached all ground-level merchants between Montrose Avenue and Madison Avenue at Bloor Street and between Broadview Avenue and Playter Boulevard at Danforth Avenue. We only used surveys completed by an owner or manager, and each establishment was visited up to four times if store owners or managers were unavailable. Following multiple unsuccessful visits, surveyors left an information sheet with contact information to conduct the survey by phone, which some merchants did. Of the businesses approached in the study, 62% participated, completing 452 surveys on Bloor Street but only 73 surveys at Danforth Avenue. This discrepancy in sample size is an important limitation of our study because it prevents us from meaningfully comparing customer counts between the two sites.

We designed the sidewalk visitor survey to capture estimated customer spending, visit frequency, visitor travel patterns, and attitudes toward the bike lane. We selected monthly spending as a prime impact variable because of its stability compared with daily spending, which could fluctuate significantly depending on day of the week or time of day.

Surveying for the visitor survey took place during 2- to 6-h periods between 11 a.m. and 8 p.m. on both weekdays and weekends, with most sampling taking place between noon and 5 p.m. Surveyors asked every third person walking on the sidewalk to participate at defined sampling points and switched sampling points at specified time intervals. We show these sampling points in Figures 1A and 1C. To reduce bias, the script of both survey types did not mention bike lanes but instead introduced itself as "a survey regarding local businesses and how people get here." Questions mentioning bike lanes were not asked until after economic data had been gathered. In all, 3,005 visitors to Bloor Street and Danforth Avenue were surveyed.

We made vacancy counts with a street-level scan. Researchers walked the entire length of the pilot bike lane installation area and the control site to note which ground-level businesses were in use. The first count was in July 2016 and the second was in July 2017.

### Data Analysis

We conducted two types of data analyses. First, a descriptive analysis compared the results between pre- and post-installation. For the visitor survey, the postinstallation period combined results from the 2016 and 2017 collection cycles to increase the sample size and level of statistical confidence. Each period was kept separate for the merchant survey, however, which collected responses from the same merchants multiple times. The analysis also compared results between the study area (Bloor Street) and control (Danforth Avenue). We used descriptive statistics to test whether a) significant changes in economic activity occurred in the study area and b) changes observed in the study area were significantly different from those in the control site. Our team used classical difference of means and one-way analyses of variances to explore the former, whereas a difference-in-differences test was used for the latter, which accounted for the sampling error in each of the four samples (Pre/post × Case/control) used to measure rates of change in the two study sites.

Recognizing that many factors influence people's spending habits and visiting patterns, including age, gender, trip purpose, and transportation choices, we used regression analysis to capture the bike lane's effect on spending and visit frequency and to control for any other differences in the survey samples. Fixed effects for time period and sampling site were used in ordinary least squares and binomial logit regressions of monthly visitor frequency and customer expenditures, respectively. For the latter, we categorized ordinal responses into two groups, less than and more than 100 Canadian dollars (CAD) spent per month.

### Limitations From Timing and Seasonality

The timing of data collection was subject to project approvals and the City of Toronto's reporting requirements for the Bloor Street pilot project. The decision to conduct the surveys in the fall was informed by the National Bicycle and Pedestrian Documentation Project's (2010) data collection instructions, which establish that surveys should ideally be conducted in mid-September. BIA representatives were also supportive of surveying in the fall: Although no mid-winter or mid-summer sampling represents a study limitation, fall provides a more representative sample of year-round economic activity than summer or winter measurements could independently. Project approval dates meant we first conducted visitor surveys in October 2015 and merchant surveys in November 2015. For comparability purposes, we collected visitor and merchant surveys 1 year later, in October and November 2016, respectively. We conducted the third round of data collection in May 2017 (both visitor and merchant surveys) to accommodate the city's timelines for reporting on the pilot. The *City of Toronto Cycling Study* (2010) finds that seasonal cycling incidence is similar in spring and fall, suggesting that transportation behaviors at these times are similar and thus comparable. The May 2017 visitors' survey on Bloor Street contained fewer respondents from the 30-years-or-younger age category than other collection cycles. This difference is likely because fewer university students take classes in May than in October.

Several survey questions required respondents to report on travel and spending behavior. Respondents likely based their answers on the previous months, so their retail and transportation experiences in late summer/early fall may be different from those in late winter/early spring. The NYC DOT recommends monitoring economic impact for 2 to 3 years following a streetscape change to account for possible anomalies (NYC DOT, 2013). This was not possible in this study because of the political constraints of the 1-year pilot.

### Other Data and Limitations

Retail sales tax data were not available to the study team or to the City of Toronto. Unlike in the United States, these data are generally not accessible in Canada because of information and privacy laws, which prevented us from examining sales data as in NYC DOT's (2012, 2013) studies. The Ontario BIA (Archer & McGibbon, 2017) does not recommend collecting retail sales data by surveying merchants because of challenges with data sourcing, transparency, accuracy, and business owners' reluctance to share actual retail sales information. For these reasons, and considering the problematic outcome of Stantec's (2011) surveys inquiring about retail sales in Vancouver, the study partners collectively decided to rely on vacancy rates, self-reported customer counts, visit frequency, and customer spending to assess local economic impacts.

We were interested in other data sources that we could not access during the pilot, including public transit usage, parking usage, collision reports, and data from card payment processing providers. Except for transit usage, these data sets were eventually collected by the City of Toronto (2017) for their separate impact evaluation of the pilot. The city's parking study finds the pilot area experienced a 5.95% net loss of parkers (City of Toronto, 2017). If this rate applied to shoppers specifically, it potentially meant a reduction of 0.6% of customers in the pilot area. This assumes—as per our measurements—that 10% of shoppers arrived by car and were affected. Likewise, collisions were tracked, and their rates significantly decreased: Bicycle-motorized vehicle collisions remained constant at around 22 per year, though the volume of cyclists increased by 49% (City of Toronto, 2017). This is consistent with our survey findings on perceptions of safety, shown in the online Technical Appendix A, where the percentage of cyclists who "felt safe" riding on Bloor Street increased from 9.3% to 77.1%. Other types of collisions and near-misses also decreased (City of Toronto, 2017).

City of Toronto staff also obtained credit and debit card transaction data from Moneris, Canada's largest processor of card-based payments. Card-based spending increased 4.45% in the pilot area, compared with 3.73% in the area surrounding the pilot and 2.21% at Danforth Avenue (same control site as in our study; City of Toronto, 2017). These data are consistent with our findings of an improving business environment in the pilot area. City staff also reported an increase in consumption of 4.96% citywide, which was marginally higher than that of the pilot area and more than double the growth rate at the Danforth Avenue control site (City of Toronto, 2017).

There are important limitations, however, with using debit and credit card transaction data to estimate changes in the business environment. An increase in the value of payments made with cards does not necessarily entail an increase in the value of all payments made, and more research is needed to understand how these figures fluctuate over time. Nevertheless, transaction data remain another useful economic indicator consistent with a stable or improving local economy.

### *Note on the Control Merchant Sample*

Because of a smaller control site and lower participation rates, we could not obtain a large enough merchant sample on Danforth Avenue to conduct reliable statistical analyses comparing merchant data. We collected only 28 merchant surveys at the control site in 2015, 22 in 2016, and 23 in 2017, with a response rate that dropped from 56% pre-intervention to less than 41% in post-intervention samples. This contrasts with our Bloor Street sample, which averaged 150 merchants and a 66% response rate in each cycle (a detailed breakdown is in Table 3). Other control site data are still useful for assessing larger trends in spending, travel patterns, and attitudes.

## Economic Indicators on Bloor Street Improved or Remained Stable Following the Installation of Bike Lanes

### *Reported Monthly Spending per Customer Increased on Bloor Street*

Descriptive statistics, sample sizes, and test results are summarized in Table 3 (merchant survey) and Table 4 (visitor survey). Table 4 presents raw proportions for the visitor survey, as well as the significance levels of a series of independent sample difference of proportions tests. An expanded version of Table 4 can be found in Technical Appendix A. In addition, Figures 2A and 2B display average customer spending per month pre-/post-intervention on Bloor Street and Danforth Avenue, respectively. We discuss visitor survey results and their implications (including derived mode share) below before considering merchant survey results, our regression modeling outcomes, and vacancy rate findings.

We find visitors to Bloor Street were more likely to spend more than \$100 per month following the implementation of the bike lanes than before ($p < .001$). Spending grew even more among cyclists ($p < .1$). The proportion of visitors spending more than \$100 among those arriving by car also increased substantially ($p < .05$).

On Danforth Avenue, the proportion of customers spending more than \$100 per month also increased significantly; the increase was not significantly different from the increase on Bloor Street.

### *Proportion of Cyclists Increased on Bloor Street, Proportion of Drivers Held Steady*

Another interesting insight is that the proportion of visitors arriving at Bloor Street by car did not change significantly, but the proportion of visitors arriving by bicycle more than doubled from 6.9% to 18.1% ($p < .001$). Although not a direct economic impact, mode share data are worth addressing in this context where some merchants feared the reduction of on-street parking would lead to a sharp drop in customers.

These mode share trends are observable not just among "all visitors" but also when examining visitors who specifically declared they were on a retail trip (shopping, services, or restaurant). On the day of the survey—and just for retail trips—the proportion of customers arriving by car did not change (8.8% pre-intervention, 8.9% post-intervention), whereas the proportion arriving by bicycle rose from 7.4% to 19.6% ($p < .001$).

Table 3

**Merchant survey results: Relevant descriptive statistics.**

| | Bloor 2015: Before bike lanes | Bloor 2016: After bike lanes | Bloor 2017: After bike lanes | Test 1[a] | Test 2[b] | Test 3[c] |
|---|---|---|---|---|---|---|
| Sample size | 163 | 153 | 136 | | | |
| Response rate | 69% | 66% | 62% | | | |
| Business type surveyed | | | | | | |
| Retail | 30.3% | 27.5% | 37.5% | | | ψ |
| Food service/bar | 38.7% | 44.4% | 41.9% | | | |
| Service | 30.3% | 26.8% | 19.1% | | * | |
| Other | 0.6% | 1.3% | 1.5% | | | |
| No. customers | | | | | | |
| Serve >100 customers on a weekday | 33.8% | 40.0% | 55.0% | | *** | * |
| Retail | 27.3% | 44.7% | 52.1% | | * | |
| Food service/bar | 48.3% | 49.2% | 70.9% | | * | * |
| Service | 18.2% | 20.6% | 30.8% | | | |
| Serve >100 customers on a Saturday | 46.3% | 57.6% | 61.5% | ψ | * | |
| Retail | 37.2% | 55.3% | 61.7% | | * | |
| Food service/bar | 67.8% | 75.9% | 83.6% | | ψ | |
| Service | 23.7% | 29.4% | 19.2% | | | |

Notes:
a. 2015–2016 Bloor prop test.
b. 2015–2017 Bloor prop test.
c. 2016–2017 Bloor prop test.
ψSignificant at .1 level. *Significant at .05 level. **Significant at .01 level. ***Significant at .001 level.

Table 4

**Descriptive statistics results for visitor surveys.**

| | Bloor: Before bike lanes | Bloor: After bike lanes | Control (Danforth): Before | Control (Danforth): After | Test 1[a] | Test 2[b] | Test 3[c] | Test 4[d] | Test 5[e] |
|---|---|---|---|---|---|---|---|---|---|
| Sample size | 842 | 1,577 | 173 | 412 | | | | | |
| Expenditure >$100 per month | | | | | | | | | |
| All visitors | 44.2% | 53.3% | 56.8% | 69.9% | *** | ** | ** | *** | |
| Bike subset | 44.4% | 58.1% | 61.5% | 62.7% | ψ | | | | |
| Driver subset | 34.3% | 51.3% | 48.3% | 67.9% | * | * | | * | |
| Transit subset | 34.8% | 31.6% | 41.5% | 48.1% | | | | ** | |
| Walk subset | 53.1% | 62.8% | 66.7% | 81.8% | * | * | * | *** | |
| Visits 15 or more days per month | | | | | | | | | |
| All visitors | 47.3% | 60.5% | 55.0% | 66.8% | *** | ** | ψ | * | |
| Bike subset | 58.9% | 67.4% | 69.2% | 67.3% | | | | | |
| Driver subset | 25.0% | 50.0% | 34.5% | 48.7% | *** | | | | |
| Transit subset | 28.3% | 38.2% | 31.7% | 38.3% | ** | | | | |
| Walk subset | 63.3% | 71.4% | 70.6% | 85.4% | ** | ** | | *** | |
| Travel mode on day of survey | | | | | | | | | |
| Walk | 49.8% | 48.0% | 50.6% | 48.4% | | | | | |
| Bike | 6.9% | 18.1% | 7.7% | 12.7% | *** | | | * | ψ |
| Car | 8.3% | 9.9% | 17.3% | 19.2% | | | *** | *** | |
| Transit | 35.0% | 24.1% | 24.4% | 19.7% | *** | | ** | ψ | |
| Travel mode: Just retail trips | | | | | | | | | |
| Walk | 48.2% | 48.2% | 52.4% | 50.0% | | | | | |

*(Continued)*

*Color version available at* ***tandfonline.com/rjpa***

**Table 4** (*Continued*)

| | Bloor: Before bike lanes | Bloor: After bike lanes | Control (Danforth): Before | Control (Danforth): After | Test 1[a] | Test 2[b] | Test 3[c] | Test 4[d] | Test 5[e] |
|---|---|---|---|---|---|---|---|---|---|
| Bike | 7.4% | 19.6% | 9.7% | 10.3% | *** | | | *** | ** |
| Car | 8.8% | 8.9% | 15.3% | 21.3% | | | * | *** | |
| Transit | 35.6% | 23.3% | 22.6% | 18.4% | *** | | ** | ψ | |
| Travel mode: Just shopping trips | | | | | | | | | |
| Walk | 54.8% | 52.1% | 55.6% | 51.1% | | | | | |
| Bike | 8.0% | 22.0% | 11.1% | 11.4% | *** | | | ** | ** |
| Car | 6.2% | 8.0% | 14.4% | 19.6% | | | * | *** | |
| Transit | 31.1% | 17.9% | 18.9% | 17.9% | *** | | * | | * |
| Parking | | | | | | | | | |
| Find it difficult to find car parking | 7.8% | 32.6% | 14.3% | 24.7% | *** | | | | ψ |

Notes:
a. Difference-in-proportions test: pre-Bloor to post-Bloor.
b. Difference-in-proportions test: pre-Danforth to post-Danforth.
c. Difference-in-proportions test: pre-Bloor to pre-Danforth.
d. Difference-in-proportions test: post-Bloor to post-Danforth.
e. Difference-in-differences test: Change on Bloor vs. change on Danforth.
[ψ]Significant at .1 level. *Significant at .05 level. **Significant at .01 level. ***Significant at .001 level.

Although the proportion of cyclists increased at Danforth Avenue as well, a difference-in-differences test finds the increase at Bloor Street was significantly larger, especially for just retail trips and shopping trips ($p < .01$). It is important to note that mode share calculations reflect proportions, not volumes. A relative decrease in transit mode share does not necessarily imply a drop in transit ridership: It could indicate more people arriving through other modes, whereas transit ridership remains steady.

Mode share data also show only a limited proportion of customers were likely to be directly inconvenienced by the bike lanes: Before the intervention, 91.7% of customers surveyed on Bloor Street had not arrived by car. Although the proportion of those arriving by car remained constant, those reporting difficulties finding parking rose from 7.8% to 32.6% ($p < .001$). Likewise, those reporting these difficulties on Danforth Avenue increased from 14.3% to 24.7%. The differences in parking difficulties at Bloor Street and Danforth Avenue post-intervention were not significant.

### *Number of Customers Served by Merchants Increased on Bloor Street*

Results for the descriptive analysis of merchant survey data and sample sizes are presented in Table 3, with each row corresponding to a different survey variable. The first three columns provide raw proportions, and the next three summarize the results of difference-in-proportions *t* tests. There are two differences in the design of these tests compared with that of the visitor

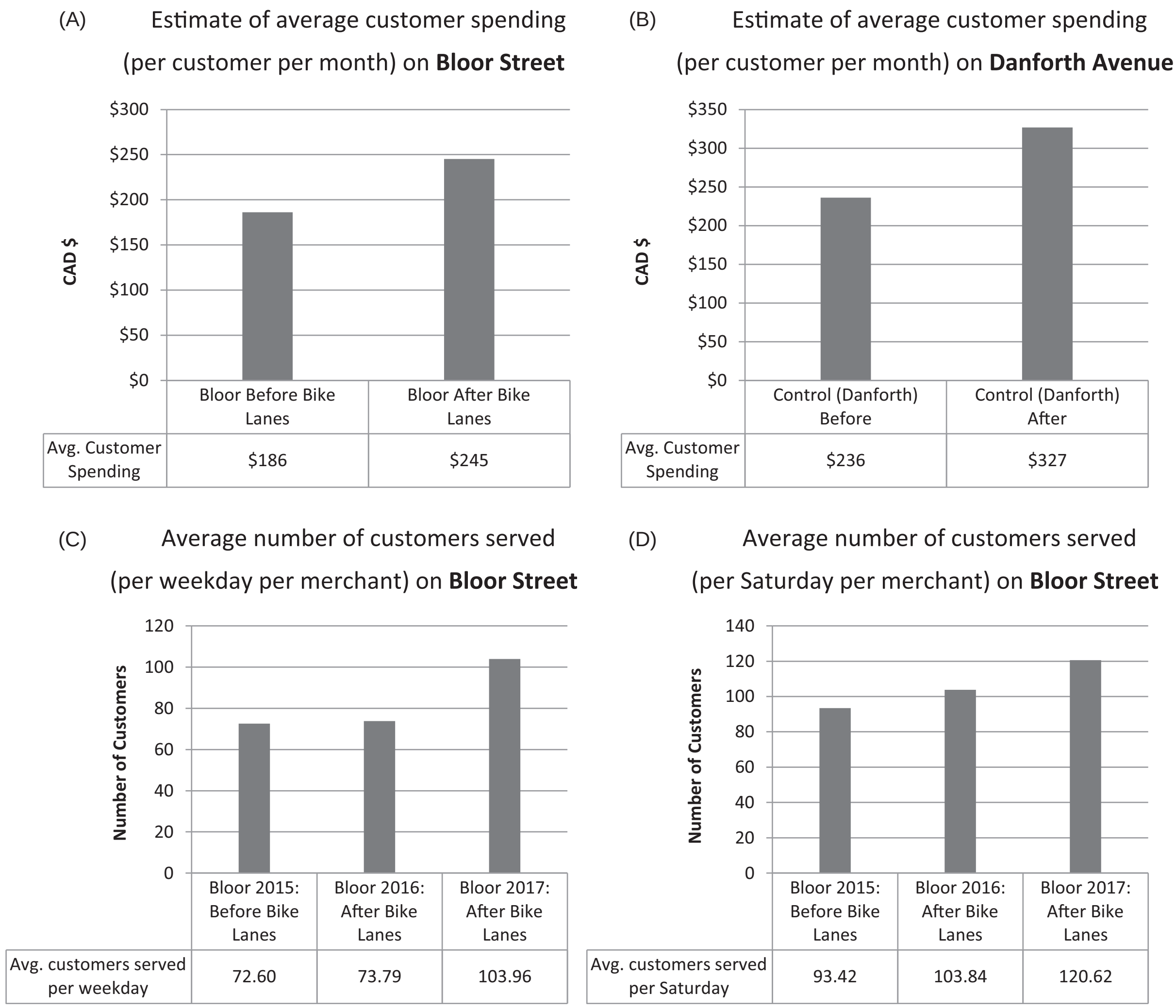



*Figure 2. (A) Estimate of average customer spending per customer per month on Bloor Street. (B) Estimate of average customer spending per customer per month on Danforth Avenue, control site. (C) Average number of customers served per weekday per merchant on Bloor Street. (D) Average number of customers served per Saturday per merchant on Bloor Street.*

survey. First, the two post samples cannot be merged because they contain repeated measurements from the same merchants. Second, we omit comparisons with the Danforth Avenue site because the merchant sample size is small and therefore not suitable for detailed statistical analysis. An expanded version of Table 3 is found in Technical Appendix B.

The number of merchants on Bloor Street reporting more than 100 customers per day increased substantially and significantly for food service/bar and retail establishments on both Saturdays and weekdays. No significant changes were detected for service establishments. This significant increase in the reported number of customers suggests the higher monthly spending per customer measured in the visitor surveys effectively translates to more economic activity on Bloor Street (as opposed to a shift in the proportion of customers due to a loss in some customer demographics). For reference, Figures 2C and 2D show the average number of customers served per merchant on Bloor Street for weekdays and Saturdays, respectively.

### *People Arriving by Bicycle and Those Who Support the Bike Lanes Report Higher Monthly Spending*

We use regression modeling to quantify the independent effects of the bike lane on self-stated visitor expenditures and visiting frequency by controlling for the effects of visitor-related characteristics such as age, gender, place of residence, etc. As for the descriptive statistics performed earlier, we combine the two post–bike lane samples.

A list of the variables present in the multivariate models is provided in Technical Appendix C. The full sample includes 3,005 respondents. However, after cleaning the data for missing entries, the analysis sample was reduced by 3.1% to 2,912 respondents. Despite the loss of sample size, there are no systematic differences between the variable means in the full sample and analysis sample.

More detailed descriptions and the results of three logistic regression model specifications for the monthly expenditure variable are provided in Technical Appendix D. The most basic model (Model 1) shows that all else being equal, post-implementation visitors on Bloor Street were 50% more likely to spend more than $100 per month compared with the pre-implementation visitors (odds ratio = 1.48, $p = .055$). Increases were also apparent for Danforth Avenue, as indicated by the ratio of the two odds ratios (2.1/1.2 = 1.75).

The coefficients for control variables in the expenditure models indicate significant positive effects of living and working in the area, of visit frequency, and of being middle-aged. Gender is insignificant in all model specifications.

Model 2, which interacts cycling with the strata terms, shows cyclists had a 16% increase in odds of spending $100 per month compared with other mode users on Bloor Street. This provides evidence that the overall increase in likelihood of spending in the post–Bloor Street strata is attributable to the increase among cyclists.

The third model, which focuses on visit purpose and bike lane support, shows visitors who were on a shopping/restaurant/service trip when intercepted were also twice as likely to spend $100 or more per month, and those who provided positive feedback about the bike lane were 24% more likely to spend $100 per month.

### *Visit Frequency on Bloor Street Went Up by 3 Days per Month*

We also explore changes in self-stated visit frequency using ordinary least squares regression (details are provided in Technical Appendix E). A moderate goodness-of-fit is indicated by the $R^2$ of 43%. Here, we interpret regression coefficients as the marginal effect of a one-unit increase in each variable on the number of days visited per month. The main finding is visit frequency on Bloor Street went up by 3 days per month, whereas visit frequency on Danforth Avenue saw no significant change. Furthermore, the model indicates walkers and cyclists visit at about the same level of frequency, whereas drivers and transit users visited nearly 4 days fewer per month. Unsurprising, those living or working in the study area visited 13 more days per month compared with others. Interestingly, there were no significant differences between genders or age groups.

### *Vacancy Rates Held Steady*

Vacancy rates held steady in the study area and control site between July 2016 and July 2017. In our Bloor Street study area, there was one less commercial vacancy in 2017, a −0.4% change. In the entire bike lane pilot project area, from Avenue Road to Shaw Street, one more vacancy was reported, representing a 0.3% increase. At the control site there were two fewer vacancies in 2017, a −1.7% change. Details are shown in Table 5.

## Bloor Street Bike Lanes: Positive or Neutral Impact

Our results indicate the business environment on Bloor Street improved during the time of the study: Reported visitor spending rose, visit frequency increased, estimated customer counts show growth in the number of customers, and vacancy rates held steady.

It is worth noting that more than 70% of visitors walked or took transit to Bloor Street both before and after the intervention. These visitors' journeys were mostly unaffected by the street's reconfiguration, and any changes in visiting and spending habits among most visitors were likely in response to factors unrelated to the bike lane.

Results from the Danforth Avenue (control) site are helpful to assess whether changes in these local economic indicators suggest a positive or neutral impact. Danforth Avenue performed equivalently in terms of visitor spending, and vacancy rates decreased slightly. There were no changes in visit frequency in the control site compared with a 3-day increase in the pilot area.

Other data we collected from the visitor survey are consistent with positive changes in the pilot area. The proportion of shoppers driving to the neighborhood remained unchanged at 9%, and that of shoppers arriving on bicycles rose considerably from 8% to 22%. Furthermore, although people arriving by car were more likely to experience difficulties finding parking on Bloor Street than before, the proportion of respondents reporting this problem was not significantly different from that at the control site.

Table 5

**Changes in vacancies and vacancy rates.**

| Location | No. ground-level commercial spaces | 2016: Vacancies before Bloor bike lanes (vacancy rate) | 2017: Vacancies after Bloor bike lanes (vacancy rate) | Change in vacancies (change in vacancy rate) |
|---|---|---|---|---|
| Bloor Corridor, entire length of bike lane, Avenue Rd. to Shaw St. | 345 | 24 (7.0%) | 25 (7.2%) | +1 (+0.3%) |
| Bloor Corridor, only in Korea Town and Bloor Annex BIAs | 247 | 16 (6.5%) | 15 (6.1%) | −1 (−0.4%) |
| Control (Danforth), Broadview Ave. to Chester Ave.) | 116 | 6 (5.2%) | 4 (3.4%) | −2 (−1.7%) |

We also find monthly customer spending was related to proximity rather than parking. Being close makes it easier to visit, and those who live or work in the area were found to visit 13 days more per month than those who live or work further away. Locally based visitors were 2.6 times more likely to spend at least $100 per month. For each additional day visited, the likelihood of spending $100 or more increased by 7.3%.

Most people making these short, frequent trips chose to walk and, increasingly, to cycle. People who drove or took transit visited nearly 4 fewer days per month. More visiting affords more opportunities to spend, and on Bloor Street, people who walk or bike were the most likely to spend $100 or more per month, both before and after the bike lane's installation. After installation, cyclists had a 16% increased likelihood of spending at least $100 over people who walked. These findings align with the results of a 2009 study in the Bloor Annex neighborhood, which also finds people on bikes and on foot visited the most often and spent the most money per month (Sztabinski, 2009).

Of nearly 2,000 visitors surveyed in the post-test, more than 90% of those on Bloor Street and more than 80% on Danforth Avenue arrived without a car. Despite the potential need to carry items purchased, shoppers were not more likely than other visitors to use a car.

### *Lessons for Research*

We find visitor and merchant surveys useful tools for assessing the economic impacts of projects affecting merchants along commercial strips. Surveying merchants and customers before and after interventions leads to more meaningful results than can be obtained with a single survey after implementation, as in Stantec (2011). A large sample of visitor surveys is important to track monthly customer spending and allows for robust calculations of mode share, whereas data on customer counts (derived from merchant surveys) are useful to appropriately contextualize these results. Partnering with local businesses contributes to higher merchant participation rates.

Although debit and credit card transaction data are not advisable as a standalone indicator of economic impacts without an understanding of how these values fluctuate over time, this type of data can be used prospectively to complement survey-based studies. It may prove especially useful where retail sales data are unavailable. Parking data may likewise be used to complement and inform mode share estimates derived from visitor surveys.

We encourage researchers to include controls (comparison sites) in their studies and to allocate additional resources to collect representative samples if necessary. The complete absence of controls in the economic impact study conducted by the City of Calgary (2016a), for example, makes its findings difficult to interpret: Did bike lanes contribute to reducing economic activity, or do the data reflect a regional economic downturn? Control sites may consist of similar neighborhoods and/or citywide measurements. NYC DOT

(2013) offers the most comprehensive execution, with multiple controls for each site. Poirier (2018) uses neighboring but not abutting businesses as control with interesting results, and McCormick (2012) successfully uses adjacent sections of the same street, but these solutions may not offer enough buffer from the intervention depending on the context.

### *Lessons for Planning Practitioners*

Overall, our study results are consistent with the literature. We find no evidence of the negative economic impacts following the installation of the bike lanes that many merchants fear (McCormick, 2012; NYC DOT, 2012, 2013; Rowe, 2013). This appears to confirm the suitability of bike lane installations in vibrant downtown retail streets and should encourage the design and implementation of similar bike lane interventions in other merchant-lined urban streets with similar visitor profiles.

Because many cyclists already frequented Bloor Street, we would not extrapolate our findings to neighborhoods where customer behavior is markedly different in this regard. Streets like Queen Street West in Toronto, where Chan et al. (2016) find that only 4% of visitors arrived by car (and 19% cycled), are ideal candidates in terms of their business environments' likely resilience when adding bike lanes at the cost of parking. Our results suggest food service establishments, bars, and retail in these locations may not only withstand but possibly benefit from such interventions. This is consistent with previous findings by Poirier (2018) and Clifton et al. (2012, 2013).

Based on our experience, we advise planners to consider incorporating local economic impact indicators in projects where merchants participate as major stakeholders. Doing so results in a more transparent and evidence-based decision-making process. Nevertheless, the results of our study and others cited above suggest that in settings where cyclists, pedestrians, and transit users predominate, cycling infrastructure is unlikely to constrain local economic activity. Moreover, prospective parking loss should be expressed as a potential impact on only that share of visitors arriving by car and as a proportion of total available spots in the neighborhood. Merchant concerns regarding loss of car parking may reflect overestimations in car mode share among their customers.

Our study provides evidence that downtown corridors lined with retail, like Bloor Street, are strong candidates to benefit from the inclusion of bike lanes at the cost of some on-street parking. Toronto's Bloor Street bike lanes were made permanent on November 7, 2017, with City of Toronto councilors voting overwhelmingly in favor of the project (36–6). City staff and the media described the pilot project as Toronto's most intensely studied transportation project (Rieti, 2017).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## ACKNOWLEDGMENTS

*We could not have completed our study without the diligence and rigor of graduate students Michelle Kearns and Kelsey Carriere and our team of more than 20 research assistants from the University of Toronto.*

## RESEARCH SUPPORT

*This study was supported by the City of Toronto, the Metcalf Foundation, the Bloor Annex Business Improvement Area, and the Korea Town Business Improvement Area.*


## SUPPLEMENTAL MATERIAL

*Supplemental data for this article can be found on the publisher's website.*

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# Business Impacts of Access Changes

https://vtrc.virginia.gov/media/vtrc/vtrc-pdf/vtrc-pdf/26-R38.pdf


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**Final Report VTRC 26-R38**


VIRGINIA TRANSPORTATION RESEARCH COUNCIL
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<table>
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<tr><td colspan="2">6. Performing Organization Code:</td></tr>
<tr><td colspan="2">7. Author(s):<br>James S. Gillespie, Isaiah E. Batman, Katya E. Benham</td><td colspan="2">8. Performing Organization Report No.:<br>VTRC 26-R38</td></tr>
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<tr><td colspan="2">11. Contract or Grant No.:<br>124697</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agencies’ Name and Address:<br>Virginia Department of Transportation<br>1221 E. Broad Street<br>Richmond, VA 23219<br><br>Federal Highway Administration<br>400 North 8th Street, Room 750<br>Richmond, VA 23219-4825</td><td colspan="2">13. Type of Report and Period Covered:<br>Final</td></tr>
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<tr><td colspan="4">15. Supplementary Notes:<br>This is an SPR-B report.</td></tr>
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16. Abstract:


Some types of geometric improvements that the Virginia Department of Transportation (VDOT) has begun to build in the past two decades, such as the reduction in the number of arterial access points, the replacement of a traditional four-way intersection with a roundabout, or a restricted crossing U-turn, or left-turn prohibitions, have elicited expressions of concern from businesses that operate on property adjoining the improvements. The business operators’ concern is that the improvement, by creating more circuitous access for motorists, will reduce customer traffic, with a consequent effect on the business’s revenue or on the value of the affected commercial parcel. VDOT has never compiled a quantitative, Virginia-specific dataset on how access changes have affected adjacent businesses.

This study sought to fill that deficit by estimating the effects of changes in access on assessed parcel values before and after a VDOT reconstruction that altered the geometrics of an intersection or a road segment. Although business impacts could ideally be measured as taxable sales, such data were not feasible to obtain, and thus, assessed parcel values were the study focus. The study compiled information on 91 commercial properties fronting VDOT reconstruction projects, and on 67 similar commercial properties nearby, not fronting the projects, at 30 VDOT projects in 16 counties and three independent cities. Information collected included two different measures of the change in motorized access—the number of additional turns and additional distance traveled—that resulted from construction and assessed real estate values during a nine-year window from four years before the year construction was completed to four years after the year of construction completion. This nine-year window was sampled to have a strong opportunity to capture the lagged effects of changes in access in case such changes were not immediately reflected in project assessments. The analysis found that, within the nine-year window, the changes in access that the investigators measured had no statistically distinguishable effect on the property value assessments of the commercial properties fronting the VDOT reconstruction projects.

The analysis found some evidence of a small negative correlation between VDOT reconstruction work and the growth of assessed property value, via a relationship that the model employed in the study did not capture. When the commercial parcels were split into three groups of businesses, based on their expected sensitivity to access changes, this correlation was detected only in the two groups believed less likely to be sensitive. This correlation was not detected in the group expected to be most sensitive, such as gas stations, convenience stores, and fast-food restaurants.


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<tr><td colspan="2">17. Key Words:<br>Highway access management, Physical access control, Economic and social factors, Evaluation and assessment</td><td colspan="2">18. Distribution Statement:<br>No restrictions. This document is available to the public through NTIS, Springfield, VA 22161.</td></tr>
<tr><td>19. Security Classif. (of this report):<br>Unclassified</td><td>20. Security Classif. (of this page):<br>Unclassified</td><td>21. No. of Pages:<br>49</td><td>22. Price:</td></tr>
</table>

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# FINAL REPORT

# BUSINESS IMPACTS OF ACCESS CHANGES

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In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

Virginia Transportation Research Council
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Charlottesville, Virginia

May 2026
VTRC 26-R38

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**ABSTRACT**

Some types of geometric improvements that the Virginia Department of Transportation (VDOT) has begun to build in the past two decades, such as the reduction in the number of arterial access points, the replacement of a traditional four-way intersection with a roundabout, or a restricted crossing U-turn, or left-turn prohibitions, have elicited expressions of concern from businesses that operate on property adjoining the improvements. The business operators' concern is that the improvement, by creating more circuitous access for motorists, will reduce customer traffic, with a consequent effect on the business's revenue or on the value of the affected commercial parcel. VDOT has never compiled a quantitative, Virginia-specific dataset on how access changes have affected adjacent businesses.

This study sought to fill that deficit by estimating the effects of changes in access on assessed parcel values before and after a VDOT reconstruction that altered the geometrics of an intersection or a road segment. Although business impacts could ideally be measured as taxable sales, such data were not feasible to obtain, and thus, assessed parcel values were the study focus. The study compiled information on 91 commercial properties fronting VDOT reconstruction projects, and on 67 similar commercial properties nearby, not fronting the projects, at 30 VDOT projects in 16 counties and three independent cities. Information collected included two different measures of the change in motorized access—the number of additional turns and additional distance traveled—that resulted from construction and assessed real estate values during a nine-year window from four years before the year construction was completed to four years after the year of construction completion. This nine-year window was sampled to have a strong opportunity to capture the lagged effects of changes in access in case such changes were not immediately reflected in project assessments. The analysis found that, within the nine-year window, the changes in access that the investigators measured had no statistically distinguishable effect on the property value assessments of the commercial properties fronting the VDOT reconstruction projects.

The analysis found some evidence of a small negative correlation between VDOT reconstruction work and the growth of assessed property value, via a relationship that the model employed in the study did not capture. When the commercial parcels were split into three groups of businesses, based on their expected sensitivity to access changes, this correlation was detected only in the two groups believed less likely to be sensitive. This correlation was not detected in the group expected to be most sensitive, such as gas stations, convenience stores, and fast-food restaurants.

# FINAL REPORT

# BUSINESS IMPACTS OF ACCESS CHANGES

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## INTRODUCTION

The Virginia Department of Transportation (VDOT) awards hundreds of contracts every year for improvements to the highway system the agency operates. As the funds available for these contracts are limited, it is essential to be able to predict and compare the relative benefits and costs of a "menu" of potential highway improvements. VDOT staff generally have good models, based on extensive historical data, to predict a project's up-front construction cost. VDOT staff generally have good models to predict the impacts of an improvement on travel time, vehicle operating costs, crash risk, and pollutant emissions within the area where the improvement's effect is felt.

VDOT staff have no model and relatively little information, however, to predict the business impacts on commercial establishments that adjoin the new facilities when a highway investment changes traveler access to one or more parcels that adjoin the highway. Business impacts may be reflected as changes in customer traffic, property values, sales prices, tax revenue, or rents. This lack of data is felt because questions about a shift in customer traffic arise in both public hearings and in right-of-way negotiations. Two reasons for research now on forecasting the quantitative business impacts that result from changes in traveler access to commercial parcels are (1) the passage of Virginia Senate Bill 666 in 2022 and (2) the recent removal of a restricted crossing U-turn (RCUT) intersection reconstruction project from the Six-Year Improvement Plan due to public opposition that hinged in part, ostensibly, on their expected effect on customer traffic.

### Senate Bill 666

In 2022, Senate Bill 666 amended §§25.1-100 and 25.1-230.1 of the Code of Virginia to redefine "lost profits" for a business or farm operation for the purpose of determining just compensation in an eminent domain proceeding. This legislation is expected to have a significant effect on the cost of right-of-way acquisition, already one of the least predictable elements of project cost. It is therefore expected to affect the cost estimates in planning studies and the recommendations that emerge from these studies (LegiScan, 2022; Trackbill, 2022).

VDOT planning studies consider various designs, traditional or innovative, to address operations and safety issues. Reduction of traffic conflict points, one safety consideration in many planning studies, often leads toward a design that modifies the motorized access to a commercial or agricultural property fronting the road. Senate Bill 666 increases the likelihood that a VDOT planning study that addresses traffic conflicts will have to assess the effect each potential design will have on neighboring properties.

## Unanswered Questions about Restricted Crossing U-Turns

A shift in customer traffic between one establishment and another does not register as a *net* benefit or cost to the community that the highway network serves. A standard benefit-cost analysis of a highway project will not capture this effect. Nonetheless, such a shift in customer traffic can matter greatly to the owner or renter of an individual real estate parcel.

A recent safety project in Pittsylvania County, involving the construction of an RCUT in the place of a previously existing four-way signalized intersection, made its way to the public hearing stage of development, even into the Department's Six-Year Improvement Plan, only to be withdrawn later in the face of opposition from the local government (Hunziker, 2023; Mirza, 2023; Wilborn, 2023). The public hearing for a similar RCUT project in Gloucester County received multiple negative comments, leading the county board of supervisors to vote against it (Bass, 2023). This sort of opposition is not unique to RCUTs. A proposed roundabout design in Halifax County was withdrawn partly because of concerns about the effect on businesses fronting the affected VDOT right-of-way (Fitzwater, 2024). VDOT seeks stakeholder opinion as a matter of policy and attempts to address concerns raised at public hearings. That being said, to pull a project late in the design stage means that effort has been wasted on a "dead-end" project and that a solution to the problem the project was designed to remedy is going to be delayed.

Stakeholders at local meetings raised questions about a variety of effects that the transformation from four-way signalized to RCUT might entail. The safety and operational effects have been well documented at the national level (Bared, 2009) and are also explained in VDOT publications (VDOT, 2023). In the face of questions about the impact on customer traffic at commercial establishments adjoining the intersection, however, VDOT staff recognized a need for more information about the range of possible effects and the factors that determine their size.

## An Illustration of a Change in Motorized Access

For some vehicles moving through an intersection, the conversion from four-way to RCUT affects access to properties at the corners of the intersection (Federal Highway Administration, n.d.). Figure 1 shows that compared with a four-way intersection, the RCUT forces northbound left-turning vehicles to follow a more circuitous and time-consuming path to reach the business.

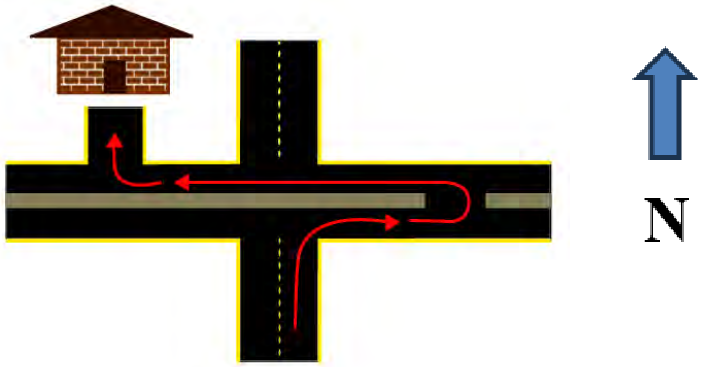


**Figure 1. Northbound Traffic Seeking to Access a Business**

### Problem Statement

The recent pushback against RCUTs may partly arise from the traveling public's unfamiliarity with their design, a factor that may diminish naturally with time if VDOT continues to build them. However, RCUTs are only one type of reconstruction that alters motorized access. Businesses express concerns about other types of access changes, such as median closures. Thus, the problem facing VDOT is that the effects of changes in motorized access on businesses is not known. This problem applies to a wide variety of reconstruction projects beyond RCUTs.

This lack of knowledge can be felt in at least two points of the transportation planning and project development process. One is in discussions with the public, which may occur through required public hearings but also through optional (non-required) information meetings in which members of the public provide input on a variety of project alternatives. The second point is in right-of-way acquisition, for which VDOT staff need supporting information when engaging with property owners whose property will undergo a change in motorized access. In both cases, having better information about the business impacts of changes in access can improve the discussion of project alternatives.

## PURPOSE AND SCOPE

The purpose of this study was to estimate the effect a commercial establishment can expect when a VDOT reconstruction project changes motor vehicle access to the establishment's property. Three primary considerations determined the study scope:

- The study was confined to VDOT reconstruction projects, in order that the findings might be based on Virginia-specific data.
- The study sample included multiple types of geometric improvements, in order that the sample size might be larger and the findings might be sufficiently general to have relevance for multiple types of improvements.
- The two definitions of motorist access that were selected to measure the changes in access were calculable using only the data available.

# METHODS

The research approach consisted of five sequential steps that culminated in a calibrated Virginia business impacts model as the final step.

1. Conduct a literature review.
2. Propose a business impacts model.
3. Identify Virginia sites.
4. Collect data.
5. Develop the business impacts model.

## Literature Review

VDOT has begun in recent years to introduce several new intersection designs into the Commonwealth of Virginia's highway network. The roundabout is one of the older, more frequently constructed innovative designs (Carlton, 2024). VDOT has adopted several other newer designs into its toolkit (VDOT, 2018).

Publications that study the association between highway geometrics and customer behavior are not numerous and thus do not, by themselves, meet the research need. However, they provide useful starting points for the remaining four methods used in this study.

### Motorized Access

Kennedy (2019) identified "vehicle ingress and egress" as one of the location factors that can influence the value of a commercial parcel. The same author identified "transportation"—meaning transit, cyclist, and pedestrian access in this case—and "surrounding property"—that is, proximity to potential customers—and "traffic count" as location factors that can influence the value of a parcel.

Huffman (2023) discussed the trade-offs that may hinge on the choice of access connections to private commercial property and off-site improvements in the vicinity of the property. Access connections and off-site improvements may affect accessibility, safety, mobility, and aesthetics, and each of these may affect the market value of a parcel.

Plazak and Preston (2005) reported the findings of a study funded by the Minnesota Department of Transportation that modeled the economic impacts of converting a high-speed, at-grade arterial known as Trunk Highway 12, or U.S. Highway 12, to a freeway-standard facility renamed Interstate 394. This road, connecting downtown Minneapolis with the western suburbs of the Twin Cities metropolitan area, was reconstructed from 1985 to 1993. Commercial parcels, which formerly were entered directly from the arterial, were afterward entered via new frontage roads on either side of the reconstructed freeway. The investigators compiled several before and after measures of economic conditions, including (1) the number of businesses, (2) the rate of business turnover, (3) gross retail sales, including taxable services, (4) employment, and (5) commercial land values. The investigators also interviewed a representative sample of 14 business owners on the U.S. Highway 12-Interstate 394 corridor. During the study period from

1984 through 2004, land use shifted from residential space to retail space and to office and service sector space, and traffic on the road roughly doubled. In other words, the corridor was urbanizing. The study found that the highway reconstruction met its primary objectives: adding traffic capacity, preserving flow, and improving safety "dramatically." Furthermore, the study found that the statistical indicators of business conditions generally showed growth at or above the average for the metropolitan area and the state as a whole. Individual business owners who were interviewed gave mixed responses: two fast-food restaurants reported a positive trend in sales after the reconstruction; two big-box retail stores reported a positive trend in sales after the reconstruction; and a handful of sit-down restaurants, some of them affected by right-of-way acquisition, expressed fears beforehand about the effects both on their visibility and their accessibility from the highway. That said, these establishments continued to operate at the same locations after the reconstruction but reported that the new system of frontage roads confused customers, especially first-time customers. Two auto dealerships, also affected by the right-of-way acquisition, expressed the same fears beforehand about visibility and accessibility from the highway. That said, both dealerships remained at the same locations as of 2005. A gas station continued to operate at the same location after the reconstruction. Plazak and Preston (2025) noted incidentally in their introduction, "Although the safety and traffic flow benefits of access management have been well-documented …, the literature on the impacts of access management projects on adjacent commercial businesses and land parcels is much less abundant."

Hodge (2024) described a similar methodological approach to evaluate the effect of "complete streets" investments in a sample of Massachusetts towns. Complete Streets policies entail geometric modifications and other changes. The consequences for motor vehicle access are not necessarily positive because the policies' goal is to balance and, to the extent possible, enhance safety and access for travelers by *all* modes—transit, motor vehicle, bicycle, and foot traffic. The investigators measured the economic impact of the complete streets modifications using three measures: the change in property values in the affected neighborhood, the change in the number of jobs, and the change in the number of commercial establishments. The study found a detectable positive effect on property values in two of the towns studied, a negative effect in one town, and an impact indistinguishable from zero in two towns. In response to a question after the presentation, the presenter stated that the investigators certainly would have loved to use retail sales figures as a measure but were not able to obtain them.

## Innovative Intersections

Schneider et al. (2019) obtained before and after sales tax receipts at the intersection level to compute average customer traffic before and after construction of an RCUT, also referred to as a J-turn. They collected these data for ten intersections in four study locations in the state of Louisiana. The investigators found no decrease in taxable sales between the two-year period before the improvements and the two-year period after but rather a slight overall increase.

Miller (2020) conducted a preliminary exploration of the business impacts of access changes to inform VDOT colleagues who were fielding questions about the new RCUT intersection design. This memorandum identified some of the likely challenges to data collection. Miller had to rely on impact measurements from other states because the newness of RCUTs made it nearly impossible to collect both before and after data from Virginia RCUT projects. The memorandum reviewed published information from other states as of 2020 and extracted some tentative conclusions for application in Virginia.

Barnes et al. (2022) obtained data from four intersections adjoining commercial parcels, two intersections adjoining industrial parcels, and four intersections adjoining residential parcels. The investigators adopted four separate approaches to measuring the empirical impact and the perceived effect of conversion from a signalized intersection to an RCUT intersection: (1) night-time radiance data, a proxy measure of economic activity on each parcel; (2) a survey of the neighboring businesses, as a measure of commercial neighbors' perceptions; (3) residential real estate sale prices, as a measure of the road user benefits (or costs) capitalized into the price of nearby parcels; and (4) a survey of nearby residents. The radiance data delivered "mixed results with most models resulting in a null effect." The business survey data suggested that commercial properties that received many late-afternoon customers expected the most positive impacts, and industrial properties expected the most negative impacts. The analysis of residential real estate prices delivered mixed results. The survey of residents indicated that residents were willing to "pay" for safety with added wait time at the intersection but that the residents revealed a stronger dislike of added time waiting to turn left than their dislike of added time to their commute as a whole. The investigators interpreted this revelation to mean that the residents, as drivers, preferred traffic that continues to *flow*. The North Carolina Department of Transportation (2023) refers to RCUTs as "reduced conflict intersections," or "RCIs".

Kimley-Horn (2024), in cooperation with VDOT staff, conducted case studies of ten recently constructed innovative intersections in the Commonwealth of Virginia. Four of the intersections were remade as RCUTs, three as unsignalized or continuous-green "T" intersections, two as quadrant roadways, and one as a partially displaced left turn. The investigators examined the before and after crash data at these locations as a measure of the impact on safety. They examined the mean travel speed before and after as a measure of the impact on traffic flow. The investigators also interviewed businesses adjacent to or close to the reconstructed intersections to assess the effect of the new geometries. The investigators' success rate in obtaining responses slightly exceeded 50%: of the 28 approached, 15 responded. Most businesses reported either positive or neutral impacts on customer traffic after reconstruction. One convenience store and two hotels reported a negative impact on customer traffic.

A Georgia study, underway at the time of this writing, will examine "any associated changes to economic performance of the impacted businesses nearby" following the construction of RCUTs. Study GA RP 24-12, funded by the Georgia Department of Transportation (2025), managed by Sabbir Ahmed, and conducted by Yichang Tsai, was initiated in January 2025 and is expected to be completed in October 2026.

### Other Literature

Uncertainty about the business impacts of access to the parking lots of the businesses fronting the road has prolonged the process of reaching a satisfactory design decision for a few specific VDOT projects. Lantz, Jr. et al. (2008) reported findings from interviews with VDOT staff involved in the project scoping process. "Interviewees gave a range of answers for the duration of project scoping, but all answers were between 3 and 6 months." Scoping is part of the preliminary engineering (PE) phase of the project delivery process. Miller and Turner (2014) reported that, from 2004 to 2012, the percentage of pooled VDOT project costs spent on PE ranged from 11.2% to 18.8%. When one evaluates the risk that uncertainty about the impact of access changes will prolong the PE phase of project delivery and considers the possibility that additional information about the impact can reduce this risk, these baseline estimates of the duration and cost of PE may be kept in mind.

### Summary of Inferences from the Literature

The literature provided four insights that affected how the remaining methodology should be applied.

- Most studies have used only a small number of sites, so one contribution would be to find a way to increase the sample size beyond just a few sites.
- The choice of what attribute to measure—sales tax data, property sales data, business turnover, or surveys of customers or proprietors—is influenced by the ease or difficulty of obtaining the data element, and all have been used as proxies for customer traffic.
- Different types of geometric changes, such as RCUTs or simple median closures, can be represented in some way as a change in access.
- The effect of other factors that change at the same time that access changes, such as economic conditions, should be considered in a study.

## A Proposed Business Impacts Model

To build a model of the impact of a change in motorized access on customer traffic, one must assemble several pieces. First, one must obtain one or more direct or indirect measures of customer traffic. Second, one must obtain one or more direct or indirect measures of motorized access, the factor whose effect on customer traffic is to be tested. Third, one would also like to obtain measures of the other uncontrolled factors that may influence customer traffic.

### Choice of Customer Traffic Measures

*An Ideal Measure: Taxable Sales*

Several indicators of economic activity are available to measure the impact on business properties. Schneider et al. (2019) used taxable sales, a relatively direct measure of customer traffic. Barnes et al. (2022) used (1) night-time radiance, (2) survey responses from neighboring businesses, and (3) the price of nearby parcels. The first and third of these indicators may be expected to be correlated with customer traffic, and the second may be expected to reflect the perception or expectation of an effect on customer traffic.

As business owners expressed fear of lost sales in the public meetings, sales records seemed the first and best measure of business impact. The investigators made inquiries with the Virginia Department of Taxation regarding the possibility of obtaining historical taxable sales records under terms compliant with the Virginia tax rules for preserving taxpayer confidentiality.

These inquiries eventually received a regretful but definitive negative answer (Michael Palmer, “personal communication,” December 5, 2023; Palmer, 2024).

*A Surrogate Measure: Real Estate Assessments*

VDOT’s Right-of-Way Division consults certain indirect measures of attractiveness to customers during their preparations for negotiations and court proceedings to determine the value of a real estate taking. Two examples of these indirect measures are (1) the amount of rent generated by an arm’s-length lease agreement and (2) the appraised value of the parcel.

Given that taxable sales are out of consideration, the investigators opted for real estate assessments. These assessments are public records, available at the level of the individual commercial parcel. The reasoning that underlies the use of real estate values as a proxy for customer sales holds that if a superior location attracts above-average sales, some fraction of the above-average net revenue that the resident business anticipates will be capitalized into the rent, or into the asking price, of the real estate (Kennedy, 2019). If a change in motorized access makes a commercial parcel’s location more or less favorable, then the rent or the price of the parcel may reflect that change.

However, at the very outset of this study, the technical review panel provided the investigators with feedback on the behavior they expected of real estate assessments. Technical review panel members expected real estate assessments not to react quickly to changes in highway geometry. Any value movement, other than movement on trend with the neighborhood, was likely to become manifest only when the parcel, or a comparable neighboring parcel, changed hands at a recorded price (Randall Snow, “personal communication,” October 7, 2023). Thus, a way to address this lag was required.

*Interviews with Real Estate Appraisers*

To better understand the strengths and weaknesses of real estate appraisals for this study, the investigators held conversations, either by telephone or e-mail, with four persons in four different Virginia county assessors’ offices, each familiar with the appraisal practices in that county and sometimes with practices in other counties as well (Collier, “personal communication,” August 4, 2025; Foster, “personal communication,” August 6, 2025; Kilby, 2025; Liggan, 2025).

The investigators also spoke with one fee appraiser, familiar with the practices in appraisals performed for customers such as mortgage lenders, real estate developers, or estate executors (Will Sanford, “personal communication,” August 4, 2025). Because they intended to use real estate assessments to measure customer traffic indirectly in a regression model, the investigators sought to understand the behavior over time that they might expect to see in real estate assessments.

The first question was, “Would a change in parking lot access, resulting from a reconstruction of the road geometrics, in and of itself induce your appraisers to revise the estimated value of a commercial parcel?” The county assessors said that their appraisers generally would *not* revise assessments based solely on geometric change; they would wait to see if a property sale revealed a change in value. The fee appraiser said that a fee appraisal might possibly take into account a change in the ease of ingress and egress. The fee appraiser and two of the county assessors mentioned spontaneously that, for occupants of commercial parcels, visibility tended to be a more important location factor than simplicity of access.

The second question was, “Would a change in traffic volume on the road fronting the parcel induce your appraisers to revise the estimated value of a commercial parcel?” The county assessors said that they would indeed expect traffic volume to influence a parcel’s value. Nonetheless, they said that their appraisers would tend to wait for a property sale to confirm their expectation. The fee appraiser said that a fee appraisal quite likely would consider a change in traffic volume.

*Summary: The Need for a Time Lag in the Model*

The expectations of the county assessors matched the expectations of the technical review panel. The expected behavior of real estate assessments as a measure of customer traffic provided a strong rationale for building and estimating a mathematical model that allowed for a response with a possibly substantial time lag. This consideration stood somewhat in conflict with the fact that long observation periods “after completion” were not going to be available for many of the VDOT projects of interest because many of the innovative intersections had been constructed so recently. The investigators opted to model a four-year time window beyond the year containing the project completion date to increase the likelihood of capturing the lagged effects of changes in access.

## Choice of Access Measures

The investigators sought to build a model that could conduct an apples-to-apples comparison of the impact of access changes caused by a wide variety of reconstruction projects. To achieve this goal, the investigators opted for measures of access change that transcended specific project types and specific highway geometries.

Given the origin of the research question, in fears expressed by business operators or their supporters that the change in access would affect customer traffic, the investigators sought measures of access change that would capture the point of view of the potential customer who might or might not choose to pull into the parking lot of a certain business establishment. To achieve this goal, the investigators opted for measures of access change that the operator of a motor vehicle would experience directly as an annoyance.

The investigators defined two primary measures of a change in access.

- A driver approaching from a given direction might be influenced by the number of turning movements that he or she must execute to enter the parking lot of the affected commercial parcel.
- A driver approaching from a given direction might be influenced by the distance that he or she must travel to enter the parking lot of the affected commercial parcel.

The explanatory power of the before and after measures of motorized access in the statistical analysis would constitute the finding that answers the research question. Figure 2 illustrates how the measures of change in access would be computed.

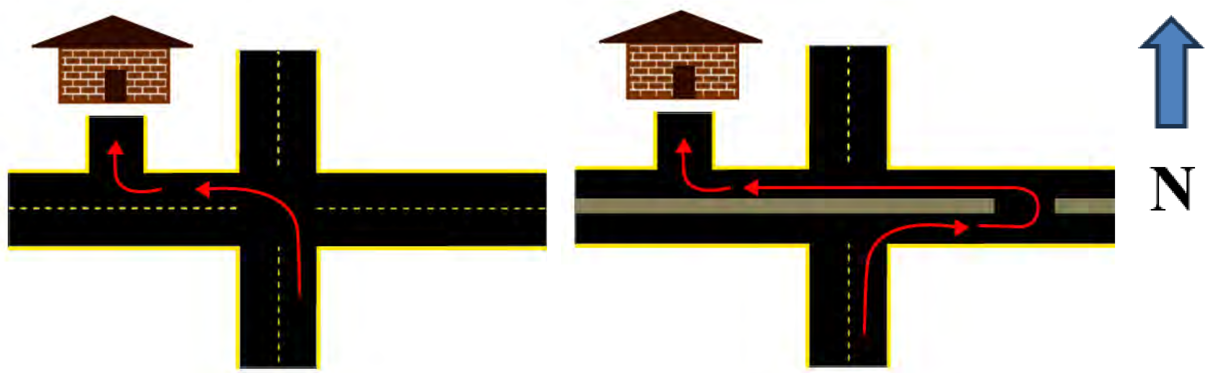


**Figure 2. Example of Access Changes. (Left) Before reconstruction, northbound traffic requires 0.1 miles and two maneuvers—a left turn to the westbound lane and then a right turn into the parking lot. (Right) After reconstruction, northbound traffic requires 0.3 miles and three maneuvers—a right turn to the eastbound lane, a U-turn, and then a right turn into the parking lot.**

The investigators added a third explanatory variable, a treatment group dummy variable, which would carry a value of one (1) for every parcel that fronted on a VDOT reconstruction project and would carry a value of zero (0) for every parcel that did not. The reasoning behind this choice was that, although the investigators believed their measures of access change were realistic and intuitively compelling, they wanted to allow for the possibility that VDOT reconstruction work could affect customer traffic through an unknown causal mechanism, which their measures of access change failed to capture. If that were the case, the treatment group dummy might capture it. This variable was not a measure of change in access specifically but rather a proxy for any factor—population growth, traffic congestion, crash risk, or other influences—that might happen to be correlated with both VDOT reconstruction work and the appeal of a commercial location.

The investigators considered another way to define and measure access change: a driver approaching from a given direction might be influenced by the travel time required to enter the parking lot of the affected commercial parcel. The investigators ultimately rejected this measure. For one thing, measurement of the travel time requirement would require more elaborate traffic modeling. For another, the travel time requirement would not necessarily be evident to a driver approaching the commercial establishment. By contrast, the two measures selected could be calculated by visual inspection of the before and after road geometrics using data sources such as plans, and a driver approaching the commercial establishment would likely perceive them.

### Choice of Control Variables

Three other factors were identified that, in addition to ease of motorized access, could influence the value of a parcel: the business type, local trends in real estate values, and trends in local traffic volumes.

*Business Types*

The type of commercial enterprise that operates on an affected real estate parcel may make a difference. One might suppose that the businesses most vulnerable to changes in access would be establishments that depend on spontaneous customer visits, such as gas stations, convenience stores, and fast-food restaurants. These enterprises tend to attract customer visits that are not planned far in advance — possibly not before the driver hits the road. These enterprises also tend to have competitors, offering similar goods and services, only a short drive away. The investigators grouped the commercial establishments in their sample into three business type categories.

1. Gas stations, convenience stores, and fast-food (drive-through) restaurants. Customer traffic at these businesses was expected to be most sensitive to a change in motorized access.
2. Sit-down restaurants (possibly offering carry-out but not offering drive-through), hotels, grocery stores, pharmacies, and banks. Customer traffic at these businesses was expected to be less sensitive to a change in motorized access.
3. All other establishments, including variety retailers (e.g., Walmart and Target), smaller variety stores (e.g., Dollar General), shopping centers, healthcare offices, and education establishments. Providers of automotive goods and services other than fuel also fell in this category. As visits to these establishments are usually planned, customer traffic at these businesses was expected to be least sensitive to a change in motorized access.

*Trends in Local Real Estate Values*

The investigators wanted to control for the influence of locality-wide factors such as population growth that might have an independent effect on assessed real estate values. The Virginia Department of Taxation (2025) publishes an annual *Assessment Sales Ratio* that reports in its Table 4 estimates of the total fair market value in each county and city, and data from 1998 to 2023 were used for this study. These estimated totals do not match the totals that one would obtain if one summed the assessed values in the county record office. However, they are highly correlated and readily accessible. The investigators included these countywide estimates as a control variable.

*Trends in Local Traffic Volumes*

Geometric modifications of the roadway are believed to affect customer traffic at business establishments that front the roadway by affecting the inclination of passing motorists to pull into the parking lot. Changes over time in traffic volume, as they would change the size of the “pool” of potential customers, would presumably also change the amount of spontaneous customer traffic. The investigators included the average annual daily traffic (AADT) for each direction approaching the intersection or segment that was reconstructed.

## Identify Virginia Sites

The investigators built their database around two lists of projects provided by members of the technical review panel: innovative intersections and those requiring right of way.

The first of these sources was a list of 32 "innovative intersections," assembled by VDOT's Innovative Intersections Task Group and brought to the investigators' attention by the Transportation Mobility Planning Division (TMPD). This list included reconstructions of traditionally configured intersections to one of seven different more-or-less innovative designs: the quadrant roadway intersection, the (partial) displaced left turn intersection, the (unsignalized) continuous green T intersection, the RCUT, the diverging diamond intersection, the jughandle intersection, or the single-point urban interchange.

The second source was a list of 26 projects brought to the investigators' attention by VDOT's Right-of-Way Division (RWD). These projects included some element of right-of-way acquisition, typically also the construction of a median where one was not previously present. The investigators elicited a couple of additional suggestions from the VDOT district offices.

The commonality between these two sources is that the change in access may affect how a customer accesses a parcel. From the former source, an example is the replacement of the signalized intersection at Mountain Run Lake Road and U.S. Highway 29 in Culpeper with an RCUT. This change required drivers on the minor road who intended a through movement or a left-turn movement to turn right at the center of the intersection and then make a U-turn at a location on the major road 100 yards from the center of the intersection. From the latter source, an example is the reconstruction of the interchange at U.S. Highway 29 and Rogers Road (State Route 666), also outside Culpeper. The construction on Rogers Road of long stretches of median, where none existed previously, similarly precluded some left turns, increasing the maneuvers required for vehicles to access some of the neighboring businesses.

## Data Collection

The investigators began compiling their database with two lists of projects provided by technical review panel members from TMPD and RWD. During the early months of this study, the investigators also took advantage of statewide meetings to solicit additional suggestions from VDOT district office planning staff, location and design staff, and traffic engineering staff. These "publicity efforts" included a meeting of the Innovative Intersections Task Group on August 15, 2023, the District Planners' Meeting on August 24, 2023, and a Transportation Planning Research Advisory Committee meeting on October 27, 2023. Two important considerations in data collection were the sample size and the data sources.

### Sample Size

The sample consisted of a treatment group of commercial parcels close enough to one of the VDOT projects to experience a possible direct effect on motorized access and a control group of commercial parcels in locations similar to those of the treatment group parcels but far enough from the VDOT projects to avoid a direct effect on motorized access.

*The Treatment Group*

The treatment group was a sample of commercial parcels fronting VDOT projects that met the following criteria:

1. The construction or implementation of the project resulted in geometric changes that affected access to real estate fronting the reconstructed road segments.
2. Before and after observations that afforded measurement of motorized access to the neighboring real estate parcels were available.
3. Before and after observations that afforded measurement of the change in assessed value of the neighboring real estate parcels were available.

The availability of both before and after observations proved to be a significant constraint. At some reconstructed intersections, the neighboring commercial parcels were not developed until after reconstruction, so no before observations were available. Some of the most recently constructed innovative intersections, on the other hand, were too new to allow the collection of after observations.

*The Control Group*

The control group was a sample of commercial parcels that met the following criteria:

1. The parcel occupied a location relatively close to the location of one or more parcels in the treatment group.
2. The business that operated on the parcel fell in the same business type category as one or more of the parcels at the nearby VDOT project location.
3. Before and after observations that afforded measurement of the change in assessed value of the real estate parcels were available.

Figure 3 illustrates the heuristic method used to identify comparable commercial parcels for the control group. A road segment that VDOT reconstructed in Powhatan County is near the map's center. A Bojangles restaurant at 1850 Stavemill Crossing Lane is close to the VDOT project, which may affect the restaurant. This location is at the origin of the route shown in blue in Figure 3. A search for nearby restaurants finds Frisby's Restaurant at 2150 Anderson Highway, 1.5 miles west of the VDOT project and presumably not directly affected by the VDOT project. This location is the red "thumbtack" icon at the destination end of the route shown in blue. Bojangles is a fast-food restaurant in the first business type category, and Frisby's is a sit-down restaurant in the second business type category, which is not a perfect comparison but usefully close.

Table 1 shows that 91 treated parcels and 67 control parcels were included in the study sample.

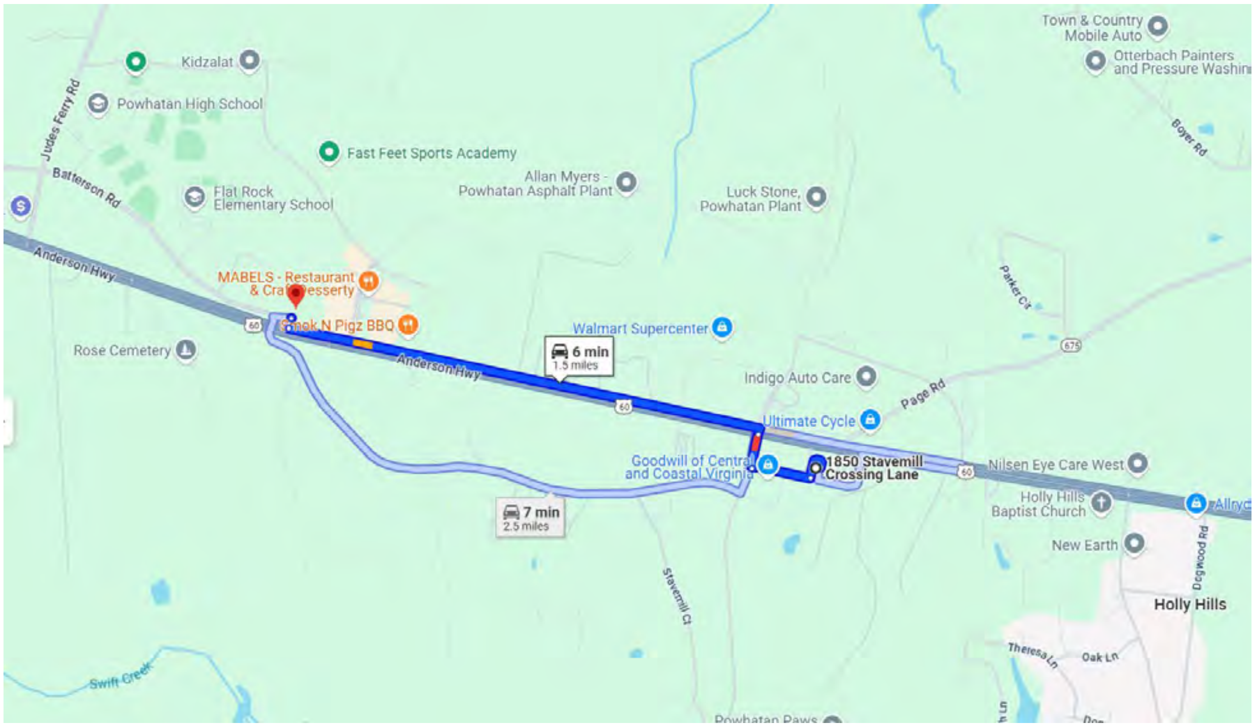


**Figure 3. Screenshot from the Google Maps Website, Requested to Provide Directions from 1850 Stavemill Crossing Lane to 2150 Anderson Highway. ©Google Maps, May 23, 2025.**

**Table 1. Number of Sites**

| | Business Type 1[a] | Business Type 2[b] | Business Type 3[c] | Total |
|---|---|---|---|---|
| Treatment | 20 | 14 | 57 | 91 |
| Control | 19 | 14 | 34 | 67 |
| Total | 39 | 28 | 91 | 158 |

[a] Expected to be most sensitive to access changes (e.g., gas stations). [b] Expected to be less sensitive to access changes (e.g., grocery stores). [c] Expected to be least sensitive to access changes (e.g., healthcare offices).

*Choices and Consequences in Filtering the Dataset*

Lacking taxable sales records, the investigators had to rely on property tax records and aerial photographs to determine that a business was operating during the window from four years before to four years after the completion of a reconstruction project. The choices they made in implementing this approach had two consequences. First, they accepted some reduction in sample size and some downward bias in the average growth of real estate assessments in exchange for a focus on businesses that operated in the same building throughout the observation period at each project. Second, the investigators accepted some additional heteroscedasticity in the sample in exchange for a greater sample size and broader coverage.

When available tax records and photographs indicated that the business commenced operations after the completion of VDOT reconstruction—for example, if an aerial photograph showed that the building on the parcel was not constructed until the completion date or later—the investigators excluded the commercial parcel in question. This exclusion was a debatable choice. Had this study focused on measuring economic development, clearly the right choice for the investigators would have been to include parcels on which buildings were removed or constructed. Exclusion of commercial parcels on which building removal or construction occurred during the time window around the completion of a VDOT project imparted a strong downward bias to the average change in assessed real estate value. The parcels where removal or construction had occurred were those where economic development was most obvious, and they tended to be the parcels whose assessed values rose the most. In fact, this study focused on the effect VDOT work had on existing businesses that continued to operate. With this purpose, the investigators restricted the sample to parcels on which the same business continued to operate in the same building.

When the available documentation indicated that the business commenced operation at least one year before the completion of reconstruction, the investigators included the commercial parcel in question. In some cases, in which property tax assessments could not be obtained for a full four years before or a full four years after VDOT construction, the investigators included a parcel with a truncated window of seven or eight years of data, rather than nine years. This concession, too, was a debatable choice. It certainly introduced some extra heteroscedasticity into the sample because one could not assume that an average annual growth rate during a six- or seven-year interval contained the same amount of statistical "noise" as an average annual growth rate during a eight-year interval. On the other hand, this concession obtained a larger sample with more coverage in terms of both sheer numbers and geographic representation.

*Additional Summary Sample Statistics*

Additional summary data from the projects that the investigators examined provide an impression of the frequency with which VDOT undertakes projects that change the geometrics of a road segment or intersection in a way that changes motorized access to adjoining real estate. They also provide an impression of the amounts of PE and right-of-way expenditures that VDOT has made on reconstruction projects of this sort.

The investigators were able to obtain completion dates or estimate them for 48 of the projects that came to their attention. They were able to identify the commercial parcels adjoining the same 48 projects. Table 2 shows the distribution of projects by their recorded or estimated year of completion. As shown, most of the projects in the sample were completed in 2017, 2018, 2019, or 2020, with the largest number of 11 completed in 2017. The projects that were completed sufficiently long ago to be eligible for the regression analysis come from 2009 to 2022. During this 14-year period, the average number of projects per year averages three.

**Table 2. Distribution of Projects, by Year of Completion**

| Completion Years | 2009–2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021–2022 | 2023 or Later |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of projects | 4 | 2 | 2 | 2 | 11 | 5 | 8 | 7 | 4 | 3 |

Table 3 shows the distribution of projects by the number of commercial parcels identified as fronting each of these 48 projects. The number four was an arbitrary cap rather than a theoretical limit on the number of commercial parcels that a VDOT reconstruction project may affect. The investigators sampled no more than four treatment group commercial parcels from any single VDOT project, although the geometric changes that the project wrought might have extended to the frontage of more than four parcels. It is evident, all the same, that the majority of the VDOT projects in the sample adjoined fewer than four commercial parcels that happened to contain an existing business. Eight of the VDOT projects that met the investigators' criteria were fronted by no existing businesses at all. The average number of existing businesses fronting these 38 projects was 2.4. The 30 projects represented in the statistical analysis in Table 3 exclude the eight that were fronted by no existing businesses and exclude several more that were excluded because of data shortcomings.

**Table 3. Distribution of Projects, by Number of Active Commercial Parcels that Fronted Them**

| **Number of Active Commercial Parcels** | **0** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|---|
| Number of projects | 8 | 5 | 9 | 12 | 14 |

The investigators were able to obtain final cost figures for 38 of the projects that came to their attention. The distribution of PE expenditures for these 38 projects was markedly skewed, with a long right-hand "tail." The minimum PE expenditure was zero, the median PE expenditure was $2,000,000, the average was $2,974,000, and the maximum expenditure was $14,127,000. The distribution of right-of-way expenditures was even more strongly skewed. The minimum right-of-way expenditure was zero, the median expenditure was $3,310,000, the average was $8,650,000, and the maximum was $90,898,000. These expenditures are not inflated, so the older PE figures understate the purchasing power they would represent at 2025 prices. The same consideration applies to the right-of-way expenditure figures. On the other hand, because only an unidentified small fraction of the right-of-way totals was devoted to the acquisition of commercial real estate, the right-of-way expenditures likely overstate the amount of right-of-way expenditure that could possibly be sensitive to the change in motorized access that the reconstruction project causes.

Both the frequency distribution and the PE expenditure estimates must be considered undercounts for three reasons. First, these summary statistics unquestionably omit a few VDOT reconstruction projects that came to the investigators' attention but whose costs the investigators failed to retrieve. Second, they unquestionably omit recent projects, which the investigators excluded because they recognized they would not be able to collect sufficient "after" data. Third, these summary statistics almost certainly omit some projects that would have met the criteria for this study but never came to the investigators' attention.

## Data Sources

For each VDOT project, the construction completion date was obtained, when possible, from the six-year improvement program in the iSYP or the Project Pool database. In some cases, when the requisite date was lacking, the completion date was estimated from another date in iSYP that was not lacking. In a few cases, the completion date was inferred from the sequence of year-stamped aerial photographs of the location available in Google Earth.

For each VDOT project, the before and after geometries were obtained, when possible, from plans available in the ProjectWise library. In many cases, the sequence of aerial photographs available from Google Earth confirmed the geometries. In a few cases, when plans were unavailable, the aerial photographs provided the before and after geometries.

For each commercial parcel, assessed real estate values for four years before the year of completion to four years after the year of completion were obtained from the tax office in the county or city of the parcel location.

For each commercial parcel in the treatment group, the annual estimates of total fair market value in the surrounding county from four years before to four years after the relevant VDOT work were obtained from the Virginia Department of Taxation's (2025) annual *Assessment Sales Ratio* publications. For each parcel in the control group, the annual estimates of total fair market value in the surrounding county were likewise obtained for the years covering the period from four years before to four years after the VDOT work at the nearest parcel in the treatment group.

For each commercial parcel in the treatment group, the AADT volume from four years before completion to four years after completion was retrieved from the VDOT Traffic Monitoring Program (VDOT, 2025). For each parcel in the control group, AADT was retrieved for the years covering the period from four years before to four years after the VDOT work at the nearest parcel in the treatment group. The number of AADT volumes tabulated each year would equal the number of approaches at the intersection. Reconstruction of a four-way intersection would require tabulation of four AADT volumes each year from the four approaches, reconstruction of a three-way intersection would require tabulation of three AADT volumes each year, and reconstruction of a road segment would require the tabulation of two AADT volumes each year.

## Development of the Business Impacts Model

Ordinary least squares regression in this study posits a functional relationship $\Delta PV_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \varepsilon_i$, where $\Delta PV_i$ is a dependent variable of interest (in this case, the change in parcel values over time), $x_{1i}$ and $x_{2i}$ are independent variables whose values one can use to predict the value of $\Delta PV_i$, and $\varepsilon_i$ is a random "error" that follows a Gaussian distribution, whereas $\beta_0$, $\beta_1$, and $\beta_2$ are parameters to be estimated. Under these assumptions, choosing the parameter estimates of $b_0$, $b_1$, and $b_2$ that minimize the sum of squared errors $\Sigma(\Delta PV_i - b_0 - b_1 x_{1i} - b_2 x_{2i})^2$ amounts to choosing the parameter estimates that maximize the likelihood of observing the set of observations $(\Delta PV_1, x_{1\text{-}1}, x_{2\text{-}1})$, $(\Delta PV_2, x_{1\text{-}2}, x_{2\text{-}2})$, …, $(\Delta PV_{159}, x_{1\text{-}159}, x_{2\text{-}159})$ where 159 observations (i.e., 159 parcels) are in the dataset. In other words, an ordinary least squares estimate is also a maximum-likelihood estimate if the errors (the influences unmodeled) are truly Gaussian.

### Equation 1—The Log-Log Equation

Equation 1 represents the first regression model that was estimated, where the dependent variable—$\Delta lnPV_i$—is the change in the logarithm of the assessed value of the parcel.

$$\Delta lnPV_i = \beta_0 + \beta_1 \cdot \Delta lnAvg_i + \beta_2 \cdot \Delta ln\Sigma AADT_{ij} + \beta_3 \cdot \Sigma\Delta T_{ij} + \beta_{31} \cdot \delta_{1i} \cdot \Sigma\Delta T_{ij} + \beta_{32} \cdot \delta_{2i} \cdot \Sigma\Delta T_{ij} + \beta_4 \cdot \Sigma\Delta D_{ij} + \beta_{41} \cdot \delta_{1i} \cdot \Sigma\Delta D_{ij} + \beta_{42} \cdot \delta_{2i} \cdot \Sigma\Delta D_{ij} + \beta_5 \cdot TG_i + \beta_{51} \cdot \delta_{1i} \cdot TG_i + \beta_{52} \cdot \delta_{2i} \cdot TG_i + \varepsilon_i \quad \text{(Equation 1)}$$

Where:
i indexes the parcels.
j indexes the approaches to each parcel.
t indexes the year of completion of VDOT work neighboring each parcel.
k, used in the following definitions but not in Equation 1, indexes the years.

$\beta_0$, $\beta_1$, $\beta_2$, $\beta_3$, $\beta_{31}$, $\beta_{32}$, $\beta_4$, $\beta_{41}$, $\beta_{42}$, $\beta_5$, $\beta_{51}$, and $\beta_{52}$ are parameters to be estimated.

$\Delta lnPV_i$ is a real number equal to the natural logarithm of the ratio between the assessed value of parcel i four years after completion of VDOT work, t+4, and the assessed value four years before, t-4, divided by the eight years, the length of the observation period (i.e., $\Delta lnPV_i = ln(PV_{i,t+4} / PV_{i,t-4})/8$). The 8 may be explained as supposing a project is completed in 2015, such that years 2011, 2012, 2013, and 2014 are the before period, and years 2016, 2017, 2018, and 2019 are the after period. Eight yearly changes occur between the first and last observations, beginning with 2011–2012 and ending with 2018–2019. In some cases in which the earliest retrievable value was from a year later than t-4 or the latest retrievable value was from a year earlier than t+4, the divisor would be smaller than 8.

$\Delta lnAvg_i$ is a real number equal to the natural logarithm of the ratio between the county average estimated total market value of real estate in the county where parcel i is located, four years after completion of VDOT work, t+4, and the county average estimated total market value of real estate four years before, t-4, divided by eight years, the length of the observation period (i.e., $\Delta lnAvg_i = ln(Avg_{i,t+4} / Avg_{i,t-4})/8$). In some cases in which the latest retrievable estimate was from a year earlier than t+4, the divisor would be smaller than 8.

$\Delta ln\Sigma AADT_{ij}$ is a real number equal to the average annual growth rate of the natural logarithm of the sum of AADT on all legs of approach to the intersection or segment on which VDOT worked, from four years before completion of the work, t-4, to four years after completion, t+4 (e.g., the slope of the regression line through the logarithms of the nine sums $\Sigma AADT_{i,j,k}$). Because the AADT time series were somewhat more volatile than the assessed value time series or the estimated total market value time series, especially during the COVID-19 pandemic, the investigators opted to compute the average growth rate not simply by computing the average rate between the first and last years but rather by regressing the natural logarithms of the total AADT volumes in each of the nine years against the year numbers. The slope of the resulting regression line through the log values of AADT, although still sensitive to changes in the first- and last-year values, was less sensitive than the $\Delta lnPV_i$ and $\Delta lnAvg_i$ computations would have been.

$\Sigma AADT_{i,j,k}$ is the sum of the AADT volumes at intersection i over all directions of approach j during all years from year k=t-4 to year k=t+4.

$\Sigma\Delta T_{ij}$ is a whole number equal to the weighted average of $\Delta T_{i,j}$ over all directions of approach j, the weights being the AADT on each approach as a fraction of total AADT on all approaches.

$\Delta T_{i,j} = T_{i,j,t+1} - T_{i,j,t-1}$ is a whole number equal to the change in the number of turns required for a vehicle approaching from direction j to enter the parking lot of parcel i from the year before completion of VDOT work, t-1, to the year after, t+1.

$\Sigma\Delta D_{ij}$ is a real number equal to the weighted average of $\Delta D_{i,j}$ over all directions of approach j, the weights being the AADT on each approach as a fraction of the total AADT on all approaches.

$\Delta D_{i,j} = D_{i,j,t+1} - Distance_{i,j,t-1}$ is a real number equal to the change in the distance (in thousands of feet) that a vehicle approaching from direction j must travel to enter the parking lot of parcel i from the year before completion of VDOT work, t-1, to the year after, t+1.

$TG_i$ is a dummy variable that equals one (1) if parcel i belongs to the treatment group and zero (0) if parcel i belongs to the control group.

$\delta_{1i}$ is a dummy variable that equals one (1) if parcel i belongs to the Business Type 1 category and zero (0) if parcel i does not belong to that category.

$\delta_{2i}$ is a dummy variable that equals one (1) if parcel i belongs to the Business Type 2 category and zero (0) if parcel i does not belong to that category.

$\varepsilon_i$ is a random normal variable—i.e., an error term—unique to parcel i.

Note that t is the year of construction completion. Therefore, the observation period captured nine annual observations, from the year four years before completion (t-4) to the year four years after completion (t+4). For the purposes of computing rates of change, the observation period spanned eight years.

**Equation 2—The Log-Log Equation that Omits the Business Type Categories**

To assess the sensitivity of the results to changes in the model specification, the investigators ran alternative regressions that involved fewer variables or a different functional form. Equation 2 represents the second regression model that was estimated. Once again, the dependent variable, $\Delta PV_i$, is the change in the assessed value of the parcel.

$$\Delta PV_i = \beta_0 + \beta_1 \cdot \Delta Avg_i + \beta_2 \cdot \Delta\Sigma AADT_{ij} + \beta_3 \cdot \Sigma\Delta T_{ij} + \beta_4 \cdot \Sigma\Delta D_{ij} + \beta_5 \cdot TG_i + \varepsilon_i, \quad \text{(Equation 2)}$$

The symbols represent the same variables as defined for Equation 1, but the business type dummy variables are omitted. This omission pools all commercial parcels into a single group rather than into three separate business type groups, imposing the restriction that all business establishments, regardless of type, be assumed to have the same sensitivity to changes in motorized access.

Comparing the results of regressing Equation 1 and regressing Equation 2 on the same dataset affords a test of the importance, if any, of the distinction among the three categories of businesses.

**Equation 3—The Linear Equation**

Equation 3 represents the third regression model that was estimated. The dependent variable, $\Delta PV_i$, is the change in the assessed value of the parcel.

$$\Delta PV_i = \beta_0 + \beta_1 \cdot \Delta Avg_i + \beta_2 \cdot \Delta\Sigma AADT_{ij} + \beta_3 \cdot \Sigma\Delta T_{ij} + \beta_{31} \cdot \delta_{1i} \cdot \Sigma\Delta T_{ij} + \beta_{32} \cdot \delta_{2i} \cdot \Sigma\Delta T_{ij} + \beta_4 \cdot \Sigma\Delta D_{ij} + \beta_{41} \cdot \delta_{1i} \cdot \Sigma\Delta D_{ij} + \beta_{42} \cdot \delta_{2i} \cdot \Sigma\Delta D_{ij} + \beta_5 \cdot TG_i + \beta_{51} \cdot \delta_{1i} \cdot TG_i + \beta_{52} \cdot \delta_{2i} \cdot TG_i + \varepsilon_i \qquad \text{(Equation 3)}$$

Equation 3 closely resembles Equation 1. The three terms that are different are $\Delta PV_i$, $\Delta Avg_i$, and $\Delta\Sigma AADT_{ij}$. These terms are defined as follows.

$\Delta PV_i$ is a real number equal to the eighth root of the ratio between the assessed value of parcel i four years after the completion of VDOT work, t+4, and the assessed value four years before, t-4, the eighth root being taken because eight years is the length of the observation period (i.e., $\Delta PV_i = (PV_{i,t+4} / PV_{i,t-4})^{1/8}$). In some cases in which the earliest retrievable value was from a year later than t-4 or the latest retrievable value was from a year earlier than t+4, the root taken would be the seventh or the sixth, rather than the eighth, so the power shown in the equation would be $1/7$ or $1/6$ rather than $1/8$.

$\Delta Avg_i$ is a real number equal to the eighth root of the ratio between the county average estimated total market value of real estate in the county where parcel i is located, four years after the completion of VDOT work, t+4, and the county average estimated total market value of real estate four years before, t-4, the eighth root being taken because eight years is the length of the observation period (i.e., $\Delta Avg_i = (Avg_{i,t+4} / Avg_{i,t-4})^{1/8}$). In some cases in which the latest retrievable estimate was from a year earlier than t+4, the root taken would be seventh or the sixth.

$\Delta\Sigma AADT_{ij}$ is a real number equal to the average annual growth rate of the sum of AADT on all legs of approach to the intersection or segment on which VDOT worked, from four years before the completion of the work, t-4, to four years after completion, t+4 (e.g., the slope of the regression line through the nine sums $\Sigma AADT_{i,j,k}$). As in Equations 1 and 2, the investigators opted to compute the average growth rate not simply by computing the average rate between the first and last years but rather by regressing the total AADT volumes in each of the nine years against the year numbers.

$\Sigma AADT_{i,j,k}$, as before, is the sum of the AADT volumes at intersection i over all directions of approach j during all years from year k=t-4 to year k=t+4.

Equation 1 above expresses the average growth rate of assessed value between year Y–4 and the year Y+4 as a *rate of increase* between the value in one year and the value in the following year. This number will be slightly greater than zero if the growth rate is positive and slightly less than zero if the growth rate is negative, rather than as the natural logarithm of that ratio. By contrast, Equation 3 expresses the average growth rate of assessed value as a *ratio* between the value in one year and the value in the previous year. This number will be slightly greater than one if the growth rate is positive and slightly less than one if the growth rate is negative. Likewise, Equation 3 expresses the average growth rate of the estimated true market value of real estate in the county as a ratio rather than as a rate of increase and, so likewise, the growth rate of the total AADT on the approach legs of the intersection. Equations 1 and 3 are both *ad hoc* specifications. The investigators have no strong theoretical grounds to prefer one over the other. Comparing the results of regressing Equation 1 and regressing Equation 3 on the same dataset will provide a basis for judging which of the two—the log-log specification, Equation 1, or the linear specification, Equation 3—is a better fit to the available data.

## RESULTS

The investigators generated three sets of regression results: the first regression with all variables (Equation 1), a second regression equation with a smaller number of variables (Equation 2), and a third regression equation that used the linear functional form (Equation 3) rather than the logarithmic form.

### First Regression with All Variables

Table 4 lists the full results of the first regression. The first column indicates the parameters from Equation 1. The second column indicates the explanatory variable to which each parameter β corresponds. The third, fourth, fifth, and sixth columns show the point estimate, standard error, t-statistic, and p-value, respectively, for each parameter in the model.

**Table 4. Regression 1 Results[a]**

| Parameter | Variable | Point Estimate | Standard Error | t-statistic | P-Value (2 tails) |
|---|---|---|---|---|---|
| $\beta_0$ | Intercept term | 0.00536 | 0.00946 | 0.56641 | 0.57198 |
| $\beta_1$ | County mean real estate appreciation | 0.37047 | 0.13406 | 2.76354 | 0.00645 |
| $\beta_2$ | Local traffic volume | – 0.15694 | 0.09705 | – 1.61723 | 0.10799 |
| $\beta_3$ | 1st access measure: number of turns | 0.00804 | 0.01445 | 0.53413 | 0.55666 |
| $\beta_{31}$ | Bus. Type 1 × 1st access measure | 0.01553 | 0.05065 | 0.30663 | 0.75956 |
| $\beta_{32}$ | Bus. Type 2 × 1st access measure | – 0.00330 | 0.03940 | – 0.08373 | 0.93338 |
| $\beta_4$ | 2nd access measure: travel distance | 0.01625 | 0.01234 | 1.31687 | 0.18995 |
| $\beta_{41}$ | Bus. Type 1 × 2nd access measure | – 0.05867 | 0.04178 | – 1.40437 | 0.16233 |
| $\beta_{42}$ | Bus. Type 2 × 2nd access measure | – 0.01366 | 0.05115 | – 0.26715 | 0.78973 |
| $\beta_5$ | Occurrence of reconstruction dummy | – 0.00990 | 0.00616 | – 1.60676 | 0.11027 |
| $\beta_{51}$ | Bus. Type 1 × reconstruction dummy | 0.01325 | 0.01032 | 1.28382 | 0.20124 |
| $\beta_{52}$ | Bus. Type 2 × reconstruction dummy | – 0.01190 | 0.01127 | – 1.05552 | 0.29293 |

Bus. = Business. [a] The model shown in Table 4 explained 14.41% of the variation in the change in assessed parcel values. The sum of squared residuals equaled 0.15171 with 146 degrees of freedom.

The statistical estimates of the parameters $\beta_3$, $\beta_{31}$, $\beta_{32}$, $\beta_4$, $\beta_{41}$, $\beta_{42}$, $\beta_5$, $\beta_{51}$, and $\beta_{52}$ address the research question: the $\beta_3$s as a group measure the sensitivity of assessed property values to changes in the number of turns required; the $\beta_4$s as a group measure the sensitivity to the travel distance required; and the $\beta_5$s as a group measure the correlation between assessed values and the occurrence of VDOT reconstruction work.

The statistical estimates of the parameters $\beta_0$, $\beta_1$, and $\beta_2$ do not address the research question directly, but they improve model fit and thereby facilitate the estimation and interpretation of the above parameters. The first parameter, $\beta_0$, allows for the regression line to cross the y-axis at the point that affords the best fit to the observed data. The second parameter, $\beta_1$, accounts for the countywide trend in real estate prices to ensure that this trend does not obscure the influence of the access measures. The third parameter, $\beta_2$, similarly accounts for the neighborhood-wide trend in local traffic volumes to ensure that this trend does not obscure the influence of the access measures.

The interpretation of Table 4 is based on the following seven sets of parameters:

- R-squared statistic.
- Intercept.
- The coefficient for county mean real estate appreciation.
- The coefficient for local traffic volume growth.
- The coefficients for the first access measure (number of turns).
- The coefficients for the second access measure (travel distance).
- The coefficients for the occurrence of reconstruction.

### The R-Squared Statistic

The rather small value of the R-squared statistic indicates that other factors, besides those compiled in this study and displayed in Table 4, have a big influence on the change in a parcel’s assessed value.

### Intercept

The t-statistic of the constant term $\beta_0$ estimate indicates that the estimate does not differ significantly from zero. The constant term has to do only with the “fit” of the regression equation. Neither the magnitude nor the sign of the constant term affects the evaluation of the motorized access measures.

### County Mean Real Estate Appreciation

$\beta_1$ is the coefficient on the change in the county total estimated fair market value. The countywide changes in fair market value were expected to serve as a baseline against which variations due to local effects, such as VDOT roadwork, would stand out. This estimate has a positive sign, suggesting that the assessed values of the parcels in the sample group tend to increase as the fair market value of the average parcel in the county rises, as would be expected. The estimate of the coefficient on this variable differs from zero with a fairly high level of statistical significance. The p-value indicates that an estimate this large in magnitude would have only a 1.66% probability of occurring if the true value of the coefficient were zero. This estimate does not affect the evaluation of the motorized access measures.

## Local Traffic Volume Growth

$\beta_2$ is the coefficient on the change in the sum of AADT on all legs of approach for which recorded traffic volumes were retrievable. In a few cases, the investigators were unable to retrieve AADT on the minor road of an intersection. The countywide changes in fair market value were expected to account for influences on commercial parcel value that would be felt countywide. The changes in AADT were expected to account for the influence of traffic volume growth—that is, greater exposure to potential customers—that would be felt locally. The investigators supposed that this influence would be largely independent of the influence of the geometric change that the VDOT reconstruction work effected. In fact, the point estimate of the coefficient for this explanatory variable is negative. The p-value associated with this estimate indicates that an estimate of this magnitude would have an 11.17% probability of occurring if the true value were zero, so the estimate borders on statistical significance. Again, however, this estimate does not affect the evaluation of the motorized access measures.

## First Access Measure (Number of Turns)

The parameters $\beta_3$, $\beta_{31}$, and $\beta_{32}$ apply to the access measure "change in number of turns required." This access measure constituted an attempt to capture the motorist's perception of the complexity of the maneuver that he or she must make to enter an establishment's parking lot. The estimates of these coefficients provide no evidence that a commercial parcel's real estate assessment is sensitive to a change in the number of turns required to access the parcel. Table 5 displays the interpretation of these parameters for commercial parcels of the first, second, and third business types.

**Table 5. Results for First Access Measure: Change in Required Number of Turns**

| Parameter | Variable[a] | Point Estimate | Standard Error | T-statistic | P-Value (2 tails) |
|---|---|---|---|---|---|
| $\beta_3+\beta_{31}$ | Coefficient on 1st access measure when business type is 1 | 0.02358 | 0.05267 | 0.44760 | 0.32755 |
| $\beta_3+\beta_{32}$ | Coefficient on 1st access measure when business type is 2 | 0.00475 | 0.04196 | 0.11309 | 0.45506 |
| $\beta_3$ | Coefficient on 1st access measure when business type is 3 | 0.00804 | 0.01445 | 0.55666 | 0.57861 |

[a] The first access measure is the change in the number of turns required to access the parcel.

For commercial parcels in the Business Type 1 category, the businesses expected to be most sensitive to changes in access, the implied coefficient is $\beta_3 + \beta_{31} = 0.02358$, the sum of the coefficient on the change measure *plus* the coefficient on the change measure times the Business Type 1 dummy. For commercial parcels in the Business Type 2 category, the less sensitive businesses, the implied estimate is $\beta_3 + \beta_{32} = 0.00475$, the sum of the coefficient on the change measure plus the coefficient on the change measure times the Business Type 2 dummy. For commercial parcels in the Business Type 3 category, non-sensitive businesses, the implied estimate is $\beta_3 = 0.00804$, the coefficient on the change measure alone.

The point estimates imply that an increase in the number of turns that a motorist must make to enter a commercial establishment's parking lot tends to have a *positive* impact on the parcel's assessed value. The low t-statistics and correspondingly high p-values indicate that each of these estimates has a fairly high probability—32.76%, 45.51%, or 57.86%—of occurring by chance, however, even under the null hypothesis that the true coefficients equal zero.

**Second Access Measure (Travel Distance)**

The parameters $\beta_4$, $\beta_{41}$, and $\beta_{42}$ apply to the access measure "change in required travel distance." This access measure constituted an attempt to capture the motorist's perception of how far out of the way he or she must drive to enter an establishment's parking lot. Table 6 displays the interpretation of these parameters for commercial parcels of the first, second, and third business types.

**Table 6. Results for Second Access Measure: Change in Required Travel Distance**

| Parameter | Variable[a] | Point Estimate | Standard Error | T-statistic | P-Value (2 tails) |
|---|---|---|---|---|---|
| $\beta_4+\beta_{41}$ | Coefficient on 2nd access measure when business type is 1 | – 0.04243 | 0.04356 | – 0.97389 | 0.16586 |
| $\beta_4+\beta_{42}$ | Coefficient on 2nd access measure when business type is 2 | 0.00258 | 0.05261 | 0.04911 | 0.48045 |
| $\beta_4$ | Coefficient on 2nd access measure when business type is 3 | 0.01625 | 0.01234 | 1.31687 | 0.18995 |

[a] The second access measure is the change in distance required to access the parcel.

For commercial parcels in the Business Type 1 category, the businesses expected to be most sensitive to changes in access, the implied coefficient is $\beta_4 + \beta_{41} = -0.04243$, the sum of the coefficient on the change measure *plus* the coefficient on the change measure times the Business Type 1 dummy. For commercial parcels in the Business Type 2 category, the businesses expected to be less sensitive, the implied coefficient is $\beta_4 + \beta_{42} = 0.00258$, the sum of the coefficient on the change measure plus the coefficient on the change measure times the Business Type 2 dummy. For commercial parcels in the Business Type 3 category, the businesses expected to be non-sensitive, the implied coefficient is $\beta_4 = 0.01625$, the coefficient on the change measure alone.

The point estimates imply that an increase in the distance a motorist is required to drive to reach a commercial parcel's parking lot would have a small positive impact on the assessed value of a parcel that houses a Business Type 1 establishment (gas station, convenience store, or fast-food restaurant), a small negative impact on the assessed value of a parcel that houses a Business Type 2 establishment (sit-down restaurant, hotel, grocery store, pharmacy, or bank), and a small positive impact on the assessed value of a parcel that houses a Business Type 3 establishment (all other kinds of enterprises). However, the t-statistics and the p-values indicate that each of these estimates has a fairly high probability—16.59%, 48.05%, or 19.00%—of occurring by chance, even under the null hypothesis that the true coefficient is zero.

**Occurrence of Reconstruction**

The parameters $\beta_5$, $\beta_{51}$, and $\beta_{52}$ apply to the backup explanatory variable, the treatment group dummy. This explanatory variable was intended to capture any association between VDOT reconstruction and property values which the previous two access measures failed to capture. Table 7 displays the interpretation of these parameters for commercial parcels of the first, second, and third business types.

**Table 7. Results for Treatment Group Dummy**

| Parameter | Variable[a] | Point Estimate | Standard Error | T-statistic | P-Value (2 tails) |
|---|---|---|---|---|---|
| $\beta_5+\beta_{51}$ | Coefficient on 3rd access measure when business type is 1 | 0.00335 | 0.01202 | 0.27876 | 0.39041 |
| $\beta_5+\beta_{52}$ | Coefficient on 3rd access measure when business type is 2 | – 0.02180 | 0.01285 | – 1.69684 | 0.04593 |
| $\beta_5$ | Coefficient on 3rd access measure when business type is 3 | – 0.00990 | 0.00616 | – 1.60676 | 0.11027 |

[a] The treatment group dummy takes a value of one if the parcel adjoined a VDOT reconstruction project that made geometric changes that could affect motor access and zero if the parcel did not.

For commercial parcels in the Business Type 1 category, the businesses expected to be most sensitive, the implied coefficient in Table 5 is $\beta_5 + \beta_{51} = 0.00088$, the sum of the coefficient on the treatment group dummy *plus* the coefficient on the treatment group dummy times the Business Type 1 dummy. For commercial parcels in the Business Type 2 category, the businesses expected to be less sensitive, the implied coefficient is $\beta_5 + \beta_{52} = -0.02440$, the sum of the coefficient on the change measure plus the coefficient on the change measure times the Business Type 2 dummy. For commercial parcels in the Business Type 3 category, the businesses expected to be non-sensitive, the implied coefficient is $\beta_5 = -0.00990$, the coefficient on the change measure alone.

The point estimates imply that VDOT construction work, via some mechanism that the model applied in this study did not capture, has a tiny positive correlation with the assessed value of a parcel that houses a Business Type 1 establishment. However, the t-statistic and the p-value indicate that the estimate of the sum $\beta_5 + \beta_{51}$ has a fairly high probability of occurring by chance, 39.04%, even under the null hypothesis that the true coefficient is zero. The point estimates imply that VDOT construction work, via some mechanism that the model applied in this study did not capture, has a small negative impact on the assessed value of a parcel that houses a Business Type 2 or 3 establishment. The t-statistics and p-values indicate that the estimate of the sum $\beta_5 + \beta_{52}$ and the estimate of $\beta_5$ alone have relatively low probabilities of occurring by chance under the null hypothesis, 4.59% and 11.03%, respectively.

It is notable, perhaps surprising, that Types 2 and 3 businesses, those believed to rely little on unplanned visits by passing motorists, would exhibit a detectible correlation with the presence of VDOT reconstruction, and Type 1 businesses would not.

### One Numerical Example that Illustrates the Mechanics of the Regression Model

This subsection will use the regression results to *estimate* the change in the assessed real estate value of one parcel in the dataset, a parcel occupied by a grocery retailer in Saluda, Virginia, a Food Lion at 12532 Tidewater Trail. This computation will illustrate the contribution that each term in Equation 1 makes to the total value of the dependent variable.

A VDOT project completed in 2015, project number 103461 in the Supplemental Materials, involved the reconstruction of the intersection of Tidewater Trail (U.S. Highway 17) and General Puller Highway (U.S. Highway 17 Business) in Saluda. Before the reconstruction, westbound vehicles on General Puller Highway were permitted to pass straight through the intersection to enter the store's parking lot on the other side. They also were permitted to turn left into the southbound lane of Tidewater Trail. Northbound vehicles on Tidewater Trail were permitted to make left turns into the store's parking lot, and southbound vehicles on Tidewater Trail were permitted to make left turns onto General Puller Highway heading east. After the reconstruction, a low concrete wall created a physical barrier between northbound vehicles turning left from Tidewater Trail into the store's parking lot on the west side of the road and southbound vehicles turning left from Tidewater Trail onto General Puller Highway eastbound. This wall *prevented* westbound vehicles on General Puller Highway from proceeding straight through the intersection to the store parking lot. In the future, these drivers wishing to enter the parking lot would have to turn right onto Tidewater Trail, turn left at a cut in the median about 360 feet further north, and enter the parking lot there. The wall also prevented vehicles from turning left from General Puller Highway into the southbound lane of Tidewater Trail, although this prohibition affected no neighboring commercial parcels.

For each term in Equation 1, the first, second, third, and fourth columns in Table 8 show the symbol representing the variable, the common name of the variable, the symbol representing the coefficient on the variable, and the estimated value which the regression assigns to the coefficient. The fifth, sixth, and seventh columns show the range of values—lowest, median, and highest—that each variable takes across the range of all parcels in the dataset. The eighth column shows the specific value of each variable for the parcel at 12532 Tidewater Trail in Saluda.

The ninth column shows the product of the estimated coefficient times the variable value. Each of these products is one of the terms in Equation 1. The sum of these 12 terms is the average annual growth rate of assessed value, which the regression *estimates* for the parcel at 12532 Tidewater Trail. The regression residual is the difference between the true growth rate of the assessed value and this estimate.

The prohibition of left turns and straight-through movements at the intersection from the minor road (General Puller Highway) means that vehicles coming from General Puller Highway must make more turns and travel a longer distance to enter the Food Lion parking lot. The first access measure, the change in the number of turns, $\Sigma\Delta T_{ij}$, therefore shows a positive change. The second access measure, change in travel distance, $\Sigma\Delta D_{ij}$, therefore shows a positive change. Because the example parcel adjoins an intersection that VDOT reconstructed, the parcel is a member of the treatment group, not the control group. Therefore, the treatment group dummy $TG_i$ has a value of one (1).

The business that operates on the example parcel is a grocery store. By the investigators' definition this business falls into the Business Type 2 category. For this parcel i, therefore, the business type dummy $\delta_{1i}$ has a value of zero and the business type dummy $\delta_{2i}$ has a value of one. The fact that $\delta_{1i}$ equals zero explains why the interaction terms $\delta_{1i}\cdot\Sigma\Delta T_{ij}$ and $\delta_{1i}\cdot\Sigma\Delta D_{ij}$ and $\delta_{1i}\cdot TG_i$ each have a value of zero. The fact that $\delta_{2i}$ equals one explains why the interaction terms

$\delta_{2i} \cdot \Sigma\Delta T_{ij}$ and $\delta_{2i} \cdot \Sigma\Delta D_{ij}$ and $\delta_{2i} \cdot TG_i$ have values equal to the terms $\Sigma\Delta T_{ij}$ and $\Sigma\Delta D_{ij}$ and $TG_i$, respectively.

**Table 8. Computation of the Estimated Change in Assessed Value from Year t-4 to Year t+4.**

| Variable Symbol | Variable Common Name | Para-meter Symbol | Para-meter Estimate | Variable Lowest Value | Variable Median Value | Variable Highest Value | Example Parcel Value | Additive Term in Eq. 1 |
|---|---|---|---|---|---|---|---|---|
| | Constant term | β0 | 0.00536 | (1) | (1) | (1) | (1) | 0.00536 |
| $\Delta Avg_i$ | County mean real estate appreciation | $\beta_1$ | 0.37047 | – 0.01357 | 0.05799 | 0.08630 | – 0.01357 | – 0.00503 |
| $\Delta\Sigma AADT_{ij}$ | Local traffic volume | $\beta_2$ | – 0.15694 | – 0.06805 | – 0.00232 | 0.07179 | 0.00996[a] | – 0.00151 |
| $\Sigma\Delta T_{ij}$ | 1st access measure: no. of turns | $\beta_3$ | 0.00804 | – 0.45143 | 0 | 1.81505 | 0.22353 | 0.00180 |
| $\delta_{1i} \cdot \Sigma\Delta T_{ij}$ | Bus. Type 1 × 1st access measure | $\beta_{31}$ | 0.01553 | – 0.18436 | 0 | 0.61538 | 0 | 0 |
| $\delta_{2i} \cdot \Sigma\Delta T_{ij}$ | Bus. Type 2 × 1st access measure | $\beta_{32}$ | – 0.00330 | 0 | 0 | 0.91837 | 0.22353 | – 0.00074 |
| $\Sigma\Delta D_{ij}$ | 2nd access measure: travel distance | $\beta_4$ | 0.01625 | – 1.20780 | 0.000 | 2.58244 | 0.06147 | 0.00100 |
| $\delta_{1i} \cdot \Sigma\Delta D_{ij}$ | Bus. Type 1 × 2nd access measure | β41 | – 0.05867 | – 0.11735 | 0.000 | 0.54763 | 0 | 0 |
| $\delta_{2i} \cdot \Sigma\Delta D_{ij}$ | Bus. Type 2 × 2nd access measure | β42 | – 0.01366 | – 0.13842 | 0.000 | 0.46633 | 0.06147 | – 0.00084 |
| $TG_i$ | Treatment group: reconstruction | β5 | – 0.00990 | 0 | 1 | 1 | 1 | – 0.00990 |
| $\delta_{1i} \cdot TG_i$ | Bus. Type 1 × Treatment group | β51 | 0.01325 | 0 | 0 | 1 | 0 | 0 |
| $\delta_{2i} \cdot TG_i$ | Bus. Type 2 × Treatment group | β52 | – 0.01190 | 0 | 0 | 1 | 1 | – 0.01190 |
| **$\Delta PV_i$** | **Change in assessed value** | | | **– 0.13572** | **0.01996** | **.20565** | **– 0.00033** | **– 0.02181** |

Bus. = Business; Eq. = equation. [a] For the nine years from Y-4 to Y+4 (2011–2019 in this case), the combined average annual daily traffic volumes on the three legs approaching the intersection totaled 7,700, 8,000, 8,050, 8,100, 85,00, 8,500, 8,550, 8,350, and 8,300. The natural logarithms of these nine totals were taken and regressed against the year numbers (2011, …, 2019). The slope of the resulting regression line is the growth rate shown in Table 8, which is -0.00996. This computation, rather than the simpler one used to compute the dependent variable $\Delta PV_i$ and the independent variable $\Delta Avg_i$, was adopted for the reasons noted in the Development of the Business Impacts Model subsection of this report's Methods section.

The terms in the ninth column sum to make the *estimated* annual growth rate of assessed value for the parcel in question, shown near the lower right corner of Table 8. The last box in the eighth column shows the *actual* growth rate of assessed value for the parcel in question. The growth rate which the regression predicts for this particular parcel is an underestimate of the actual growth rate: –0.02044 versus the true –0.00033.

Recall that this change in assessed value, shown as $\Delta PV_i$, is the natural log of the annual change in assessed value (e.g., $\ln(PV_{i,t+4} / PV_{i,t-4})/8$). Thus, the forecast is exp(-0.02181) = 0.98, indicating that the model forecasts the assessed value would drop 2% per year. In reality, the true change was exp(-0.00033) = 0.9997, meaning that the assessed value dropped 0.03% per year.

## The Second, More Restrictive Regression Model

Table 9 lists the full results of the second regression. The first column indicates the parameters from Equation 2. The second column indicates the explanatory variable to which each parameter β corresponds. The third, fourth, fifth, and sixth columns show the point estimate, standard error, t-statistic, and p-value, respectively, for each parameter in the model.

**Table 9. Regression 2 Results[a]**

| Parameter | Variable | Point Estimate | Standard Error | t-statistic | P-Value (2 tails) |
|---|---|---|---|---|---|
| $\beta_0$ | Intercept term | 0.00524 | 0.00939 | 0.55820 | 0.57753 |
| $\beta_1$ | County mean real estate appreciation | 0.37265 | 0.13284 | 2.80520 | 0.00569 |
| $\beta_2$ | Local traffic volume | – 0.16630 | 0.09468 | – 1.75648 | 0.08102 |
| $\beta_3$ | 1st access measure: number of turns | 0.00922 | 0.01246 | 0.73974 | 0.46060 |
| $\beta_4$ | 2nd access measure: travel distance | 0.01297 | 0.01089 | 1.19130 | 0.23539 |
| $\beta_5$ | Treatment group: reconstruction | – 0.01069 | 0.00540 | – 1.97977 | 0.04953 |

[a] The model shown in Table 9 explained 11.49% of the variation in the change in assessed parcel values. The sum of squared residuals equaled 0.15688 with 152 degrees of freedom.

The statistical estimates of the parameters $\beta_3$, $\beta_4$, and $\beta_5$ address the research question. Comparing with Equation 1 shows that Equation 2 imposes the six restrictions that the parameters $\beta_{31}$, $\beta_{32}$, $\beta_{41}$, $\beta_{42}$, $\beta_{51}$, and $\beta_{52}$, which were free to take non-zero values in Equation 1, must equal zero in Equation 2. In other words, Equation 2 does not allow for the possibility that some business types may be more or less sensitive to changes in access than others. Because Equation 2 requires the estimation of six fewer parameters, the regression leaves 152 degrees of freedom instead of 146.

The first three rows of results in Table 9 show that the estimates of the parameters $\beta_0$, $\beta_1$, and $\beta_2$ are largely unaffected by the restriction on the other three parameters.

The estimates of the parameters $\beta_3$, $\beta_4$, and $\beta_5$, now restricted to be the same across all business types, take on values that resemble comparatively closely the values that Table 4 showed for Business Type 3, the most numerous group of parcels in the dataset. The estimates of the coefficients on the first and second access measures remain not statistically distinguishable from zero. The p-values indicate that the estimate of $\beta_3$, which reflects the effect of a change in the number of turns required, has a magnitude that could be expected with 46.06% probability even if the coefficient had a true value of zero, and the estimate of $\beta_4$, which reflects the effect of a change in the travel distance required, has a magnitude that could be expected with 23.54% probability. The estimate of $\beta_5$, which reflects some link between VDOT work and assessed value that the access measures in the model did not capture, also takes on a value close to the value seen for Business Type 3 in Equation 1 and has a magnitude that could be expected with a probability of only 4.95% if the coefficient's true value were zero.

An F statistic, based on a comparison between the sum of squared residuals from the first regression and the sum of squared residuals from the second regression, provides a test of the hypothesis, embodied in Equation 2, that the extra six restrictions in Equation 1 are not binding: that is, that the parameters $\beta_{31}$, $\beta_{32}$, $\beta_{41}$, $\beta_{42}$, $\beta_{51}$, and $\beta_{52}$ in Equation 1 truly equal zero, so that the same parameters $\beta_3$, $\beta_4$, and $\beta_5$ apply to businesses of all three types. This F statistic, with 6 and 146 degrees of freedom, has a value of 0.82942, implying a p-value of 0.45106. In other words, an F statistic this big has a 35.52% chance of occurring even if the restrictions are not binding. For this dataset, at least, the null hypothesis that businesses of all types are equally sensitive to the access measures and to the treatment group variable cannot be rejected.

## The Third, Linear Regression Model

Table 10 lists the full results of the third regression. The first column indicates the parameters from Equation 3. The second column indicates the explanatory variable to which each parameter β corresponds. The third, fourth, fifth, and sixth columns show the point estimate, standard error, t-statistic, and p-value, respectively, for each parameter in the model.

**Table 10. Regression 3 Results**[a]

| Parameter | Variable | Point Estimate | Standard Error | t-statistic | P-Value (2 tails) |
|---|---|---|---|---|---|
| $\beta_0$ | Intercept term | 0.81470 | 0.16330 | 4.98911 | 0.00000 |
| $\beta_1$ | County mean real estate appreciation | 0.35195 | 0.13270 | 2.65226 | 0.00888 |
| $\beta_2$ | Local traffic volume | – 0.15970 | 0.09995 | – 1.59784 | 0.11224 |
| $\beta_3$ | 1st access measure: number of turns | 0.00840 | 0.01498 | 0.56055 | 0.57579 |
| $\beta_{31}$ | Bus. Type 1 × 1st access measure | 0.01572 | 0.05250 | 0.29948 | 0.76500 |
| $\beta_{32}$ | Bus. Type 2 × 1st access measure | – 0.00345 | 0.04085 | – 0.08447 | 0.93280 |
| $\beta_4$ | 2nd access measure: travel distance | 0.01709 | 0.01279 | 1.33616 | 0.18358 |
| $\beta_{41}$ | Bus. Type 1 × 2nd access measure | – 0.06017 | 0.04329 | – 1.38980 | 0.16671 |
| $\beta_{42}$ | Bus. Type 2 × 2nd access measure | – 0.01450 | 0.05301 | – 0.27345 | 0.78489 |
| $\beta_5$ | Occurrence of reconstruction dummy | – 0.01032 | 0.00638 | – 1.61576 | 0.10830 |
| $\beta_{51}$ | Bus. Type 1 × reconstruction dummy | 0.01307 | 0.01070 | 1.22152 | 0.22386 |
| $\beta_{52}$ | Bus. Type 2 × reconstruction dummy | – 0.01255 | 0.01168 | – 1.07452 | 0.28436 |

Bus. = Business. [a] The model shown in Table 10 explained 14.09% of the variation in the change in assessed parcel values. The sum of squared residuals equaled 0.16292 with 146 degrees of freedom.

As in the Equation 1 regression, the statistical estimates of the parameters $\beta_3$, $\beta_{31}$, $\beta_{32}$, $\beta_4$, $\beta_{41}$, $\beta_{42}$, $\beta_5$, $\beta_{51}$, and $\beta_{52}$ address the research question: the $\beta_3$s as a group measure the sensitivity of assessed property values to changes in the number of turns required; the $\beta_4$s as a group measure the sensitivity to the travel distance required; and the $\beta_5$s as a group measure the correlation between assessed values and the occurrence of VDOT reconstruction work. As the Methods section notes, Equations 1 and 3 are equally defensible *ad hoc* specifications of the relationship between the growth rate of assessed parcel value and the explanatory variables. No basis for judging between them exists except the empirical basis of ascertaining which equation better fits the data.

A comparison of Tables 10 and 4 reveals that the estimate of every parameter has the same sign in Equation 3 as it had in Equation 1. With the exception of the constant term, the values of the parameter estimates in Equation 3 are quite similar to those in Equation 1. The standard errors of the estimates, their t-statistics, and their P-values also change little.

The change in the size of the constant term is an artifact of the change in specification. To fit a set of average growth rates expressed as ratios (numbers slightly greater than or less than one) rather than as rates of increase (numbers slightly greater than or less than zero), the constant term has to be close to one rather than close to zero.

The parameters on the measures of access change in all cases have the same signs in Equation 3 as in Equation 1, and they are all statistically insignificant. The parameters for the dummy variable that indicates the presence or absence of reconstruction have the same signs in Equation 3 as in Equation 1. As was the case with Equation 1, the parameters on the reconstruction dummy imply that the growth rates of assessed value of commercial parcels occupied by a Type 2 or Type 3 business—the types expected to be less sensitive to changes in access—exhibit a small, statistically significant correlation with the occurrence of VDOT reconstruction work.

The difference between the models that Equations 1 and 3 represent is rather subtle. If one plots a graph of the growth rate versus one of the measures of change in access, holding other variables constant, one obtains from Equation 3 a straight line—each one-unit change in the access measure produces the same amount of change in the growth rate. Doing the same thing, one obtains a curved line from Equation 1—each one-unit change in the access measure produces a bigger change in the growth rate than the previous unit of change produced. No standard statistic, such as a t-statistic or F statistic, tests the null hypothesis that the two model specifications in Equations 1 and 3 fit the data equally well.

The investigators computed the values that the fitted model Equation 1 predicts for the dependent variable $\Delta \ln PV_i$ for each parcel i in the dataset. Next, they derived the values that these predicted values imply for the dependent variable $\Delta PV_i$ in Equation 3: $\exp(\Delta \ln PV_i) = \Delta PV_i$ for each parcel i. Last, they computed the residual, $R_i = \Delta PV_i$ (actual) – $\Delta PV_i$ (predicted by Equation 1), for each parcel and summed the squared residuals. This sum equaled 0.16260. They compared it with the sum of squared residuals for Equation 3, $R_i = \Delta PV_i$ (actual) – $\Delta PV_i$ (predicted by Equation 3). This sum, as Table 10 reports, equaled 0.16292.

The investigators similarly computed the values that the fitted model Equation 3 predicts for the dependent variable $\Delta PV_i$ for each parcel in the dataset. Next, they derived the values that these predicted values imply for the dependent variable $\Delta \ln PV_i$ in Equation 1: $\ln(\Delta PV_i) = \Delta \ln PV_i$ for each parcel i. Last, they computed the residual, $R_i = \Delta \ln PV_i$ (actual) – $\Delta \ln PV_i$ (predicted by Equation 3), for each parcel and summed these squared residuals. This sum equaled 0.15209. They compared it with the sum of squared residuals for Equation 1, $R_i = \Delta \ln PV_i$ (actual) – $\Delta \ln PV_i$ (predicted by Equation 1). This sum, as Table 4 reports, equaled 0.15171.

Regardless of whether the residuals are computed in Equation 1's or Equation 3's terms, the predictions of Equation 1 produce a slightly lower sum of squared residuals. This is evidence that Equation 1 fits the data set slightly better.

# DISCUSSION

The findings reported previously invite comment that falls into five broad themes. The first is the strengths and weaknesses of the measure of business impact. The second is the effective sample size. The third is the strengths and weaknesses of the selected measures of access change. The fourth is the complexity of the relationship between VDOT reconstruction work and the value of commercial real estate. The fifth theme is directions for future research.

## Use of Assessed Values Rather than Sales Data

The data the investigators collected for this study were reasonably well suited to address the questions of VDOT's Right-of-Way Division staff but somewhat less suited to address the questions of transportation planning staff. Assessed property values are one of the types of data with which Right-of-Way Division staff have to work. The limitations of assessment data reflect realistically the "fog of war" in which right-of-way negotiations take place. For planning staff, on the other hand, the questions they have encountered concern sales revenue. Assessed property values are a second best substitute for the sales data that would address the question precisely.

## Sample Size

The sample of commercial parcels used in this study was considerably larger than would have been possible even a few years ago. Miller (2020) focused on RCUT data from other states in 2020 because RCUTs in Virginia were so new that virtually no "after" data were available. For the purposes of this study, the sample was fairly small. Nonetheless, for reasons outlined previously, the findings must be considered a first cut at a dataset that will continue to expand as the Commonwealth builds more innovative intersections. Further analysis of more data might alter some of the p-values and coefficients reported in Tables 4 through 10.

Not every innovative intersection design affects the access to every commercial parcel that adjoins the roadway where the intersection is constructed. In this study, the dataset was not as rich as the investigators initially imagined because even the parcels in the treatment group, which made up more than one-half of the sample, did not always experience a change in access by the access measures the investigators defined.

Among the 158 parcels for which usably complete data were retrieved, moreover, less than one-half, or 67, housed commercial establishments in one of the two business categories (Types 1 or 2) considered more likely to be affected by a change in access. Only about one-half of these parcels, 20 in Business Type 1 and 14 in Business Type 2, were treatment group parcels, which could have experienced a change in motorized access resulting from VDOT road work. According to the access measures the investigators defined, only five Type 1 and five Type 2 businesses experienced a measurable change in the number of turns required on one or more approaches. Only thirteen Type 1 and nine Type 2 businesses experienced a measurable change in the travel distance required. In short, the set of observations available to estimate the parameters $\beta_3$, $\beta_{31}$, $\beta_{32}$, $\beta_4$, $\beta_{41}$, and $\beta_{42}$, which revealed sensitivity to measured changes in access, was actually quite small.

## Selected Access Measures

The two access measures employed in this study were intuitively appealing and comparatively easy to read directly from plans or from aerial photographs. The measures offer a good likelihood of capturing the changes in motorized access that influence motorists, in the motorists' capacity as potential customers of a commercial establishment that fronts the road on which they are driving. However, other measures of motorized access are possible, two of which are noted here.

### Turning Movements Required to Exit an Establishment

A VDOT project completed in 2012, listed as "Unknown_12" in the Supplemental Materials, involved reconstructing a section of median on Route 33 (East Market Street) in Harrisonburg. Before the reconstruction, a cut in the median allowed vehicles to make left turns from East Market Street into the parking lots of the businesses on either side of the street (a Cookout at 1688 East Market Street and a Chick-fil-A at 1691 East Market Street). The cut in the median also allowed vehicles leaving the parking lots to turn left onto East Market Street.

The VDOT work installed a concrete "island" in the middle of the median cut. After the reconstruction, this island created a physical barrier between the southbound cars, which were executing a left turn from East Market Street into the parking lot of the business on the east side of the road, and the northbound cars, which were executing a left turn from East Market Street into the parking lot of the business on the west side of the road. This island *prevented* cars leaving either parking lot from making a left turn onto East Market Street.

The access measures in this study are defined in terms of the movement required to *enter* a parking lot. They take no account of changes in the movement of vehicles *leaving* the parking lot. They therefore recognize no change in motorized access. If a change in access exiting the lot influences a motorist's decision to stop at either of the businesses on East Market Street, this study's methodology will fail to capture it.

### Length of Time Required to Enter an Establishment

A VDOT project completed in 2017, project number 98244 in the Supplemental Materials, involved reconstructing the signalized intersection of Brewers Neck Boulevard and Benns Church Boulevard in Isle of Wight County. Before the reconstruction, northbound vehicles on Benns Church Boulevard were permitted to turn right (east) onto Brewers Neck Boulevard in a dedicated turn lane that branched off just before the intersection. After the reconstruction, the modified geometrics of the intersection, along with new signage and lane markings, prevented northbound vehicles from turning right at the intersection. Drivers on Benns Church Boulevard who wished to proceed east on Brewers Neck Boulevard must now turn right further south onto Benn's Grant Boulevard, the newly constructed "quadrant" road, some 1,100 feet south of the traffic signal at the intersection of Benns Church Boulevard and Brewers Neck Boulevard.

A Citgo gas station at 19417 Brewers Neck Boulevard occupies the parcel on the northeast corner of the intersection. Vehicles can access the parking lot from the northbound lane of Benns Church Boulevard, just after they pass through the signalized intersection. Vehicles can also access the parking lot from the westbound lane of Brewers Neck Boulevard, just before they reach the intersection. Before the reconstruction, a motorist who intended to stop at the business on the northeast corner would proceed to the intersection. If the signal were green, the motorist would proceed through the intersection and turn right into the parking lot from Benns Church Boulevard. After the reconstruction, this movement remained possible. If the signal were red, however, and if the motorist were at the front of the queue approaching the red light, it is possible that the motorist might have attempted to save time—in exchange for more turns and greater distance—by turning right at the intersection and then approaching the Citgo parking lot from Brewers Neck Boulevard. After the reconstruction, a motorist forced to stop at the intersection by a red light no longer had the option of saving time by turning right onto Brewers Neck Boulevard. The motorist must wait for the signals to change and then proceed through the intersection.

The access measures in this study are defined in geometric terms: the number of turns required, the travel distance required, or the presence of a reconstruction. They take no account of travel time. In the example above, they identify the movement through the intersection and the right turn into the parking lot as the shortest turning movement: one turn, before and after; same distance, before and after. These access measures ignore the option of taking more turns if the signal is red. They therefore recognize no change in motorized access. Nonetheless, the prohibited right turn has a real impact, in a probabilistic sense, on the travel time cost of northbound motorists who wish to stop at the business on the northeast corner. If a change in the average wait time at the intersection influences a motorist's decision to stop at this business, this study's methodology will fail to capture it.

### The Complexity of the Relationship between VDOT Work and Property Values

The changes in access that the study method measured exhibited generally positive, although statistically insignificant, correlations with the growth of real estate assessments. On the other hand, the study results suggest that some mechanism, which the study did not measure, is responsible for a small, possibly statistically significant relationship between the presence of VDOT reconstruction work and increases in real estate assessments. It is not possible to say what is causally prior to what in this relationship. However, it is possible to make some remarks about the other factors that might be involved.

First, the locations of the VDOT projects included in the sample used in this study reveal that road segment or intersection reconstruction is more frequent in counties and cities where population or economic activity, or both, are increasing. These socio-economic background factors, which affect the likelihood of a VDOT reconstruction project and the traffic volume, can also influence real estate values through channels other than road work or traffic volume.

Second, the fact that each of the real estate assessments studied in this report evolved in the context of a safety enhancement or a travel delay reduction is not incidental information. The interchanges or segments whose geometry VDOT redesigns generally are those where a problem has been identified. A history of crashes may have revealed a safety problem; traffic volumes may have revealed a current or upcoming congestion problem. Business establishments are certainly sensitive to crashes and congestion queues on the approaches to their parking lots. It cannot be assumed that the findings from a study such as this one would hold for a sample of commercial parcels whose motorized access was affected by construction that was *not* designed to address safety or capacity concerns—for example, right-of-way acquisition to extend an airport runway or to expand a port facility.

### Directions for Future Study

This area offers several long-term research options. One option is to reuse the same study design used herein after the number of completed Virginia innovative intersections has been substantially expanded, such that multiple years of after-construction data can be obtained. A second option is to devise a research approach that allows the compilation of sales data from the businesses affected by a VDOT reconstruction project; such an approach would require the cooperation of businesses, as sales tax data are not publicly available in Virginia (Palmer, 2024). A third possibility is to use real estate sales data.

## CONCLUSIONS

- *The statistical analysis indicated that the two measures of access change adopted in this study had no distinguishable negative impact on the assessed values of adjoining commercial real estate parcels within a window that extended four years beyond the completion date of the VDOT reconstruction work that caused the access change*. The access measure based on the number of turns had no significant impact. The point estimates of the impact tended to be weakly positive. The access measure based on the required distance traveled had no significant impact. The point estimates of the impact tended to be weakly positive.

- *The statistical analysis indicated the presence of a small, unexplained, possibly statistically significant, negative correlation between VDOT reconstruction work and the growth of the assessed values of adjoining commercial real estate parcels*. When the parcels were treated as a single group, this correlation was negative and significant at a p-value of about 2.5%. When the parcels were treated as three groups of different business types, this correlation was negative and significant only for the two business types expected to be less sensitive to access changes at p-values of about 4.1% and 6.4%, respectively. The regression results neither suggest a causal mechanism for this correlation nor indicate the direction the causation flows. They indicate only that the other variables in the regression failed to capture the link. Although the correlation could result from a mechanism by which VDOT work affects customer behavior, the correlation could also result from the presence of a third factor—population growth, economic activity, traffic congestion, or safety issues—that affects both VDOT reconstruction projects and commercial real estate assessments.

- *The statistical analysis suggested that many of the influences on the time path of a parcel's real estate assessment are highly location specific*. The explanatory variables used in the statistical analysis collectively accounted for 14.41% of the variance in assessed value growth among the 158 commercial parcels in the sample. In other words, a considerable portion of the variability in the growth of assessed real estate values appeared to depend on specific local factors other than those measured.

## RECOMMENDATIONS

1. *VDOT Location and Design staff and Transportation Mobility Planning staff should incorporate the findings of this study into the materials about innovative intersections that they distribute to internal staff or to the public, as appropriate*.

2. *VDOT Right-of-Way Division staff should preserve, as a reference, a list of the treatment group and control group parcels, with identifying information pointing to the data included in the analysis*. On the occasion of a future project, when VDOT determines right-of-way acquisition is necessary, some parcels in the dataset may be usefully comparable with the parcels VDOT needs to acquire for that project.

## IMPLEMENTATION AND BENEFITS

The researcher and the technical review panel (listed in the Acknowledgments) for the project collaborate to craft a plan to implement the study recommendations and determine the benefits of doing so. This process is to ensure that the implementation plan is developed and approved with the participation and support of those involved with VDOT operations. The implementation plan and the accompanying benefits are provided here.

### Implementation

*Regarding Recommendation 1, within one year of this report's publication, VDOT's Location and Design Division will review the "long" (four-page) draft fact sheet shown as Appendix A and determine if it should be distributed to staff for internal use*.

*Also, regarding Recommendation 1, within one year of this report's publication, VDOT's Transportation Mobility Planning Division will review the "short" (one-page) draft fact sheet shown in Appendix B and determine if it is appropriate to incorporate into materials on innovative intersections for public distribution*.

*Regarding Recommendation 2, within one year of this report's publication, VDOT's Right-of-Way Division will review a table of identifying information for the parcels that have been studied in this report.* This information is in the Supplemental Materials for this report and includes the VDOT project number, the county parcel number, the street address, and whether the parcel was in a treatment group or control group. The reason for this review is that if a future planned highway reconstruction affects a commercial property similar to one of the parcels in the treatment group, then the information from the models (Equations 1 through 3) may help VDOT construct and substantiate their estimate of the potential impact, if any, on the market value of the affected property.

## Benefits

The findings reported herein do not support a presumption that negative impacts on motorized access resulting from VDOT reconstruction will affect property value negatively. They indicate that the average impact of measured changes in access is negligible or weakly positive.

The findings in this report may have an effect in two areas of VDOT practice. First, better information about the business impacts of access changes may avert the tendency for questions about these effects to prolong the public involvement and the design approval processes during the PE phase. Second, a larger pool of relevant commercial information may enhance estimates of the cost of right-of-way acquisition, thereby improving budgeting efficiency. These two cost impacts are separate and additive.

### A Shorter, and Therefore Cheaper, Preliminary Engineering Phase

First, these estimates of the impact of access changes on commercial enterprises provide answers to questions stakeholders have raised in online public input platforms and at public hearings when VDOT has presented an innovative design option. If these questions are answered quickly, then design selection and approval may proceed more quickly. As the literature review noted, expenditure in the PE category accounts for 11 to 18% of the cost of a typical VDOT reconstruction project, and the PE phase of the project delivery process may account for three-to-six months (13 to 26 weeks) of the total project delivery timeline. This report’s Introduction section noted two VDOT projects in Pittsylvania and Gloucester Counties that were affected in recent years. The summary statistics of the projects in the dataset compiled for this study are based on a group of 48 reconstruction projects of the type of particular concern to this study. The number completed sufficiently long ago to be eligible for study amounted to 45, coming from 2009 to 2022, an average of three per year. This tally is almost certainly an undercount.

That said, the number of projects affected (the two in Pittsylvania and Gloucester Counties) and the number of projects “at risk” (48, counting the three too new to be analyzed) suggest that the risk is less than or equal to one in 24, that is, less than or equal to 4.167%. The summary statistics also show that the typical PE expenditure ranged from \$2 million (the median) to \$2.974 million (the average) per project. The big “unknown” is the quantitative impact of better answers to questions about changes in access on the length of the PE phase. If the availability of the findings from this study enabled VDOT staff to bring a project to advertisement in 25 instead of 26 weeks, and if the cost of PE were proportional to the length of the PE phase, then the cost savings might be estimated as 1/26 (3.85%) of \$2 million, or \$77,000 each time such questions arise regarding a project. Given the frequency with which such questions arise, this risk mitigation might apply to 4.167% of reconstruction projects that change access: \$77,000 × 4.167% = \$3,208.33 per project. In an average year, VDOT undertakes at least three projects of this sort, probably more. The cost savings might therefore be on the order of \$3,208.33 × 3 = \$9,625 per year.

If the savings were expressed in terms of the total cost of a typical reconstruction project that changes access to a commercial parcel, once questions about lost profits due to access changes have already arisen, the avoidable PE cost might be expected to amount to at least 1/26 (3.846%) of the total PE expenditure, which historically has accounted for 11 to 18% of the total project cost: in other words, 1/26 x 11-to-18% = 0.42-to-0.69% of the total project cost. Such questions have been observed to arise in two cases out of 48, or 1/24 (4.167%). Before it is known whether questions about lost profits will arise, therefore, the average expected savings, among all projects that change access to a commercial parcel, might amount to 1/24 x 0.42-to-0.69% = 0.018-to-0.029% of the total project cost.

**A Smaller, and Therefore Cheaper, Holding of Reserves for Right-of-Way Acquisition**

Second, examples of commercial parcels subject to potential changes in motorized access in previous VDOT projects—parcels whose information was collected during this project—may enable the Right-of-Way Division staff to narrow the uncertainty of the cost estimate they use when they budget for a future real estate acquisition. The summary statistics compiled for this study indicate that the typical right-of-way expenditure ranged from \$3.31 million (the median) to \$8.65 million (the average) per project. As these expenses represent the acquisition of numerous parcels of real estate, most of which were not commercial, the median and average shed little light on the amount of money that might be at stake in negotiations with any one particular commercial landowner. Let us assume, purely for the sake of simplicity, that the acquisition cost is \$500,000. The 20-80 low-high confidence range is very large, however, greater than a factor of two: \$250,000 to \$1,000,000. The "cushion" that must be factored into the cost estimate to cover the high-end contingency is correspondingly large, and the funds must be held in a demand account, paying low or no interest, until the project cost is known with greater certainty. *If* the parcel data compiled for this study allowed the low-high confidence range to be compressed from \$250,000 to \$1,000,000 down to \$333,333 to \$750,000, the required cost "cushion" would be reduced by \$250,000, freeing up \$250,000 to be held in a higher interest-bearing account or to be budgeted for another purpose, rather than be held in a low- or non-interest-bearing account for the duration of the right-of-way acquisition phase. If the time from funding to right-of-way acquisition were six months (26 weeks), then the foregone interest cost saved would be on the order of ½ year × 5% per year × \$250,000 = \$6,250 for one project. If these savings occurred on three projects per year, the total savings would be on the order of \$18,750 per year.

The possession of more parcel records may conceivably shorten the right-of-way acquisition process in a manner similar to the way that possession of better answers to questions about the effect of access changes may shorten the length of the PE phase. Using the same numerical example as in the previous paragraph, if the right-of-way acquisition were completed one week faster, it would lead to a carrying cost savings of $^1/_{26}$ year × 5% per year × \$750,000 = \$1,442.31 for a single project. If these savings occurred on three projects per year, the total savings would be on the order of \$4,326.93.

If these assumptions about the implications of the findings for the average length of design approval and the implications of the compiled database be realistic, then it would follow that a rough total benefit, again assuming three applicable VDOT projects per year, would be on the order of $9,625 + $18,750 + $4,326.93, or a bit more than $32,700, per year.

## ACKNOWLEDGMENTS

This study was supported by a technical review panel consisting of Sharad Uprety, VDOT Central Office Transportation and Mobility Planning Division, champion; Linda LaSut, VDOT Fredericksburg; James Damer, VDOT Northern Virginia Right-of-Way Division; Randall Snow, VDOT Hampton Roads Right-of-Way Division; Kaitlyne Cooper, VDOT Central Office Right-of-Way and Utilities Division; Vanna Lewis and Matt Daly, Federal Highway Administration, Virginia Region; and Lance Dougald, Virginia Transportation Research Council. Brad Reed, VDOT Staunton Planning Division, and Vernon "Butch" Heishman, VDOT Central Office Location and Design Division, provided additional helpful review comments.

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## APPENDIX A

## "Long" Draft Fact Sheet: Business Impacts of Access Changes

### Study Purpose

Construction projects such as median closures, the replacement of a traditional four-way intersection with a restricted crossing U-turn (RCUT), or left-turn prohibitions, change the maneuver some motorists must make to reach a parcel adjoining the roadway. Parcel owners and lessees, particularly those who operate a business, have expressed an interest in how these changes in motorized access affect the value of such parcels in Virginia. Accordingly, the study *Business Impacts of Access Changes (Study No. 124967)* examined how changes in access influence the assessed value of parcels used for business purposes from 2010 to 2023.

### Changes in Access due to Reconstruction

The study examined 158 commercial parcels: a treatment group of 91 parcels adjoining 30 VDOT reconstruction projects, with completion dates ranging from 2009 to 2022 and a control group of 67 comparable parcels at nearby locations. Each of the VDOT projects entailed a possible change in motorized access for traffic coming *from* at least one approach direction *to* at least one adjoining commercial parcel (Figure A1).

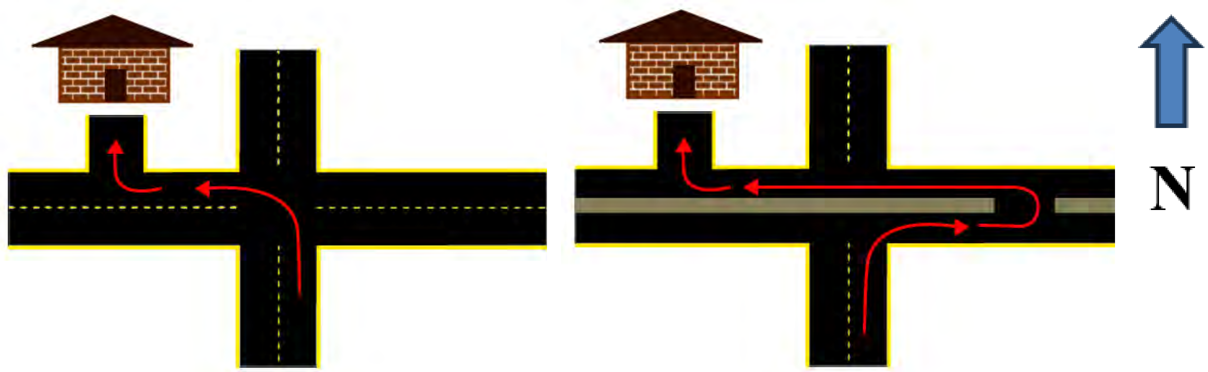


**Figure A1. Example of Access Changes. (Left) Before reconstruction, northbound traffic requires 0.1 miles and two maneuvers—a left turn to the westbound route and then a right turn into the parking lot. (Right) After reconstruction, northbound traffic requires 0.3 miles and three maneuvers—a right turn to the eastbound route, a U-turn, and then a right turn into the parking lot.**

*How was a change in motorized access measured?*

Each parcel's change in motorized accessibility, before and after the VDOT reconstruction, was quantified in two ways: (1) for each direction of approach, the change in the number of turning movements that a vehicle coming from that direction would have to make to access the parcel's parking lot and (2) for each direction of approach, the change in the distance that a vehicle coming from that direction would have to drive to access the parcel's parking lot. For a treatment group parcel, the changes might be zero or non-zero. For a control group parcel, the changes were zero.

For example, if VDOT constructed a median or closed the existing median at a certain location, left turns would no longer be possible at that spot. Motorists coming from an approach direction such that they formerly could have entered a commercial parcel's parking lot by making a *left* turn would subsequently have to pass the parcel, execute a U-turn, approach the parcel from the other direction, and enter the parking lot by making a *right* turn. The changes in motorized accessibility, described previously, would be reflected in both the number of turns and the distance traveled. Figure A1 shows an example where the construction of a median increases the number of turning maneuvers by one and increases the distance traveled by 0.2 miles.

*How was the impact on a business measured?*

Each treated parcel's change in assessed value from four years before the VDOT work to four years after the VDOT work was tabulated. The changes in the values of the control group parcels were tabulated for the same period as the VDOT project near them. The effect of any access changes was measured by the change in assessed value.

Each parcel was classified into one of three groups. The businesses deemed most dependent on spontaneous stop-in customer traffic, and therefore most likely to be affected by a change in motorized access, were assigned to Group 1 (gas stations, convenience stores, and fast-food establishments). The businesses deemed less likely to be affected were assigned to Group 2 (sit-down restaurants, hotels, grocery stores, pharmacies, and banks). The remaining businesses, deemed unlikely to be affected, were assigned to Group 3 (a broad range of establishments, including variety retailers, suppliers of automotive goods and services other than fuel, healthcare providers, education providers, and others). These group codes allowed the analysis to address the possibility that one group might be more sensitive to changes in motorized access than another group.

The inclusion of a control group of comparable parcels, each classified into one of the three groups, allowed the analysis to establish a baseline change in assessed real estate value against which the changes in the assessed values of the treatment group could be contrasted.

At each location, two background variables that were believed to influence the change in a parcel's assessed value were also tabulated. The first of these variables was the change in the estimated true value of all real estate in the county or city of the parcel location, from four years before construction to four years after construction. The second of these variables was the change in annual average daily traffic (AADT) on each road segment by which a motor vehicle might approach the parcel. These explanatory variables, it was hoped, would filter out local factors that might make a parcel in one location appreciate faster than a parcel in another county.

**How did changes in motorized access affect business parcels in Virginia?**

Three research questions emerged. First, did the assessed values of the parcels in the treatment group show a rate of change different from those of the parcels in the control group, once background influences such as the countywide average change in value and local changes in AADT were taken into account? Second, if a measurable difference did exist, was it associated statistically with the measured changes in motorized accessibility? Third, was an effect detectable on the businesses in one group but not in another group?

These data showed four results.

- *Many of the influences on a parcel's real estate assessment appear to be location specific*. The explanatory variables used in the statistical analysis—that is, all the variables except for the change in real estate assessments—collectively explained 14% of the variance in the growth of assessed value on the sample of 158 commercial parcels. In other words, a considerable portion of the variability in the growth of assessed real estate values appears to depend on specific local factors beyond the measures of motorized access change, county-average real estate value change, and AADT change included in this analysis.
- The *change in the number of turning movements required to access a business parcel* was not associated with the change in the parcel's assessed value from four years before to four years after the access modification. In other words, as Figure A1 shows, if reconstruction of an intersection or a road segment meant that a motorist approaching from the east would have to execute a U-turn and a right turn to enter a business's parking lot, where previously the motorist would have had to execute a single left turn, this change was not reflected in the real estate assessment.
- The *change in the distance traveled to access a business parcel* was not associated with the change in the parcel's assessed value from four years before to four years after the access modification. In other words, if reconstruction of an intersection or a road segment meant that a motorist approaching from the east would have to drive 300 yards further to enter a business's parking lot than the distance the motorist previously would have had to drive, this change was not reflected in the real estate assessment.
- *Some evidence suggests a small, negative correlation between VDOT reconstruction work and the growth of assessed property value, via some relationship that the model employed in the study did not capture*. This correlation was positive and was not statistically significant for businesses believed to be the most sensitive to access, such as convenience stores or gas stations. This correlation was negative and was statistically significant for businesses not believed to be highly sensitive to changes in access, such as hotels or banks.

The complete Virginia study is available at https://vtrc.virginia.gov/reports/.

A recent study by Kimley-Horn, under a VDOT contract, produced some survey findings that flesh out the numerical findings of this study.

- *Most businesses reported either positive or neutral impacts on customer traffic after reconstruction*. One convenience store and two hotels reported a negative impact on customer traffic.

**How did changes in motorized access affect business parcels in other states?**

A few other states that have begun rebuilding intersections using non-traditional designs have also studied the effects of changes in motorized access on the adjoining businesses.

- A Minnesota study examined businesses before and after the reconstruction of an at-grade, free-access arterial (Trunk Highway 12 / U.S. Highway 12) as a limited-access freeway (Interstate 394). The effect on access to businesses fronting the road was similar to that on access to some of the businesses fronting an innovative intersection. The study period, 1984 to 2004, extended ten years beyond the completion of the road work in 1993. The statistical indicators of business health that the investigators studied—the number of businesses, turnover rate on a given parcel, gross retail sales, employment, and commercial land values—generally showed growth at or above the average for the metropolitan area and the state as a whole. The study, by David J. Plazak and Howard Preston (2005), is titled *Long-Term Impacts of Access Management on Business and Land Development Along Minnesota 394*.
- A Louisiana study examined before-construction and after-construction sales tax receipts at the intersection level to compare the average customer traffic before and after the construction of one particular type of access change: an RCUT. The investigators studied ten intersections in four study locations in Louisiana. They found no decrease in taxable sales between the two-year period before the improvements and the two-year period after but rather a slight overall increase. The study, by Helmut Schneider, Stephen Barnes, Emily Pfetzer, and Corey Hutchinson (2019), is titled *Economic Effect of Restricted Crossing U-Turn Intersections in Louisiana* and a summary is available here.
- A North Carolina study also looked at the economic impact of one type of access change: conversion from a signalized intersection to an RCUT intersection. For the portion of the study that focused on business parcels, the investigators obtained data from four intersections adjoining commercial parcels and from two intersections adjoining industrial parcels. A survey of the neighboring businesses showed that commercial properties that received many late-afternoon customers expected the most positive impact, and industrial properties expected the most negative impact. The study, by Donald C. Barnes, Adam T. Jones, Lizzette Pérez Lespier, Peter Schuhmann, Manoj Vanajakumari, and Ethan D. Watson (2022), is titled *Economic Impact of Superstreets*.
- A Georgia study is underway that will examine “any associated changes to economic performance of the impacted businesses nearby” RCUTs. The study, managed by Sabbir Ahmed and conducted by Yichang Tsai, is titled *Economic Analysis of RCUT Access Impacts in Georgia* and is expected to be completed in October 2026.

## APPENDIX B

## "Short" Draft Fact Sheet: Business Impacts of Access Changes

### Study Purpose

Median closures, left-turn prohibitions, and restricted crossing U-turns (RCUTs) change how some motorists access nearby parcels. Virginia businesses expressed interest in how these travel changes affect the value of these parcels. The study *Business Impacts of Access Changes (Study No. 124967)* examined how access changes affected the assessed value of business parcels.

### Changes in Access due to Reconstruction

The study examined 158 commercial parcels: a treatment group of 91 parcels adjoining 30 VDOT reconstruction projects, with completion dates ranging from 2009 to 2022, and a control group of 67 comparable parcels at nearby locations. Each project changed motorized access, such as a median closure, for traffic coming *from* at least one direction *to* at least one parcel.

### Study Findings

- Neither a change in the *number of turning movements* nor a change in the *travel distance* required to access a business parcel showed an association with a change in the parcel's assessed value from four years before to four years after the access modification.
- *Much of the variability in the change in assessed real estate values appears to depend on specific local factors* besides changes in turning movements or travel distance, county average real estate value changes, and average annual daily traffic changes.

### Other Published Findings

- A separate Virginia study surveyed businesses at ten locations where VDOT built an innovative intersection. After reconstruction, seven businesses reported positive or neutral impacts on customer traffic, and three businesses reported negative impacts on traffic.
- A Louisiana study examined before-construction and after-construction sales tax receipts at the intersection level to compare the average customer traffic before and after the construction of an RCUT, focusing on ten intersections across four study locations. No decrease was evident in taxable sales between the two-year period before the improvements and the two-year period after but rather a slight overall increase.
- A North Carolina study examined conversion from signalized intersections to RCUT intersections. For business parcels, the investigators obtained data from four intersections adjoining commercial parcels and from two intersections adjoining industrial parcels. A survey of the neighboring businesses showed that commercial properties that received many late-afternoon customers expected the most positive impact, and industrial properties expected the most negative impact.

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# Economic Value of Walkability

**21 December 2025**

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## Abstract

This paper describes ways to evaluate the value of walking (the activity) and walkability (the quality of walking conditions, including safety, comfort and convenience). Walking and walkability provide a variety of benefits, including basic mobility, consumer cost savings, cost savings (reduced external costs), efficient land use, community livability, improved fitness and public health, economic development, and support for equity objectives. Current transportation planning practices tend to undervalue walking. More comprehensive analysis techniques, described in this paper, are likely to increase public support for walking and other nonmotorized modes of travel.

Presented at the Transportation Research Board, 82nd Annual Meeting January 2003, Washington, DC, Paper 03-2731, where it won the TRB Committee on Pedestrian's 2003 Outstanding Paper Award. Published in *Transportation Research Record 1828*, Transportation Research Board (www.trb.org), 2003, pp. 3-11 and in Volume 10, Number 1, 2004, of *World Transport Policy & Practice* (www.eco-logica.co.uk/WTPPhome.html).

## Introduction

Active travel (walking, bicycling and their variants) plays important and unique roles in an efficient transport system:

- Walking is a common human activity that provides mobility, exercise and pleasure.
- Typically 10-20% of trips are entirely by active modes and most motorized trips involve walking and bicycling links, to access public transit and between parked vehicles and destinations. Parking lots, terminals, airports, and commercial centers are all pedestrian environments. Improving active travel can improve motorized transport.
- Active travel provides affordable, basic transport. Physically, economically and socially disadvantaged people often rely on walking and cycling, so improving non-motorized transport can help achieve social equity and economic opportunity objectives.
- Active transport is the most common form of physical exercise. Increasing walking and bicycling is often the most practical way to improve public fitness and health.
- Active mode improvements can achieve transport planning goals including reduced congestion, energy consumption and pollution emissions. They can also help achieve community goals such as compact development and neighborhood livability.
- Pedestrian environments (sidewalks, paths and hallways) are a major portion of the public realm. Many beneficial activities (socializing, waiting, shopping and eating) occur in pedestrian environments, and so are affected by their quality. Shopping districts and resort communities depend on walkable environments to attract customers.
- Walking and cycling are popular recreational activities. Improving walking and cycling conditions provides enjoyment and health benefits to users, and it can support related industries, including retail, recreation and tourism.

Conventional planning tends to assume that transport progress is linear, with newer, faster modes replacing older, slower modes. This *series model* assumes that the older modes are unimportant, and so, for example, there is no harm if faster vehicle traffic degrades walking and bicycling conditions. From this perspective automobile travel should be prioritized over active travel.

Walk → Bike → Train → Bus → Car → Airplane

Walk + Bike + Train + Bus + Car + Airplane

*Conventional planning assumes that faster is better, so motorized modes should be prioritized over slower but more inclusive, affordable, healthy and resource-efficient active modes.*

But there is plenty of evidence that even as motorized travel increases, people continue to walk and bicycle for both transportation and recreational purposes. In many situations the best way to improve urban transport is to improve walking and cycling conditions and restrict automobile travel. Although this does not increase travel speeds it improves the overall convenience, comfort and affordability of access to destinations.

Active transportation tends to be more affordable and resource efficient than alternative forms of transportation and recreation, as summarized in Table 1. This is not to suggest that walking and cycling can serve every purpose, but it does highlight the potential financial and resources savings it can provide.

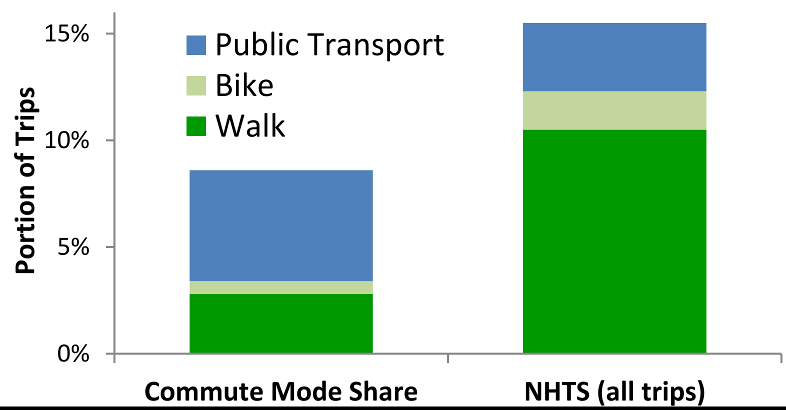
***Table 1*** **Non-motorized Transport Is Generally Cheaper Than Alternatives**

| Affordable and Efficient | Expensive and Resource Intensive |
|---|---|
| Walk and bike for transport | Own and operate an automobile |
| Walk and bike for exercise | Join a health club |
| Walk and bike children to school | Chauffeur children to school |
| Build sidewalks | Build roads and parking facilities |

*Walking and cycling tend to be affordable compared with alternatives.*

Conventional travel data tend to undercount and therefore undervalue active travel because they often ignore short trips (those within a traffic analysis zone), non-work travel, travel by children, recreational travel, and nonmotorized links of multimodal trips (Litman 2003). For example, most travel surveys classify "auto-walk," or "walk-transit-walk" trips simply as "auto" or "transit" Walking links are often ignored even if they take place on public rights-of-way and involve as much time as motorized links. Commonly-cited statistics, such as census commute mode share data, indicate that less than 5% of trips are by walking and bicycling, more comprehensive sources such as the National Household Travel Survey indicate that about 13% of trips are actually by active modes.

***Figure 1*** **Non-Auto Mode Shares (U.S. Census, 2017 NHTS)**




*Commonly-cited statistics, such as census commute mode share data, tend to undercount non-auto modes, particularly walking and bicycling trips. More comprehensive sources, such as the National Household Travel Survey (NHTS) indicate that walking and bicycling trips are two to six times more common than indicated by commute mode share data.*

One study estimated that nonmotorized trips are six times more common than conventional surveys indicate (Rietveld 2000). Conventional planning tends to ignore many types of pedestrian activity such as people sitting or waiting on sidewalks (Haze 2000). If instead of asking, "What portion of trips *only* involve walking," we ask, "What portion of trips involves *some* walking," walking would be recognized as a common and important mode.

This tendency to undervalue nonmotorized travel can be particularly harmful because transportation decisions often involve tradeoffs between different travel modes (Litman 2003b). Wide roads, high traffic speeds and large parking facilities create barriers to walking, so evaluation practices that undervalue walking tend to create automobile dependent communities.

Transportation agencies use standard ways to evaluate transportation improvements. Their economic analysis is dominated by travel time savings. This favors faster modes, such as automobile travel, over slower active modes. For example, it justifies roadway expansion projects even if wider roads and higher speed traffic increase pedestrian and bicycling delay. This undervaluation of slower modes:

- Shifts resources from walking facilities to roads and parking.
- Favors automobile-oriented land use patterns (wide roads, generous parking, low density, single-use) over pedestrian-oriented development.
- Undervalues traffic management practices that support walking, such as traffic calming.
- Undervalues pedestrian safety investments.

To their credit, many transportation professionals support active modes; they intuitively realize that walking and bicycling play important roles in an efficient and equitable transportation system. However, this occurs despite, rather than as a result of, conventional transportation survey data and evaluation methods.

This is a timely issue because there is increased recognition of the benefits of transportation diversity (Litman 2001a), and support for creating more walkable communities. Better tools for evaluating walkability can help with many transportation and land use planning decisions (Reimann and J.F. Chriqui 2019; Litman 2002).

This paper investigates the value of walking (the activity) and walkability (the quality of walking conditions, including factors such as the existence of walking facilities and the degree of walking safety, comfort and convenience). It identifies categories of economic benefits, describes how they can be measured, and the degree to which these are reflected in current transportation and land use planning. This paper can only provide a general review of these issues – more research is needed to create practical tools that can be used by transport planners to quantify the full benefits of walkability.

Most analysis in this paper applies to any form of nonmotorized transportation, including cycling and skating and wheelchair use. For simplicity I use the term “walking” and “walkability”, but readers may wish to substitute “nonmotorized travel” and “nonmotorized travel conditions” to be more inclusive.

## How Walking Is Undervalued

Conventional planning tends to undervalue active modes in the following ways:

### *Difficult to Measure*

Walking and walkability are more difficult to evaluate than motorized travel. Travel surveys tend to undercount walking and bicycling trips, and most communities have little data on the extent and quality of sidewalks, crosswalks and bikeways. Most travel models give little consideration to active travel.

### *Low Status*

Walking is generally considered a lower status activity compared with motorized travel. Civic leaders and transportation professionals generally prefer to be associated with improvements to air travel, driving conditions, and major transit service, since they are perceived as more important. Because it is used by lower-income people, walking tends to be stigmatized while motorized transport tends to be associated with success and progress.

### *Low Cost*

Walking tends to be overlooked because it is so affordable. As a result there is no organized walking industry and little dedicated funding. Improved walkability can provide consumer cost savings, but such avoided costs are difficult to predict and are often given little consideration.

### *Benefits Ignored*

Conventional planning tends to ignore or undervalue benefits such as fitness and public health benefits of active transportation, enjoyment of walking and cycling, and improved mobility options for non-drivers. The role that nonmotorized travel plays in supporting public transit and rideshare travel is often overlooked. Many transportation economic evaluation models even ignore benefits such as reduced congestion, parking cost savings and consumer cost savings that result when travel shifts from driving to nonmotorized modes.

### *Taken For Granted ("It Will Take Care of Itself")*

Decision-makers often take walking for granted and assume that it can take care of itself (Goodman and Tolley 2003). For example, it is possible to walk along roads that lack sidewalks, either in the roadway or on dirt paths that develop along road shoulders. As a result, walk and cycling facilities are often given low priority. Such insensitivity to walking conditions is misplaced: areas with poor walkability tend to have significantly less walking and more driving than more walkable areas.

## Categories of Economic Impacts

*Economics* refers to the allocation of valuable resources. This can include both market resources (money, labor and land) and nonmarket resources (safety, clean air, wildlife habitat and aesthetic features). *Economic impacts* refers to benefits and costs, that is, an increase or reduction in resource value.

This section describes major categories of economic impacts associated with walking, the degree to which they are recognized in current transport evaluation, and how they can be evaluated (Litman 2002a; “TDM Evaluation,” VTPI 2008; Litman 2009). The *Active Transport Quantification Tool* (ICLEI 2007) provides a methodology for valuing the active transportation benefits, including savings from avoided driving, increased happiness, and reductions in coronary heart disease, diabetes risk, congestion, pollution and crash risk. The report, *Evaluating Public Transit Benefits and Costs* (Litman 2004b) provides similar analysis for transit economic evaluation, which provides a model and useful information for evaluating non-motorized transportation.

### *Accessibility*

*Accessibility* (or just *Access*) refers to the ability to reach desired goods, services and activities (Litman 2003b). Walking is an important form of access, both by itself and in conjunction with other modes (transit, driving, air travel, etc.). Walking provides basic mobility, that is, many people rely on walking to access activities with high social value, such as medical services, essential errands, education and employment (“Basic Mobility,” VTPI 2008). It is particularly important for people who are transportation disadvantaged (people with disabilities, elders, children, and people with low incomes). Poor walking conditions can contribute to *social exclusion*, that is, the physical, economic and social isolation of vulnerable populations. Pedestrian access to public transit is an important accessibility factor.

#### Evaluation Methods

Several methods can be used to evaluate walkability, taking into account the quality of pedestrian conditions and the geographic distribution of destinations (FDOT 2002; “Evaluating Nonmotorized Transportation,” VTPI 2008). Accessibility can be evaluated using resident surveys, field surveys and Geographic Information Systems (GIS) to determine the portion of important destinations (medical services, shops, schools, jobs, government offices, etc.) that can be conveniently reached by walking or walk-transit-trips, particularly by disadvantaged populations. The value of marginal changes in walking conditions can be quantified using contingent valuation surveys to determine the value people place on improved pedestrian accessibility, and cost savings compared with other access options (such as driving).

## *Consumer Savings*

Walkability affects consumer transport costs. Improved walkability allows consumers to save on vehicle expenses. For example, one study found that households in automobile-dependent communities devote 50% more to transportation (more than $8,500 annually) than households in communities with more accessible land use and more multi-modal transportation systems (less than $5,500 annually) (McCann 2000).

### Evaluation Methods

Consumer savings from improved walkability can be evaluated based on potential transportation cost savings. For example, walkability improvements that allow more people to walk or ride transit, rather than drive, can reduce vehicle ownership and operating costs.

At a minimum, shifting reduced driving saves fuel and oil, which typically total about 10-15¢ per vehicle-mile reduced, and more under congested conditions. Vehicle operating cost savings can be particularly large because walking tends to substitute for short trips when vehicle engines are cold, during which they are less efficient. In addition, depreciation, insurance and parking costs are partly variable, since increased driving increases the frequency of vehicle repairs and replacement, reduces vehicle resale value, and increases the risks of crashes, traffic and parking citations. These additional mileage-related costs typically average 10-15¢ per mile, so cost savings total 20-25¢ per mile reduced. Savings are greater if improved travel options allow a household to own fewer vehicles. Potential savings are summarized in the table below.

***Table 2*** **Potential Vehicle Cost Savings** ("Vehicle Costs," VTPI 2008)

| Category | Description | How It Can Be Measured | Typical Values |
|---|---|---|---|
| **Vehicle Operating Costs** | Fuel, oil and tire wear. | Per-mile costs times mileage reduced. | 10-15¢ per vehicle-mile. Higher in congestion. |
| **Long-Term Mileage-Related Costs** | Mileage-related depreciation, mileage lease fees, user costs from crashes and tickets. | Per-mile costs times mileage reduced. | 10¢ per vehicle-mile. |
| **Special Costs** | Tolls, parking fees, Parking Cash Out, PAYD insurance. | Specific market conditions. | Varies. |
| **Vehicle Ownership** | Reductions in fixed vehicle costs. | Reduced vehicle ownership times vehicle ownership costs. | $3,000 per vehicle-year. |
| **Residential Parking** | Reductions in residential parking costs due to reduced vehicle ownership. | Reduced vehicle ownership times savings per reduced residential parking space. | $100-1,200 per vehicle-year. |

*Reducing automobile travel can provide a variety of consumer savings. (2001 U.S. dollars).*

The "Vehicle Costs" chapter of *Transportation Cost and Benefit Analysis* (Litman 2009) provides information on potential cost savings.

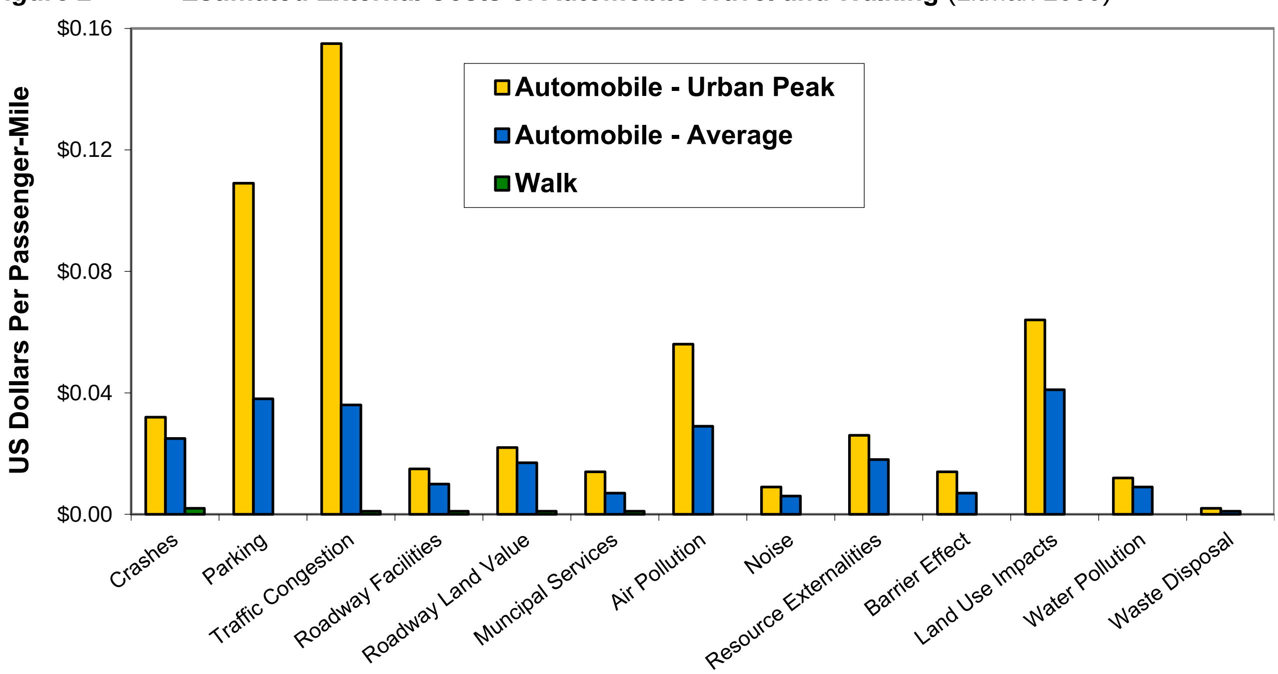
## *Public Cost Savings (Reduced Transport Externalities)*

Motor vehicle use imposes various public costs for road and parking facilities, traffic congestion, crash risk, and environmental damages (Murphy and Delucchi 1998; Litman 2010). Shifting travel from motorized to non-motorized modes reduces these external costs. Walking substitutes for relatively short vehicle trips, which tend to have high costs per vehicle-mile. In particular, energy consumption and pollution emissions are several times higher than average for short trips when engines are cold, and parking costs are high when measured per vehicle-mile, since these costs are divided into few miles. A short walking trip often substitutes for a longer motor vehicle trip. As a result, each percentage shift of vehicle trips to walking can reduce transport external costs by several percentage points, particularly under urban-peak conditions when emission and parking costs are high.

### Evaluation Methods

A variety of methods are used to calculate the external cost savings that result when travel shifts from driving to non-motorized modes (Litman 2009). Figure 1 illustrates one comparison of the estimated external costs of driving and walking. Shifting travel from driving to walking can help reduce various external costs, providing savings estimated to average approximately 25¢ per vehicle-mile reduced, and 50¢ per vehicle-mile reduced under urban-peak conditions.

***Figure 2*** **Estimated External Costs of Automobile Travel and Walking** (Litman 2009)




*This figure compares the estimated external costs of automobile and pedestrian travel. Shifting from driving to walking provides savings averaging approximately 25¢ per vehicle-mile reduced, and 50¢ per vehicle-mile reduced under urban-peak conditions.*

## *Land Use Efficiency*

Low-density development with large amounts of land paved for roads and parking imposes various economic, social and environmental costs (Appleyard 1981; Burchell 1998; Litman 2002; "Land Use Evaluation," VTPI 2008; USEPA 2001). Walkability improvements can help reduce these costs by reducing the amount of land required for transport facilities and encouraging more accessible, clustered land use patterns, and supporting Smart Growth development patterns (Ewing, Pendall and Chen 2002; "Smart Growth," VTPI 2008). This provides economic, social and environmental benefits.

### Evaluation Methods

There are many factors to consider when evaluating the impacts of transportation decisions on land use patterns. Evaluating these impacts requires:

1. An understanding of how transportation in general, and walkability in particular, affect land use patterns (Litman 2002). Compared with driving, walking requires far less space for travel and parking, does not require building setbacks to mitigate traffic noise, and encourages more clustered development patterns. As a result, walkable communities can devote less land to pavement and tend to result in higher development densities than is common with more automobile-oriented transport systems, reducing per capita land consumption.
2. An understanding of the economic impacts of different types of land use patterns, including the economic, social and environmental benefits from reduced impervious surface (Arnold and Gibbons 1998) and more clustered development patterns (Burchell, et al. 1998). The table below summarizes various land use benefits from improved walkability. Not every walkability improvement provides every one of these benefits, but in general, a more walkable community will achieve most of them.

**Table 3 Land Use Benefits of Improved Walkability**

| Economic | Social | Environmental |
|---|---|---|
| Improved accessibility, particularly for non-drivers.<br>Reduced transportation costs.<br>Increased parking efficiency (parking facilities can serve more destinations).<br>Can increase local business activity and employment.<br>Support for transit and other alternative modes.<br>Special support for some businesses, such as walking tourism.<br>Healthcare savings from improved exercise. | Improved accessibility for people who are transport disadvantaged.<br>Reduced external transportation costs (crash risk, pollution, etc.).<br>Increased neighborhood interaction and community cohesion.<br>Improved opportunities to preserve cultural resources (e.g., historic buildings).<br>Increased exercise. | Reduced land needed for roads and parking facilities.<br>Openspace preservation.<br>Reduced energy consumption and pollution emissions.<br>Improved aesthetics.<br>Reduced water pollution.<br>Reduced "heat island" effects. |

*This table summarizes various benefits from a more walkable community.*

## *Community Livability and Cohesion*

### Description

*Community Livability* refers to the environmental and social quality of an area as perceived by residents, employees and visitors (Weissman and Corbett 1992; "Livability," VTPI 2008). *Community cohesion* (also called *social capital*) refers to the quality of relationships among people in a community, as indicated by the frequency of positive interactions, the number of neighborhood friends and acquaintances, and their sense of community connections, particularly among people of different economic classes and social backgrounds (Forkenbrock and Weisbrod, 2001). These are valuable themselves and can provide indirect benefits including increased safety and health, and increased property values and economic development (CTE 2007; Litman 2011).

Walkability has major impacts on community livability. Streets are a major portion of the public realm, that is, places where people interact with their community. More attractive, safe and walkable streets increase community livability (Forkenbrock and Weisbrod 2001). Residents on streets with higher traffic volumes and speeds are less likely to know their neighbors, and show less concern for their local environment, than residents on streets with less vehicle traffic (Appleyard 1981).

### Evaluation Methods

Community livability and cohesion provide various direct and indirect benefits. It can affect property values and business activity in an area, which can be measured with various techniques such as hedonic pricing and contingent valuation (LGC 2001; Litman 2009; Sohn, Moudon and Lee 2012). This may not reflect total livability benefits, since benefits to non-residents are not necessarily reflected in property values. The value of walkability varies, depending on several factors:

- Pedestrian-friendly, new urbanist community design tends to increase property values (Eppli and Tu 2000).
- In automobile dependent areas, sidewalks may have little effect on adjacent property values.
- Reduced vehicle traffic can increase adjacent property values, in part, because it improves walking safety and comfort (Bagby 1980).
- Proximity to public trails often increases residential and commercial property values (NBPC 1995).

To the degree that improved walkability increases community cohesion, it may help reduce crime and other social problems in an area (Litman 2002). However, such relationships are difficult to measure and walkability is just one of many related factors that affects community cohesion.

## *Health*

*Physical Activity* refers to physical exercise. Inadequate physical activity is a major contributor to health problems (Litman 2004). Health experts recommend at least 30 minutes of moderate exercise a day, at least 5 days a week, in intervals of ten-minutes or more (Surgeon General 1999).

**Diseases Associated With Physical Inactivity** (Killingsworth and Lamming 2001)

- Heart disease
- Hypertension
- Stroke
- Diabetes
- Obesity
- Osteoporosis
- Depression and dementia
- Some types of cancer

An increasing portion of the population, including many children, lack regular physical activity. Although there are many ways to be physically active, walking is one of the most practical ways to increase physical activity among a broad population. Walking tends to be particularly important for elderly, disabled and lower-income people who have few opportunities to participate in sports or formal exercise programs. Health experts believe that more balanced transportation systems can contribute to improved public health by accommodating and encouraging active transport (Sallis, et al. 2004; Bassett, et al. 2008).

A few published studies have quantified the health benefits of transport and land use planning decisions that increase physical activity ("Safety and Health," Litman 2009). Boarnet, Greenwald and McMillan (2008) develop a framework for quantifying the value of reduced mortality from urban design improvements that increase walking activity. The table below summarizes the estimated benefits of various changes in neighborhood walkability factors from a median to the seventy-fifth (lower value) and ninety-fifth (higher value) percentile, for example, if the number of intersections within ½ mile increased by 0.3816 (lower value) or 1.1844 (higher value), for a hypothetical 5,000 resident neighborhood. A detailed study found that women who live in more walkable New York neighborhoods have significantly lower risk of obesity-related cancers. (India-Aldana, et al. 2023).

***Table 4*** **Health Benefits Neighborhood Walkability** (Boarnet, Greenwald and McMillan 2008)

| Neighborhood Walkability Changes | Total Benefits | | Per Capita Benefits | |
|---|---|---|---|---|
| | Lower | Higher | Lower | Higher |
| Increase number of intersections within ½ mile | $2,255,107 | $23,205,007 | $451 | $4,641 |
| Increased retail employment density | $466,574 | $18,331,955 | $93 | $3,666 |
| Increased employment density | $155,525 | $19,492,206 | $31 | $3,898 |
| Increased Population density | $1,555,247 | $8,353,802 | $311 | $1,671 |
| Distance from central business district | $4,510,215 | $61,725,318 | $902 | $12,345 |

*This table summarizes estimated value of health benefits from neighborhood design changes that increase walking. "Lower" and "Higher" values indicate results of various assumptions.*

Of people with safe places to walk within ten minutes of home, 43% achieve recommended activity levels, compared with just 27% of those who lack safe places to walk (ECU 2004b). Tomalty and Haider (2009) evaluated how community design factors (density and mix, street connectivity, sidewalk supply, street widths, block lengths, etc.) and a subjective *Walkability Index* rating (based on residents' evaluations) affect walking and biking activity, and health outcomes in 16 diverse neighborhoods. The analysis reveals a statistically significant association between improved walkability and more walking and cycling activity, lower body mass index (BMI), and lower hypertension. Regression analysis indicates that people living in more walkable neighbourhoods are more likely to walk for at least 10 daily minutes and are less likely to be obese than those living in less walkable areas, regardless of age, income or gender.

Stokes, MacDonald and Ridgeway (2008) developed a model to quantify public health cost savings from a new light rail transit system in Charlotte, NC. Using estimates of future riders, the effects of public transit on physical activity (daily walking to and from the transit stations), and area obesity rates they estimate the potential yearly public health cost savings from this project. They estimate that the light rail system would provide cumulative public health cost savings of $12.6 million over nine years. Land Transport New Zealand's *Economic Evaluation Manual* (EEM) provides monetary values for the health benefits of active transportation resulting from both TDM measures and active transportation infrastructure (LTNZ 2010). It assumes that half of the benefit is internal to the people who increase their activity level by walking or cycling, and half are external benefits to society such as hospital cost savings. The values for cyclists and pedestrians are shown in the table below.

***Table 5*** **Active Transportation Health Benefits** (LTNZ 2010)

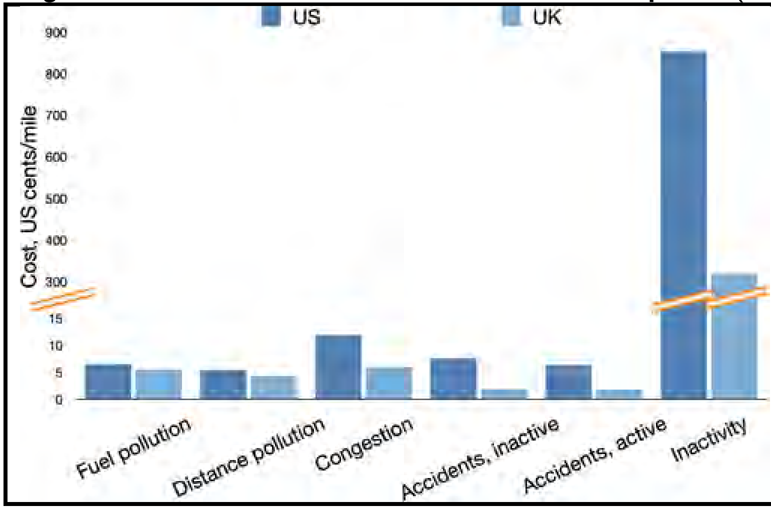
| | | Internal | External | 2007 USD/mile |
|---|---|---|---|---|
| | low | 0.05 | 0.05 | 0.10 |
| Cycling | mid | 0.10 | 0.10 | 0.19 |
| | high | 0.19 | 0.19 | 0.38 |
| | low | 0.12 | 0.12 | 0.24 |
| Walking | mid | 0.24 | 0.24 | 0.48 |
| | high | 0.48 | 0.48 | 0.96 |

*These values reflect the health benefits of increased walking and cycling for economic analysis.*

Walking has a relatively high crash fatality rate per mile of travel, but this is offset by reduced risk to other road users and by the fact that pedestrians tend to travel less overall than motorists (for example, a walking trip to a local store often substitutes for a longer car trip to a more distant shopping center). International research suggests that shifts to nonmotorized transport increases road safety overall (Litman and Fitzroy 2005; "Safety Evaluation," VTPI 2008). For example, the Netherlands has a high level of nonmotorized transport, yet per capita traffic deaths and the cyclist death rate per million km ridden is much lower than in more automobile dependent countries (Pucher and Dijkstra 2000).

London School of Economics researchers estimate that physical inactivity is, by far, the largest cost of automobile travel, and increased physical fitness and health is the largest benefit of active travel, as illustrated in the following graph.

***Figure 3*** **Social Costs of Car Travel in 2022 prices** (van den Bijgaart, et al. 2023)




*The health costs of physical inactivity are by far the largest social cost from car use, and the health benefits of physical exercise tend to be the largest benefit of improving and increasing active travel.*

### Evaluation Methods

Public surveys can be used to determine the degree that people in an area rely on walking for exercise, and the degree to which improved walkability would increase physical activity by otherwise sedentary people (Boarnet, Greenwald and McMillan 2008). The "Safety and Health" chapter of *Transportation Cost and Benefit Analysis* (Litman 2009) contains more information on methods for quantifying these benefits.

## *Economic Development*

*Economic Development* refers to progress toward a community's economic goals, including increases in economic productivity, employment, business activity and investment (Litman 2011). Walkability can affect economic development in several ways (LGC 2001; Leinberger and Alfonzo 2012).

Tolley (2011) evaluated the impacts on to retailers and local residents from improving commercial street walking and cycling conditions. He found that streetscape enhancements that improve walking and cycling conditions tend to increase property values and rents, attract new businesses, and increase local economic activity. Analyzing bicycle and automobile parking space requirements he concluded that bicycle parking can produce much higher levels of retail spend than the same space devoted to car parking. He also concluded that a large proportion of retail expenditure comes from local residents and workers, many of whom walk or bicycle, in contrast to car-borne customers who are more likely to be "drive-through" shoppers, stopping to pick up one item on the way to another destination.

The New York City Department of Transportation includes indicators of economic vitality (sales tax receipts, commercial vacancies, number of visitors) when evaluating street redesigns that add walking, cycling and public transit facilities, change traffic speeds or change vehicle parking conditions (NYCDOT 2013). In several examples, walking, cycling and public transit improvements have improved economic performance:

- Establishing bike paths on 8th and 9th Avenues in Manhattan increased local business retail sales up to 49% compared with 3% borough-wide.
- Expanding walking facilities in Union Square North (Manhattan) reduced commercial vacancies 49%, compared to a 5% increase borough-wide.
- Converting an underused parking lot into a public park on Pearl Street (Brooklyn) increased nearby retail sales volumes by 172%, compared to 18% borough-wide.
- Converting a curb lane into a public seating area on Pearl Street (Manhattan) increased sales volumes at adjacent businesses by 14%.
- Establishing a bus lane and other bus transit improvements on Fordham Road (Bronx) increased nearby retail sales 71% compared to 23% borough-wide.
- Developing bus- and bike-lanes on First and Second Avenue reduced commercial vacancy rates 47%, compared with 2% borough-wide.

Pedestrian-friendly commercial districts ("Mainstreets") can be important for urban revitalization (Bohl 2002; "Downtowns," VTPI 2008). Research by Hack (2013) indicates that walkable shopping areas are often economically successful, improved walkability tends to increase commercial and residential land values, many want to live within walking distances of commercial services, and that current market trends are likely to increase demand for walkable shopping districts.

People often overestimate the importance of shoppers motor vehicle access, and therefore vehicle parking, and underestimate the value of access by walking, cycling and public transport. For example, a survey of customers at New York City shopping street found that a minority drive, and that shifting street space from vehicle parking to pedestrians would likely increase total business activity in the area. Shoppers who value wider sidewalks over parking spent about five times as much money, in the aggregate, as those who value parking over sidewalks (Schaller Consulting 2006).

Rowe (2013) used retail sales data (based on sales tax receipts) to analyze the impacts that development of bike lanes, and the resulting loss of some on-street parking spaces, had on local business districts in Seattle, Washington neighborhoods. The results indicated substantial (up to 400%) increases in sales volumes after bicycle lane installation.

Another study (Sztabinski 2009) examined the impacts of proposed bike lanes on retailers along Toronto, Canada's Bloor Street. The analysis indicated that expanding sidewalks, and adding bicycle and bus lanes tends to support local economic development, even if it reduces on-street parking. It found that:

- 90% of customers walk, bike or travel by public transit to shops.
- Even during peak periods no more than about 80% of metered parking spaces on the street are occupied.
- Although customers who arrive by automobile spend more per trip on average, customers who arrive by foot and bicycle visit the most often and spend most per month on average.
- More merchants who believe that a bike lane or widened sidewalk would increase business than merchants who think those changes would reduce business.
- The loss of on-street parking required for a bike lane or wider sidewalks could easily be accommodated in nearby off-street parking lots.

A study of consumer expenditures in British towns found that customers who walk spend more per week than those who drive, and transit and car travelers spend similar amounts.

***Table 6*** **Consumer Expenditure by Mode** (Accent Marketing & Research)

| Mode | Weekly Expenditures |
|---|---|
| Bus | £63 |
| Car | £64 |
| On foot | £91 |
| Train/tube | £46 |
| Other (taxi, cycle...) | £56 |

*This survey found higher weekly expenditures by consumers who travel by walking than those who drive or rider transit to downtown shopping districts in the UK.*

Expenditures on fuel and vehicles tend to provide relatively little employment and business activity compared with other common consumer expenditures ("TDM and Economic Development," VTPI 2008; Litman, 2004b). Walking that substitutes for driving, and therefore reduces fuel consumption and dependency on fuel and vehicles imported from other regions tends to provide economic development benefits.

### Evaluation Methods

Walkability can affect economic development in several ways, each must be considered separately (Litman 2002). Market surveys and property assessments can be used to identify how walkability factors affect commercial activity (such as retail sales), consumer satisfaction, competitiveness, employment, tax revenue, and property values in an affected area. Economic analysis techniques using input-output tables can be used to determine how changes in consumer expenditures affect regional employment and business activity (Weisbrod 2000).

## *Economic Opportunity and Resilience*

Gilderbloom, Riggs and Meares (2015), and Won, Chanam and Li (2017) indicate that more walkable neighborhoods have lower housing foreclosure rates.

## *Social Equity*

Equity refers to the distribution of resources and opportunities. Transport decisions can affect equity in various ways. There are several different equity issues, including *horizontal equity* (which assumes that people should generally be treated equally), and *vertical equity* (which assumes that society should provide extra support to disadvantaged people) (Litman 2001). Walkability can help achieve various equity objectives including a fair distribution of public resources to non-drivers, financial savings and improved opportunity for people who are physically and economically disadvantaged, and basic mobility.

### Evaluation Methods

Because there are different types of equity, several factors should be considered when evaluating transportation equity impacts. The table below describes five equity indicators that can be used to evaluate the overall equity impacts of changes in walkability.

***Table 7*** **Equity Summary** ("Equity Evaluation," VTPI 2008)

| Indicator | Description |
|---|---|
| **Treats everybody equally.** | This reflects whether a policy treats each group or individual equally. |
| **Individuals bear the costs they impose** | This reflects the degree to which user charges reflect the full costs of a transportation activity. |
| **Progressive with respect to income** | This reflects whether a policy makes lower-income households better or worse off. |
| **Benefits transportation disadvantaged** | Whether a policy makes people who are transportation disadvantaged better off by increasing their options or providing financial savings. |
| **Improves basic mobility and access** | This reflects whether a policy favors more important transport (emergency response, commuting, basic shopping) over less important transport. |

*This table describes five indicators of transportation equity that can be used when evaluating walkability equity impacts.*

The most practical approach to evaluating equity impacts is to define equity objectives and performance indicators, and then evaluate the degree to which a particular policy or project helps achieve them ("Transportation Planning," VTPI 2008). Equity benefits are difficult to monetize (there is no easy way to add equity benefits to other benefits such as vehicle cost savings or increased property values), but most communities seem to place a high value on achieving equity objectives (Forkenbrock and Weisbrod 2001).

## Summary of Economic Impacts

Table 10 summarizes the categories of economic benefits described above that should be considered when evaluating walking. In most situations, several impacts should be considered, with results added to determine total benefits. For example, a particular walkability improvement may improve accessibility, provide consumer cost savings, increase community livability (and therefore local property values), improve public fitness and health, benefit the local economy (increasing employment, tax revenue and property values), and support strategic land use and equity objectives. The project's full value is the sum of these individual benefits.

***Table 8*** **Walkability Economic Impacts**

| Name | Description | Measuring Techniques |
|---|---|---|
| **Accessibility** | Degree that walking provides mobility options, particularly for people who are transportation disadvantaged. | Travel modeling, analysis of travel options. |
| **Consumer cost savings** | Degree to which walking provides consumer transportation cost savings. | Consumer expenditure surveys |
| **Public cost savings (reduced external costs)** | Degree that walking substitutes for vehicle travel and reduces negative impacts. | Determine to what degree walking reduces motor vehicle travel, and the economic savings that result. |
| **Efficient land use** | Degree that walking helps reduce the amount of land used for roadway and parking facilities, and helps create more accessible, clustered land use. | Identify the full economic, social and environmental benefits of more pedestrian-oriented land use. |
| **Livability** | Degree that walking improves the local environment. | Property values, business activities, consumer preference surveys. |
| **Public fitness and health** | Degree that walking provides physical exercise to people who are otherwise sedentary. | Travel and health surveys to determine the number of people who benefit from walking exercise. |
| **Economic development** | Degree to which walking makes commercial areas more attractive and shifts consumer expenditures to goods that provide more regional economic activity and employment. | Market surveys and property assessments. Input-output table analysis. |
| **Equity** | Degree that walkability helps achieve various equity objectives. | Various indicators of horizontal and vertical equity. |

*This table summarizes various categories of impacts to consider when evaluating walking.*

## Planning Applications

*The value of walkability can be incorporated into transport planning decisions in various ways, reflecting various perspectives and assumptions. Three approaches are described below.*

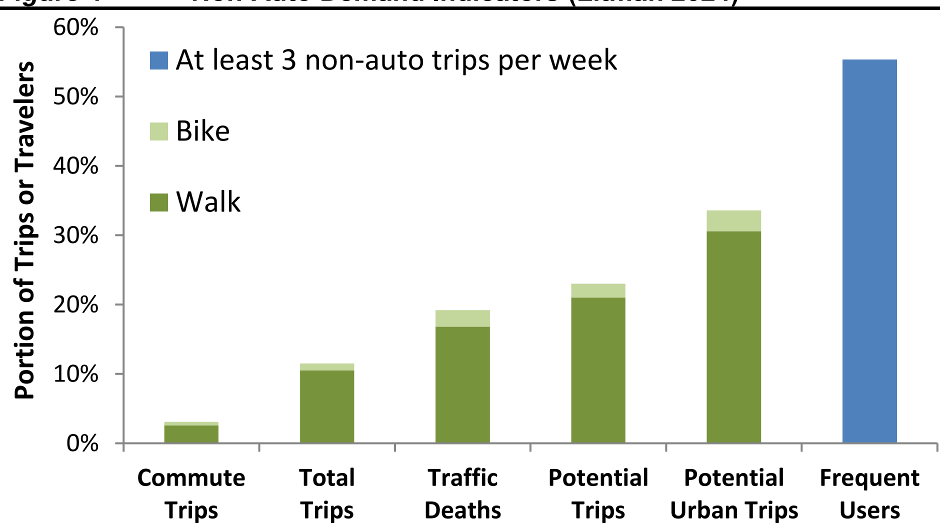
### *Proportional Share*

Transportation fairness and efficiency can be evaluated based on the degree that public resources (money, road space, planning priority, etc.) reflect a mode's share of travel demands (Litman 2022). For example, if travellers would like to make 10% of their trips by active modes, they should receive up to 10% of public resources, or more if justified to achieve strategic goals or to make up for previous underinvestment.

According to the National Household Travel Survey about 13% of U.S. trips are made active modes, with increased rates where walking and bicycling conditions are improved, indicating latent demands (travellers would like to walk and bicycle, but cannot due to underinvestment). Although walking and bicycling trips tend to be shorter than motorized mode trips, and so represents a smaller portion of person-mileage, a shorter active mode trip often substitutes for a longer automobile trip. For example, consumers may choose between walking to a nearby store or driving to a regional shopping center. There is no obvious reason that society should subsidize automobile trips and motorists at a greater rate than walking trips and non-drivers.

North American communities typically spend about $50 annually per capita on sidewalks and bikeways, a tiny amount compared with expenditures on public transit, roads and government-mandated parking facilities. This represents less than 5% of public spending on transportation infrastructure, which is a much smaller than the portion of total trips currently made by active modes, or the portion of trips that could be made by these modes if they received more investment and support.

***Figure 4*** **Non-Auto Demand Indicators (Litman 2024)**




*Active travel is approximately 4% of commute trips, 13% of total personal trips, 20% of traffic deaths, a third of urban trips if their conditions are improved. About half of all travelers use non-auto modes at least three times per week.*

There are several reasons that walkability improvements might deserve *more* than a proportional share of transportation resources:

- As described earlier, walking provides basic mobility and serves trips with high social value.
- Walking is particularly important for people who are transportation disadvantaged. Walkability improvements provide equity benefits, and bear special costs associated with serving people with disabilities.
- Some walking facility improvements can be included in other transport budgets (e.g., transit facilities, airports, parking facilities, ferry terminals, etc.) because they serve these modes.
- Walking provides both transportation and recreation benefits. It therefore deserves funding from both transportation and recreation budgets. For example, it may be appropriate to devote 10% of a jurisdiction's transportation budget *and* 20% of its recreation budget to pedestrian facilities.

If we apply the principle that each mode should receive its proportional share of transportation resources, this suggests that walking should receive 10-20% of *total* transportation resources (not just municipal transport agency funds), five to ten times what is currently devoted to walking facilities and services, in addition to a significant share of recreational funding.

### *Cost Allocation*

*Transportation cost allocation* evaluates to what degree each user group pays its share of transportation facilities and services through special user charges such as road tolls, fuel taxes and vehicle registration fees (FHWA 1997; Litman 2009). This reflects the principles of horizontal equity (consumers should pay for what they get and get what they pay for unless a subsidy is specifically justified), and economic efficiency (prices should equal marginal costs) ("Market Principles," VTPI 2008).

Many people assume that because motorists pay fuel taxes and other roadway fees, nonmotorized modes underpay their fair share of transportation costs. This is not necessarily true. Although vehicle use fees fund major highways, local roads are funded through general taxes that residents pay regardless of how they travel, and motor vehicles impose other public costs besides roadway expenditures. An average household pays several hundred dollars annually in general taxes for local roads and traffic services, and pays hundreds of dollars in parking subsidies. When all impacts are considered, motorists generally underpay their share of costs, while walking receives less than its fair share of resources (Litman 2005; Litman 2009). The example below illustrates this point.

### Example

Two neighbors each pay $300 annually in local taxes that fund transport facilities and services. Mike drives 10,000 miles annually on local roads, while Frances walks 3,000 miles. The table below compares their tax payments and transportation costs.

***Table 12*** **Local Transportation Payments and Costs**

| | Mike | Frances |
|---|---|---|
| A. Annual local mileage | 10,000 | 3,000 |
| B. Household's general taxes used for road related services. | $300 | $300 |
| C. Motorist user fees spent on local road (0.2¢ per mile). | $24 | $0 |
| D. Total road system contribution (B + C) | $324 | $300 |
| E. Tax payment per mile of travel (B/A). | 3.2¢ | 10¢ |
| F. Roadway costs (cars = 5¢/ml, walking = 0.2¢/ml) | $500 | $48 |
| *Net (D – F)* | *Underpays $176* | *Overpays $252* |

*Non-drivers pay almost as much as motorists for local transportation facilities and services, but impose lower costs. As a result, they tend to overpay their fair share.*

Although an *average* household pays its share of transport taxes, those who drive less than average subsidize their neighbors who drive more than average. These subsidies can be significant, totaling hundreds of dollars annually for somebody who relies primarily on nonmotorized transport. These cross subsidies are far greater when other external motor vehicle costs are also considered, such as public resources devoted to parking facilities, uncompensated crash damages, and environmental damages (Litman, 2009).

This suggests that applying cost allocation principles, motorists should pay significantly more than they currently do in user fees, and more resources should be devoted to nonmotorized transport facilities or nondrivers should receive tax discounts ("Market Reforms," VTPI 2008).

## *Benefit-Cost Analysis*

A third approach to evaluating transportation policies and programs, and the approach that is considered best for maximizing efficiency, is benefit-cost analysis (Litman 2001b). This compares the incremental costs and benefits of a policy or project.

Benefit-cost analysis is applied to individual policies and projects, so it is difficult to make broad conclusions as to what effect its application would have on transport decision making. However, for reasons described below, it is likely that more rigorous application of benefit-cost analysis would tend to increase the resources devoted to walking.

- As described earlier, current transportation planning practices tend to undercount walking. Better counting of walking trips will tend to recognize more demand, and therefore greater potential benefits from walkability improvements.

- Few economic analyses account for the full range of benefits from improved walkability and increased walking described in this paper. More comprehensive analysis is likely to identify greater benefits and so justify greater investments.
- Only recently have nonmotorized evaluation tools been developed, such as pedestrian level-of-service rating. Applying such tools can improve our ability to predict how a particular policy or project will affect nonmotorized travel, which can justify greater investments in walkability.
- There is increasing recognition of the diminishing economic benefits from increased highway investments (Boarnet and Haughwout, 2000; "TDM and Economic Development," VTPI 2008), the significant social costs of automobile dependency, and the large potential social benefits of a more diverse transportation system (Litman, 2001a).
- There is increasing recognition of the value of smart growth land use management to achieve social objectives ("Smart Growth," VTPI 2008). These strategies place a high value on walkability.
- Current transportation funding is biased against nonmotorized modes. Only a small portion of total transport funds may be used for nonmotorized facilities, and financial match requirements are sometimes higher. More neutral investment policies would increase the amount of money available for walking.

More comprehensive benefit-cost analysis requires better techniques to measure and predict travel impacts of improved walkability, and to evaluate the full economic impacts that result, including indirect and nonmarket impacts that are not usually quantified in transport planning such as environmental, economic development and equity impacts.

## Examples

The study, *Walking the Walk: How Walkability Raises Housing Values in U.S. Cities*, by Joseph Cortright (2009) found that improved walkability tends to increase home values. It analyzed 94,000 residential real estate transactions in 15 major U.S. markets to evaluate how various factors affect sale values, including conventional factors such as size, number of bedrooms and bathrooms, age, neighborhood income, distance from Central Business District, and access to jobs, plus Walk Score (www.walkscore.com), which calculates proximity to amenities (restaurants, coffee shops, schools, parks, stores, libraries, etc.) and assigns a rating from 0 (least walkable) to 100 (most walkable). Walk Scores of 70+ indicate neighborhoods where it's possible to get by without a car.

The study found that a one-point Walk Score increase is typically associated with an increase of $700 to $3,000 in house values, depending on the market. Shifting from average to above-average Walk Scores typically increased a home's value by $4,000 to $34,000, depending on the metro area. The gains were larger in denser, urban areas like Chicago and San Francisco and smaller in less dense markets like Tucson and Fresno.

For example, in Charlotte, NC, houses in the Ashley Park neighborhood, with Walk Score values averaging 54 have median prices of$280,000, while an otherwise similar home in the Wilmore neighborhood, which has Walk Scores averaging 71, would be valued at $314,000. Controlling for all other factors including size, number of bedrooms and bathrooms, age, neighborhood income levels, distance from the Central Business District and access to jobs, shifting a house from Ashley Park to more walkable Wilmore would increase its value by $34,000 or 12%.

Similarly, in analysis of Washington DC neighborhoods, Leinberger and Alfonzo (2012) found that as the number of urban design features that facilitate walkability and attract pedestrians increase, so do office, residential, and retail rents, retail revenues, and for-sale residential values. For example, a place with good walkability, on average, commands $302 per month more in residential rents and has for-sale residential property values of $82/sq. ft. more relative to the place with fair walkability, holding household income levels constant.

Balsas (2017) analyzed walking activity and recent efforts at augmenting walkability conditions in various cities using a WPPFUS framework which considers Walking levels, Purposes, Primacy of walking, Facilities, Unique features and Safety concerns. It recommends policies to make cities for people and not for automobiles and commitment to resolving pedestrian safety concerns, including improved design, planning, building and maintenance of streets and public spaces.

## Conclusions

Conventional transportation planning practices treat walking as a minor transport mode and recognize only modest benefits from improved walkability and increased walking activity. This results from evaluation practices that undercount nonmotorized travel and undervalue walking benefits.

From other perspectives it is clear that walking is a critical component of the transport system, and that improved walkability and increased walking can provide significant benefits to society. Improved walkability increases accessibility, provides consumer and public cost savings, increases community livability, improves public health and supports strategic economic development, land use and equity objectives. A variety of methods can be used to evaluate these impacts.

Conventional planning practices may conclude that walking currently receives a fair and efficient share of transportation resources. However, this reflects an undercounting of walking trips, an undervaluation of walking benefits, and undervaluation of motor vehicle costs. More comprehensive evaluation indicates that walking receives less than its appropriate share of transportation resources, and that walkability improvements can provide a high economic return on investment.

Greater appreciation of the full benefits of walking could change planning priorities. It would justify devoting more government funding to walking facilities and programs, shifting road space from traffic and parking lanes to sidewalks and paths, policies to create more walkable land use patterns, and greater efforts to manage motor vehicle traffic to improve walking safety and comfort. These shifts support and are supported by other transport and land use management reforms that improve transportation options, reduce automobile dependency and create more accessible land use.

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TRANSPORT REVIEWS
2021, VOL. 41, NO. 4, 401–431
https://doi.org/10.1080/01441647.2021.1912849



# Economic impacts on local businesses of investments in bicycle and pedestrian infrastructure: a review of the evidence

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**ABSTRACT**

Local officials in North America frequently face opposition to new or expanded bicycle or pedestrian facilities. The most vocal opponents are usually motorists and local business owners who fear that the removal of or reductions in vehicular parking or travel lanes will reduce patronage from motorists and that any increased patronage from pedestrians or cyclists will not offset the lost revenues. A lack of direct evidence on the economic impacts of facilities on local businesses has made it difficult to support or debunk such fears. A lack of quantitative evidence in particular has prevented the incorporation of such impacts into cost–benefit analyses. The issue has received enough attention from researchers in recent years that a review of the evidence is now warranted. We reviewed the relevant literature and identified 23 studies, focusing on the US and Canada, that either (1) quantified and compared consumer spending between active travellers and automobile users ($n = 8$), or (2) quantified an economic impact to local businesses following the installation of bicycle or pedestrian facilities ($n = 15$). Taken together, the studies indicate that creating or improving active travel facilities generally has positive or non-significant economic impacts on retail and food service businesses abutting or within a short distance of the facilities, though bicycle facilities might have negative economic effects on auto-centric businesses. The results are similar regardless of whether vehicular parking or travel lanes are removed or reduced to make room for the active travel facilities. The studies also highlight best practices for designing future research. Ten of the 15 studies that quantified an economic impact to local businesses used both before-and-after data and comparison sites or other statistical controls for variables unrelated to the active travel facility "treatment;" six of those used statistical testing.

**ARTICLE HISTORY**
Received 3 November 2020
Accepted 27 March 2021

**KEYWORDS**
Bicycle facilities; pedestrian facilities; active travel; local business; economic impacts

## Introduction

"[Safe bike lanes are a] no regret investment," European Commission Vice President Frans Timmerman, October, 2020. (Sutton, 2020)

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> "People were just crazy angry about it," Newton City Councilor Alicia Bowman, referring to opposition to the installation of a bike lane that involved the removal of parking, October, 2020. (MilNeil, 2020)

Cities across North America have often faced opposition when proposing new or expanded bicycle and pedestrian facilities. An ambitious plan to install bike lanes throughout New York City starting in 2007, for example, provoked a heated backlash that played out in community meetings, the local media, and public protests (Sadik-Khan, 2016). Although the city succeeded in installing an extensive network of 1,375 miles of bike lanes, opposition continues to bubble up when new facilities are proposed (Hu, 2021). Many other cities confronted similar if more muted controversy following the reallocation of street space to bicycles and pedestrians in response to the COVID-19 pandemic. As cities move to make the initial changes permanent, seeing them as a "no regret" approach, they often face opposition and even anger from at least some parts of the community.

The most vocal opponents in such cases are usually people who drive and local business owners. Because active travel infrastructure often requires the removal of or reduction to vehicular parking or travel lanes, opponents worry that the active travel infrastructure will make it harder to drive or park in the project area (Bubbers, 2019; Chapple, McCoy, & Poirier, 2018). Business owners worry that this will reduce patronage from customers arriving by car, and that any increased patronage from customers arriving by foot or bicycle will not offset the lost revenues (Bopp, Sims, & Piatkowski, 2018; Drennen, 2003; Liu & Shi, 2020b; McCoy, Poirier, & Chapple, 2019). This opposition can impede and even prevent approval and implementation of active travel projects. A lack of direct evidence on the economic impacts of facilities on local businesses has made it difficult to support or debunk the claims of negative economic impacts on local businesses (Hack, 2013; New York City Department of Transportation, 2013; Stantec, 2011); the lack of quantitative evidence in particular has prevented the incorporation of such impacts into cost–benefit analyses.

Although bicycle and pedestrian investments generate many direct and indirect economic impacts (Flusche, 2012; Krizek, 2007; Weigand, 2008) the direct impacts of active travel facilities on businesses abutting or in close proximity to them are often at the heart of local controversies. The issue of economic impacts on local businesses has received enough attention from researchers in recent years that a stand-alone review of the evidence is now warranted and could be especially helpful in informing local debates. In this paper we examine the literature on the economic impacts to local businesses of new or improved bicycle and pedestrian facilities. Taken together, the 23 studies we reviewed indicate that creating or improving active travel facilities generally has positive or non-significant economic impacts on retail and food service businesses abutting or within a short distance of the facilities, though bicycle facilities might have negative economic effects on auto-centric businesses (like gas stations, auto repair shops, auto parts stores, and large home-goods stores). The results are similar regardless of whether vehicular parking or travel lanes are removed or reduced to make room for the active travel facilities. Overall, the available evidence suggests that fears of disastrous consequences for local businesses are unfounded.

## Method

We reviewed the literature on the economic impacts on local businesses of creating or improving bicycle and pedestrian facilities. Guided by the types of concerns voiced by business owners and discussed above, we focused our review on studies that (1) quantified and compared consumer spending between active travellers (bicyclists or pedestrians) and automobile users, or (2) quantified an economic impact to local businesses following the installation of bicycle or pedestrian facilities. We define bicycle and pedestrian facilities as infrastructure or streetscape amenities designed to support active travel. Bicycle facilities include bicycle paths (class I facilities, though they are typically not located adjacent to local businesses), bicycle lanes (class II facilities), bicycle boulevards (class III facilities, usually demarcated with sharrows), cycle tracks (class IV facilities), and bicycle parking, for example.[1] We did not include bikeshare facilities in this review. Pedestrian facilities include sidewalks, pedestrian plazas, pedestrian seating, pedestrian crossings (or improvements thereto), and landscaping of the pedestrian space, among other amenities. We define local businesses as businesses abutting or in close proximity to the active travel facilities. We define economic impacts as the direct impacts to local businesses from creating or improving active travel facilities, indicated by such measures as local business sales (or sales tax revenues), number of customers, average visitor spending, employment, commercial vacancy rates, new business openings, and business owner perceptions. Active travel investments also have other economic impacts, ranging from the job creation and materials purchases associated with construction of active travel facilities to the indirect economic effects of improved health and safety related to active travel (Flusche, 2012; Krizek, 2007; Weigand, 2008). But we focus here on the economic impacts most visible and directly relevant to local businesses.

To identify sources, we searched the Transportation Research International Documentation (TRID) database, Web of Science, and Google Scholar in the summer of 2020 using the following search terms:

> ("bicycle facilities" OR "bicycle infrastructure") AND ("economic" OR "business" OR "property value" OR "sales"), and ("pedestrian facilities" OR "pedestrian infrastructure") AND ("economic" OR "business" OR "property value" OR "sales")

We also reviewed the reference lists from the selected sources to identify additional studies that did not appear in our web searches. Because so few peer-reviewed studies examine our topic of interest – the economic impacts on local businesses of creating or improving bicycle and pedestrian facilities – we included both peer-reviewed studies and non-peer-reviewed "gray" literature. That is why we searched Google Scholar – to locate more gray literature. In total, our searches yielded 23,320 results, 97% (22,600) of which came from our Google Scholar searches. We screened each of the 720 documents retrieved from the TRID and Web of Science searches by scanning the title, abstract, and/or other available summary. For the two Google Scholar searches, we screened about 1,000 total records, using the same scanning approach. We stopped screening once we reached 100 consecutive irrelevant records. We found 91 documents that appeared to be relevant out of the nearly 1,750 documents we screened. We reviewed the full text of those documents.

We excluded studies (either on screening or after full document review) that did not either (1) quantify and compare consumer spending between active travellers and automobile users, or (2) quantify direct impacts to local businesses from creating or improving active travel facilities, using the definitions of bicycle facility, pedestrian facility, local business, and economic impact provided above. We did not exclude studies based on research design. But we did restrict our review to original research studies; we excluded second-hard reports of study results, even if we could not find the original research document cited in the report. We also restricted our review to studies reported in the English language, studies published between 2000 and 2020, and studies in the United States and Canada. We focused on studies in the US and Canada in large part because opposition to new active travel facilities has often been fierce in those two countries (Bubbers, 2019; Chapple et al., 2018; Sadik-Khan, 2016), making this research particularly relevant and useful for planners and policymakers there. In addition, a preliminary review of our search records indicated that the vast majority of relevant English-language studies were done in the US and Canada, which is unsurprising given the relative surge in active travel projects (and accompanying opposition) there compared to European countries with more established active travel facilities (Kornas, Bornbaum, Bushey, & Rosella, 2017; Pucher, Buehler, & Seinen, 2011).

In total, we found 23 studies meeting our inclusion criteria, including 5 peer-reviewed articles, 4 research reports produced by universities, 5 reports produced by a governmental agency, 5 reports produced by a non-profit organisation or consulting firm, and 4 student theses. We examine the studies' findings and methodologies in the next section, then summarise our results and discuss the implications for practice and future research in the final section.

## Results

Table 1 lists the 23 studies, their locations, their research topics, and the number and types of facilities studied (only for the studies that quantify the economic impacts to local businesses following the installation of specific active travel facilities).

Of the 23 studies we reviewed, eight analyzed the differences in visitor spending in a commercial area by the travel mode the visitors used to get there. Three of the studies looked at Toronto, Ontario. Two studied San Francisco, California. And one each was based in Portland (Oregon), Victoria (British Columbia), and Davis (California). Taken together, the eight studies indicate that cyclists and pedestrians generally spend more per month in commercial areas than visitors who arrive by car or transit, but do not reliably spend different amounts per trip.

The remaining 15 studies analyzed the economic impacts of specific active travel facilities (or networks of facilities) on local businesses. Those studies analyzed a total of 45 unique facilities in 16 cities in the US and Canada – New York City (10 facilities), San Francisco (7), Minneapolis, Minnesota (5), Seattle, Washington (4), Denver, Colorado (3), Portland (2), Vancouver, British Columbia (2), Chicago, Illinois (2), Indianapolis, Indiana (2), Memphis, Tennessee (2), Toronto (1), Calgary, Alberta (1), Oakland, California (1), Los Angeles, California (1), and Washington, DC (1). The facilities included 35 bicycle facilities, six pedestrian facilities, and four mixed facilities with both pedestrian and bicycle infrastructure. Of the bicycle facilities, 17 were individual class IV cycle track projects, 14 were individual class II bicycle lane projects, two were class III bicycle boulevard projects, one was a group of four cycle track projects in downtown Calgary, and one was the full network of bicycle lanes and boulevards added between 1996 and 2013 in San Francisco. The pedestrian facilities included plazas, street seating, street lighting, trees and

**Table 1.** Summary of studies reviewed.

| Source | Study location | Research topic | Number of facilities | Facility types |
|---|---|---|---|---|
| Arancibia et al. (2019) | Toronto, Ontario, Canada | Economic impact to local businesses after installation of active travel facilities | 1 | Bicycle facility |
| Bent and Singa (2009) | San Francisco, California, USA | Consumer spending by travel mode | – | – |
| Chan et al. (2016) | Toronto, Ontario, Canada | Consumer spending by travel mode | – | – |
| City of Calgary (2016) | Calgary, Alberta, Canada | Economic impact to local businesses after installation of active travel facilities | Group of 4 facilities | Bicycle facilities |
| City of Oakland (2017) | Oakland, California, USA | Economic impact to local businesses after installation of active travel facilities | 1 | Bicycle facility |
| Clifton et al. (2013) | Portland, Oregon, USA | Consumer spending by travel mode | – | – |
| Drennen (2003) | San Francisco, California, USA | Economic impact to local businesses after installation of active travel facilities | 1 | Bicycle facility |
| Forkes and Smith (2010) | Toronto, Ontario, Canada | Consumer spending by travel mode | – | – |
| Liu and Shi (2020b) | Memphis, Tennessee, USA<br>Minneapolis, Minnesota, USA<br>Portland, Oregon, USA<br>San Francisco, California, USA | Economic impact to local businesses after installation of active travel facilities | 7 | Bicycle facilities and pedestrian facilities |
| Liu and Shi (2020a) | Indianapolis, Indiana, USA<br>Minneapolis, Minnesota, USA<br>Seattle, Washington, USA | Economic impact to local businesses after installation of active travel facilities | 7 | Bicycle facilities and pedestrian facilities |
| McCormick (2012) | Los Angeles, California, USA | Economic impact to local businesses after installation of active travel facilities | 1 | Bicycle facility |
| McCoy et al. (2019) | San Francisco, California, USA | Economic impact to local businesses after installation of active travel facilities | Entire network | Bicycle facilities |
| Monsere et al. (2014) | Austin, Texas, USA<br>Chicago, Illinois, USA<br>Portland, Oregon, USA<br>San Francisco, California, USA<br>Washington, DC, USA | Economic impact to local businesses after installation of active travel facilities | 6 | Bicycle facilities |
| New York City (2012) | New York City, New York, USA | Economic impact to local businesses after installation of active travel facilities | 4 | Bicycle facilities, pedestrian facilities, and mixed facilities |
| New York City (2013) | | | 6 | |

(*Continued*)

**Table 1.** Continued.

| Source | Study location | Research topic | Number of facilities | Facility types |
|---|---|---|---|---|
| | New York City, New York, USA | Economic impact to local businesses after installation of active travel facilities | | Bicycle facilities, pedestrian facilities, and mixed facilities |
| Poirier (2018) | San Francisco, California, USA | Economic impact to local businesses after installation of active travel facilities | 3 | Bicycle facilities |
| Popovich and Handy (2014) | Davis, California, USA | Consumer spending by travel mode | - | - |
| Rijo (2015) | Denver, Colorado, USA | Economic impact to local businesses after installation of active travel facilities | 3 | Bicycle facilities |
| Rowe (2013) | Seattle, Washington, USA | Economic impact to local businesses after installation of active travel facilities | 2 | Bicycle facilities |
| San Francisco City Transportation Authority (2010) | San Francisco, California, USA | Consumer spending by travel mode | - | - |
| Stantec (2011) | Vancouver, British Columbia, Canada | Economic impact to local businesses after installation of active travel facilities | 2 | Bicycle facilities |
| Straatsma and Berkhout (2014) | Victoria, British Columbia, Canada | Consumer spending by travel mode | – | – |
| Sztabinski (2009) | Toronto, Ontario, Canada | Consumer spending by travel mode | – | – |

landscaping, medians, and various other streetscape additions or alterations, often in combination. The mixed facilities were all located in New York City and paired either cycle tracks or bike lanes with streetscape improvements for pedestrians. Most of the 15 studies assessed the economic impact of the facilities with before and after data on local business sales, but some used number of customers, self-reported customer spending, commercial vacancy rates, commercial property values, employment, or business owner perceptions. Most (11) of the studies also compared data from comparison sites. Only six of the studies used statistical testing to improve their inferences. Taken together, the 15 studies indicate that creating or improving active travel facilities generally has positive or non-significant economic impacts on retail and food service businesses abutting or within a short distance of the facilities.

The rest of the results section is split by topic. We first discuss the eight studies on visitor spending by travel mode. We then discuss the 15 studies on the economic impacts of specific active travel facilities, with subsections for bicycle facilities, pedestrian facilities, and mixed facilities.

## *Spending by travel mode*

One indication of the direction of the economic impact to local businesses of adding active travel facilities in the same area is the difference in spending habits of visitors based on the travel mode they use to get there. It is generally well established in the active travel literature that adding bicycle and pedestrian facilities to an area tends to increase cyclist and pedestrian use of that area (Volker, Handy, Kendall, & Barbour, 2019a, 2019b). That increased use should translate into increased spending at local businesses in the area if consumer spending remains the same among visitors who arrive by other travel modes (like driving and transit). However, business owners often worry that adding active travel facilities will dissuade motorists from visiting the area, leading to a net decline in spending (Bopp et al., 2018; Drennen, 2003; Liu & Shi, 2020b; McCoy et al., 2019). The net effect on spending depends on two factors: changes in the number of trips by each mode after installation of an active travel facility, and the average spending of each group of consumers (by travel mode).

At least eight studies have compared visitor spending by travel mode. Table 2 summarises the location, methods, and findings of the eight studies.

Four of the studies were in the US, and four were in Canada. Six of the studies – two in San Francisco, three in Toronto, and one in Victoria – were done via intercept surveys of adult passersby in downtowns or retail corridors of urban areas. One study utilised cross-sectional surveys of residents of an entire city, with questions targeted at consumer spending in the downtown area of Davis, California (Popovich & Handy, 2014). Another study used exit surveys of patrons leaving restaurants, bars, and convenience stores across a range of neighbourhood types in Portland, Oregon (Clifton et al., 2013).

All eight studies calculated and compared *per-month* spending by travel mode, which reflects the combination of number of trips and spending per trip. Six of the studies concluded that cyclists and/or pedestrians spent more per month than motorists, though only two of them confirmed that the amounts were statistically different (Forkes & Smith, 2010; Popovich & Handy, 2014). The Portland study found that cyclists and pedestrians spent more, on average, at restaurants, bars, and convenience stores than those who drove, but motorists spent more at supermarkets (Clifton et al., 2013). The eighth study – one of the three Toronto studies – found no statistically significant difference between how likely motorists and non-motorists were to spend over $100 per month (Straatsma & Berkhout, 2014).

Four of the eight studies also analyzed *per-trip* spending by travel mode. The results were more mixed. Both San Francisco studies found that those who arrived on foot and those who arrived by bike, taxi, or other (a lumped category) spent less per trip than motorists on average (Bent & Singa, 2009; San Francisco City Transportation Authority, 2010), though neither tested the results statistically. A study from a smaller California city (Davis) found that cyclists spent more on average on downtown retail purchases than motorists (food service, bar, and other service business purchases were excluded), a difference which was marginally significant statistically ($p = 0.128$) (Popovich & Handy, 2014). The Portland study found that pedestrians spent more on average at bars than motorists, but less at restaurants and convenience stores, and much less at supermarkets. It found that cyclists spent more on average at convenience stores than motorists, but less at restaurants and bars, and much less at supermarkets. The study also found that both cyclists and pedestrians spent much less at supermarkets than motorists, though the supermarkets were located in less urban areas (only 3 of 11 in central business districts or urban core neighbourhoods) than the restaurants (22 of 39), bars (9 of 13), and convenience stores (9 of 26) (Clifton et al., 2013). The latter findings is not surprising, given that grocery shoppers are limited in their purchases by the hauling capacity of their chosen

**Table 2.** Summary of studies on consumer spending by travel mode.

| Source | City | Area & context | Method | Mode | Spending/ trip | Spending/ month |
|---|---|---|---|---|---|---|
| Bent and Singa (2009) | San Francisco, California, USA | Downtown | Intercept surveys ($n$ = 1,187) | Walk<br>Bike/taxi/other<br>Transit<br>Auto | \$47<br>\$62<br>\$40<br>\$88 | \$291<br>\$152<br>\$274<br>\$259 |
| Chan et al. (2016) | Toronto, Ontario, Canada | Queen Street (a commercial corridor near downtown) | Intercept surveys ($n$ = 698) | Walk | - | 58% spend > \$100 |
| | | | | Bike | - | 57% spend > \$100 |
| | | | | Transit | - | 39% spend > \$100 |
| | | | | Auto | - | 37% spend > \$100 |
| Clifton et al. (2013) | Portland, Oregon, USA | 13 bars, across a range of contexts (CBDs, urban cores, and regional centres) in the Portland metropolitan region | Intercept surveys as patrons left businesses ($n$ = 99) | Walk<br>Bike<br>Transit<br>Auto | \$22.30<br>\$16.90<br>\$19.00<br>\$19.98 | \$63.94<br>\$81.90<br>\$36.25<br>\$40.78 |
| Clifton et al. (2013) | Portland, Oregon, USA | 26 convenience stores across a range of contexts (CBDs, urban cores, regional centres, suburban town centres, and suburban areas) in the Portland metropolitan region | Intercept surveys as patrons left businesses ($n$ = 260) | Walk<br>Bike<br>Transit<br>Auto | \$6.02<br>\$7.95<br>\$7.46<br>\$7.61 | \$64.81<br>\$81.76<br>\$60.37<br>\$68.95 |
| Clifton et al. (2013) | Portland, Oregon, USA | 39 restaurants across a range of contexts (CBDs, urban cores, regional centres, suburban town centres, and suburban areas) in the Portland metropolitan region | Intercept surveys as patrons left businesses ($n$ = 281) | Walk<br>Bike<br>Transit<br>Autos | \$17.56<br>\$10.97<br>\$15.64<br>\$19.52 | \$32.01<br>\$48.40<br>\$49.39<br>\$40.06 |
| Clifton et al. (2013) | Portland, Oregon, USA | 11 supermarkets restaurants across a range of contexts (urban cores, regional centres, suburban town centres, and suburban areas) in the Portland metropolitan region | Intercept surveys as patrons checked out or left businesses ($n$ = 17,919) | Walk<br>Bike<br>Transit<br>Autos | \$31.42<br>\$36.61<br>\$35.86<br>\$57.39 | \$386.18<br>\$337.83<br>\$300.58<br>\$440.19 |
| Forkes and Smith (2010) | Toronto, Ontario, Canada | Bloor Street (a retail corridor) | Intercept surveys ($n$ = 510) | Non-auto | - | Significantly more likely to spend >\$100 ($p$<0.000) |
| | | | | Auto | - | Significantly less likely to spend >\$100 ($p$<0.000) |

(*Continued*)

**Table 2.** Continued.

| Source | City | Area & context | Method | Mode | Spending/ trip | Spending/ month |
|---|---|---|---|---|---|---|
| Popovich and Handy (2014) | Davis, California, USA | Downtown Davis (material goods retailers only) | Random cross-sectional surveys of city residents | Bike<br>Auto | \$59.16<br>\$53.83 | \$248.62<br>\$182.10 |
| San Francisco City Transportation Authority (2010) | San Francisco,z California, USA | Columbus Avenue (a residential and retail corridor) | Intercept surveys (n~800) | Walk<br>Bike/taxi/other<br>Transit<br>Auto | \$36<br>\$41<br>\$36<br>\$52 | \$360<br>\$328<br>\$252<br>\$208 |
| Straatsma and Berkhout (2014) | Victoria, British Columbia, Canada | Downtown | Intercept surveys ($n =$ 504) | Walk<br>Bike<br>Transit<br>Auto | - | No significant difference in reported monthly spending between modes |
| Sztabinski (2009) | Toronto, Ontario, Canada | Bloor Street (a retail corridor) | Intercept survey | Walk | - | 76% reported spending ≥\$100 |
| | | | | Bike | - | 50% reported spending ≥\$100 |
| | | | | Transit | - | 34% reported spending ≥\$100 |
| | | | | Auto | - | 39% reported spending ≥\$100 |

transportation mode (Clifton et al., 2013). One could expect a similar result at any business where large-volume purchases are common, like big-box retail stores.

Taken together, the four studies reporting on spending per trip indicate that active travellers do not reliably spend more or less per trip in urban downtowns or retail corridors than motorists. That would mean that adding a bicycle or pedestrian facility to an urban downtown or retail corridor would not reduce consumer spending at local businesses – especially restaurants, bars, and smaller retail stores – unless it reduced more motorist trips to those businesses than the number of additional cyclist and pedestrian trips it generated.

## *Economic impacts of bicycle and pedestrian facilities*

The second group of studies reviewed provides more direct measures of the direction and magnitude of the economic impact on local businesses. At least 15 studies have analyzed the economic impacts of specific active travel facilities (or networks of facilities) on local businesses abutting or within a short distance of the facilities. The studies used a wide range of methods to assess the economic impact of 45 unique active travel facilities (35 bicycle facilities or facility networks, six pedestrian facilities, and four projects with both bicycle and pedestrian facilities) in business districts, commercial corridors, or other urban areas across 16 cities in the US and Canada. Tables 3–5 summarise the studies of bicycle facilities, pedestrian facilities, and mixed facilities, respectively. The tables include the location and a description of facilities added and removed, the metrics used to gauge the economic impacts on local businesses, the analytic method used, the use of control sites, the study timeframe, and the directional results by metric (positive economic impact, negative impact, or an unclear or non-significant effect).

The studies use a wide range of metrics to gauge the economic effects on local businesses, including retail and/or food service sales (used for 31 of the facilities), employment (14 facilities), visitor spending (nine facilities), number of customers (eight facilities), commercial vacancy rates or number of new businesses (five facilities), commercial property values (one facility), and merchant perceptions (one facility). Some studies use more than one metric for each facility (Arancibia et al., 2019; City of Calgary, 2016; City of Oakland Department of Transportation, 2017; Liu & Shi, 2020a, 2020b; McCormick, 2012; Poirier, 2018). Regardless of metric, 12 of the 15 studies (analyzing 37 facilities) compared economic data from before and after the active travel facility was completed. The other three studies surveyed either businesses (Drennen, 2003; Stantec, 2011) or local residents (Monsere et al., 2014) after the facilities were completed to gauge how much the facility had affected business sales or patronage.

Knowing how much an economic indicator changes after an active travel facility intervention is essential to understanding the facility's economic impact on local businesses. But it is not sufficient: "Because urban economies are a complex system, changes in sales for individual businesses can be the result of many different factors; street design is just one" (New York City Department of Transportation, 2013, p. 11). To get a truer picture of the economic impact of active travel facilities on local businesses, it is important to control for variables unrelated to the active travel facility "treatment", either with statistical modelling and/or by using a comparison site that had similar baseline characteristics but was not treated with an active travel facility (or accompanying removal of or reduction in vehicular travel facilities).

Eleven of the 15 studies (analyzing 37 facilities) compared the economic effects on businesses abutting or within a short distance of the active travel facilities to those in one or more "control" sites (Arancibia et al., 2019; Liu & Shi, 2020a, 2020b; McCormick, 2012; McCoy et al., 2019; New York City Department of Transportation, 2012, 2013; Poirier, 2018; Rijo, 2015; Rowe, 2013; Stantec, 2011). Ten of those studies used data from both before and after the facility installation; only Stantec (2011) did not. And six of the studies (analyzing 20 facilities) used statistical testing techniques to better discern whether the active travel treatments were indeed correlated with – if not the cause of – changes in economic indicators (Arancibia et al., 2019; Liu & Shi, 2020a, 2020b; McCormick, 2012; McCoy et al., 2019). Those six studies provide a more internally valid indication of the direction of the economic impact of active travel facilities on local businesses than the studies that only present descriptive statistics of the economic impact metrics. The six studies all show either a statistically significant positive correlation (eleven bicycle facilities and two pedestrian facilities) or no statistically significant effect one way or the other (seven bicycle facilities), as shown in Tables 3 and 4 and discussed by facility type below. None of the studies shows a negative correlation.

The nine studies that did not use statistical testing also found positive economic outcomes for a majority of the studied active travel facilities. They found positive effects for 10 bicycle facilities (City of Oakland Department of Transportation, 2017; Drennen, 2003; Monsere et al., 2014; New York City Department of Transportation, 2012, 2013; Poirier,

**Table 3.** Summary of studies on the economic impacts of bicycle facilities on local businesses.

| Source | City and street | Added | Removed | Length | Analytic method | Study timeframe | Measure | Effect |
|---|---|---|---|---|---|---|---|---|
| Arancibia et al. (2019) | Toronto, Ontario, Canada – Bloor Street[a] | Bike lanes on both sides of the street | 136 on-street vehicular parking spaces | ~1.5 miles | Descriptive statistics, difference-in-proportions testing, difference-in-difference analysis, and logistic regression; control = yes | 8 months pre-installation to 9 months post-installation | Monthly spending by visitors | Positive, but no sig. diff. from control |
| | | | | | | | Commercial vacancy rate | No or unclear effect |
| | | | | | | | Number of customers – retail stores | Positive |
| | | | | | | | Number of customers – food service/bars | Positive |
| | | | | | | | Number of customers – service businesses | Positive |
| | | | | | | | Overall conclusion | No negative economic impact |
| City of Calgary (2016) | Calgary, Alberta, Canada – 8th Avenue, 9th Avenue, 12th Avenue, 5th Street[b] | Two-way cycle tracks on all four streets | Unclear | ~4.0 miles across all four facilities | Descriptive statistics; control = no | 9 months pre-installation to 15 months post-installation | Weekly spending by visitors (visitor intercept survey) | Negative |
| | | | | | | | Weekly visits to businesses (visitor intercept survey) | No or unclear effect |
| | | | | | | | Customers per day (merchant survey) | Negative |
| City of Oakland (2017) | Oakland, California, USA – Telegraph Avenue[b] | Parking-protected cycle tracks on both sides of the street | One vehicular travel lane in each direction | ~0.5 miles | Descriptive statistics; control = no | 7 months pre-installation to 5 months post-installation | Retail sales tax revenues | Positive |
| | | | | | | | New businesses | Positive |
| Drennen (2003) | San Francisco, California, USA – Valencia Street[a] | Bike lanes on both sides of the street | One vehicular travel lane | ~2.0 miles | Descriptive statistics; control = no | 4.5 years post-installation | Merchant perceptions of "impact on business and sales" | Positive |
| Liu and Shi (2020b) | Memphis, Tennessee, USA – Madison Avenue[b] | Bike lanes on both sides of the street | One vehicular travel lane in each direction | ~1.25 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, interrupted time | Multiple years pre- and post-installation | Retail sales | Positive |
| | | | | | | | Retail employment | Negative |
| | | | | | | | Food service sales | No or unclear effect |

(*Continued*)

**Table 3.** Continued.

| Source | City and street | Added | Removed | Length | Analytic method | Study timeframe | Measure | Effect |
|---|---|---|---|---|---|---|---|---|
| | | | | | series; control = yes | | | |
| Liu and Shi (2020b) | Memphis, Tennessee, USA – Broad Avenue[b] | Two-way parking-protected bike lane | Width of travel lanes reduced | ~0.3 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, interrupted time series; control = yes | Multiple years pre- and post-installation | Retail sales | No or unclear effect |
| | | | | | | | Retail employment | No or unclear effect |
| | | | | | | | Food service employment | Positive |
| Liu and Shi (2020b) | Minneapolis, Minnesota, USA – Central Avenue[b] | Bike lanes on both sides of the street | Width of travel lanes reduced | ~1.25 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, interrupted time series; control = yes | Multiple years pre- and post-installation | Retail sales | No or unclear effect |
| | | | | | | | Retail employment | Positive |
| | | | | | | | Food service sales | Positive |
| | | | | | | | Food service employment | Positive |
| Liu and Shi (2020b) | Minneapolis, Minnesota, USA – Franklin Avenue[b] | Bike lane | One parking lane | ~0.75 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, interrupted time series; control = yes | Multiple years pre- and post-installation | Retail employment | No or unclear effect |
| | | | | | | | Food service employment | Positive |
| Liu and Shi (2020b) | San Francisco, California, USA – 17th Street[b] | Bike lanes on both sides of the street | Some vehicular parking | ~0.5 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, interrupted time series; control = yes | Multiple years pre- and post-installation | Retail sales | Positive or no effect |
| | | | | | | | Retail employment | Positive or no effect |
| | | | | | | | Food service sales | Negative or no effect |
| | | | | | | | Food service employment | Negative or no effect |
| Liu and Shi (2020b) | Portland, Oregon, USA – Stark Street & Oak Street Corridor[b] | A bike lane on each of two parallel one-way streets | One vehicular travel lane on each street | ~0.75 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, | Multiple years pre- and post-installation | Retail sales | Positive |
| | | | | | | | Retail employment | Positive |
| | | | | | | | Food service sales | Positive or no effect |
| | | | | | | | Food service employment | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | interrupted time series; control = yes | | | No or unclear effect |
| Liu and Shi (2020a) | Indianapolis, Indiana, USA – Massachusetts Avenue[b] | Two-way cycle track | One vehicular travel lane | ~0.3 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, interrupted time series; control = yes | Multiple years pre- and post-installation | Retail employment | No or unclear effect |
| | | | | | | | Food service employment | Positive |
| Liu and Shi (2020a) | Indianapolis, Indiana, USA – Virginia Avenue[b] | Two-way cycle track | One vehicular travel lane | ~0.75 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, interrupted time series; control = yes | Multiple years pre- and post-installation | Retail employment | No or unclear effect |
| | | | | | | | Food service employment | Positive |
| | | | | | | | Food service sales | Positive |
| | | | | | | | Food service wages | Positive |
| Liu and Shi (2020a) | Minneapolis, Minnesota, USA – Riverside Avenue[b] | Bike lanes on both sides of the street | One vehicular travel lane | ~0.75 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, interrupted time series; control = yes | Multiple years pre- and post-installation | Retail sales | No or unclear effect |
| | | | | | | | Retail employment | No or unclear effect |
| | | | | | | | Food service sales | No or unclear effect |
| | | | | | | | Food service employment | No or unclear effect |
| Liu and Shi (2020a) | Minneapolis, Minnesota, USA – North Second Street[b] | Bike lanes on both sides of the street | One vehicular parking lane and width reduction of vehicular travel lanes | ~3.25 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, interrupted time series; control = yes | Multiple years pre- and post-installation | Retail sales | Positive |
| | | | | | | | Retail employment | No or unclear effect |
| | | | | | | | Food service employment | Positive |
| Liu and Shi (2020a) | Seattle, Washington, USA – Second Avenue[b] | Two-way cycle track | Parking lane and one vehicular travel lane replaced with a | ~0.75 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, | Multiple years pre- and post-installation | Retail employment | Positive |
| | | | | | | | Food service employment | No or unclear effect |

(Continued)

**Table 3.** Continued.

| Source | City and street | Added | Removed | Length | Analytic method | Study timeframe | Measure | Effect |
|---|---|---|---|---|---|---|---|---|
| | | | combo left-turn/ parking lane | | Interrupted time series; control = yes | | | |
| Liu and Shi (2020a) | Seattle, Washington, USA – Broadway[b] | Two-way cycle track | Various re-arrangements | ~1.25 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, interrupted time series; control = yes | Multiple years pre- and post-installation | Retail employment | No or unclear effect |
| | | | | | | | Food service employment | Positive |
| McCormick (2012) | Los Angeles, California, USA – York Boulevard[c] | Bike lanes on both sides of the street | Two vehicular travel lanes replaced with a centre turn lane | ~1.3 miles | Descriptive statistics, difference-in-means testing, difference-in-proportions testing, hedonic price modelling; control = yes | 5 years pre-installation to 6 years post-installation | Commercial property values | No or unclear effect |
| | | | | | | | Sales tax revenue | No or unclear effect |
| | | | | | | | Business turnover | No or unclear effect |
| | | | | | | | New business openings | No or unclear effect |
| McCoy et al. (2019) | San Francisco, California, USA[d] | Bike lanes or bike boulevards | Varies | Varies | Descriptive statistics, difference-in-means testing, multivariate regression; control = yes | 1996–2014 (number of years of pre- and post-installation data varies – depends on the construction date of the nearest bicycle facility) | Business sales (storefront retail, food service, and other service-providing businesses) | Mostly no effect, except negative effect for auto-oriented and home goods business on corridors with bike lanes |
| Monsere et al. (2014) | Austin, Texas, USA – Barton Springs Road[e] | One-way cycle track | Nothing | ~0.5 miles | Descriptive statistics; control = no | ~1 year post-installation | Likelihood of nearby residents visiting a business on the corridor (from post-intervention survey) | Positive |
| Monsere et al. (2014) | Chicago, Illinois, USA – Dearborn Street[b] | Two-way cycle track | One vehicular travel lane and 21 vehicular parking spaces | ~1.2 miles | Descriptive statistics; control = no | ~1 year post-installation | Likelihood of nearby residents visiting a business on the corridor (from post-intervention survey) | Negative |
| | | One-way cycle tracks on both | Parts of a dedicated turn or bus lane | ~0.8 miles | Descriptive statistics; control = no | ~1 year post-installation | Likelihood of nearby residents visiting a | Negative |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Monsere et al. (2014) | Chicago, Illinois, USA – Milwaukee Avenue[b] | sides of the street | and 69 vehicular parking spaces | | | | business on the corridor (from post-intervention survey) | |
| Monsere et al. (2014) | Portland, Oregon, USA – NE Multnomah Street[b] | One-way cycle tracks on both sides of the street and 27 vehicular parking spaces | Bike lanes on both sides of the street and two vehicular travel lanes | ~0.8 miles | Descriptive statistics; control = no | ~1 year post-installation | Likelihood of nearby residents visiting a business on the corridor (from post-intervention survey) | Positive |
| Monsere et al. (2014) | San Francisco, California, USA – Oak and Fell Streets[c] | One-way cycle tracks along a couplet of one-way streets | 28 vehicular parking spaces on one street and 27 on the other, plus a bike lane on one street | ~0.3 miles | Descriptive statistics; control = no | ~1 year post-installation | Likelihood of nearby residents visiting a business on the corridor (from post-intervention survey) | Positive |
| Monsere et al. (2014) | Washington, D.C., USA – L Street[b] | One-way cycle track | Parts of a vehicular travel lane and 150 vehicular parking spaces | 1.12 miles | Descriptive statistics; control = no | ~1 year post-installation | Likelihood of nearby residents visiting a business on the corridor (from post-intervention survey) | Positive |
| New York City (2012) | New York City, New York, USA – First and Second Avenues[b] | One-way cycle tracks on both streets, and dedicated bus lanes on both streets | Unclear | Unclear | Descriptive statistics; control = yes | 1 year pre-installation to 3 years post-installation | Commercial vacancy rate | Positive (reduced vacancy) |
| New York City (2013) | New York City (Manhattan), New York, USA – 9th Avenue[b] | Cycle track (one-way street) | One vehicular travel lane replaced with a left-turn lane | ~0.5 miles | Descriptive statistics, aggregated trend analysis; control = yes | 1 year pre-installation to 3 years post-installation | Retail and food service sales | Positive |
| Poirier (2018) | San Francisco, California, USA – Valencia Street[a] | Bike lanes on both sides of the street | One vehicular travel lane | ~2.0 miles | Descriptive statistics; control = yes | 2 years pre-installation to 2 years post-installation | Total sales at local-serving businesses | Positive |
| | | | | | | | Total sales at all businesses | Positive |
| | | | | | | | Sales/employee at local-serving businesses | Positive |
| Poirier (2018) | San Francisco, California, USA – | Sharrows on one vehicular | Unclear | ~0.3 miles | Descriptive statistics; control = yes | 2 years pre-installation to 2 years post-installation | Total sales at local-serving businesses | Positive |
| | | | | | | | | Negative |

(*Continued*)

**Table 3.** Continued.

| Source | City and street | Added | Removed | Length | Analytic method | Study timeframe | Measure | Effect |
|---|---|---|---|---|---|---|---|---|
| | Columbus Avenue[c] | travel lane in each direction | | | | | Total sales at all businesses | |
| | | | | | | | Sales/employee at local-serving businesses | Negative |
| | | | | | | | Sales/employee at all businesses | Positive |
| Poirier (2018) | San Francisco, California, USA – Polk Street[a] | Bike lane on one side of the street | Unclear | ~0.25 miles | Descriptive statistics; control = yes | 2 years pre-installation to 2 years post-installation | Total sales at local-serving businesses | Positive |
| | | | | | | | Total sales at all businesses | Negative |
| | | | | | | | Sales/employee at local-serving businesses | Positive |
| | | | | | | | Sales/employee at all businesses | Negative |
| Rijo (2015) | Denver, Colorado, USA – Larimer Street[a] | Bike lanes on both sides of the street | One vehicular travel lane | ~1.0 miles | Descriptive statistics, aggregated trend analysis; ANOVA with post-hoc means difference test; control = yes | 20 months pre-installation to 3 years post-installation | Total sales at retail, food services, accommodations, and some arts, entertainment and recreation businesses | Positive |
| | | | | | | | Total sales tax revenues from retail, food services, accommodations, and some arts, entertainment and recreation businesses | Positive |
| Rijo (2015) | Denver, Colorado, USA – 15th Street[b] | Cycle track (one-way street) | One vehicular travel lane | ~0.7 miles | Descriptive statistics, aggregated trend analysis; ANOVA with post-hoc means difference test; control = yes | 38 months pre-installation to 15 months post-installation | Total sales tax revenues from retail, food services, accommodations, and some arts, entertainment and recreation businesses | Positive |
| Rijo (2015) | Denver, Colorado, USA – 15th Street[b] | Sharrows on one vehicular travel lane (one-way street) | Nothing | ~0.3 miles | Descriptive statistics, aggregated trend analysis; ANOVA with post-hoc | 38 months pre-installation to 15 months post-installation | Total sales tax revenues from retail, food services, accommodations, and some arts, | No effect |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | means difference test; control = yes | | entertainment and recreation businesses | |
| Rowe (2013) | Seattle, Washington, USA – Greenwood Avenue North[b] | Bike lanes on both sides of the street | One vehicular travel lane | ~1.0 miles | Descriptive statistics, aggregated trend analysis; control = yes | 1 year pre-installation to 2 years post-installation | Retail sales | No effect or unclear |
| Rowe (2013) | Seattle, Washington, USA – NE 65th Street[b] | Bike lane on one side of the street and sharrows on the other side | 12 vehicular parking spots | Unclear | Descriptive statistics, aggregated trend analysis; control = yes | 1.5 years pre-installation to 1.25 years post-installation | Retail sales | Positive |
| Stantec (2011) | Vancouver, British Columbia, Canada – Dunsmuir Street[b] | Two-way cycle track | One-way bike lane and 16 parking spaces | ~0.5 miles | Descriptive statistics; control = yes | 1 year post-installation | Self-reported sales from retail, service, and hotel businesses | Negative |
| Stantec (2011) | Vancouver, British Columbia, Canada – Hornby Street[b] | Two-way cycle track | One-way bike lane and 156 parking spaces | ~1.25 miles | Descriptive statistics; control = yes | 6 months post-installation | Self-reported sales from retail, service, and hotel businesses | Negative |

[a]Retail corridor; [b]Business district; [c]Mixed residential and commercial corridor; [d]Mixed commercial and recreational corridor; [e]All streets in the city with class II or class III bicycle facilities added between 1996 and 2013.

**Table 4.** Summary of studies on the economic impacts of pedestrian facilities on local businesses.

| Source | City and street | Added | Removed | Length | Analytic method | Study timeframe | Measure | Effect |
|---|---|---|---|---|---|---|---|---|
| Liu and Shi (2020b) | San Francisco, California, USA – Polk Street[a] | Street trees and lighting | One vehicular travel lane | ~0.5 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, interrupted time series; control = yes | Multiple years pre- and post-installation | Retail sales<br>Retail employment<br>Food service sales | Positive<br>Positive or no effect<br>Positive |
| Liu and Shi (2020a) | Minneapolis, Minnesota, USA – Lyndale Avenue South[a] | Landscaped median, curb extensions, ADA upgrades, and pedestrian-scaled lighting | One vehicular travel lane in each direction | ~3.0 miles | Descriptive statistics, aggregated trend analysis, difference-in-difference analysis, interrupted time series; control = yes | Multiple years pre- and post-installation | Retail sales<br>Retail employment<br>Food service sales<br>Food service employment | Positive<br>No or unclear effect<br>No or unclear effect<br>Positive |
| New York City (2012) | New York City (Brooklyn), New York, USA – Pearl Street[a] | Pedestrian plaza | Unclear | Unclear | Descriptive statistics; control = yes | 1 year pre-installation to 3 years post-installation | Retail and food service sales | Positive |
| New York City (2012) | New York City (Manhattan), New York, USA – Pearl Street[a] | Seasonal seating area for local patrons | One vehicular travel lane | Unclear | Descriptive statistics; control = yes | 1 year pre-installation to 3 years post-installation | Retail and food service sales | Positive |
| New York City (2013) | New York City (Manhattan), New York, USA – St. Nicholas/ Amsterdam Avenue[b] | Intersection re-designed to reduce vehicle-pedestrian conflict points, narrow pedestrian crossings, and convert roadway to landscaped pedestrian space with seating; some vehicular parking added | Reduced the number of travel lanes entering the intersection | ~0.25 miles (across all streetscape improvements) | Descriptive statistics, aggregated trend analysis; control = yes | 1 year pre-installation to 2 years post-installation | Retail and food service sales | Positive |
| New York City (2013) | New York City (Brooklyn), New York, USA – Willoughby Plaza[a] | A plaza with seating, trees, and planters | Vehicular travel lanes and parking | ~0.1 miles | Descriptive statistics, aggregated trend analysis; control = yes | 1 year pre-installation to 3 years post-installation | Retail and food service sales | Positive |
| New York City (2013) | New York City (Manhattan), New York, USA – Columbus Avenue[b] | Parking-protected bike lane (one way); landscaped pedestrian safety islands | Vehicular travel lanes were narrowed | ~1.0 miles | Descriptive statistics, aggregated trend analysis; control = yes | 1 year pre-installation to 2 years post-installation | Retail and food service sales | No or unclear effect |

[a]Business district; [a]Mixed residential and commercial corridor or hub.

2018; Rowe, 2013), four pedestrian facilities (New York City Department of Transportation, 2012, 2013), and three mixed facilities (New York City Department of Transportation, 2012, 2013). They found no or unclear effects for three bicycle facilities and one mixed facility (Poirier, 2018; Rowe, 2013). And they found negative effects for five bicycle facilities (City of Calgary, 2016; Monsere et al., 2014; Stantec, 2011).

Overall, the studies indicate positive effects for the vast majority of active travel facilities – 57% for bicycle facilities, 100% for pedestrian facilities, and 75% for mixed facilities. However, the differences in contexts, facility types, and economic indicators and analytic methods used between the 15 studies prevent estimation of an average magnitude of the effect. The 15 studies are discussed in more detail in the next three subsections, organised by facility type (bicycle, pedestrian, and mixed).

### *Bicycle facilities*

All 15 studies analyzed at least one bicycle facility (Table 3). The 15 studies estimated the economic impact on local businesses of 35 unique bicycle facilities, including 17 individual cycle track projects, 14 individual bicycle lane projects (one of which – the Valencia Street bicycle lane in San Francisco – was analyzed by two different studies: Drennen, 2003; Poirier, 2018), two bicycle boulevard projects, a group of four cycle track projects in downtown Calgary (City of Calgary, 2016), and the full network of bicycle lanes and boulevards added between 1996 and 2013 in San Francisco (McCoy et al., 2019). The individual facilities ranged in length from 0.25 miles to 3.25 miles, with averages of 0.71 miles for cycle track facilities, 1.2 miles for bicycle lanes, and 0.3 miles for bicycle boulevards.

The studies found positive economic effects for 20 of the 35 facilities (57% of the facilities), including 14 facilities that were accompanied by vehicular travel lane removal or width reduction, or removal of on-street vehicular parking spaces. The studies found unclear or no significant economic effects for 10 facilities (29%), including the entire network of class II (bike lanes) and class III (bicycle boulevards) facilities in San Francisco that were added between 1996 and 2013 (McCoy et al., 2019). The studies found negative economic effects for five facilities (14%), including the group of four cycle track projects in downtown Calgary. But none of the three studies that reported negative economic effects used statistical testing, and all of them had additional limitations that prevent statistically supported conclusions about the economic effect (City of Calgary, 2016; Monsere et al., 2014; Stantec, 2011). By contrast, the six studies (analyzing 18 facilities) that used statistical testing techniques found either positive or no significant economic impact on local businesses.

The two most recent studies to use statistical testing are Liu and Shi (2020a and 2020b). They are also the most comprehensive in terms of the number of geographies studied and the breadth of statistical modelling employed. The two studies analyzed the economic impacts from 12 bicycle facility additions, including two in Indianapolis, two in Memphis, four in Minneapolis, one in Portland, one in San Francisco, and two in Seattle. There were seven class II bike lanes and five class IV cycle tracks. The authors first selected at least one comparison corridor for each facility. They then applied aggregated trend analysis as well as two quasi-experimental econometric modelling techniques – difference-in-difference analysis and interrupted time series analysis. They used four sources of data (Census Longitudinal Employer-Household Dynamics data, Quarterly Census of Employment and Wages data, retail sales tax data, and National Establishment Time

**Table 5.** Summary of studies on the economic impacts of mixed bicycle and pedestrian facilities on local businesses.

| Source | City and street | Added | Removed | Length | Analytic method | Study timeframe | Measure | Effect |
|---|---|---|---|---|---|---|---|---|
| New York City (2012) | New York City, New York, USA – Union Square North[b] | One-way cycle track, pedestrian plaza, and redesigned intersections | Unclear | Unclear | Descriptive statistics; control = yes | 1 year pre-installation to 3 years post-installation | Commercial vacancy rate | Positive (reduced vacancy) |
| New York City (2013) | New York City (Brooklyn), New York, USA – Vanderbilt Avenue[a] | Bike lanes on both sides of the street, pedestrian safety islands, and a tree-lined median on one block | One vehicular travel lane in each direction replaced with a centre turn lane | ~0.3 miles | Descriptive statistics, aggregated trend analysis; control = yes | 1 year pre-installation to 3 years post-installation | Retail and food service sales | Positive |
| New York City (2013) | New York City (Bronx), New York, USA – Bronx Hub[a] | Curb bulbouts and other pedestrian space, planters, trees, and a network of new bike lanes in and out of the area | Reduced the number of travel lanes entering the intersection | ~0.5 miles (across all streetscape improvements) | Descriptive statistics, aggregated trend analysis; control = yes | 1 year pre-installation to 3 years post-installation | Retail and food service sales | Positive |
| New York City (2013) | New York City (Manhattan), New York, USA – Columbus Avenue[c] | Parking-protected bike lane (one way); landscaped pedestrian safety islands | Vehicular travel lanes were narrowed | ~1.0 miles | Descriptive statistics, aggregated trend analysis; control = yes | 1 year pre-installation to 2 years post-installation | Retail and food service sales | No or unclear effect |

[a]Retail corridor or hub; [b]Business district; [c]Mixed residential and commercial corridor.

Series data) and four primary economic indicators (retail sales, retail employment, food service sales, and food service employment). For the aggregated trend analysis, they compared baseline economic indicator data (often the average from the three years before construction) to the three years after construction. They used a longer timeline for the econometric analyses, including data from multiple years pre- and post-facility installation. For nine of the 12 study sites, they concluded that the addition of the bicycle facility had positive economic impacts on local businesses (where their metrics showed either all positive effects or a mix positive effects and non-significant effects), despite removal of or reductions in vehicular travel lanes or on-street parking spaces accompanying seven of the bicycle facilities. That included all five of the cycle tracks and four of the bike lanes. They found unclear or insignificant economic impacts on the remaining three bike lanes.

In addition to Liu and Shi's (2020a, 2020b) two studies, four other studies used statistical testing to analyze the economic effects of bicycle facility additions. Rijo (2015) assessed the economic impact of three bicycle facilities installations in Denver, Colorado – a 0.7-mile class IV cycle track (and associated removal of one vehicular travel lane), a 1.0-mile class II bike lane (and associated removal of one vehicular travel lane), and a 0.3-mile class III bike boulevard. For each facility, the study compared gross sales and total sales tax from businesses along the length of the facility to those of similar businesses along three comparison corridors and the city as a whole. The study focused on businesses in the retail and food and accommodations services sectors, along with a few other consumer-focused businesses; it excluded auto-centric businesses like gas stations and car repair shops. The study employed aggregate trends analysis and ANOVA with post-hoc means difference testing, using data for the 20 months before and three years after installation of the bike lane and the 38 months before and 15 months after installation of the cycle track and bike boulevard. The study found positive effects for both the cycle track and bike lane and an insignificant difference in effect for the bike boulevard relative to the comparison sites.

Besides Rijo (2015) and Liu and Shi's (2020a, 2020b) two studies, the other three studies that used statistical testing found largely null effects (Arancibia et al., 2019; McCormick, 2012; McCoy et al., 2019). McCoy et al. (2019) used National Establishment Time Series data for over 3,000 storefront retail, food service, and other service-providing businesses in San Francisco to model the average change in sales following installation of a class II or class III bicycle facility. The study included all class II and III facilities added between 1996 and 2012, and measured the change in sales as the average sales for a business in the year (s) after installation of the nearest facility minus the average sales in the year(s) prior to facility construction (in 2014 US dollars; number of years pre- and post-intervention varied by year of installation). The authors used multivariate regression to model the change in sales, controlling for proximity to the bike infrastructure (businesses within 100 feet of a facility were considered to be abutting), business type and age, change in the number of on-street parking spaces associated with installation of class II facilities, and various other neighbourhood and corridor characteristics. The study found no statistically significant association between change in sales and either location on the same corridor as a class II or class III facility or change in on-street parking on corridors with class II facilities. However, the model results did show a significant positive association between change in sales and being located on a "neighborhood" road with a class II facility, and a statistically significant decrease in sales for automobile-oriented businesses (like gas stations and car dealerships) and home goods stores abutting a class II facility.

Arancibia et al. (2019) analyzed the economic impact of a 1.5-mile class II bike lane addition (and associated removal of 136 on-street parking spaces) on Bloor Street in downtown Toronto using five metrics: (1) monthly spending by visitors, (2) commercial vacancy rates, (3) number of customers at retail businesses there, (4) number of customers at food service businesses and bars, and (5) number of customers at service businesses. The authors obtained the visitor spending data via surveys of visitors to the treatment corridor (Bloor Street) and a comparison street, conducted eight months before, and two and nine months after facility installation. They assessed commercial vacancy rates using field observations from the treatment and control corridors one month before and nine months after facility installation. They obtained the customer data from surveys of merchants seven months before, and three and nine months after facility construction. The study used difference-in-proportions tests and logistic regression to analyze the visitor spending data, both between the treatment and control corridors and longitudinally within the treatment corridor. The study also used difference-in-proportions tests – albeit just with data from the treatment corridor – to assess the impact of the bike lane addition on business patronage. The study compared descriptive statistics to assess the effect on commercial vacancy rates. Overall, the study found no negative economic impacts to local businesses from the bike lane addition.

McCormick (2012) analyzed the economic effect on local businesses of a road diet that converted two of the vehicular travel lanes into a left-hand turn lane and class II bike lanes on both sides of a 1.3-mile stretch of York Boulevard in Los Angeles. The study found no significant difference (using a Chi-square test) in business turnover or new business creation post-road diet between the treatment corridor and a contiguous 0.9-mile portion of York Boulevard that did not receive a road diet. The study likewise found no significant pre–post or treatment-control difference in commercial and residential property sale prices, using both t-tests and hedonic price modelling. The study also found no clear economic effect from its qualitative analysis of aggregate sales tax revenue.

In addition to the six studies (covering 18 facilities) that employed statistical testing, another seven studies that did not use statistical testing also found non-negative economic impacts on local businesses following the installation of bicycle facilities. Those seven studies found positive or unclear effects from 12 separate facilities, two class IV cycle tracks in New York City (New York City Department of Transportation, 2012, 2013), two cycle tracks in Seattle (Rowe, 2013), one cycle track in Oakland (City of Oakland Department of Transportation, 2017), one cycle track in Austin (Monsere et al., 2014), one cycle track in Portland (Monsere et al., 2014), one cycle track in Washington, DC (Monsere et al., 2014), and a cycle track, two class II bike lanes, and a class III bike boulevard in San Francisco (Drennen, 2003; Monsere et al., 2014; Poirier, 2018). However, only four of those studies used comparison sites to help control for variables unrelated to the active travel facility "treatment."

The New York City Department of Transportation (2012)found that the commercial vacancy rate declined 47% for abutting businesses after the installation of class IV cycle tracks (along with dedicated bus lanes) on First and Second Avenues in Manhattan, compared to a 2% increase borough wide. The NYC Department of Transportation (2013) also found a relatively greater increase in retail and food service sales (excluding auto-centric businesses) along a 0.5-mile stretch of 9th Avenue three years after installation of a one-way cycle track than in the borough as a whole or any of the three comparison corridors.

Rowe (2013) found that retail sales in the year following installation of cycle track (on one side of the street) and bike boulevard (on the other) on NE 65th Street in Seattle increased comparatively more for the businesses in the project corridor than in either the comparison corridor or the neighbourhood as a whole. That same study also found relatively equivalent trends in retail sales from businesses along the treatment corridor, comparison corridor, or neighbourhood for the three years after installation of a 1.0-mile cycle track on Greenwood Avenue. The fourth study to use comparison sites – Poirier (2018) – compared the percentage change in total sales and sales per employee for businesses abutting three separate bicycle facilities to all other businesses in the blocks surrounding the facilities across a 5-year time frame (2 years before installation of the facilities compared to the 2 years post installation). They found a relatively greater percentage increase in both metrics for businesses abutting the 2.0-mile bike lane installed on Valencia Street (including for both all abutting businesses and a local-serving subset of those businesses that excluded auto-centric businesses) than for the non-abutting businesses in the control blocks. They found mixed effects for other two facilities, a 0.3-mile class III bike boulevard on Columbus Avenue and a 0.25-mile bike lane on Polk Street.

Overall, the studies that used statistical testing and/or comparison sites found positive (15) or otherwise non-negative (10) economic effects for 25 of the 35 total facilities. By contrast, only three studies we reviewed found negative economic impacts (from a total of five separate facilities). And all three studies had methodological limitations that prevent statistically supported conclusions about the direction of the economic effect (City of Calgary, 2016; Monsere et al., 2014; Stantec, 2011). The City of Calgary (2016) surveyed pedestrians (intercept surveys) and merchants along four corridors in downtown Calgary both before and after class IV cycle tracks were added to the corridors. The surveys showed a reduction in average visitor spending per month after the facilities were added (despite respondents reporting an identical visitation frequency), as well as a reduction in the average number of customers per day reported by businesses. But the study did not use any comparison sites or perform any statistical modelling to control for larger economic trends or other factors that could account for the reductions in reported spending and customer visits.

Monsere et al. (2014) surveyed residents within a quarter mile of recently installed class IV cycle tracks in six urban areas about whether they were more or less likely to visit a business in the corridor after the cycle tracks were added. A greater percentage of the surveyed residents near two of the facilities (both in Chicago) responded that they were less likely to visit a business than responded that they were more likely to do so (though a majority indicated there was no change). But these results do not necessarily mean that businesses near those two facilities suffered economically (or benefited economically in the other four locations). For one, the study asked about visitation frequency but not spending per trip – it is possible that residents shopped less frequently at the affected businesses, but spent more when they did. In addition, residents are likely not the only patrons at the affected businesses, so changes in their spending patterns might not actually correlate to economic changes for the businesses. Furthermore, any changes in residents' shopping behaviour could be caused by unrelated economic trends or other factors. As the authors of the study note, "[t]here are several challenges in identifying connections between bicycle facilities and economic changes. These changes may be subtle or tied to an overall change in character of a corridor or neighborhood" (Monsere et al., 2014, p. 136).

Stantec (2011) surveyed retail, service, and hotel businesses along two corridors in Vancouver, British Columbia in which class IV cycle tracks had recently been added, as well as businesses in two comparison corridors. The 32% ($n = 73$) of businesses that responded reported an average decline in sales of 11% on one street and 2% on another, compared to a 1% decline and 2% increase on the respective control corridors. However, due to the small sample size and for other reasons, the authors did not test the statistical significance of the differences in reported sales trends or control for other variables. Furthermore, the authors noted that the survey responses might be biased towards those businesses that were vocally opposed to the cycle tracks from the beginning (there was organised business opposition to the cycle tracks before they were installed): "since the averages established in the grade-level [business tenants] and owners surveys may reflect the more vocal minority, they must be moderated to some degree by the non-respondents that make up the majority of businesses" (Stantec, 2011, p. 19).

While the three studies that found negative impacts had significant methodological limitations, there is some evidence from the other studies that adding bicycle facilities might dampen sales for auto-centric businesses abutting the facilities. For example, McCoy et al. (2019, p. 277) found that while "bicycle infrastructure and changes in on-street parking supply generally did not have a significant effect on the change in sales" in San Francisco, auto-centric businesses on streets with class II bike lanes showed a statistically significant decline in sales, after controlling for other factors in their ordinary least squares regression model. Poirier (2018) similarly found that while local-serving businesses (which excluded auto-centric businesses) abutting a retail corridor (Polk Street) in San Francisco had a relative increase in sales compared to non-abutting businesses, all abutting businesses (which included auto-centric businesses) had a relative decline in sales. Liu and Shi (2020b) obtained a similar result for businesses along another retail corridor (17th Street) in San Francisco where class II bike lanes were added in each direction. Using an aggregated trend analysis, they found a relatively greater increase in sales and employment among the subset of abutting retail businesses that excluded auto-focused businesses than for all retail businesses combined.

In sum, the weight of the evidence indicates that bicycle facilities are likely to provide a positive – or at least non-negative – economic co-benefit to local retail and food service businesses, even where vehicular travel lanes or parking are removed or reduced in the process. However, there is some evidence from three of the studies reviewed that auto-focused businesses (like auto parts or repair shops, gas stations, and large home-goods stores) might experience stagnant or reduced sales (Liu & Shi, 2020b; McCoy et al., 2019; Poirier, 2018). Between the different types of bicycle facilities, the studies indicate that class II bike lanes and class IV cycle tracks might be more likely to produce positive economic benefits for local businesses than class III bicycle boulevards. The three studies that examined bicycle boulevard additions all found an unclear or insignificant economic effect (McCoy et al., 2019; Poirier, 2018; Rijo, 2015).

### *Pedestrian facilities*

Four of the 15 studies analyzed at least one pedestrian facility (Table 4). The four studies estimated the economic impact on local businesses of six unique pedestrian facilities, including 0.5 miles of street trees and lighting in a San Francisco business district (Liu & Shi, 2020b), about three miles of landscaped median, curb extensions, disability access upgrades, and pedestrian-scaled lighting in a Minneapolis business district (Liu & Shi, 2020a), a pedestrian plaza in Brooklyn (New York City Department of Transportation, 2012), a seasonal seating area for local patrons in Manhattan (New York City Department of Transportation, 2012), a 0.25-mile conversion of roadway into landscaped pedestrian space with seating along with a redesigned intersection in Manhattan (New York City Department of Transportation, 2013) and a pedestrian plaza with seating, trees, and planters in Brooklyn (New York City Department of Transportation, 2013). The studies found positive economic effects for all six facilities, including five facilities that were accompanied by vehicular travel lane removal or width reduction, or removal of on-street vehicular parking spaces.

The only two studies to use statistical testing were Liu and Shi (2020a and 2020b). They analyzed the economic impacts from two of the eight total pedestrian facility additions across all studies. As discussed above, the authors of those studies first selected at least one comparison corridor for each facility. They then applied aggregated trend analysis as well as two quasi-experimental econometric modelling techniques using four sources of data and four primary economic indicators. For the aggregated trend analysis, they compared baseline economic indicator data from the year before construction to data for the three years after installation. They used a longer timeline for the econometric analyses, including data from multiple years pre- and post-facility installation. They concluded that the addition of each pedestrian facility – 0.5 miles of street trees in San Francisco and a landscaped median and other streetscape modifications and amenities in Minneapolis – had positive economic impacts on local businesses. Their metrics showed a mix of positive effects and non-significant effects for both facilities, despite removal of vehicular travel lanes in both cases.

While the other two studies did not employ statistical testing, they did use comparison sites to make better inferences about the economic impact of three of the studied facilities. The NYC Department of Transportation (2012) found that retail sales (excluding auto-centric businesses) increased 172% for the surrounding businesses after installation of pedestrian plaza in Brooklyn, compared to an 18% increase borough-wide. The NYC Department of Transportation (2013) also found that retail and food service sales (excluding auto-centric businesses) increased proportionally more at the businesses adjacent to both a 0.25-mile roadway-pedestrian space conversion in Manhattan and a pedestrian plaza in Brooklyn than those in the respective boroughs and three comparison sites for the projects (two and three years after installation, respectively).

In sum, the weight of the evidence indicates that pedestrian facilities are likely to provide a positive economic benefit to local retail and food service businesses (the focus of all four studies), even where vehicular travel lanes or parking are removed or reduced in the process.

### *Mixed facilities (bicycle and pedestrian)*

Two of the 15 studies analyzed at least one facility that included both pedestrian and bicycle infrastructure improvements (Table 5) (New York City Department of Transportation, 2012, 2013). The two studies estimated the economic impact on local businesses of four mixed facilities in total, all in New York City, including a one-way cycle track and pedestrian plaza in Union Square North (New York City Department of Transportation, 2012), 0.3 miles of class II bike lanes, pedestrian safety islands, and a tree-lined median in Brooklyn (New York City Department of Transportation, 2013), improved pedestrian space in the Bronx Hub along with a network of new bike lanes in and out of the hub (New York City Department of Transportation, 2013), and one mile of a one-way cycle track and landscaped pedestrian safety islands in Manhattan (New York City Department of Transportation, 2013). They found positive economic effects for the first three facilities, two of which included removal of vehicular travel lanes. They found no major effect one way or the other for the fourth combined facility in Manhattan. The studies did not use statistical testing, but they did use comparison sites to make better inferences about the economic impact of the facilities. The studies used aggregated trend analysis for all four facility-level analyses, where they compared data from one year before facility construction to data from two or three years after construction for either retail and food service sales (the Brooklyn, Bronx Hub, and Manhattan facilities) or commercial vacancy rate (the Union Square North cycle track and pedestrian plaza) for the ground-level businesses abutting or nearby the facility addition versus all retail and food service businesses borough-wide.

## Implications for practice and future research

A growing body of literature has attempted to measure the economic impacts on local businesses of new or improved bicycle and pedestrian facilities, particularly in the US and Canada. The impact is most commonly measured as changes in local business sales, but studies have also used number of customers, visitor spending, commercial vacancy rates, commercial property values, employment, and business owner perceptions as proxies for the economic effects on local businesses. These impacts are in addition to the many other types of direct and indirect economic impacts generated by active travel investments, including the direct economic impact of facility construction in the form of jobs created and materials purchased, as well as the indirect economic impacts from health improvements associated with active transportation. The 23 studies we reviewed can be roughly categorised into two groups: (1) those that analyze the differences in visitor spending in a commercial area by the travel mode the visitors used to get there; and (2) those that analyze the economic impacts of specific active travel facilities (or networks of facilities) on local businesses.

The eight studies in the first group used surveys to estimate per-visitor spending in primarily urban commercial areas of Toronto (three studies), San Francisco (two), Victoria (one), Portland (one), and Davis (one). The results indicate that cyclists and pedestrians generally spend more per month in urban downtowns and retail corridors than visitors who arrive by car, but do not reliably spend different amounts per trip. One implication of those results is that adding a bicycle or pedestrian facility in urban downtowns or retail corridors would not reduce consumer spending at local businesses unless it reduced more motorist trips to the area than the number of additional cyclist and pedestrian trips it generated. We do not review the literature on the effect of active travel facilities on motorist volumes here. But there is evidence that active travel improvements like road diets (Gudz, Fang, & Handy, 2016; Huang, Stewart, & Zegeer, 2002) and complete streets retrofits (Shu, Quiros, Wang, & Zhu, 2014) can increase bicycling or pedestrian volumes while having little to no effect on vehicular traffic flow. In addition, a recent review of the literature on changes in bicycle ridership following installation of a new bicycle facility concluded that "sizeable percentage increases in ridership can be expected along the routes of new Class I, Class II, and Class IV facilities" (Volker et al., 2019a, p. 20; Volker & Handy, 2019).

The 15 studies in the second group assessed the economic impact of 45 unique active travel facilities in business districts, commercial corridors, or other urban areas across 16 cities in the US and Canada, usually using before and after data on local business sales or another economic indicator. The 45 facilities comprised 35 bicycle facilities (17 individual cycle track projects, 14 individual bike lane projects, two individual bike boulevard projects, one group of four cycle track projects, and the full network of bike lanes and boulevards added between 1996 and 2013 in San Francisco), six pedestrian facilities (including plazas, street seating, street lighting, trees and landscaping, medians, and various other streetscape additions or alterations), and four mixed facilities (pairing either cycle tracks or bike lanes with streetscape improvements for pedestrians; all in New York City). Taken together, the results from the second group of studies indicate that creating or improving active travel facilities generally has positive or non-significant economic impacts on retail and food service businesses abutting or within a short distance of the facilities, even when vehicular parking or travel lanes are reduced to make room for the active travel facilities. While three of the 15 studies found negative economic impacts from a total of five separate facilities (all of which were bicycle projects), all three had methodological limitations that prevent statistically supported conclusions about the direction of the economic effect. However, the more robust studies provide some evidence that bike facilities could have negative economic effects on auto-centric businesses (like gas stations, auto repair shops, auto parts stores, and large home-goods stores).

With respect to the question of variation by facility type, the studies indicate that cycle tracks and bike lanes might be more likely to have positive economic effects on local businesses than bike boulevards. For pedestrian and mixed facilities, the wide range of potential streetscape improvements makes generalisation difficult, especially given the relatively limited literature. But the four studies we reviewed indicate almost universally positive effects – they found positive economic impacts from all six pedestrian facilities and three of the four mixed facilities they analyzed (with the fourth mixed facility showing no major effect one way or the other). These results are consistent with studies showing the positive economic impacts on local businesses of neighbourhood walkability, including through hedonic price modelling (Pivo & Fisher, 2011) and market analysis (Boarnet, Joh, Siembab, Fulton, & Nguyen, 2011).

In addition to their substantive results, the second group of studies also highlights lessons for designing future research on the economic impacts to local businesses of adding active travel facilities. The most robust studies – those from which inferences can most validly be drawn – will both (1) use before-and-after data to calculate the degree of change in the chosen economic indicator, and (2) control for variables unrelated to the active travel facility "treatment", with statistical modelling and/or by using one or more comparison sites that had similar baseline characteristics but was not treated with an active travel facility (Arancibia et al., 2019; Liu & Shi, 2020b; New York City Department of Transportation, 2013; Tehnopolis Group, 2016). Without using data from before and after facility construction, it is difficult to determine whether an economic impact occurred. A common rule of thumb is to use at least one year of data pre-intervention and two years of data post-intervention, at least when analyzing business sales, though it is always better to have more data points and might be necessary for some statistical analyses, like interrupted time series (Liu & Shi, 2020b) Even with ample before-and-after data, it is still difficult to discern whether the economic impact on local businesses was caused by adding the active travel facility or something else (like a broader shift in the economy) without also using comparison sites or covariate controls.

The choice of economic indicator is also important. Most studies we reviewed used a measure of sales from businesses abutting the studied facility, usually retail and/or food service sales (or sales tax). Sales data is ideal because it is the most direct and immediate measure of economic impacts to local businesses, and because it can often be obtained for all businesses of interest from a governmental or other repository, which avoids the self-selection or other biasing that can happen when surveying business owners or customers. However, sales data is not always readily available, especially in Canada (due to information and privacy laws, as discussed in Arancibia et al., 2019) and in US jurisdictions that do not collect sales tax (though private sector sources of sales data, like the National Establishment Time Series, can sometimes be used instead, like in McCoy et al., 2019, and Liu & Shi, 2020a, 2020b). In those cases, researchers can use a different metric (like employment) or approximate business sales with surveys (e.g. of consumer spending, as in Arancibia et al., 2019).

Employing these best practices can be time-consuming and expensive, which is likely one reason there are not more such studies. Even so, 10 of the 15 studies we reviewed used both before-and-after data and controls, and six studies went further and used statistical testing to improve inferences about the economic effect on local businesses of adding active travel facilities. These methods ranged from simple tests for differences in means or proportions (Arancibia et al., 2019; McCormick, 2012; McCoy et al., 2019) to analysis of variance with post-hoc means difference testing (Rijo, 2015) to hedonic price modelling (McCormick, 2012) and multivariate regression (Arancibia et al., 2019; McCoy et al., 2019), to difference-in-difference analysis (Arancibia et al., 2019; Liu & Shi, 2020a, 2020b) and interrupted time series modelling (Liu & Shi, 2020a, 2020b). Although the number of studies is relatively small, the quality of the studies is generally good.

Overall, the evidence reviewed in this paper is important as cities move to increase their investments in bicycle and pedestrian facilities as a part of efforts to reduce driving as a way to forestall climate change or for other reasons altogether. Opposition to bicycle and pedestrian investments often stems from concerns over negative impacts on local businesses, particularly in the US and Canada. The available evidence suggests that such fears are unfounded and that local governments can indeed invest in bicycle and pedestrians without regret.

## Note

1. Bike facilities are typically classified as class I (bike or shared use paths), class II (bike lanes), class III (marked routes shared with vehicles), or class IV (cycle tracks) bicycle facilities. The California Department of Transportation (2017) and Fitch, Thigpen, Cruz, and Handy (2016) illustrate the four types of facilities and describe the classifications in more detail.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Funding

The research presented in this article was funded by the California Air Resources Board (contract 16TTD004). The statements and conclusions in this article are those of the contractor and not necessarily those of the California Air Resources Board. The mention of third party sources, or their use in connection with material reported herein, is not to be construed as actual or implied endorsement of such sources.

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