

# Economic impact on local businesses of road safety improvements in Seattle: implications for Vision Zero projects

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## ABSTRACT

**Background** Local transportation agencies implementing Vision Zero road safety improvement projects often face opposition from business owners concerned about the potential negative impact on their sales. Few studies have documented the economic impact of these projects.

**Methods** We examined baseline and up to 3 years of postimprovement taxable sales data for retail, food and service-based businesses adjacent to seven road safety projects begun between 2006 and 2014 in Seattle. We used hierarchical linear models to test whether the change in annual taxable sales differed between the 7 intervention sites and 18 nearby matched comparison sites that had no road safety improvements within the study time frame.

**Results** Average annual taxable sales at baseline were comparable at the 7 intervention sites (US\$44.7 million) and the 18 comparison sites (US\$56.8 million). Regression analysis suggests that each additional year following baseline was associated with US\$1.20 million more in taxable sales among intervention sites and US\$1.14 million more among comparison sites. This difference is not statistically significant ( $p=0.64$ ). Sensitivity analyses including a random slope, using a generalised linear model and an analysis of variance did not change conclusions.

**Discussion** Results suggest that road safety improvement projects such as those in Vision Zero plans are not associated with adverse economic impacts on adjacent businesses. The absence of negative economic impacts associated with pedestrian and bicycle road safety projects should reassure local business owners and may encourage them to work with transportation agencies to implement Vision Zero road safety projects designed to eliminate traffic-related injuries.

## INTRODUCTION

Over 1.3 million persons die and over 20 million persons are injured globally in motor vehicle-related crashes each year. Such injuries are the leading cause of death among persons ages 5–29 years. Over half of road traffic deaths occur among pedestrians, bicyclists and motorcyclists.<sup>1</sup> Almost all motor vehicle crashes are preventable through appropriate safety programmes, projects and policies that improve the physical environment and/or influence human behaviour.

Initiated in Sweden in 1997, Vision Zero is a road safety project developed to eliminate all road traffic fatalities and injuries through street design changes

## WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Local business owners may be concerned about the potential negative sales impact of road safety projects that may reduce traffic and parking near their stores, but few studies have documented the economic impacts of such projects.

## WHAT THIS STUDY ADDS

⇒ In one of the largest studies published to date, we found no adverse economic impacts of road safety projects in Seattle by examining baseline and up to 3 years of postintervention sales data for businesses adjacent to seven road safety projects and for 18 nearby matched comparison sites.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The absence of negative economic impacts associated with pedestrian and bicycle road safety projects should reassure local business owners and may encourage them to work with transportation agencies to implement Vision Zero road safety projects designed to eliminate traffic-related injuries.

such as reducing road speeds, creating road diets, increasing pedestrian crossings and accounting for driver error in design.<sup>2–4</sup> Vision Zero's goal is 'that no one is killed or seriously injured as a consequence of road accidents within the road transport system'.<sup>5</sup> Its other objectives include slowing motor vehicle speeds, attracting investment and new businesses, creating safe and attractive streets, meeting the needs of local residents and visitors, promoting pedestrian, bicycle and transit use, and reducing the need for traffic enforcement.<sup>6</sup>

Vision Zero projects typically include one or more components of the US Federal Highway Administration toolbox of countermeasures to prevent pedestrian injuries which describes specific street design changes and their expected risk reduction.<sup>7</sup> Methods commonly used to evaluate Vision Zero projects include before and after measures of street use, road safety and speed.<sup>1 8 9</sup> Speed measurements are a good proxy for the risk of crashes and injuries.<sup>10 11</sup> Reductions in deaths and injuries attributable to Vision Zero projects are well documented.<sup>2 3 12–14</sup>

While there is clear evidence that Vision Zero projects improve safety, cities considering these



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interventions often meet opposition from business owners who believe that these street design changes may negatively impact their sales.<sup>6</sup> A few studies have focused on the economic impacts of Vision Zero projects on businesses within project areas. A study in San Francisco of bike improvements along Valencia Street, a popular commercial corridor, suggested a possible positive economic impact on businesses along this route, but the analysis did not provide pre–post data or comparison locations to assess outcomes.<sup>6</sup> In a Toronto study based on a survey of merchants and shoppers, investigators found no negative economic consequences of replacing on-street parking spaces with bike lanes on a downtown retail corridor, but the report did not provide actual sales data.<sup>15</sup>

In New York City, a study using retail sales tax data found that most of the street design projects analysed showed a positive but statistically non-significant association with improved economic success of adjacent businesses.<sup>16</sup> In Seattle, a study using retail sales tax data found no adverse economic consequences when comparing two sites that added bike lanes to several comparison sites and to the larger business area.<sup>17</sup> Using longitudinal sales data from local businesses in corridors with street improvements in San Francisco, a study concluded that bicycle infrastructure generally did not impact businesses, positively or negatively, with a few exceptions.<sup>18,19</sup> A study of street improvements at 14 sites in 6 US cities found mostly positive or in a few cases mixed economic impacts on food and retail businesses when examining sales and employment data using aggregated trend, difference-in-difference and interrupted time series analytical techniques.<sup>20,21</sup> A review of 23 studies of bicycle and pedestrian infrastructure improvement projects in the USA and Canada found that creating or improving active travel facilities generally has positive or non-significant economic impacts on retail and food service businesses abutting or near the facilities.<sup>22</sup>

Vision Zero projects could benefit small businesses in urban areas by bringing economic revitalisation to a commercial corridor.<sup>6</sup> Street design changes are most likely to impact retail, food and service businesses.<sup>19,20</sup> Business concerns about traffic-calming projects include possible loss of parking for customers and access for delivery trucks. Other societal concerns include the risk of gentrification and displacement of low-income community residents as an area is economically revitalised.

Seattle adopted a Vision Zero program in 2015, bringing a new name to and expanding the scope of the city's existing street design safety projects.<sup>4</sup> This study seeks to better understand the economic vitality of the businesses in the locations where road safety improvement projects have been implemented in Seattle.

## METHODS

### Study sites

Adapting methods from prior studies,<sup>16–21</sup> we identified commercially zoned sites in the City of Seattle that received road safety improvements along with nearby comparison sites that had no recent road safety projects. Information on such road improvements was identified from Seattle Department of Transportation's records, blog posts such as the Seattle Bike Blog, news articles and the Street View feature in Google Maps. The presence of businesses at the site at the time of the road safety project was confirmed using the Google Street View 'Time Portal' feature. From this analysis, we identified seven road safety project sites initiated between 2006 and 2014 for which one baseline year and at least two postimplementation years of sales data were available.



**Figure 1** Before and after example of a road safety project: installation of two-way protected bike lanes and a road diet on Broadway in Seattle's Capitol Hill neighbourhood. Source: Google Street View.

The intervention sites were in six of Seattle's seven City Council Districts, which reflect unique neighbourhood characteristics and provide a city-wide perspective. Two of the seven projects were from district 7 that includes the downtown commercial core with the city's heaviest concentration of retail and food service businesses. No suitable projects were identified in district 1 (West Seattle). Each intervention site was physically inspected by the lead author with pre and post street design features confirmed through review of Google Street View images. **Figure 1** illustrates a road diet and two-way protected bike lane project included in our study.

Selection criteria for comparison sites included (a) being commercially zoned with no road safety projects in process during the study period, (b) being in the same City Council District, (c) having similar traffic rates as the intervention site and (d) having active businesses in the North American Industry Classification System (NAICS) groups listed below. Two or three comparison sites that met all criteria were identified for each intervention site.

### Measures and data

We submitted a public records data request to the Washington State Department of Revenue (DOR), accompanied by GIS shapefiles that defined boundaries for the 7 intervention and 18 comparison sites. Requested data included taxable sales for businesses within the two-digit NAICS codes 44 (retail trade), 45 (retail trade), 72 (accommodation and food services) and 81 (other services).<sup>23,24</sup> We selected these NAICS codes to focus on street design changes that may impact retail businesses dependent on street-level activity, such as restaurants, gas stations, bakeries, coffee shops, bars, car washes, drycleaners, salons, pharmacies and grocery stores. We excluded NAICS codes for

sectors less reliant on street-level activity, such as manufacturing, construction and public administration.

DOR provided annual taxable sales data for specific years for businesses in the intervention and comparison sites. The economic impact of the road safety projects was assessed by examining the change in annual taxable sales per site for up to 3 years following the safety project's introduction. Taxable sales data per year were adjusted to 2016 dollars.<sup>25</sup> Time was measured in years from the baseline implementation year, with the implementation year coded as time 0. For example, for the Stone Way sites, time 0 refers to 2006, time 1 to 2007 and time 2 to 2008.

### Analytical methods

We first examined whether intervention and comparison sites were comparable in taxable sales at baseline. We visualised trajectories of sales over time using a Loess smoother to determine whether linear models were appropriate.<sup>26</sup>

Based on these descriptive analyses, we used hierarchical linear models to test whether the change in taxable sales over time differed between the intervention and comparison sites. Hierarchical models are suitable for the analysis of longitudinal data, where repeated measures from the same subject are necessarily correlated and thus violate the independence assumption of standard regression models. Error terms were clustered by site to account for the autocorrelation. We also included a random intercept to allow for the variation in baseline levels across sites while estimating a common slope parameter.

We modelled total taxable sales as a function of an interaction between site type (comparison=0, intervention=1) and year (range: 0–3). In these models, the intercept reflects estimated mean sales for the comparison groups in the year of implementation. The site type coefficient is the difference in sales during the baseline year between the intervention and comparison sites. We would expect this coefficient to be close to 0 and not statistically significant, indicating that the sales for the intervention and comparison groups are comparable at baseline. The time coefficient reflects the rate of change per year among the comparison

sites. The interaction term reflects the extent to which the rate of change in the intervention group differs from the rate of change in the comparison groups. A non-significant interaction term would suggest that the change over time did not differ between intervention and comparison groups.

In sensitivity analysis, we included a random slope in addition to a random intercept to examine whether results were sensitive to this modelling choice. We also used a gamma distribution with a log link suitable for the analysis of cost data to increase confidence in our inferential conclusions.<sup>27</sup> To further increase our confidence that results were not due to bias in our choice of analytical models, we ran a repeated measures analysis of variance (ANOVA) model. In addition, difference-in-difference regression analyses by site were conducted.

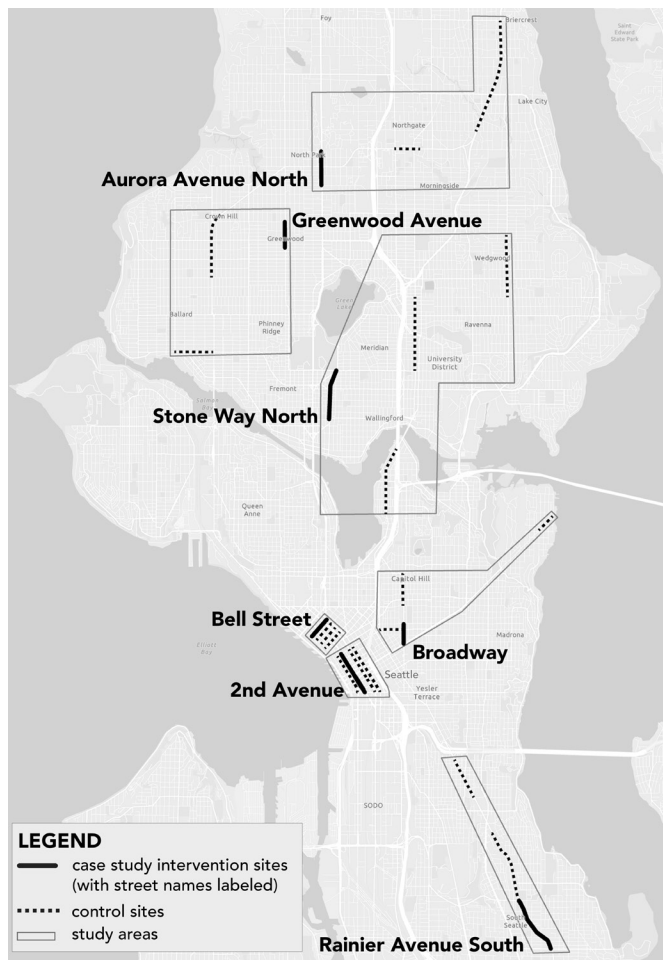
### RESULTS

The characteristics of the road safety intervention and comparison sites are listed in table 1 and their geographical locations are shown in figure 2. The median length of the intervention sites was 7 blocks (range 3–10 blocks); the median length of the comparison sites was 7.5 blocks (range 3–16 blocks). The exact location, length and commercial use of each study site are documented in detailed maps in the full thesis report from which this paper is adapted (<https://digital.lib.washington.edu/researchworks/handle/1773/46214>).

The study sites reflect the diversity of Seattle's urban landscape and include streets within the downtown core, large arterial corridors and mixed-used neighbourhoods. Five of the intervention sites included physical street design changes such as bicycle lanes, bicycle signals, a road diet and recanalisation to create a centre turn lane, and left-turn pockets at intersections, along with improved signal timing and prohibiting right-turn-on-red.<sup>28–32</sup> The sixth project, Bell Street, incorporated a Woonerf style street redesign that prioritised people over cars by installing bulb outs, curb ramps, tables, chairs, bike parking, public art and other indicators of shared space while discouraging through traffic.<sup>33</sup> The seventh project, Aurora Avenue N, focused on increased law enforcement to decrease speeding and

**Table 1** Characteristics of road safety intervention and comparison sites, Seattle

Neighbourhood description	Intervention site (reference)	Comparison sites	Type of intervention	Year project initiated
Downtown core	2nd Ave, Pike St to Yesler Way <sup>28</sup>	1st Ave, Pike St to Yesler Way 4th Ave, Pike St to Yesler Way 5th Ave, Pike St to Yesler Way	Two-way bike facility and road diet	2013
Arterial with wide mix of restaurants and service establishments	Broadway, E Pine St to E Madison St <sup>29</sup>	Broadway, Roy St to E Denny Way E Pike St, Boren Ave to Broadway E Madison St, McGilvra Blvd E to 43rd Ave E	Two-way bike facility and road diet	2013
Four lane arterial north of downtown with mix of residential and commercial/retail establishments	Stone Way N, N 40th St to N 50th St <sup>30</sup>	Eastlake Ave E, E Newton St to I-5 Roosevelt Way NE, NE 50th St to NE 70th St 35th Ave NE, NE 70th St to NE 87th St	Bike lane and road diet	2006
Arterial through primarily residential neighbourhood with mix of restaurants and service establishments	Greenwood Ave N, NW 83rd St to NW 90th St <sup>31</sup>	15th NW/Holman NW, NW 75th St to 14th Ave NW NW Market, 15th Ave NW to 24th Ave NW	Bike lane and road diet	2009
Major north-south arterial located in southern section of city, some light industry along route	Rainier Avenue S, S Alaska St to S Juneau St <sup>32</sup>	Rainier Ave S, S Byron St to S Alaska St Rainier Ave S, S Mass St to S Bayview St	Road diet and safety project	2014
Adjacent to downtown, restaurants and service-oriented businesses	Bell St, Western Ave to 5th Ave <sup>33</sup>	Blanchard St, Western Ave to 5th Ave Lenora St, Western to 5th Ave Virginia St, Western to 5th Ave	Woonerf style redesign	2013
Major north-south arterial located in northern section of city, some light industry along route	Aurora Ave N, N 100th St to N 109th St <sup>34</sup>	NE Northgate Way, 5th Ave NE to 11th Ave NE Lake City Way NE, NE 115th St to NE 145th St	Speed and safety project	2010



**Figure 2** Geographical location of 7 road safety intervention sites and 18 comparison sites examined in this report, Seattle.

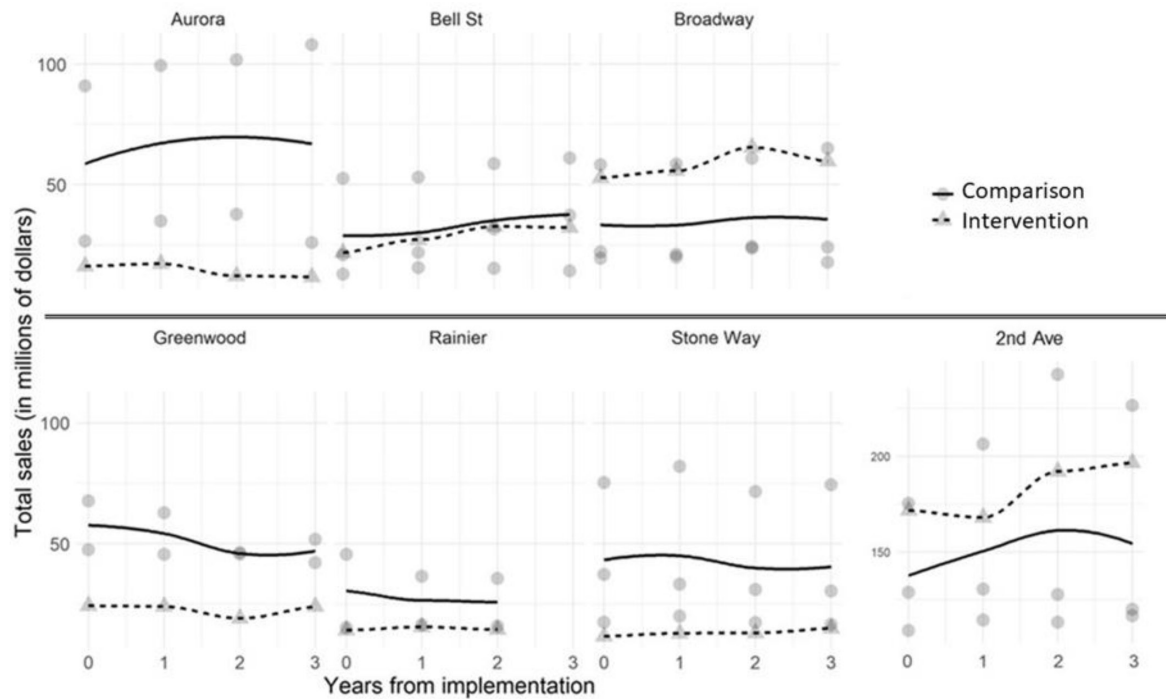
other moving violations.<sup>34</sup> Although this project included no physical street design changes during the years studied, this site was included because the city considers it to be one of their road safety intervention projects.

Table 2 reports baseline taxable sales at the intervention and comparison sites. At baseline, the 7 intervention sites had a median of 61 retail establishments (range 37–95), and the 18 comparison sites had a median of 63.5 retail establishments (range 28–236). On average, the 7 intervention sites reported mean annual sales of US\$44.7million (range US\$11.6M–US\$172.0M) in the baseline year, while the 18 comparison sites reported mean annual sales of US\$56.8million (range US\$12.9M–US\$175.0M). Two-sample t-tests indicated that these differences were not statistically significantly different ( $p=0.5$ ). Figure 3 presents plots of the annual taxable sales over time by site, adjusted to 2016 dollars and with a Loess smoother to visualise the trajectory. These plots suggest that the trends over time are reasonably linear, indicating the choice of linear models to be appropriate.

Table 3 reports the results of our regression analysis. Model-estimated taxable sales at time 0 were US\$44.35M for intervention sites and US\$57.59M for comparison sites which are similar to the reported sales. On average among comparison sites, taxable sales increased by an estimated US\$1.14M each year following baseline. This rate of change was 1.05 times higher (95% CI –3.37 to 5.47) among intervention sites, suggesting an estimated increase of US\$1.20M per year among intervention sites. This difference in estimated change in annual sales between the intervention and comparison sites was not statistically significant ( $p=0.64$ ). Sensitivity analyses including a random slope, using the generalised model with a Gamma distribution, and an ANOVA, as well as stratified difference-in-difference analyses by site, did not change conclusions. Results were similar when excluding the Aurora Avenue site that had policy but not physical road safety interventions and when excluding two comparison sites that were missing one or more NAICS categories.

**Table 2** Baseline annual taxable sales for 7 road safety project intervention and 18 comparison sites in Seattle, adjusted to 2016 dollars

Intervention site	Baseline year	Comparison site	Baseline year
Second Avenue	US\$171 696 304	1st Ave (Pike St to Yesler Way)	US\$128 821 230
		4th Ave (Pike St to Yesler Way)	US\$175 277 923
		5th Ave (Pike St to Yesler Way)	US\$108 873 825
		Broadway (Pine to Madison)	US\$52 867 019
Broadway (Pine to Madison)	US\$52 867 019	Broadway (Roy to Denny)	US\$58 258 821
		E Pike St (Boren to Broadway)	US\$19 499 549
		E Madison St (McGilvra to 43rd)	US\$22 063 910
Stone Way N	US\$11 620 609	Eastlake Ave E (Newton to I-5)	US\$17 448 182
		Roosevelt Way NE (50th–70th)	US\$37 284 617
		35th Ave NE (70th–87th)	US\$75 261 481
Greenwood Ave N	US\$24 241 417	15th Ave NW/Holman Rd NW (NW 75th St to 14th Ave NW)	US\$67 697 273
		NW Market St (15th–24th)	US\$47 435 348
Rainier Ave S (Alaska to Juneau)	US\$14 225 285	Rainier Ave S (Mass to Bayview)	US\$15 233 071
		Rainier Ave S (Byron to Alaska)	US\$45 517 818
Bell Street	US\$21 835 362	Blanchard St (Western to 5th)	US\$12 851 091
		Lenora St (Western to 5th)	US\$21 005 640
		Virginia St (Western to 5th)	US\$52 604 111
Aurora Ave N	US\$16 170 271	NE Northgate Way (5th–11th)	US\$26 512 980
		Lake City Way NE (115th–145th)	US\$90 930 770



**Figure 3** Total taxable sales at baseline and up to 3 subsequent years for 7 road safety project intervention sites and 18 comparison sites in Seattle, adjusted to 2016 dollars and overlaid with a Loess smoothed trajectory.

## DISCUSSION

We assessed the economic impact of 7 road safety improvement projects relative to 18 comparison sites in Seattle. Our study is one of the largest to date examining the economic impact of road safety projects on adjacent businesses based on sales data. Our results found no evidence for any difference in the trajectory of total sales over time between road safety intervention and comparison sites. On average, taxable sales increased in both the intervention and comparison sites over time.

While the road safety interventions did not appear to adversely impact total taxable sales, there was a decrease in the total number of retail businesses in 6 of the 7 intervention sites and in 16 of the 18 comparison sites over the period studied, for reasons that are unclear but may reflect broader economic trends. Turnover of small businesses on commercial streets is not uncommon.<sup>35</sup> A more detailed examination of which specific businesses opened, continued and/or closed during the study period would be informative.

Several limitations should be considered in interpreting the findings of this study. First, the selected comparison sites were similar to the intervention sites but may have differed by other unmeasured factors such as nearby residential density or ease of adjacent parking. Second, our findings represent associations between the road safety projects and sales data and do not suggest a causal relationship. Third, the analyses used combined

sales data for retail, food and service businesses, and do not reveal if some business types were economically impacted by the road safety projects more than others. Fourth, results are limited to the years for which sales data were obtained; additional preintervention and postintervention data would be needed to do more extended time series analyses required for causal analysis and to examine long-term trends such as the impacts of the COVID-19 pandemic. Fifth, data were available only for taxable sales and not for items that are tax-exempt in Washington state (groceries, prescription medicine and gasoline); trends in taxable and tax-exempt sales may differ. Sixth, we did not examine injury trends in the intervention and comparison areas because it was beyond the scope of this report and the number of pedestrian injury events in the blocks studied would likely be small; instead, we relied on prior studies that documented the effectiveness of road safety interventions. Finally, the study was conducted in Seattle and results may not be generalisable to other cities.

Future research could include an evaluation of the economic impacts of enforcement efforts alone and of the economic impacts of road safety interventions on automobile-related businesses such as gas stations and car washes. In addition, one could examine why specific businesses opened and closed at the study sites as well as survey past and present business owners to assess whether they made any changes in anticipation of road safety interventions that might disrupt their businesses. Other future research could examine the impacts on economic activity during the construction period for road safety projects.

In conclusion, results suggest that road safety improvement projects such as those in Vision Zero plans both reduce injuries and are associated with no adverse economic impacts on adjacent retail, food and service businesses. The absence of negative economic impacts associated with road safety projects should reassure local business owners and may encourage them to work with transportation agencies to implement Vision Zero road

**Table 3** Hierarchical linear model results estimating changes in taxable sales over time for road safety project intervention and comparison sites in Seattle, in millions of dollars

	Coefficient (95% CI)	P value
Intercept	57.59 (35.55 to 79.84)	<0.001
Time	1.14 (-1.20 to 3.47)	0.34
Site type	-13.24 (-56.65 to 30.17)	0.54
Time×site type	1.05 (-3.37 to 5.47)	0.64

safety projects designed to eliminate traffic-related injuries and fatalities.

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**Contributors** DRO conceived the study, collected and analysed the data, and wrote the 81 page master's thesis report from which this manuscript is adapted. JA conducted the statistical analyses, assisted in interpreting the results and wrote the statistical methods and results sections of the manuscript. PAF provided guidance on the conduct of the study as a member of the thesis committee and contributed to writing the manuscript. ALD provided guidance on the conduct of the study as a member of the thesis committee, took primary responsibility for adapting the thesis report into this manuscript, and serves as guarantor for the overall content of the study. All authors reviewed and approved the final manuscript.

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#### REFERENCES

- World Health Organization (WHO). Road traffic injuries. 2022. Available: <https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries>
- Bergh T, Carlsson A, Larsson M. Swedish vision zero experience. *International Journal of Crashworthiness* 2003;8:159–67.
- Kristianssen A-C, Andersson R, Belin M-Å, et al. Swedish vision zero policies for safety – a comparative policy content analysis. *Safety Science* 2018;103:260–9.
- Seattle Department of Transportation. Vision zero: Seattle's plan to end traffic deaths and serious injuries by 2030. 2015. Available: <https://www.seattle.gov/Documents/Departments/beSuperSafe/VisionZeroPlan.pdf>
- Belin MÅ, Tillgren P, Vedung E. Vision zero--a road safety policy innovation. *Int J Inj Contr Saf Promot* 2012;19:171–9.
- Drennen E. *Economic effects of traffic calming on urban small businesses*. San Francisco State University, 2003. Available: <https://www.yumpu.com/en/document/view/19316642/economic-effects-of-traffic-calming-on-urban-small-businesses>
- U.S. Department of Transportation Federal Highway Administration. Toolbox of countermeasures and their potential effectiveness for pedestrian crashes. 2013. Available: [https://safety.fhwa.dot.gov/ped\\_bike/tools\\_solve/ped\\_tctpepc/](https://safety.fhwa.dot.gov/ped_bike/tools_solve/ped_tctpepc/)
- Johansson R. Vision Zero – implementing a policy for traffic safety. *Safety Science* 2009;47:826–31.
- Strandroth J. Validation of a method to evaluate future impact of road safety interventions, a comparison between fatal passenger car crashes in Sweden 2000 and 2010. *Accid Anal Prev* 2015;76:133–40.
- Grundy C, Steinbach R, Edwards P, et al. Effect of 20 mph traffic speed zones on road injuries in London, 1986-2006: controlled interrupted time series analysis. *BMJ* 2009;339:b4469.
- Richards DC. *Relationship between speed and risk of fatal injury: pedestrians and car occupants*. Department for Transport: London, 2010. Available: [https://nacto.org/docs/usdgr/relationship\\_between\\_speed\\_risk\\_fatal\\_injury\\_pedestrians\\_and\\_car\\_occupants\\_richards.pdf](https://nacto.org/docs/usdgr/relationship_between_speed_risk_fatal_injury_pedestrians_and_car_occupants_richards.pdf)
- Seattle Department of Transportation. City of Seattle bicycle and pedestrian safety analysis. 2016 Available: [https://www.seattle.gov/Documents/Departments/SeattleBicycleAdvisoryBoard/presentations/BPSA\\_Draft\\_Public\\_093016.pdf](https://www.seattle.gov/Documents/Departments/SeattleBicycleAdvisoryBoard/presentations/BPSA_Draft_Public_093016.pdf)
- Elvebakk B. Vision zero: remaking road safety. *Mobilities* 2007;2:425–41.
- Jamroz K, Kustra W, Budzynski M, et al. Pedestrian protection, speed enforcement and road network structure the key action for implementing Poland's vision zero. *Transportation Research Procedia* 2016;14:3905–14.
- Arancibia D, Farber S, Savan B, et al. Measuring the local economic impacts of replacing on-street parking with bike lanes. *Journal of the American Planning Association* 2019;85:463–81.
- New York City Department of Transportation. The economic benefits of sustainable streets. 2014. Available: <http://www.nyc.gov/html/dot/downloads/pdf/dot-economic-benefits-of-sustainable-streets.pdf>
- Rowe K. *Bikenomics – Measuring the economic impact of bicycle facilities on neighborhood business districts*. University of Washington, 2013. Available: [http://bikewalkkc.org/wp-content/uploads/2016/03/Bikenomics\\_v4.pdf](http://bikewalkkc.org/wp-content/uploads/2016/03/Bikenomics_v4.pdf)
- Poirier JA. Bicycle lanes and business success: a San Francisco examination. *Transportation Research Record* 2018;2672:47–57.
- McCoy R, Poirier JA, Chapple K. Bikes or bust? Analyzing the impact of bicycle infrastructure on business performance in San Francisco. *Transportation Research Record* 2019;2673:277–89.
- Liu JH, Shi W. *Understanding economic and business impacts of street improvements for bicycle and pedestrian mobility – A multi-city multi-approach exploration [Phase 2]*. NITC-RR-1031/1161. Portland, OR: Transportation Research and Education Center (TREC), 2020. Available: <https://nitc.trec.pdx.edu/research/project/1161>
- People for Bikes. The National study of the economic impact of street improvements. 2020. Available: <https://www.peopleforbikes.org/reports/the-national-study-of-the-economic-impact-of-street>
- Volker JMB, Handy S. Economic impacts on local businesses of investments in bicycle and pedestrian infrastructure: a review of the evidence. *Transport Reviews* 2021;41:401–31.
- U.S. Census Bureau. North American industry classification system. 2017. Available: <https://www.census.gov/naics/>
- Washington State Department of Revenue. NAICS Info. 2020. Available: <https://dor.wa.gov/open-business/apply-business-license/naics-info>
- U.S. Bureau of Labor Statistics. CPI inflation calculator. 2022. Available: [https://www.bls.gov/data/inflation\\_calculator.htm](https://www.bls.gov/data/inflation_calculator.htm)
- Austin PC, Steyerberg EW. Graphical assessment of internal and external calibration of logistic regression models by using loess smoothers. *Stat Med* 2014;33:517–35.
- Etzioni R, Mandel M, Gulati R. Statistics for health data science. In: *Statistics for health data science: an organic approach*. Cham: Springer, 2020.
- Fucoloro T. Bike traffic on 2nd Ave triples after city builds protected bike lane. Seattle Bike Blog. 2014. Available: <https://www.seattlebikeblog.com/2014/09/16/bike-traffic-on-2nd-ave-increases-300-after-city-builds-protected-bike-lane/>
- Fucoloro T. A tour of Seattle's new Broadway Bikeway and how it makes life better for people walking. *Seattle Bike Blog* 2014. Available: <https://www.seattlebikeblog.com/2014/05/09/a-tour-of-seattles-new-broadway-bikeway-how-it-makes-life-better-for-people-walking/>
- Wang Y, Shen Q. A latent class analysis to understand riders' adoption of on-demand mobility services as a complement to transit. *Transportation (Amst)* 2022:1–19.
- Seattle Department of Transportation. Greenwood's makeover complete. SDOT Blog. 2010. Available: <https://sdotblog.seattle.gov/2010/11/02/greenwoods-makeover-complete/>
- Seattle Department of Transportation. Rainier Avenue South safety corridor. 2016. Available: [https://www.seattle.gov/Documents/Departments/SDOT/MaintenanceProgram/RainierAveS\\_BeforeAfter.pdf](https://www.seattle.gov/Documents/Departments/SDOT/MaintenanceProgram/RainierAveS_BeforeAfter.pdf)
- National Association of City Transportation Officials (NACTO). Bell street Park shared street, Seattle. Transit Street Design Guide. 2014. Available: <https://nacto.org/case-study/bell-street-park-seattle/>
- Seattle Department of Transportation. Aurora traffic safety project update. SDOT Blog. 2011. Available: <https://sdotblog.seattle.gov/2011/12/09/aurora-traffic-safety-project-update/>
- Meltzer R, Capperis S. Neighbourhood differences in retail turnover: evidence from New York City. *Urban Studies* 2017;54:3022–57.