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Exploring the impact of a dedicated streetcar right-of-way on pedestrian motor vehicle collisions: A quasi experimental design

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ABSTRACT

Background and Objectives: The frequency of pedestrian collisions is strongly influenced by the built environment, including road width, street connectivity and public transit design. In 2010, 2159 pedestrian collisions were reported in the City of Toronto, Canada with 20 fatalities. Previous studies have reported that streetcars operating in mixed traffic pose safety risks to pedestrians; however, few studies evaluate the effects on pedestrian-motor vehicle collisions (PMVC). The objective of this study was to examine changes in the rate and spatial patterning of PMVC, pre to post right-of-way (ROW) installation of the St. Clair Avenue West streetcar in the City of Toronto, Canada.
Methods: A quasi-experimental design was used to evaluate changes in PMVC rate, following implementation of a streetcar ROW. Collision data were extracted from all police-reported PMVC, complied and verified by the City of Toronto, from January 1, 2000 to December 31, 2011. A zero-inflated Poisson regression analysis estimated the change in PMVC, pre to post ROW. Age and injury severity were also examined. Changes in the spatial pattern of collisions were examined by applying the *G* function to describe the proportion of collision events that shared a nearest neighbor distance less than or equal to a threshold distance.
Results: A total of 23,607 PMVC occurred on roadways during the study period; 441 occurring on St. Clair Ave, 153 during the period of analysis. There was a 48% decrease in the rate of collisions on St. Clair [Incidence rate ratio (IRR) = 0.52, 95% CI: 0.37–0.74], post ROW installation. There were also decreases noted for children (IRR = 0.13, 95% CI: 0.04–0.44), adults (IRR = 0.61, 95% CI: 0.38–0.97), and minor injuries (IRR = 0.56, 95% CI: 0.40–0.80). Spatial analyses indicated increased dispersion of collision events across each redeveloped route segment following the changes in ROW design.
Conclusions/Implications: Construction of a raised ROW operating on St. Clair Ave. was associated with a reduction in the rate of collisions. Differences in pre- and post collision spatial structure indicated changes in collision locations. Results from this study suggest that a streetcar ROW may be a safer alternative for pedestrians compared to a mixed traffic streetcar route and should be considered by city planners where appropriate to the street environment.

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1. Introduction

The World Health Organization has identified road traffic collisions as an important public health problem that results in 1.2 million fatalities per year worldwide (World Health Organization, 2009). Pedestrians are more likely to be killed or injured in traffic collisions per kilometer (km) travelled, as compared to other modes of transportation (Pucher and Dijkstra, 2003). In 2010, 2159 pedestrian collisions were reported in the City of Toronto, Canada with 20 fatalities.(City of Toronto Traffic Safety Unit, 2011) The frequency of pedestrian collisions is strongly influenced by the built environment, including road width, street connectivity and public transit design (Agran et al., 1996; Korve et al., 1996; Gårder, 2004; Hess et al., 2004; Wier et al., 2009; Currie et al., 2011; Mecredy et al., 2012).

The City of Toronto's public transit system (TTC) comprises substantial networks of bus, streetcar, Wheel-trans (i.e., TTC transit service for persons with physical disabilities using accessible vehicles), and subway/rapid transit routes. At 304.6-route km and serving mainly Toronto's central city neighborhoods, the TTC streetcar network provides extensive coverage when compared against the combined subway/rapid transit system (68.3 km). The public transit operator runs its streetcars in dedicated right-of-way (ROW) and within mixed traffic environments (Currie and Shalaby, 2007).

Streetcars running at grade on-street have been identified as the least desirable design for light rail systems due to potential conflicts with other modes of transit which can impede traffic, limit transit speed and reliability, and pose safety risks to both vehicles and pedestrians (Vuchic, 1981; Korve et al., 1996). In Toronto for example, curbside transit stops, commonly employed along mixed traffic streetcar routes, place waiting passengers and disembarking passengers in a position to cross in front of or behind streetcars, streetcar tracks, and in front of mixed vehicle traffic (Currie and Shalaby, 2007). In contrast, a dedicated streetcar ROW comprises a track physically separated from other traffic with at or above grade crossings for vehicles and pedestrians (Vuchic, 1981). Operating at grade in mixed traffic may expose pedestrians to greater risk of injury or death from collisions with motor vehicles during access or egress to streetcars.

Previous studies have reported that streetcars operating in mixed traffic pose safety risks to pedestrians (Sagberg and Saetermo, 1997; Currie and Reynolds, 2010). While previous research has examined the risks related to streetcar design and pedestrian–streetcar collisions, few studies have evaluated the effects of light rail design on pedestrian-motor vehicle collisions (Korve et al., 1996). This is important as pedestrian motor vehicle conflicts have been identified as representing the highest proportion of streetcar related collisions (Currie and Reynolds, 2010). Sagberg and Saetermo (1997) compared rates of pedestrian collisions on tracks in mixed traffic to those on physically segregated tracks and found a 43% lower rate of pedestrian collisions on physically segregated tracks (Sagberg and Saetermo, 1997).

St. Clair Avenue West is a major arterial roadway, running east–west through the City of Toronto. The east–west streetscape of St. Clair is comprised predominantly of thriving commercial businesses, where north or south of the roadway is densely populated residential neighborhoods. Streetcar surface transit has been available along St. Clair Avenue, under one operator or another, since 1913 (Stevanovic-Briatico, 2008). Between 2005 and 2010, construction was carried out in stages converting the mixed traffic streetcar route on St. Clair to one operating within a dedicated ROW. The design dedicated the two center lanes of traffic for exclusive streetcar use on a raised, mountable track-bed with platform stops on either side. Two traffic lanes remained on either side of the streetcar lanes along the majority of the route (Brook McIlroy Inc. Planning and Urban Design, 2004). The St. Clair redesign occurred as a transport level service project. The goals of the project included improving transit reliability and efficiency, but may have intended and unintended impacts on safety (Brook McIlroy Inc. Planning and Urban Design, 2004; Kelman and Soberman, 2010).

This study examined rates of collisions, stratified by age and injury severity, before and after the installation of a dedicated streetcar ROW along one streetcar transit route located in Toronto, Canada (St. Clair Avenue West). The main hypothesis was that implementation of a dedicated ROW associated with a reduction in pedestrian-motor vehicle collisions. Changes in the spatial pattern of collision locations were also studied using exploratory spatial data analysis methods to explore the hypothesis that collision incidence and spatial patterning changed over time with the introduction of a streetcar ROW.

2. Materials and methods

2.1. Design

A quasi-experimental design was used to evaluate whether the rate of pedestrian motor vehicle collisions was reduced following the implementation of a streetcar ROW on St. Clair Avenue West. Collision data were extracted from all police-reported pedestrian motor vehicle collisions, compiled and verified by the City of Toronto, from January 1, 2000 to December 31, 2011. Records were excluded if collisions occurred in a parking lot or on private property.

2.2. Outcome

The outcome of interest was the frequency of pedestrian motor vehicle collisions. Pedestrian collisions were mapped onto the Toronto centerline shapefile using ArcGIS, ArcMap version 10. A 25-metre buffer (i.e., 25 metres represents the width of the street, pre-construction) was created around the centerline of the St. Clair roadway with the streetcar route to capture all pedestrian collisions that occurred on or close to the road. Any buffering beyond that distance would place collisions well inside local and arterial roads running perpendicular to the ROW.

Construction along St. Clair (Fig. 1) was carried out in three route segments between July 31, 2005 and June 30, 2010 (Yonge to Bathurst: July 31, 2005–September 2, 2007; Bathurst to Lansdowne: June 18, 2006–December 20, 2009; Lansdowne to Gunn's Loop: June 18, 2006–June 30, 2010). Construction start and end dates were determined based on dates of streetcar service cancellations due to construction, provided by the City of Toronto Traffic Safety Unit. Collisions along St. Clair were classified according to the three road segments based on similar construction start and end dates and then separated based on phase of construction into two categories: before, or after the construction period.

2.3. Statistical analyses

Regression analysis was conducted using STATA, version 12.1 and spatial point pattern analysis was conducted using the splancs library for R version 2.15.1, and ArcGIS version 9.3. To determine the effectiveness of a dedicated ROW on pedestrian motor vehicle collisions, a zero inflated Poisson regression analyses was used. The unit of analysis was segment-month, and the pre-construction period was designated as the reference value. Due to the differing time periods pre and post construction by segment, equal pre and post times, matched by season, were created for comparison. A zero inflated Poisson regression analyses, using the equation $log(collisions/segment - month) = \beta_1(pre - post)$ was used to: (1) account for the count data (i.e., number of collisions that occurred

Fig. 1. St. Clair Ave. streetcar right of way, pre (mixed traffic, at grade level pedestrian crossing) and post (physically separated tracks, above grade level pedestrian crossing) construction in the City of Toronto.

per segment-month of streetcar track), and (2) account for the excess zeros in the count data. The dependent variable in this study was the frequency of pedestrian motor vehicle collisions. The independent variable was a dichotomous variable, designated as either pre or post construction, excluding the time period during construction. The regression analyses was used to estimate incidence rate ratios (IRR), presented as the rate of collisions per segment-month, with 95% confidence intervals (CI) using the pre-construction segment as the reference value. The level of cluster (i.e., the streetcar segment) was set as a fixed effect in the model, controlling for the repeated measure. The level of statistical significance was established a priori at 5%.

A stratified analysis was used to evaluate subsets of the data by age and injury status. Collisions were age stratified using the categories: children (aged 0–15), adults (aged 16–59) and older adults (aged 60+) based on categories used by the WHO report on *Road Traffic Injury Prevention* (2004) comparing the leading cause of death by age group (Peden et al., 2004). Toronto Police Services coded injury status using the categories: no injury, minimal injury (no medical attention is required), minor injury (emergency department treatment only), major injury (hospital admission is required), and fatal injury. Misclassification by injury severity has been reported most commonly for minor injuries (Agran et al., 1990; Rosman and Knuiman, 1994; Sciortino et al., 2005), therefore, minor and minimal injuries were recoded as one category labeled "minor injury".

For the spatial point pattern analysis, separate pre- and post construction point patterns were extracted for each of the three route segments. Changes in the spatial pattern of pre- and post construction collisions were examined by applying the *G* function to describe the proportion of collision events within the set of collision events that shared a nearest neighbor distance less than or equal to a threshold distance, *s* (Gatrell et al., 1996). When the *G* function is repeatedly estimated across a vector of distances, *s*, insight is gained into the relative location of events, for example, a fast rising distribution indicates that most events were in close proximity to one another. Following Bivand et al. (2008), the distribution of the distances from the events *i*, to their nearest neighbors is defined as, $d_i = \min_j \left\{ d_{ij}, \forall j \neq i \right\}, i = 1, \ldots, n$ where d_{ij} is the Euclidean distance between an arbitrary event *i* and all other events *j*, then the estimator for the *G* function is: $\hat{G}(s) = n^{-1}\# \left\{ d_i : d_i \leq s, \forall i \in D \right\}$ The numerator is number of nearest neighbor distance elements in the set of distances *D*, less than or equal to a distance, *s*, and *n* is the total number of events in the set (Zhang et al., 2009). The hypothesis is that the shape and maximum values for $\hat{G}(s)$ would change between the pre- and post development periods following changes in route design.

Exposure using pedestrian and traffic volume data was unviable and unavailable for many intersections at the different phases of the construction period; therefore, the offset used in the regression analyses was calculated as time per segment-month.

3. Results

Over the study period (January 2000–December 2011), a total of 27,827 pedestrian–motor vehicle collisions occurred in the City of Toronto, with 23,607 occurring on roadways. Four hundred and forty one of these collisions were identified on St. Clair, 153 during the period of analysis. Fig. 2 demonstrates trends in pedestrian collisions on the St. Clair streetcar line between the years 2000 and 2011. The data suggest decreasing collisions along St. Clair, particularly during the period of service disruption, with an increase in events per route kilometer following project completion. A

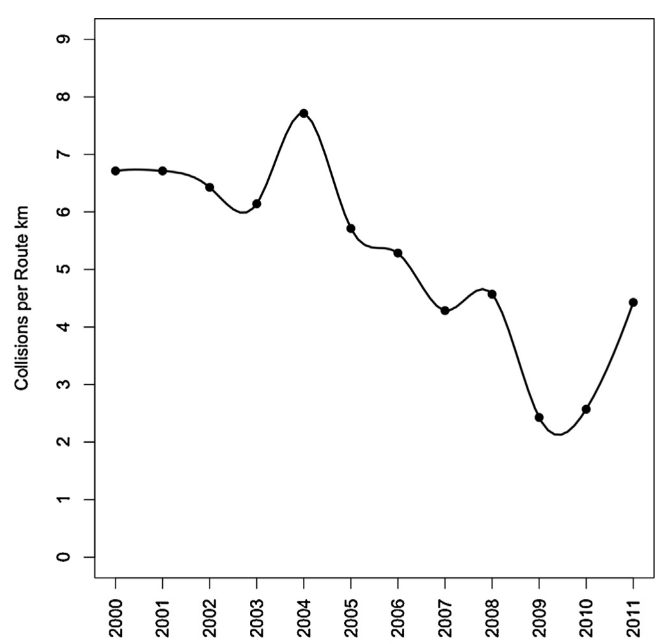

Fig. 2. Annual pedestrian collisions (per route kilometer) on the St. Clair Ave. streetcar line in the City of Toronto.

Table 1
Incidence rates and incidence rate ratios, comparing pre and post streetcar right-of-way on pedestrian motor vehicle collisions.

	Collisions (pre)	Collisions (post)	IR[a] (pre)	IR (post)	IRR[b] (95%CI)[c]
St. Clair	100	53	113.7	60.2	0.52 (0.37–0.74)
Age (years)					
Child (0–15)	23	3	26.2	3.40	0.13 (0.04–0.44)
Adult (16–59)	59	34	67.1	38.6	0.61 (0.38–0.97)
Older adult (60+)	16	12	18.2	13.6	0.75 (0.34–1.64)
Injury status					
No injury	3	2	3.4	2.3	0.67 (0.11–3.98)
Minor injury	87	49	98.9	55.6	0.56 (0.40–0.80)
Major injury	9	2	10.2	2.3	0.23 (0.05–1.15)
Fatal injury	1	0	1.1	0	–[d]

[a] Incidence rate (collisions/100 segment-months).
[b] Incidence rate ratio.
[c] Confidence interval.
[d] Insufficient data.

decreasing number of pedestrian collisions on St. Clair were observed with a peak of 54 in 2004 and a low of 17 in 2009.

The regression analyses demonstrated a significant reduction in the incidence of pedestrian collisions pre-post construction. There was a 48% reduction in the rate of collisions [Incidence rate ratio (IRR) = 0.52, 95% CI: 0.37–0.74], controlling for season. There was evidence of a differential effect on collisions, post-construction by age and injury status (Table 1). There was a statistically significant reduction in the rate of collisions pre to post ROW for children (IRR = 0.13, 95%CI: 0.04–0.44), adults (IRR = 0.61, 95% CI: 0.38–0.97), and minor injuries (IRR = 0.56, 95% CI: 0.40–0.80).

The spatial analysis suggested changes in the spatial structure of collision events between the pre and post construction periods (Fig. 3). There were noticeable differences in the shape and maximum value of $\hat{G}(s)$ for each route segment (Fig. 3). In all cases, the maximum nearest neighbor distance increased into the post-construction period (observable in Fig. 3 as the longer post-construction lines). For all route segments, $\hat{G}(s)$ shifts to the right into the post-construction phase, as demonstrated in Figs. 3 and 4, suggested collisions became less tightly concentrated, or more dispersed across each redeveloped route segment following the design changes. There was a particularly marked dispersion effect within the Bathurst to Lansdowne and Lansdowne to Gunn's Loop route segments. The pre and post collision patterns indicated differences in spatial structure, suggesting that the change in collision incidence was matched by a change in collision location.

4. Discussion

A statistically significant difference in the number of pedestrian–motor vehicle collisions before and after the implementation of a streetcar ROW was found. Stratified analysis showed significantly reduced rates for children, adults, and minor injuries. There was no significant change in rates for older adults, no-injuries, and major or fatal injuries, which may be due to the small number of collisions particularly in the case of fatal injuries where there was only one fatal collision, pre construction. The significant reduction in the collision rate noted in children in this study should be interpreted with caution. The small number of collisions that involved children in the pre and post-period would affect the estimate produced by the model. Given the report of a decrease in collisions post construction, we could speculate that any reduction could be the result of the changes to the built environment. The grade separation in the redeveloped ROW acts as a larger perceived and objective barrier to child pedestrian mobility than is the case for adults. Moreover, children are less likely to be navigating the ROW independently, and so it could be the case that adult chaperones were more likely to shift their crossing behaviour to controlled intersections when children were present.

One explanation for the overall reported reduction in pedestrian collisions following the introduction of a ROW is the better separation of pedestrians from motor vehicle traffic. Fig. 4 demonstrates a decrease in collisions from the pre to post construction periods, particularly at intersections of major arterials (e.g., Dufferin and St. Clair). We hypothesize that this decrease was in part a function of the introduction of station barriers that limit the efficacy of pedestrians attempting to access platforms from mid-block origins. Currie and Reynolds (2010) found that platform stops, where pedestrians are separated from traffic, as opposed to curbside stops, where pedestrians must cross in a mixed traffic environment without signalized intersections, were similarly safer (Currie and Reynolds, 2010). The platform stops built on St. Clair (Figure 1), which contain guardrails, provide best access to

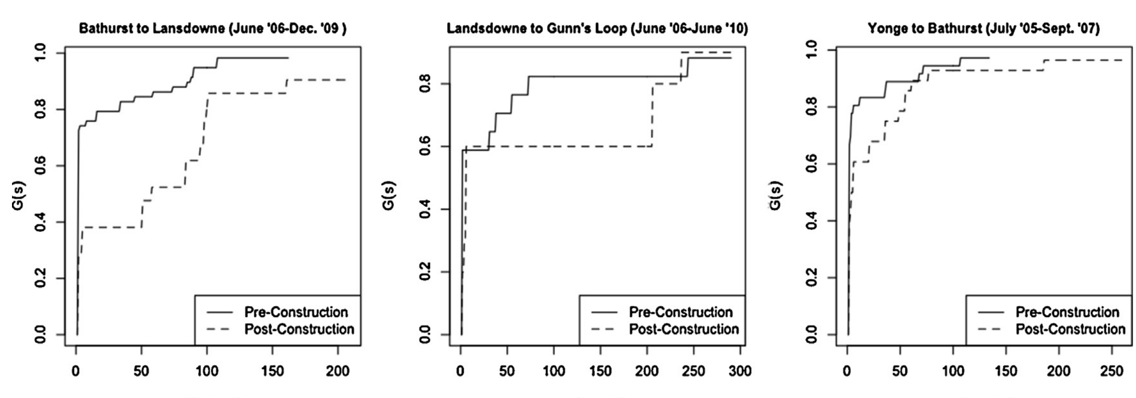

Fig. 3. Spatial structure of pre and post St. Clair Ave. construction collisions along each route segment in the City of Toronto.

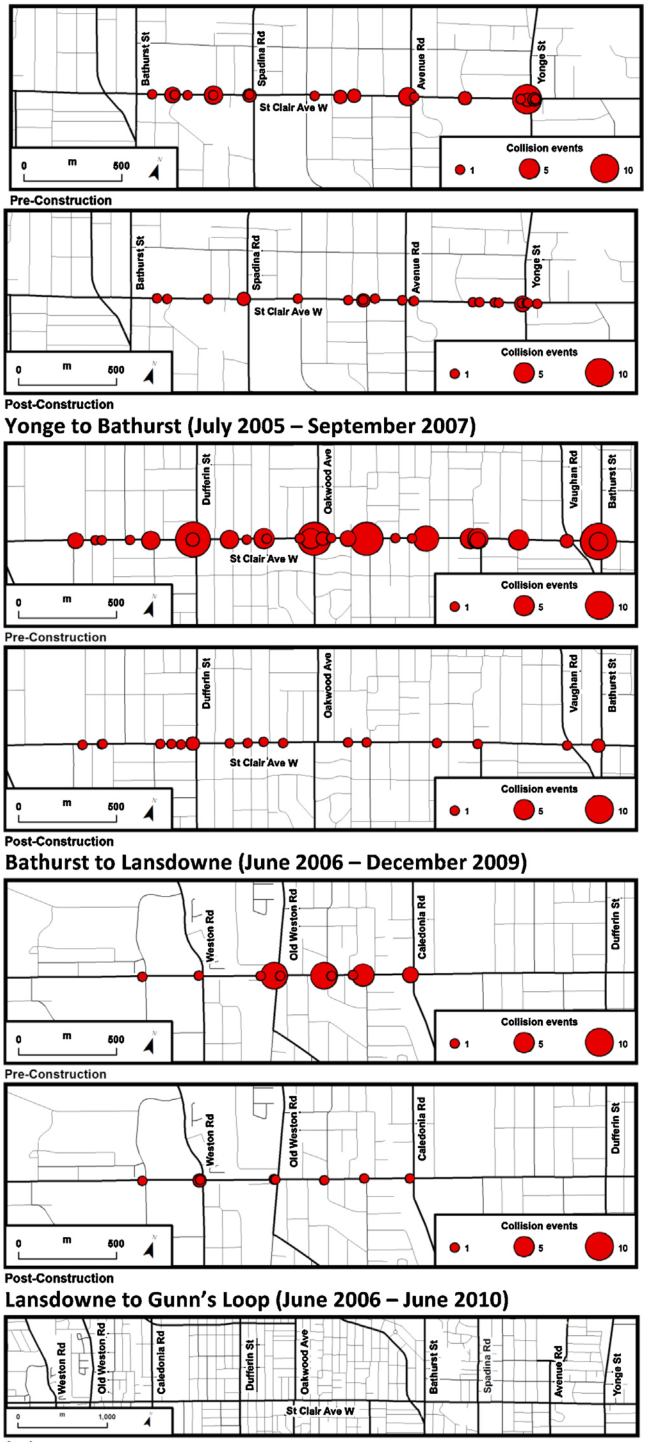

Fig. 4. Pre and post St. Clair Ave. construction collision events by three route segments: Yonge to Bathurst, Bathurst to Lansdowne, Lansdowne to Gunn's Loop, in the City of Toronto.

platforms, achieved through pedestrians using controlled intersections. The platforms were designed to be wide enough so that pedestrians could wait comfortably and safely at stops without crossing in front of traffic to board the streetcar (Brook McIlroy Inc. Planning and Urban Design, 2004).

There is a possibility of a continued presence of collisions at mid-block locations, despite the post-construction streetscape due to pedestrian exposure and pedestrian–vehicle interaction. Follow up observational study along the corridor demonstrated pedestrians crossing St. Clair from mid-block positions. This type of street crossing puts pedestrians at risk of being injured or killed by streetcar and/or vehicular traffic. The persistence of these mid-block events may be indicative of placing pedestrians into a complex traffic environment.

There is, perhaps some scope to consider social-marketing and/or educational campaigns to promote traffic safety around streetcar tracks. It might also be tempting to suggest that installation of barriers along the entire ROW would further reduce the likelihood of mid-block injury and fatality. That; however, is a politically and operationally intractable solution as emergency services make use of the ROW and require flexible points of access and egress both at and between intersections.

Another explanation for the reduction in collisions is the changed streetscape on St. Clair following ROW introduction. The ROW's structure prevents motor vehicles from going straight through St. Clair or left turning from streets where there is no signalized intersection, thereby reducing pedestrian and motor vehicle contact. The results suggested that collisions became less concentrated within certain hot spots along each segment, giving rise to a more diffuse pattern, post ROW construction. Close inspection indicated that the decline in incidence had an intrinsically spatial quality with evidence of a reduction in collisions, post-construction along specific intervals within each route segment. The location specific decline explains the increase in collision dispersion shown in Fig. 3. This could reduce the number and severity of collisions as conflicts become directed toward signalized intersections where severe injuries are less common (Siddiqui et al., 2006; Rothman et al., 2012).

Results from this study are consistent with previous research that identified a higher risk of pedestrian injury when streetcars operate in mixed traffic. Sagberg and Saetermo (1997) showed a similar reduction in collisions of 43% when comparing collisions per vehicle km in mixed traffic, compared to a physically reserved track. Korve et al. (1996) conducted a survey of 10 North American light rail systems and found that per track mile, semi-exclusive and non-exclusive ROWs are heavily overrepresented for pedestrian collisions (Korve et al., 1996). In his report "*Integrating Light Rail Transit into City Streets*" it was recommended that light rail transit be separated from traffic noting safety concerns with mixed traffic designs.

4.1. Strengths and limitations

Study strengths include the complex modeling design, in which each road segment on St. Clair acted as its own control, thus controlling for extraneous variables of location including land use mix, speed limits, demographics, and other unknown variables. The length of the study period ensured that each location was tracked for a sufficient period of time, with each segment along St. Clair followed for a minimum of 18 months, post-construction time. The length of the study period also ensured sufficient numbers of collisions to provide precise estimates of rates and the ability to conduct a stratified analysis. The use of police reported collisions as an outcome rather than more subjective outcomes used in previous studies, such as near-misses,(Currie and Reynolds, 2010) reduces the likelihood of observer bias in measuring outcomes.

This study has several limitations. The pedestrian–motor-vehicle collision data set relies on collisions reported to and by police. It has been estimated that only 24% of collisions are actually reported to police, with minor injuries less likely to be reported (Harris et al., 2004). In addition, police-recorded injury severity coding has been shown to be subject to misclassification error, particularly with less severe injuries (Agran et al., 1990; Rosman and Knuiman, 1994; Sciortino et al., 2005). Minor and minimal injuries were combined into one category in this study to account for any misclassification of less severe injuries. It is highly unlikely; however, that police would have recorded incorrect dates of collisions, which would have affected whether or not the collisions occurred pre or post-construction. Additionally, the small sample of streets with ROW in the City of Toronto reduces the generalizability of this study to other street environments.

This study made use of a model that was unable to account for changes in pedestrian exposure or important confounders such as traffic volumes, economic activities, speed and presence of on-street parking. Sufficiently detailed data were not available for any of these variables. Available pedestrian and motor vehicle volume counts indicated a possible increase in pedestrian volumes and decrease in motor vehicle volumes following construction. The post-construction streetscape on St. Clair, which included a reduction in traffic lanes, may have caused a reduction in motor vehicle volumes. Therefore, the reduction in pedestrian–motor vehicle collisions found on St. Clair may be related to a decrease in volumes of motor vehicles (Wier et al., 2009). We did not have access to data related to economic activities; however, we modeled the data using the same streetcar segment as its own control. The economic activity within each segment is relatively constant over time; thus, we discussed the changes in collisions rate, pre to post construction as a function of the changes to the physical environment. Decreased traffic speed due to lane reductions, may have also affected number of pedestrian collisions, as higher speeds are associated with a greater number and severity of collisions (Pucher and Dijkstra, 2003; Hess et al., 2004). Further, the posted speed limits on St. Clair did not change, pre to post ROW installation. Additionally, construction of the ROW likely affected the availability of on-street parking along St. Clair (Moloney, 2011). On-street parking has been associated with a higher number of pedestrian–motor vehicle collisions, due to lowered on-road visibility (Agran et al., 1996).

5. Conclusions

This study further elucidates pedestrian safety issues related to different light rail designs, and particularly platform designs. Construction of a raised ROW operating on St. Clair was associated with a reduction in the rate of collisions, particularly the rate of collisions involving children and minor injuries. Results from this study suggest that a streetcar ROW may be a safer alternative for pedestrians compared to a mixed traffic streetcar route and should be favored where appropriate to the street environment. Increased pedestrian safety may result in increased walking and use of public transit as mode of transportation (Lightman et al., 2012).

Further research is needed that can account for differences in pedestrian and motor vehicle volume, and explores similar transit interventions in different environments. A time series analysis which controls for natural trends in collisions rates could help to clarify the association between implementing a streetcar ROW and pedestrian collisions. In addition, research should explore behavioral and additional environmental changes related to streetcar ROWs, to clarify what factors contribute to a reduction in rates. In particular, further research should explore if the installation of the right of way resulted in risk migration, relocating collision incidents to neighbouring roads. Lastly, the differential effectiveness of the ROW by age should be explored further.

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References

Agran, P.F., Castillo, D.N., Winn, D.G., 1990. Limitations of data compiled from police reports on pediatric pedestrian and bicycle motor vehicle events. Accidental Anal. Prev. 22 (4), 361–370.
Agran, P.F., Winn, D.G., Anderson, C.L., Tran, C., Del Valle, C.P., 1996. The role of the physical and traffic environment in child pedestrian injuries. Pediatrics 98 (6), 1096–1103.
Bivand, R.S., Pebesma, E.J., Gomez-Rubio, V., 2008. Applied Spatial Data Analysis with R. Springer, New York.
Brook McIlroy Inc. Planning and Urban Design, 2004. St. Clair Avenue west Transit Improvements: Urban Design Summary. http://www.toronto.ca/wes/techservices/involved/transportation/st_clair_w_transit/pdf/st-clair_urban_design_summary.pdf (accessed August, 2013).
City of Toronto Traffic Safety Unit, 2011. Pedestrian Collision Summary Leaflet. http://www.toronto.ca/transportation/publications/brochures/2010_ped.pdf (accessed August, 2013).
Currie, G., Reynolds, J., 2010. Vehicle and pedestrian safety at light rail stops in mixed traffic. Transp Res. Record: J. Transp. Res. Board 2146 (4), 26–34.
Currie, G., Shalaby, A., 2007. Success and challenges in modernizing streetcar systems. Transp. Res. Record: J. Transp. Res. Board (2006), 31–39.
Currie, G., Tivendale, K., Scott, R., 2011. Analysis and mitigation of safety issues at curbside tram stops. Transp. Res. Record: J. Transp. Res. Board 2219 (4), 20–29.
Gårder, P.E., 2004. The impact of speed and other variables on pedestrian safety in Maine. Accidental Anal. Prev. 36 (4), 533–542.
Gatrell, A., Bailey, T., Diggle, P., Rowlingson, B., 1996. Spatial point pattern analysis and its application in geographical epidemiology. Trans. Instit. Brit. Geogr. 21 (1), 256–274.
Harris, A.D., Bradham, D.D., Baumgarten, M., Zuckerman, I.H., Fink, J.C., Perencevich, E.N., 2004. The use and interpretation of quasi-experimental studies in infectious diseases. Clin. Infect. Dis. 38 (11), 6–1591.
Hess, P.M., Moudon, A.V., Matlick, J.M., 2004. Pedestrian safety and transit corridors. J. Public Transport. 7 (2).
Kelman, L., Soberman, R., 2010. Getting it Right. Lessons from the St. Clair Streetcar for the Implementation of Transit City. http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2010/Jan_20_2010/Reports/Transit_City_Impleme.pdf (accessed August, 2013).
Korve, H.W., Farran, J.I., Mansel, D.M., Levinson, H.S., Chira-Chavala, T., Ragland, D.R., 1996. Integration of Light Rail Transit into City Streets. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_17-a.pdf (accessed August, 2013).
Lightman, D., Winters, M., Heeney, D., Mee, C., Chirrey, S., Campbell, M., Mishaiel, R., 2012. Road to Health: Improving Walking and Cycling in Toronto. Toronto Public Health.
Mecredy, G., Janssen, I., Pickett, W., 2012. Neighbourhood street connectivity and injury in youth: a national study of built environments in Canada. Inj. Prev. 18 (2), 81–87.
Moloney, P., 2011. St Clair streetcar project brings surprise good news for drivers. The Toronto Star http://www.thestar.com/news/gta/2011/05/24/st_clair_streetcar_project_brings_surprise_good_news_for_drivers.html
Peden, M., Scurfield, R., Sleet, D., Mohan, D., Hyder, A., Jarawan, E., Mathers, C., 2004. World Report on Road Traffic Injury Prevention. http://whqlibdoc.who.int/publications/2004/9241562609.pdf (accessed August, 2013).
Pucher, J., Dijkstra, L., 2003. Promoting safe walking and cycling to improve public health: Lessons from the Netherlands and Germany. Am. J. Pub. Health 93 (9), 1509–1516.
Rosman, D.L., Knuiman, M.W., 1994. A comparison of hospital and police road injury data. Accidental Anal. Prev. 26 (2), 215–222.
Rothman, L., Howard, A.W., Camden, A., Macarthur, C., 2012. Pedestrian crossing location influences injury severity in urban areas. Inj. Prev., http://dx.doi.org/10.1136/injuryprev-2011-040246.
Sagberg, F., Saetermo, I.-A. F., 1997. Traffic safety of tram transport in Oslo. TOI Report (367).
Sciortino, S., Vassar, M., Radetsky, M., Knudson, M.M., 2005. San Francisco pedestrian injury surveillance: mapping, under-reporting, and injury severity in police and hospital records. Accidental Anal. Prev. 37 (6), 1102–1113.
Siddiqui, N., Chu, X., Guttenplan, M., 2006. Crossing locations, light conditions, and pedestrian injury severity. Transp. Res. Record: J. Transp. Res. Board 1982 (1), 141–149.
Stevanovic-Briatico, V., 2008. City of Toronto. Road Classification System-Street Name Index. Toronto Transportation Services Division.
Vuchic, V.R., 1981. Urban Public Transportation: Systems and Technology. Prentice-Hall, Inc., Englewood Cliffs, N.J.
Wier, M., Weintraub, J., Humphreys, E.H., Seto, E., Bhatia, R., 2009. An area-level model of vehicle-pedestrian injury collisions with implications for land use and transportation planning. Accidental Anal. Prev. 41 (1), 137–145.
World Health Organization, 2009. Global Status Report on Road Safety: Time for Action. http://whqlibdoc.who.int/publications/2009/9789241563840_eng.pdf (accessed August, 2013).
Zhang, Z., Clark, A.B., Bivand, R., Chen, Y., Carpenter, T.E., Peng, W., Zhou, Y., Zhao, G., Jiang, Q., 2009. Nonparametric spatial analysis to detect high-risk regions for schistosomiasis in Guichi, China. Trans. R. Soc. Trop. Med. Hyg. 103 (10), 1045–1052.