THE CITY OF TORONTO AUTOMATED SPEED ENFORCEMENT PROGRAM EVALUATION

Final Report 2023

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Executive Summary

- This report presents findings from the first five phases (rotations) of the Automated Speed Enforcement (ASE) program in the City of Toronto which started in January 2020, as part of the City's Vision Zero 2.0 strategy.
- The program is aimed at reducing speeding in Community Safety Zones (CSZs) located near schools. This involves rotating 50 mobile ASE camera units through various CSZs for a period of three to six months This final report includes data analyses covering the period from January 2020 to December 2022.
- Although data collection was impacted by the COVID-19 pandemic, there was substantial data collected during periods without stay-home orders or school closures.
- The proportion of drivers speeding in 30, 40, and 50 km/h speed zones respectively dropped from 59.8%, 51.7%, and 58.4% pre-intervention to 43.3%, 29.2%, and 35.7% when the ASE devices were operational. This represents a 45% reduction in the proportion of vehicles speeding near schools with the deployment of ASE after adjustments made for potential confounding factors such as road types, speed limits, city region and design (i.e., pre-amalgamated City of Toronto versus inner suburbs).
- The 85th percentile vehicle speeds in 30, 40, and 50 km/h speed zones respectively dropped from 44.2 km/h, 50.4 km/h and 62.7 km/h pre-intervention period to 36.8 km/h, 43.6 km/h and 56.9 km/h when the ASE devices were operational. Overall, results show a decrease of 7.44 km/h in the 85th percentile vehicle speed when the ASE devices were implemented after adjusting for potential confounding factors.
- The percentage of drivers exceeding the speed limit decreased for nearly all sites during ASE deployment, with 36 exceptions (out of 204 locations where pre-ASE deployment data were available). Higher speed limits and vehicle speeds were predominantly found around schools in Toronto's suburbs, reflecting the prevalence of high-speed arterial roads in these areas.
- Comparisons between control sites and ASE deployments suggest that the decreases were associated with the ASE intervention.

- The Post-ASE speeds were measured at 39 sites between 28 and 45 days after removal of the device, and these showed partial persistence of the reduction of speeds.
- This automated speed enforcement program was effective in significantly reducing the number of vehicles speeding, and the overall vehicle speeds, in community safety zones near Toronto schools.

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1. Introduction

The World Health Organization (WHO) has identified speed to be a key contributing factor in all road traffic collisions, deaths and injury severity.¹ Studies have established a clear correlation between higher vehicle speeds and an increased risk of severe injuries and deaths.²⁻⁴ The risk of fatal collisions rises by 4-5% for every 1 km/h increase in the mean speed of vehicles.¹ In Ontario, speed-related fatalities have risen from 86 in 2015 to 97 in 2016, resulting in a 13% increase.⁵ While speed-related collisions pose a significant danger to all individuals utilizing the roadways, vulnerable road users, including pedestrians and cyclists, face an even greater risk. Among this group, children and the elderly are particularly susceptible to the negative impacts of speed-related collisions. This is due in part to their reduced ability to react quickly and move out of harm's way, as well as their potential to suffer more severe injuries in the event of a collision. ^{6–8} Pedestrians have less than a 50% chance of surviving an impact at speeds above 45 km/h, but a 90% chance of survival at speeds below 30 km/h.^{9,10} Therefore, mitigating the incidence of speed-related collisions through targeted interventions can have a significant impact on the safety and well-being of vulnerable road users.

Children are one of the vulnerable road user groups. Accidents or unintentional injuries are the leading cause of death for children in Canada. ¹¹ Child pedestrians are at a higher risk of road traffic injuries and deaths due to their short stature and difficulty in navigating the traffic environment.^{7,8} The City of Toronto's Vision Zero Road Safety Plan is designed as a data-driven, long-term road map that aims to eliminate traffic-related serious injuries and fatalities.^{12,13} The plan prioritizes a strategy for managing speed, improving road design, and proactively addressing dangerous mid-block crossings and turning collisions at intersections with signals. It also aims to educate and engage the general public. This plan identifies children as a vulnerable road user group and includes countermeasures aimed at improving safety around schools.

The risk of collisions between motor vehicles and pedestrians increases with higher speed limits and vehicle speeds.¹⁴ By enforcing slower speeds, drivers have a greater opportunity to react and require less distance to brake, thus lowering the chances and severity of collisions that result from high-speed impacts.^{15,16} Speed management strategies are an important component of Toronto's Vision Zero strategy and this includes road design improvements, enhanced police enforcement, lowering speed limits, public education and an automated speed enforcement program among other measures.

Automated Speed Enforcement (ASE) systems utilize a camera and speed measurement device to detect and capture images of vehicles that are driving over the posted speed limit. Images obtained from the ASE systems are then reviewed by Provincial Offences Officers to ensure all evidentiary requirements are met before a charge is laid. Research has shown that this system is successful in reducing the number of road traffic collisions, injuries, and fatalities over both the short and long term.¹⁷ Pilkington and Kinra in a systematic review of 14 observational studies assessed the efficacy of fixed, mobile, and combined fixed and mobile ASE cameras.¹⁸ The study showed that ASE led to reductions ranging from 5% to 69% in the number of

collisions, 12% to 65% in the number of injuries, and 17% to 71% in the number of fatalities in the areas immediately surrounding the camera sites.¹⁸ Similarly, Thomas et al. evaluated the safety effects of automated speed enforcement programs worldwide.¹⁹ Recommendations included that future research should include collaboration between traffic enforcement agencies and researchers to conduct controlled, randomized experiments on the safety effects of speed cameras.

The ASE program was introduced in January 2020 in the City of Toronto with 50 mobile camera units. Two cameras were placed in each of the City's wards in CSZs near schools. The ASE cameras are rotated every three to six months within the ward to address other areas with safety concerns and provide a wider-ranging deterrent effect. Road users are given a 90-day warning prior to ASE enforcement via installed warning signs. Once enforcement begins, regulatory signs replace the warning signs to inform road users that the cameras are in use.

Researchers from The Hospital for Sick Children Research Institute, in collaboration with the School of Occupational and Public Health, Toronto Metropolitan University (TMU), partnered with the City of Toronto, Transportation Services to evaluate the ASE program in terms of speed reduction. This report provides descriptive and inferential statistics of data collected from the first five phases of the ASE program (from January 2020 to December 2022).

2. Methods

2.1 Locations

During each phase of the project, the City of Toronto had a total of fifty ASE camera devices in operation, with two devices placed in each ward across the City. The ASE mobile units were positioned throughout the city during phases 1 to 5, as illustrated in **Figure 2-1**.

The ASE site selection methodology in the City of Toronto is a data-driven approach which involves an extensive analysis of speed and collision data. This approach was developed based on best practices recommended by the National Highway and Traffic Safety Administration (NHTSA), operational guidelines, feedback from researchers at the Hospital for Sick Children and TMU, and lessons learned from other Canadian jurisdictions. The selection process for ASE sites also considered factors such as planned roadwork, speed limit changes, obstacles that may affect the equipment, and the overall road environment. To ensure longerlasting road safety benefits, the ASE systems are deployed for at least three months, in addition to the 90-day warning period. During phase 4, one of the locations from the phase 1 rotation was reused, and during phase 5, two of the locations from the phase 2 rotation were reused because there were no new suitable locations available in those specific wards.



Figure 2-1. The City of Toronto Map with Phase 1 to 5 Locations and City Ward Boundaries

2.2 Outcome Measurement

Speed: The percentage of drivers exceeding the posted speed limit and 85th percentile speeds pre- and during installation of the ASE cameras were compared descriptively and graphically. The 85th percentile speed is used widely in traffic engineering and road safety.²⁰ It refers to the speed at or below which 85 percent of all vehicles are observed travelling under free-flowing conditions. Generalized Estimating Equation (GEE) was used to assess the effect of the ASE intervention on the number of vehicles exceeding the speed limit and on the 85th percentile speeds.

Pre-installation speed data: Pre-installation of ASE device (pre-ASE) vehicle speed and volume data for phase 1, phase 2, phase 4 and phase 5 were obtained from the existing City of Toronto data that was collected using pneumatic road tubes in spring 2018 and 2022. Data collection was primarily conducted on three consecutive weekdays. Where such data were not available for an area of interest, the City of Toronto collected speed and volume data (with pneumatic road tubes) prior to the ASE intervention. These data were collected on two consecutive weekdays. To investigate any variations that were unrelated to ASE deployment, data on vehicle speed and volume was collected using pneumatic road tubes during two time periods (March 2021 and April 2021) prior to the start of ticketing in phase 3. Data collection occurred one to two months before the ticketing began on three consecutive weekdays. Pre-ASE data on speed and vehicle volume was available for 204 locations, while for the other 46 locations, such data were either not available or could not be collected due to various factors such as construction or the presence of streetcar lines.

During ASE Intervention speed data: During the ASE intervention period, vehicle speed and volume data were collected using the ASE devices. **Table 2-1** shows the start and end dates, average number of operating days and overall deployment coverage of phase 1 to phase 5. ASE devices also collected data during the warning period in phase 1, which allowed further comparisons between the pre-installation, warning, and ticketing periods.

Post-ASE Intervention speed data: Following the implementation of the ASE intervention, speed and volume data were collected from a total of 39 carefully chosen locations, consisting of 11 locations from phase 1 and 28 locations from phase 3. These data were acquired for 2-3 weekdays through the utilization of pneumatic road tubes within a 28-45-day period after the removal of the cameras.

2.3 Data Validation

During phase 3, the City of Toronto conducted pneumatic road tube measurements at 23 sites in July 2021 during ASE deployment. This allowed for a comparison of 85th percentile speeds captured from the ASE devices and data collected from the pneumatic road tubes. Welch Two Sample t-test was conducted to determine the statistical significance of the difference in means of 85th percentile speeds between the two types of measurements.

Phase	Period	Start date	End date	Average active days per location (n)	Overall deployment coverage
Dhaga 1	Warning	24-Jan-2020	05-Jul-2020	133.9	91%
Phase I	Ticketing	06-Jul-2020	18-Nov-2020	109.5	95%
Phase 2	Ticketing	26-Oct-2020	31-May-2021	175.6	94%
Phase 3	Ticketing	20-May-2021	16-Nov-2021	101.3	92%
Phase 4	Ticketing	24-Nov-2021	25-May-2022	138.7	93%
Phase 5	Ticketing	07-Apr-2022	31-Dec-2022	178.5	89%

Table 2-1. Active Days of Phase 1 to Phase 5

2.4 Control Sites

At 44 different locations, data on vehicle speeds were collected using pneumatic road tubes, to serve as control sites. These locations were later designated as phase 3 locations. The proportions of vehicles exceeding speed limits and 85th percentile vehicle speeds were compared with pre-ASE and ASE period data from the same sites using paired t-test with Bonferroni correction.

2.5 Collisions

Traffic collision police- reported data were obtained from the City of Toronto, Transportation Services. Injury severity in this report was classified as no injury, minor (no hospital visit, medical attention in a hospital emergency department), major (hospital admission, e.g., fracture, internal injury, severe cuts, concussion), and fatal.

2.6 Data Analysis

Data processing and statistical analysis were carried out in R^{21} and spatial maps were created using ArcGIS²². Our descriptive analyses were stratified by speed limit on 30, 40, and 50 km/h roads. Only two of the 250 sites had a speed limit of 60 km/h. These locations were not used for the stratified analysis; however, they were incorporated into the aggregated analysis.

Generalized Estimating Equation (GEE) modelling was used to analyze the data with "independence" as the working correlation. GEE is a statistical technique that is used to analyze longitudinal or clustered data where observations are not independent. In this study, the data from each site is considered as a cluster. GEE linear regression was used to model the number of vehicles exceeding the speed limits and the 85th percentile speed as a function of the intervention phase while controlling for potential confounding factors. Poisson regression was

used to model the number of vehicles exceeding the speed limit. Additionally, the total number of vehicles were included as a log function in the regression equation to account for changes that are not unrelated to the intervention. Linear regression approach was employed with GEE to model the 85th percentile vehicle speed.

Potential confounders considered included road type (arterial, collector, local), speed limits, season (i.e., Summer and Winter) and city region and design (i.e., pre-amalgamated City of Toronto versus inner suburbs). The modelling analysis excluded roads with a speed limit of 60 km/h (n=2), as well as locations without pre-intervention data (n=46) and those that had changes in built environment (i.e. reduction of speed limit, installation of speed humps) prior to the ASE intervention period (n=15).

3. Results

3.1 Vehicle Speed

The total number of observations (total number of vehicles), summary (mean, median, minimum and maximum), 85th percentile speed and percentage of vehicles exceeding the speed limit during the ticketing period are described in **Table 3-1**. Vehicle speed summary statistics during each phase are shown in **Appendix A**. The ASE cameras recorded over 114 million observations across all five ticketing phases.

	Speed Limit			
	30 km/h (n=65)	40 km/h (n=146)	50 km/h (n=37)	60 km/h (n=2)
Overall				
Total Vehicles (n)	9,464,171	58,009,484	41,266,924	3,445,929
Mean Speed (km/h)	30.9	37.6	47.3	53.8
Median Speed (km/h)	30.0	37.0	47.6	47.3
(Min., Max.) Speed (km/h)	(1, 148)	(1, 213)	(1, 188)	(1, 175)
% of vehicles exceeding the speed limit	43.2	29.2	35.8	20.2
85th percentile Speed (km/h)	36.8	45.2	56.7	62.0
1 st 90 days				
% of vehicles exceeding the speed limit	45.3	33.7	39.8	38.5
85th percentile Speed (km/h)	38.9	48.9	59.1	64.2

Table 3-1. Vehicle Speed Summary Statistics

3.2 Validation of Speed Data Measures using Pneumatic Road Tubes

A comparison of vehicle speed data collected by pneumatic road tubes and speed data captured by the ASE devices at the same time (in July 2021 from 23 locations) is shown in **Figure 3-1**. This comparison indicates that road tubes and the ASE devices yield very similar speed measurements.



Figure 3-1. The 85th Percentile Speed between Pneumatic Road Tubes and ASE Devices in July 2021 (Phase 3 Location, n=23)

The results of the Welch Two Sample t-test indicate that the difference in means of 85^{th} percentile speeds between pneumatic road tubes and ASE cameras is not statistically significant (p-value = 0.8689) which indicates there is no evidence to suggest that the pneumatic road tube and ASE camera measures significantly different data.

3.3 Vehicles Exceeding the Posted Speed Limits

The overall percentage of speeding vehicles in all speed limit zones dropped during the ASE intervention period compared to the pre-ASE period. **Figure 3-2** shows the percentage of vehicles speeding in 30 km/h, 40 km/h and 50 km/h zones prior to the installation of the ASE devices and during the ticketing period at 193 locations where pre-ASE installation data were available.



Figure 3-2. Percentage of Vehicles Exceeding the Speed Limit (SL) – 191 Locations with Matching Pre-Data

Figure 3-3 shows a comparison of the percentage of vehicles exceeding the speed limit in 30 km/h and 40 km/h zones before the ASE installation, during the warning period, and during the ticketing period of phase 1. There was no 50 km/h speed limit roads during the phase 1 of the program. During the ticketing period, the percentage of vehicles exceeding the speed limit decreased from 49% to 28% in 40 km/h speed limit zones, while it decreased from 55% to 44% in 30 km/h speed limit zones.



Figure 3-3. Phase 1 - Percentage of Vehicles Exceeding the Speed Limit (SL) - 37 Locations with Matching Pre-data

A similar drop in the percentage of vehicles exceeding the speed limit during the ticketing period was observed during all phases. **Appendix B** illustrates the percentages of vehicle exceeding the speed limits pre-ASE and during the intervention period in phase 2, 3, 4 and 5 locations. Vehicles travelling greater than 10 km/h above the speed limit, had the most significant reductions during all phases.

Figures 3-4 and 3-5 show the percentage of speeding vehicles on 30 km/h and 40 km/h roads during the warning and ticketing periods of phase 1. The graphs illustrate a substantial reduction in speeding after the start of ticketing on July 6, 2020, which continued to decrease throughout the enforcement period. Furthermore, speeding by more than 10 km/h above the posted speed limit showed a continual decrease during the ticketing period of phase 1. Although similar graphs for other phases are available in **Appendix C**, speed and volume data were not obtainable during the warning periods other than for phase 1. During phase 1, both the warning and ticketing period. There has been a noticeable increase in compliance with the speed limits over the period of time, specifically with regards to exceeding the speed limit by 10 km/h. This trend is reflected in the graphs, where the reduction in the yellow, orange, and red portions signifies a decrease in instances where speeds exceed the speed limits by 10 km/h.



Figure 3-4. Phase 1 – Percentage of Vehicles Exceeding the Speed Limit and Traffic Volume per Hour, by Day (Speed Limit = 30 km/h)



Figure 3-5. Phase 1 – Percentage of Vehicles Exceeding the Speed Limit and Traffic Volume per Hour, by Day (Speed Limit = 40 km/h)

3.4 85th Percentile Speeds

Figure 3-6 depicts the 85th percentile speeds observed at phase 1 sites. In most locations, the 85th percentile speed during the warning and ticketing periods was lower than in the pre-ASE period. Notably, some of the greatest reduction in the 85th percentile speed was seen in areas where the posted speed limit had been lowered before ASE camera installation. **Appendix D** displays the 85th percentile speeds at sites with pre-ASE data available for other phases. Similar to phase 1, at the majority of locations, reductions in the 85th percentile speed were observed during the ticketing period compared to the pre-ASE installation period.



Figure 3-6. Phase 1 - 85th Percentile Speeds Pre-ASE (Road Tubes) and during ASE Period (ASE Cameras) (n=37). Green Circles Represent the Speed Limit during the Ticketing Period of the ASE Intervention and the Red Circles Indicate the Speed Limit before the ASE Intervention Period

Figure 3-7 shows a comparison between the percentage of vehicles falling into various speed categories before and during the ASE intervention period for all ASE deployments in Phase 1 to 5. The solid lines on the graph indicate the speed limit, and it is evident that more vehicles adhered to the speed limits during the ASE intervention period. Additionally, the dashed lines highlight the 85th percentile speeds, which were found to be closer to the speed limit during the intervention.



Figure 3-7. Percentage of Vehicles Speeding at Different Speed Intervals and 85th Percentile Speeds at 30, 40 and 50 km/h Speed Limit Roads During Pre-ASE and ASE Phase 1 to 5 Intervention Period

Figure 3-8 shows a comparison of the percentage of vehicles organized into different speed categories before and during the ASE intervention period (again phases 1-5), relative to the WHO-recommended speed of 30 km/h in residential areas with high pedestrian activity. The highlighted section of the plot clearly depicts this comparison.



Figure 3-8. Comparison of the Percentage of Vehicles Falling into Different Speed Categories Before and During the ASE Phase 1 to 5 Intervention Period, Relative to the WHO-Recommended Speed of 30 km/h. Blue Bars Indicate the Percentage of Vehicles below 30km/h, and Orange Bars Represent the Percentage of Vehicles above 30km/h

3.5 Generalized Estimating Equation Analysis Results

Table 3-2 provides the results of the GEE analysis for each independent variable while controlling for other variables in the model. The univariate model examines each independent variable separately while the multivariable model includes all independent variables simultaneously. The reference categories for the independent variables are indicated in parentheses.

	Univariate model	Multivariable model	
	RR* (95% CI**)	RR* (95% CI**)	
Period (ref: Pre-ASE)	0.56 (0.51, 0.62)	0.55 (0.51, 0.61)	
Phase (ref: Phase 1)			
Phase 2	0.91 (0.76, 1.10)	1.08 (0.85, 1.38)	
Phase 3	0.72 (0.54, 0.96)	0.76 (0.56, 1.04)	
Phase 4	0.88 (0.76, 1.01)	0.90 (0.74, 1.09)	
Phase 5	0.80 (0.67, 0.95)	0.92 (0.66, 1.02)	
Road type (ref: Arterial)			
Collector	0.99 (0.83, 1.17)	0.87 (0.72, 1.06)	
Local	0.89 (0.69, 1.15)	0.74 (0.58, 0.94)	
Speed limit (ref: 30km/h)			
40 km/h	0.73 (0.64, 0.84)	0.68 (0.58, 0.79)	
50 km/h	0.75 (0.63, 0.88)	0.61 (0.48, 0.78)	
Season (ref: Winter)			
Summer	0.76 (0.67, 0.87)	0.99 (0.85, 1.15)	
Pre-amalgamated City of Toronto (ref: inner suburbs)	0.97 (0.82, 1.15)	0.88 (0.76, 1.03)	
*RR. Risk Ratio. **CI. Confide	nce Interval. Results significant at 0.	05 are bolded.	

Table 3-2. Generalized Estimating Equation Poisson Regression Results for Number ofVehicles over the Speed Limit (Phase 1-5)

Results from the multivariable model indicate a 45% reduction in the risk (RR of 0.55) of vehicles exceeding speed limits during the ASE intervention period as compared to the pre-ASE period after adjusting for program phases, road type, speed limit, season and city region. The type of road is also associated with the number of vehicles over the speed limit, with a significant reduction in speeding on local roads compared to arterial roads. The speed limit was also associated with the proportion of vehicles speeding, with a significantly higher proportion of vehicles noted to be speeding when speed limits were set lower.

Table 3-3 shows the effect of the ASE intervention on the 85th percentile speed using a GEE linear regression model.

	Ur	nivariate model	Multivariable model				
	Int.*	β** (95% CI***)	Int.*	β** (95% CI***)			
Period (ref: Pre-ASE)	50.89	-7.41 (-8.52, -6.30)	50.28	-7.44 (-8.45, -6.44)			
Phase (ref: Phase 1)	46.06						
Phase 2		0.49 (-1.89, 2.87)		-1.75 (-3.86, 0.36)			
Phase 3		-0.02 (-2.43, 2.39)		-2.04 (-6.17, 2.09)			
Phase 4		3.51 (0.69, 6.33)		-2.45 (-4.58, -0.31)			
Phase 5		1.67 (-1.19, 4.54)		-2.61 (-4.40, 0.51)			
Road type (ref: Arterial)	52.17						
Collector		-6.17 (-8.06, -4.28)		-1.77 (-3.16, -0.37)			
Local		-9.48 (-11.6, -7.39)		-3.24 (-4.83, -1.66)			
Speed limit (ref: 30km/h)	41.21						
40 km/h		5.85 (4.14, 7.55)		4.82 (3.27, 6.36)			
50 km/h		18.3 (16.1, 20.5)		16.4 (13.9, 18.8)			
Season (ref: Winter)							
Summer	48.37	-1.64 (-3.59, 0.31)		-0.21 (-1.81, 1.39)			
Pre-amalgamated City of Toronto (ref: inner suburbs)	48.50	-5.21 (-7.37, -3.04)		-2.07 (-3.68, -0.46)			
*Int., Intercept. **\$, beta coefficient. ***CI Confidence Interval. Results significant at 0.05 are bolded.							

Table 3-3. Generalized Estimating Equation Linear Regression Results for the 85th PercentileVehicle Speed (Phase 1-5)

During the ASE intervention period, there was a statistically significant reduction in the 85th percentile speed (7.44 km/h) compared to the pre-ASE period after adjusting for program phases, road types, speed limits, season, and pre-amalgamated City of Toronto. The road type was also found to have a significant impact on the 85th percentile speed, with collector and local roads having lower speeds than arterial roads. Similarly, higher speed limits were associated with higher 85th percentile speeds.

3.6 Post-ASE period vehicle speed

Figure 3-9 depicts the percentage of vehicles that exceeded the speed limits prior to the installation of ASE cameras (pre-ASE), during the ASE intervention period, and following the removal of the cameras (post-ASE). Notably, the figure demonstrates that the post-ASE speeds are higher than those during the ASE active period but have not reached the same level as before the ASE period. These data were collected between 28 and 45 days after the removal of the ASE devices.



Figure 3-9. Percentage of Vehicles Exceeding the Speed Limit (SL) pre-, during and Post-ASE Intervention from 39 Selected Locations

Figure 3-10 illustrates the 85th percentile speeds observed at 39 selected locations during the pre-ASE, during ASE intervention, and post-ASE periods. The post-ASE 85th percentile speed was higher in 25 locations than the 85th percentile speed during intervention period and it was similar or lower in 14 locations. This comparison highlights that the ASE cameras are effective in lowering vehicle speeds.



Figure 3-10. The 85th Percentile Speeds Pre-ASE and during ASE and post-ASE Periods (n=39). Green Circles Represents the Speed Limit.

3.7 Control Sites

In **Figure 3-11**the Box and Whisker plot shows the interquartile range, median and minimum and maximum data points of pre-ASE, ASE and control groups. The p-values of paired t-test with Bonferroni correction are shown on top of the boxplots that were conducted to compare the mean percentage of vehicles travelling over the speed limit in ASE, control and pre-ASE groups. The results indicate that for all three-speed limits, the mean percentage of vehicles exceeding the speed limit was substantially and statistically significantly lower in the ASE group compared to the pre intervention speeds, or to the control group. For the 40 km/h limits, the slightly lower speeds in the Control group (compared with the pre-ASE group) also reached statistical significance.



Figure 3-11. Comparison of Proportion of Vehicles Exceeding the Speed Limits during the ASE Intervention, Control Locations and Pre-ASE period (N=44). Box and Whisker Plots with Mean (min, max) Presented for each Group. Solid Top Bar Denotes Groups that are Statistically Different to each other.

Figure 3-12 shows the p-values of paired t-test with Bonferroni correction conducted to compare the mean 85th percentile vehicle speeds in ASE, control and pre-ASE sites. It suggests that there are significant differences in 85th percentile speeds between the ASE and pre-ASE groups at the speed limit of 40 km/h, while there are no significant differences between the control and pre groups at any speed limit, and no significant differences between the ASE and control groups at any speed limit. The results suggest that the percentage of vehicles exceeding the speed limit decreased significantly after the ASE intervention, as evidenced by the significant p-values for the "ASE vs. Pre-ASE" comparison in all three-speed limit categories (30 km/h, 40 km/h, and 50 km/h). However, it is important to note that the sample size for some groups is relatively small (n=8 for each group in the 30 km/h speed limit category and n=6 for each group in the 50 km/h speed limit category). Therefore, the results should be interpreted with caution, and further research with larger sample sizes may be needed to confirm the findings.



Figure 3-12. Comparison of 85th Percentile Speeds during the ASE Intervention, Control Locations and Pre-ASE Period (N=44). Box and Whisker Plots with Mean (min, max) Presented for each Group. Solid Top Bar Denotes Groups that are Statistically Different to each other.

3.8 Motor Vehicle Collisions Involving Pedestrians

Table 3-4 shows the number of collisions involving at least one motor vehicle and a pedestrian that occurred in Toronto between October 2019 (three months prior to the ASE intervention) and December 2022 (the end of phase 5). The table also breaks down the collisions by age group, with separate counts for children aged 0 to 17 years, adults aged 18 to 65 years and older adults aged 65+ years.

Motor vehicle collisions involving pedestrians are rare occurrences, and accounted for 1.4% of all police reported collision incidents in the City between October 2019 to December 2022. The number of collisions that occurred near ASE cameras was much lower than what is shown in **Table 3-4**. The data available was insufficient to determine whether the ASE cameras had a significant impact on reducing the number of collisions involving pedestrians and motor vehicles. Furthermore, it is essential to consider the impact of the COVID-19 pandemic, which likely influenced motor traffic volume and road traffic behavior during a substantial portion of this program. In other words, the current data or evidence available is insufficient to determine whether the ASE intervention had a significant effect on reducing the incidence of pedestrian-motor vehicle collisions in the areas near the ASE intervention. Additional research is required to evaluate the impact of the ASE intervention on collisions involving pedestrians and motor vehicles.

			All ages		
Period	Injury type	0 to 17	18 to 65	Above 65	n(%)
		Years, n (%)	years, n (%)	years, n (%)	n (70)
Oct 2019 – Dec	No injury	6 (1.3)	13 (2.9)	2 (0.4)	21 (4.7)
2019	Minor	29 (6.5)	292 (65.1)	52 (11.6)	373 (83.2)
(First 3 months	Major	7 (1.6)	28 (6.3)	8 (1.8)	43 (9.6)
prior to ASE	Fatal	0 (0)	4 (0.9)	7 (1.6)	11 (2.5)
intervention)	Total	42 (9.4)	337 (75.2)	69 (15.4)	448 (100)
Jan 2020 – Jun	No injury	2 (0.5)	7 (1.7)	2 (0.5)	11 (2.7)
2020	Minor	36 (8.9)	249 (61.4)	51 (12.5)	336 (82.9)
(Phase 1 –	Major	3 (0.7)	38 (9.4)	10 (2.5)	51 (12.5)
warning)	Fatal	1 (0.2)	3 (0.7)	3 (0.7)	7 (1.7)
	Total	42 (10.3)	297 (73.3)	66 (16.2)	405 (100)
Jul 2020 – Oct	No injury	6 (2.0)	14 (4.7)	1 (0.3)	21 (7.0)
2020	Minor	25 (8.3)	169 (56.1)	45 (14.9)	239 (79.4)
(Phase 1 –	Major	0 (0)	25 (8.3)	8 (2.7)	33 (10.9)
ticketing)	Fatal	2 (0.7)	3 (1.0)	3 (1.0)	8 (2.7)
	Total	33 (10.9)	211 (70.0)	57 (18.9)	301 (100)
Nov 2020 – May	No injury	2 (0.5)	22 (5.0)	2 (0.5)	26 (5.9)
2021	Minor	29 (6.5)	265 (59.8)	63 (14.2)	357 (80.5)
(Phase 2 –	Major	4 (0.9)	36 (8.1)	10 (2.3)	50 (11.2)
ticketing)	Fatal	0 (0)	9 (2.0)	1 (0.2)	10 (2.3)
	Total	35 (7.9)	332 (74.9)	76 (17.1)	443 (100)

Table 3-4. Collisions Involving Pedestrians and Motor Vehicles in Toronto during the ASEIntervention (Phase 1 to Phase 5)

			ane IIA			
Period	Injury type	0 to 17	18 to 65	Above 65	n (%)	
		Years, n (%)	years, n (%)	years, n (%)	(, , , ,	
Jun 2021 – Oct	No injury	8 (1.8)	36 (8.2)	5 (1.1)	49 (11.2)	
2021	Minor	34 (7.8)	240 (54.9)	57 (13.0)	331 (75.7)	
(Phase 3 –	Major	2 (0.5)	29 (6.6)	11 (2.5)	42 (9.6)	
ticketing)	Fatal	1 (0.2)	6 (1.4)	8 (1.8)	15 (3.4)	
	Total	45 (10.2)	331 (71.2)	81 (18.5)	437 (100)	
Nov 2021 – May	No injury	6 (1.2)	18 (3.6)	3 (0.6)	27 (5.4)	
2022	Minor	56 (11.2)	302 (60.4)	57 (11.4)	415 (83.0)	
(Phase 4 –	Major	4 (0.8)	26 (5.2)	10 (2.0)	40 (8.0)	
ticketing)	Fatal	0 (0)	11 (2.2)	7 (1.4)	18 (3.6)	
	Total	66 (13.2)	357 (71.4)	77 (15.4)	500 (100)	
Jun 2022 – Dec	No injury	10 (1.7)	44 (7.6)	4 (0.7)	58 (10.0)	
2022	Minor	55 (9.5)	326 (56.5)	66 (11.4)	447 (77.6)	
(Phase 5 –	Major	5 (0.9)	47 (8.2)	10 (1.7)	62 (10.7)	
ticketing)	Fatal	0 (0)	6 (1.0)	3 (0.5)	9 (1.6)	
	Total	70 (12.1)	423 (73.4)	83 (14.4)	576 (100)	
The percentage is d	etermined by calc	culating the ratio of	of the number of	collisions to the	overall number	
of collisions.						

3.9 Overall Vehicle Speed Summary

Table 3-5. Percentage of Vehicles Exceeding the Speed Limit and 85th Percentile Speedsbefore and during ASE Camera Installation (Phase 1 to Phase 5 and overall)

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Overall
30 km/h	•					
Pre percentage exceeding the speed limit (%)	55.1	56.1	65	46.5	60.3	56.6
Post percentage exceeding the speed limit (%)	37.7	36.8	49.9	42.9	48.7	43.2
Pre 85th percentile speed (km/h)	50.2	48.1	40.5	40.1	42.2	44.2
Post 85th percentile speed (km/h)	36.5	36.8	38.5	36.7	39.8	36.8
40 km/h						
Pre percentage exceeding the speed limit (%)	49.2	56.1	41.7	52.5	60.7	52.1
Post percentage exceeding the speed limit (%)	27.9	25.6	28.6	31.6	32.3	29.2
Pre 85th percentile speed (km/h)	53.7	51.4	45.2	51.5	50.6	50.5
Post 85th percentile speed (km/h)	45.2	44.8	44.1	45.5	46.8	45.2
50 km/h						
Pre percentage exceeding the speed limit (%)	-	57.5	51.3	65.5	61.9	59.1
Post percentage exceeding the speed limit (%)	-	47.3	31.2	32.3	32.4	35.8
Pre 85th percentile speed (km/h)	-	64.0	57.5	66.7	63.4	62.9
Post 85th percentile speed (km/h)	-	59.4	56.7	55.2	56.7	56.7

4. Conclusions

According to this report, the ASE program led to a reduction in both the percentage of speeding drivers and the 85th percentile speeds in all five phases of the program. Our analysis suggests that there is a 45% reduction in the proportion (Risk Ratio: 0.55) of vehicles exceeding the speed limits during the ASE intervention period compared to the pre-ASE intervention period. On average, the percentage of drivers speeding dropped from 56.6% to 43.2% (13.4% absolute drop) on 30 km/h roads, 52.1% to 29.2% (22.9% absolute drop) on 40 km/h roads, and 59.1% to 35.8% (23.3% absolute drop) on 50 km/h roads. There was a notable drop in the percentage of drivers exceeding speed limits during the first phase after ASE ticketing began when compared to the warning period. Additionally, the 85th percentile speed dropped from 44.2 to 36.8 km/h on 30 km/h roads, 51.4 to 45.2 km/h on 40 km/h roads, and 63.7 to 56.7 km/h on 50 km/h roads. The analysis also revealed that the type of road, speed limit, and region of the City were also significantly associated with speeding.

The prevalence of higher speeds is particularly noticeable in Toronto's inner suburbs, where there are higher speed limits (i.e. 40 and 50 km/h) and a more complex network of arterial roads near schools. The ASE program is one of the strategies included in the City of Toronto's Vision Zero Road Safety plan, which also encompasses speed limit reductions, road design improvements, enhanced police enforcement, and public education.¹² The findings suggest that ASE can be a useful approach to reducing speeds and should be used in conjunction with the City's other speed management strategies. However, further measures may be needed to ensure that the WHO's recommended vehicle speeds (i.e. 30 km/h) are met to improve safety on city streets with high pedestrian activity.^{12,13}

This comprehensive analysis provides a thorough evaluation of the effectiveness of ASE by comparing data collected before and during its implementation. The pre-ASE data from road tubes were available for 204 out of 250 sites (82%), allowing for a robust analysis. Furthermore, the study showed a rapid decrease in vehicle speed as well as a sustained reduction in speeding over time comparing data collected during both the ASE warning period and the ticketing period for 50 sites in phase 1. Additionally, data w collected from 44 control sites during the warning period of the phase 3, and comparing the speeds of vehicles between pre-ASE, ASE and control sites further highlighted the effectiveness of the ASE program in reducing speeding. To validate the comparisons in speed measurements between ASE and pneumatic road tubes, data were collected at 23 locations during ASE deployment using road tubes. This rigorous methodology provides a reliable assessment of the impact of ASE on speeding in areas near schools.

This report also examined how vehicle speeds changed after the removal of ASE devices, specifically focusing on the percentage of vehicles exceeding speed limits and the 85th percentile speeds. The analysis compared data from the post-ASE period to the pre-ASE and during intervention periods at 39 selected locations and it indicates that traffic speeds increase after removal of ASE devices but was still lower than pre-ASE speeds. Post-ASE vehicle speeds were measured between 28 and 45 days after removal of ASE devices. These findings align with

previous research, which suggests that the time halo phenomenon may persists for days to months after the removal of ASE devices. ^{23,24}.

There were some notable limitations – not all sites had available pre-data, however, with each phase, more pre-data became available. Other time-dependent factors, such as the time of day, that may impact speeding, along with seasonal variations at a small scale, were not taken into consideration. The COVID-19 pandemic resulted in lockdowns and school closures, which may have affected driver behaviour around schools due to fewer children in CSZs. However, data were collected during phases 4 and 5 when schools were open and without stay-at-home orders.

While this report has provided valuable insights into the effectiveness of ASE on speeding, it was not possible to fully investigate the impact of ASE on collision incidents due to some limitations. One major limitation is the rarity of pedestrian-motor vehicle collisions, which requires a longer observation period for a more accurate assessment of ASE's effectiveness in collision prevention. Moreover, the uncertainties introduced by the COVID-19 pandemic may have altered both driver and pedestrian behaviour, which may have influenced the impact of ASE on collisions. Future research should aim to address these limitations by conducting long-term studies that capture a sufficient number of pedestrian-motor vehicle collisions to provide a comprehensive understanding of the effectiveness of ASE in collision prevention.

The reduction in vehicle speeds and in the percentage of vehicles speeding was substantial and occurred in all phases of the study and uniformly across the City. The design of the study ensures confidence that the speed reductions observed are directly attributable to the ASE program. Therefore, there is evidence that ASE is an effective tool for reducing traffic risk for pedestrians in Community Safety Zones near schools in Toronto.

5. References

- 1. World Health Organization. *Managing Speed*.; 2017.
- 2. Kloeden CN, McLean AJ (A. J, Glonek G, University of Adelaide. Road Accident Research Unit., Australian Transport Safety Bureau. Reanalysis of travelling speed and the risk of crash involvement in Adelaide South Australia. Published online 2002:32.
- 3. Soole DW, Watson BC, Fleiter JJ. Effects of average speed enforcement on speed compliance and crashes: A review of the literature. *Accid Anal Prev.* 2013;54:46-56. doi:10.1016/J.AAP.2013.01.018
- 4. Aarts L, Van Schagen I. Driving speed and the risk of road crashes: a review. *Accid Anal Prev.* 2006;38(2):215-224. doi:10.1016/J.AAP.2005.07.004
- 5. Ministry of Transportation of Ontario. Ontario Road Safety: Annual Report 2016.; 2016.
- 6. Child pedestrian accidents: what makes children vulnerable? *Child Safety: Problem and Prevention from Pre-School to Adolescence*. Published online August 4, 2005:76-93. doi:10.4324/9780203977958-15
- World Health Organization. Overview Fact Sheet: Children and Road Traffic Injury.;
 2015. Accessed February 14, 2022. https://www.who.int/violence_injury_prevention/child/injury/world_report/Road_traffic_i njuries_english.pdf
- 8. Peden M, Scurfield R, Sleet D, et al. *World Report on Road Traffic Injury Prevention*. World Health Organization; 2004.
- 9. Pasanen E. Driving speeds and pedestrian safety: A mathmatical model. Published online 1992.
- 10. Organisation for Economic Co-operation and Development (OECD). Speed management. Published online 2006.
- 11. Statistics Canada. Leading causes of death, total population, by age group. Published 2022. Accessed February 15, 2022. https://doi.org/10.25318/1310039401-eng
- 12. City of Toronto. *Vision Zero: Toronto's Road Safety Plan (2017-2021)*.; 2020. Accessed March 27, 2022. https://www.toronto.ca/legdocs/mmis/2019/ie/bgrd/backgroundfile-134964.pdf
- 13. City of Toronto Transportation Services. Road Safety Plan (RSP) 2017-2021.; 2016.
- 14. Rosén E, Stigson H, Sander U. Literature review of pedestrian fatality risk as a function of car impact speed. *Accid Anal Prev.* 2011;43(1):25-33. doi:10.1016/J.AAP.2010.04.003

- Svenson O, Eriksson G, Gonzalez N. Braking from different speeds: Judgments of collision speed if a car does not stop in time. *Accid Anal Prev.* 2012;45:487-492. doi:10.1016/J.AAP.2011.08.015
- 16. Kattan L, Tay R, Acharjee S. Managing speed at school and playground zones. *Accid Anal Prev.* 2011;43(5):1887-1891. doi:10.1016/J.AAP.2011.04.009
- Christie SM, Lyons RA, Dunstan FD, Jones SJ. Are mobile speed cameras effective? A controlled before and after study. *Injury Prevention*. 2003;9(4):302-306. doi:10.1136/ip.9.4.302
- Pilkington P, Kinra S. Effectiveness of speed cameras in preventing road traffic collisions and related casualties: Systematic review. *Br Med J*. 2005;330(7487):331-334. doi:10.1136/bmj.38324.646574.AE
- Thomas LJ, Srinivasan R, Decina LE, Staplin L. Safety effects of automated speed enforcement programs: Critical review of international literature. *Transp Res Rec.* 2008;(2078):117-126. doi:10.3141/2078-16
- 20. Donnell E, Hines S. Speed Concepts: Informational Guide.; 2009.
- 21. R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Accessed March 22, 2023. https://www.R-project.org/
- 22. Esri Canada. "Topographic/Topographie" [Web Map]. Scale Not Given. "The Community Map of Canada Vector Basemap." Published 2021. Accessed March 22, 2023. https://www.arcgis.com/home/item.html?id=98652eb8458a464fa95feb9bd812b29a.
- Zhou Y, Fu C, Liu H, Liu H, Liu L. Halo effects of automated speed enforcement: A literature review. *ICTE 2019 Proceedings of the 6th International Conference on Transportation Engineering*. Published online 2019:281-290. doi:10.1061/9780784482742.032
- 24. Gouda M, El-Basyouny K. Investigating time halo effects of mobile photo enforcement on urban roads. *Transp Res Rec.* 2017;2660:39-47. doi:10.3141/2660-06

6. Appendices

Appendix A: Vehicle Speed Summary Statistics

 Table 6-1. Vehicle Speed Summary Statistics during Phase 1

Speed Limit	30 I (n=	km/h =22)	40 km/h (<i>n</i> =28)		
Period	Warning	Ticketing	Warning	Ticketing	
Total Vehicles (n)	2,398,087	2,208,339	8,617,438	7,627,363	
Mean Speed (km/h)	32.1	30.0	39.5	36.4	
Median Speed (km/h)	31.0	29.0	40.0	36.0	
(Min., Max.) Speed (km/h)	(2, 126)	(1, 136)	(1, 128)	(1, 130)	
% of vehicles exceeding the speed limit	50.7	37.8	41.4	27.7	
85th percentile Speed (km/h)	41.0	37.0	47.8	44.0	
Note: The available vehicle speed data during the	he warning period is	s limited to phase	1 only.		

 Table 6-2. Vehicle Speed Summary Statistics during Phase 2

Speed Limit	30 km/h (n=17)	40 km/h (n=28)	50 km/h (n=5)
Total Vehicle (n)	2,844,301	10,085,449	7,656,890
Mean Speed (km/h)	29.7	36.9	49.9
Median Speed (km/h)	29.0	37.0	49.0
(Min., Max.) Speed (km/h)	(1, 148)	(1, 144)	(2, 142)
% over the speed limit	36.8	25.1	47.3
85th percentile Speed (km/h)	37.0	45.0	59.0

 Table 6-3. Vehicle Speed Summary Statistics during Phase 3

Speed Limit	30 km/h	40 km/h	50 km/h
	(n=17)	(n=28)	(n=5)
Total Vehicle (n)	1,586,122	9,323,498	7,718,867
Mean Speed (km/h)	31.7	37.7	46.5
Median Speed (km/h)	31.0	37.0	47.0
(Min., Max.) Speed (km/h)	(1, 112)	(1, 213)	(1, 188)
% over the speed limit	50.2	29.2	29.6
85th percentile Speed (km/h)	38.4	46.0	56.0

Speed Limit	30 km/h (n=9)	40 km/h (n=28)	50 km/h (n=12)	60 km/h (n=1)
Total Vehicle (n)	995,475	11,645,686	10,619,799	710,073
Mean Speed (km/h)	30.6	37.8	46.4	51.8
Median Speed (km/h)	30.0	38.0	47.0	52.0
(Min., Max.) Speed (km/h)	(1, 136)	(1, 129)	(1, 159)	(2, 175)
% over the speed limit	42.8	29.2	31.1	14.3
85th percentile Speed (km/h)	38.0	46.0	55.0	60.0

 Table 6-4. Vehicle Speed Summary Statistics during Phase 4

Table 6-5. Vehicle Speed Summary Statistics during Phase 5

Speed Limit	30 km/h (n=9)	40 km/h (n=29)	50 km/h (n=11)	60 km/h (n=1)
Total Vehicle (n)	1,829,934	19,417,551	15,271,392	3,080,995
Mean Speed (km/h)	32.3	39.0	46.3	55.1
Median Speed (km/h)	31.0	39.0	47.0	55.0
(Min., Max.) Speed (km/h)	(3, 141)	(1, 151)	(1, 159)	(1, 168)
% over the speed limit	48.8	32.1	31.8	26.2
85th percentile Speed (km/h)	41.0	47.0	55.0	64.0



Appendix B: Vehicles Exceeding the Posted Speed Limit

Figure 6-2. Phase 2 - Percentage of Vehicles Exceeding the Speed Limit (SL) - 41Locations with Matching Pre-data



Figure 6-1. Phase 3 - Percentage of Vehicles Exceeding the Speed Limit (SL) – 45 Locations with Matching Pre-data



Figure 6-7. Phase 4 - Percentage of Vehicles Exceeding the Speed Limit (SL) - 36Locations with Matching Pre-data



Figure 6-3. Phase 5 - Percentage of Vehicles Exceeding the Speed Limit (SL) - 42Locations with Matching Pre-data



Appendix C: Percentage of vehicles exceeding speed limits

Figure 6-4. Phase 2 – Percentage of Vehicles Exceeding the Speed Limit and Traffic Volume per Hour, by Day (Speed Limit = 30 km/h)



Figure 6-5. Phase 2 – Percentage of Vehicles Exceeding the Speed Limit and Traffic Volume per Hour, by Day (Speed Limit = 40 and 50 km/h)



Figure 6-6. Phase 3 – Percentage of Vehicles Exceeding the Speed Limit and Traffic Volume per Hour, by Day (Speed Limit = 30 km/h)



Figure 6-7. Phase 3 – Percentage of Vehicles Exceeding the Speed Limit and Traffic Volume per Hour, by Day (Speed Limit = 40 and 50 km/h)



Figure 6-8. Phase 4 – Percentage of Vehicles Exceeding the Speed Limit and Traffic Volume per Hour, by Day (Speed Limit = 30 km/h)



Figure 6-9. Phase 4 – Percentage of Vehicles Exceeding the Speed Limit and Traffic Volume per Hour, by Day (Speed Limit = 40 km/h)



Figure 6-10. Phase 4 – Percentage of Vehicles Exceeding the Speed Limit and Traffic Volume per Hour, by Day (Speed Limit = 50 km/h)



Figure 6-11. Phase 5 – Percentage of Vehicles Exceeding the Speed Limit and Traffic Volume per Hour, by Day (Speed Limit = 30 km/h)



Figure 6-12. Phase 5 – Percentage of Vehicles Exceeding the Speed Limit and Traffic Volume per Hour, by Day (Speed Limit = 40 km/h)



Figure 6-13. Phase 5 – Percentage of Vehicles Exceeding the Speed Limit and Traffic Volume per Hour, by Day (Speed Limit = 50 km/h)



Appendix D: The 85th Percentile Speeds

Figure 6-14. Phase-2 - 85th Percentile Speeds Pre-ASE (Road Tubes) and During ASE Period (ASE Cameras) (n=41)



Figure 6-15. Phase-3 – 85th Percentile Speeds Pre-ASE (Road Tubes) and during ASE Period (ASE Cameras) (n=45)



Figure 6-16. Phase-4 – 85th Percentile Speeds Pre-ASE (Road Tubes) and during ASE Period (ASE Cameras) (n=43)



Figure 6-17. Phase-5 – 85th Percentile Speeds Pre-ASE (Road Tubes) and during ASE Period (ASE Cameras) (n=36)