ATTACHMENT 1

York Region

Pedestrian and Cyclist Safety Study

Type of Document

Summary Report

Project Number

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Executive Summary

The York Region 2017 Annual Traffic Safety Report has indicated that pedestrian and cyclist collisions account for the highest percentage of injury and fatality collisions within the Region. In addition, while total collisions are decreasing, pedestrian and cyclist collisions are increasing. In this study:

- 10 years of collision data were analyzed to distinguish statistical and geospatial patterns of characteristics of collisions involving pedestrians and cyclists;
- Industry review was conducted to identify potential safety improvements and rate each on its potential effectiveness at addressing York Region collision patterns; and
- An index was developed to prioritize individual locations for upgrades based on observed and predicted safety, existing and potential demand and existing environmental conditions.

Collision data analysis

A detailed analysis of the Region's 10-year history of collisions involving pedestrians and cyclists was conducted, including geo-spatial analysis. The Geographic Information Systems (GIS) database developed for this project consisted of creating more than 100 layers, including original data, supporting data layers from York Region Self-Serve Data Depot, and data layers adapted and/or generated.

The most significant issues identified in this study were collisions occurring in urban areas, and collisions occurring at signalized intersections when motor vehicles were turning left or right. Drivers failing to yield right-of-way to pedestrians or cyclists was identified as the major cause of these collisions. Inattentiveness of drivers, which contributes to driver error, was found to be increasing in pedestrian and cyclist collisions over the study period. A secondary finding was the over-representation of young adult and elderly pedestrians and cyclists in collisions, compared to their rate of use of these modes. Additionally, while mid-block collisions were not identified as a major issue, it was observed that they typically occur where no controlled crossing exists.

Industry review of safety improvements

An extensive review of industry best practice and research into the effectiveness of potential safety improvements was conducted. A list of potential improvements suitable for York Region to address the key issues was identified, including: their positive and negative attributes; an estimate of effectiveness, costs/benefits, and timeframes to implement; and, based on this information, a ranked list of safety applications based on potential benefits to the Region.

Prioritization index of locations for improvement

To guide the implementation of pedestrian and cyclist safety improvements across the Region, a prioritized index of specific locations to be further evaluated and upgraded was developed. This index was developed using factors and variables intended specifically to address the most prominent collision patterns identified, including safety (collision history and potential for safety improvement), demand (existing pedestrian volumes and potential demand based on proximity to retail, transit, schools and high-density residential areas) and existing conditions (overall traffic volumes, turning traffic volumes, speed and number of lanes on approach roadways).

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1 Introduction

1.1 Context

The York Region 2017 Annual Traffic Safety Report has indicated that pedestrian and cyclist collisions account for the highest percentage of injury and fatality collisions within the Region. From 2008 to 2017, average daily vehicle volumes have increased year-over-year on average, from approximately 2.2 million vehicles to 2.45 million vehicles. Over this period, total collisions have ranged between approximately 7,500 and 10,500 per year and show a decreasing trend.

During the same period, cyclist- and pedestrian-related collisions show an increasing trend of approximately 3% per year on average, as presented in **Figure 1**, despite a significant decrease observed in 2017. Combined pedestrian and cyclist collisions range from approximately 175 to 300 per year, accounting for approximately 2.6% of all collisions in York Region during this period.

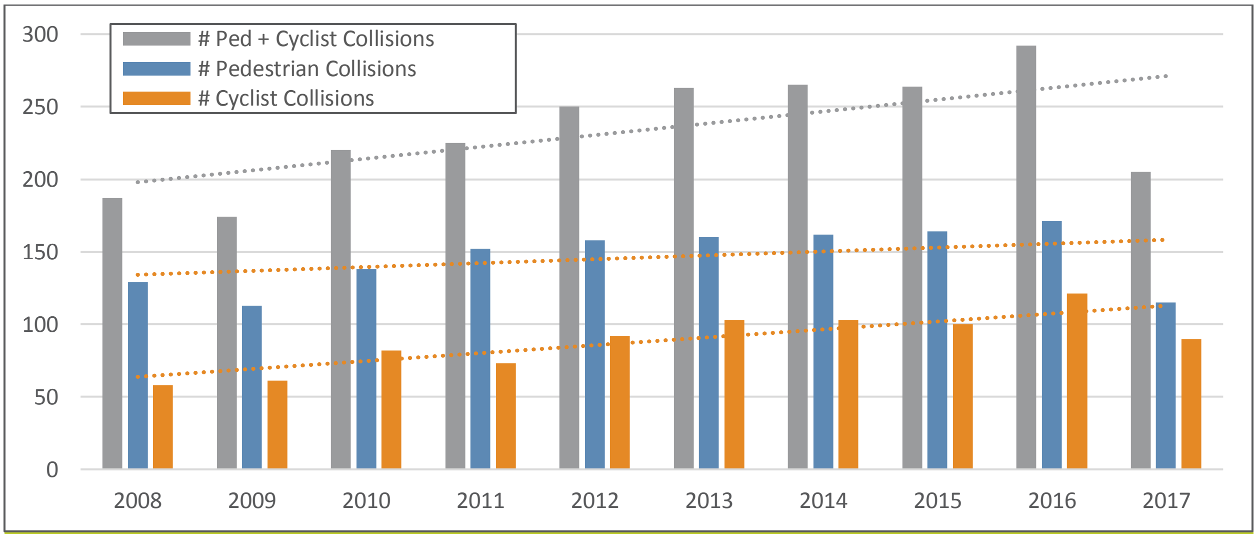


Figure 1 – York Regional Roads Pedestrian and Cyclist Collisions (2008 to 2017)

As a result, York Region requested EXP Services to conduct a Traffic Safety Study to analyze pedestrian and cyclist related collisions within the Region to identify potential quantified improvements to improve safety for these vulnerable road users. This report summarizes the analysis, findings, applicable safety improvements and recommendations of the study.

1.2 Objective

The primary goal of this study was to identify patterns of collisions characteristics in York Region; investigate immediate and long-term safety measures that could benefit pedestrians and cyclists throughout York Region; and develop a prioritization index of locations for safety improvements to be implemented.

2 Collision Data Analysis

2.1 Methodology

2.1.1 York Region Context

Prior to performing statistical analysis, discussions were undertaken with York Region staff to determine trends and specific concerns, including potential location and facility correlations, to inform the analysis. During this process, multiple regional data sets were obtained for statistical and geospatial analysis, as described below. These data included:

- Traffic volume data (AADT at intersections and mid-block locations)
- Collision data (10-year collisions involving pedestrians and cyclists)
- Traffic control data (signals, regulatory signage, red light cameras, etc.)
- Roadway network (speed zones, number of lanes, illumination, etc.)
- Active transportation network (sidewalks, multi-use paths, cycling facilities, etc.)
- Transit network (e.g. bus stop locations)
- Existing facilities network (schools, parks, hospitals, shopping centres, parking, etc.)
- Population density and distribution data

2.1.2 Statistical Analysis of Collision Data

Motor Vehicle Accident Report (MVAR) data was obtained for all collisions throughout York Region involving pedestrians and/or cyclists over the past 10 years. These data were examined, quantified and categorized, and observations of patterns were made. Pedestrian and cyclist collisions were analyzed separately. Of approximately 90,000 total collisions from 2008 to 2017, 1,462 collisions (1.6%) involved pedestrians and 883 collisions (1.0%) involved cyclists.

The data were analyzed, and patterns were identified with respect to many collision-specific and locational criteria, including:

- Severity of collision (i.e. property damage only; minimal, minor or major injury; fatality)
- Roadway characteristics including posted speed and number of lanes
- Collision location (midblock or intersection) and type of traffic control (i.e. traffic signals, stop sign, pedestrian crossover, no control, etc.)
- Environmental (i.e. weather, time of day) and lighting conditions
- Age of road users involved (pedestrians/cyclists and vehicle drivers)
- Condition of road users involved (i.e. normal, inattentive, fatigue, alcohol/drug, etc.)
- Action of vehicle driver involved (i.e. driving properly, failure to yield right-of-way, improper turn, speeding, disobeyed control, etc.)
- Vehicle maneuver (i.e. going ahead, turning left, turning right, slowing/stopping, etc.)
- Action of pedestrian/cyclist involved (i.e. crossing with right-of-way, crossing without right-of-way, running onto road, etc.)

2.1.3 Geospatial Analysis of Collision Data

Traffic collision data are inherently spatial—collisions (pedestrian/cyclists) occur at discrete locations with multiple events possible for each location. An exhaustive geospatial analysis of the 2,345 pedestrian and cyclist collisions which occurred during the 10-year period was conducted using ESRI ArcGIS software. A total of 95 separate geospatial plots were created to analyze the data set. This assisted in the identification of geographic patterns of collisions (and collisions of specific types) and highlighted correlations between collisions and site-specific characteristics.

Mapping of Collision Characteristics

Collisions were mapped in several ways to identify and visualize patterns. For example, the distribution of pedestrian and cyclist collisions was mapped by municipality and compared to overall population distribution. These are shown graphically in **Figure 2**.

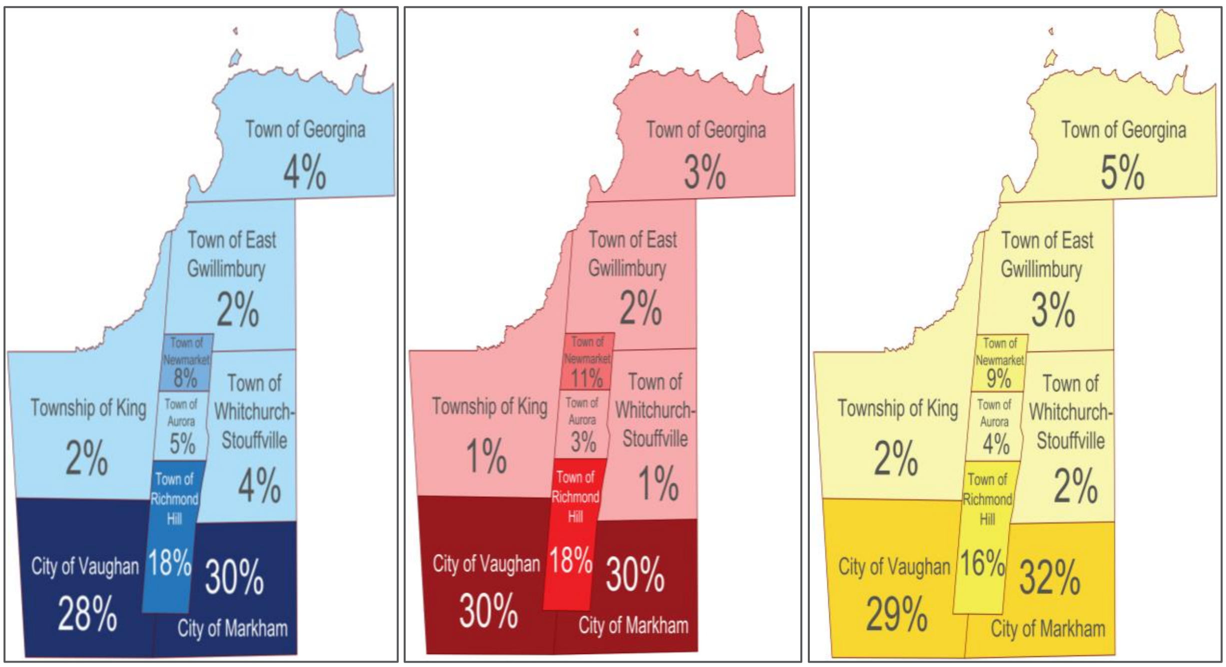


Figure 2 – Distribution of Population (Left), Pedestrian Collisions (Centre) and Cyclist Collisions (Right)

Collision frequency was mapped to identify overall patterns. **Figure 3** and **Figure 4** show these for pedestrians and cyclists respectively. The frequency maps show not only individual high frequency locations (e.g. Yonge Street at Mulock Drive for pedestrian collisions) but also high frequency *corridors* (e.g. Kennedy Road from Steeles Avenue to Hwy. 7 for cyclist collisions).

The following characteristics, which had been identified through the statistical analysis, were also mapped: time of day, day of week, month, and year (each separately); night versus day; road location (intersection versus mid-block); vehicle maneuver; and traffic control. In addition, fatal collisions were mapped separately. Although relatively rare, it was important to see if there were any evident geospatial patterns.

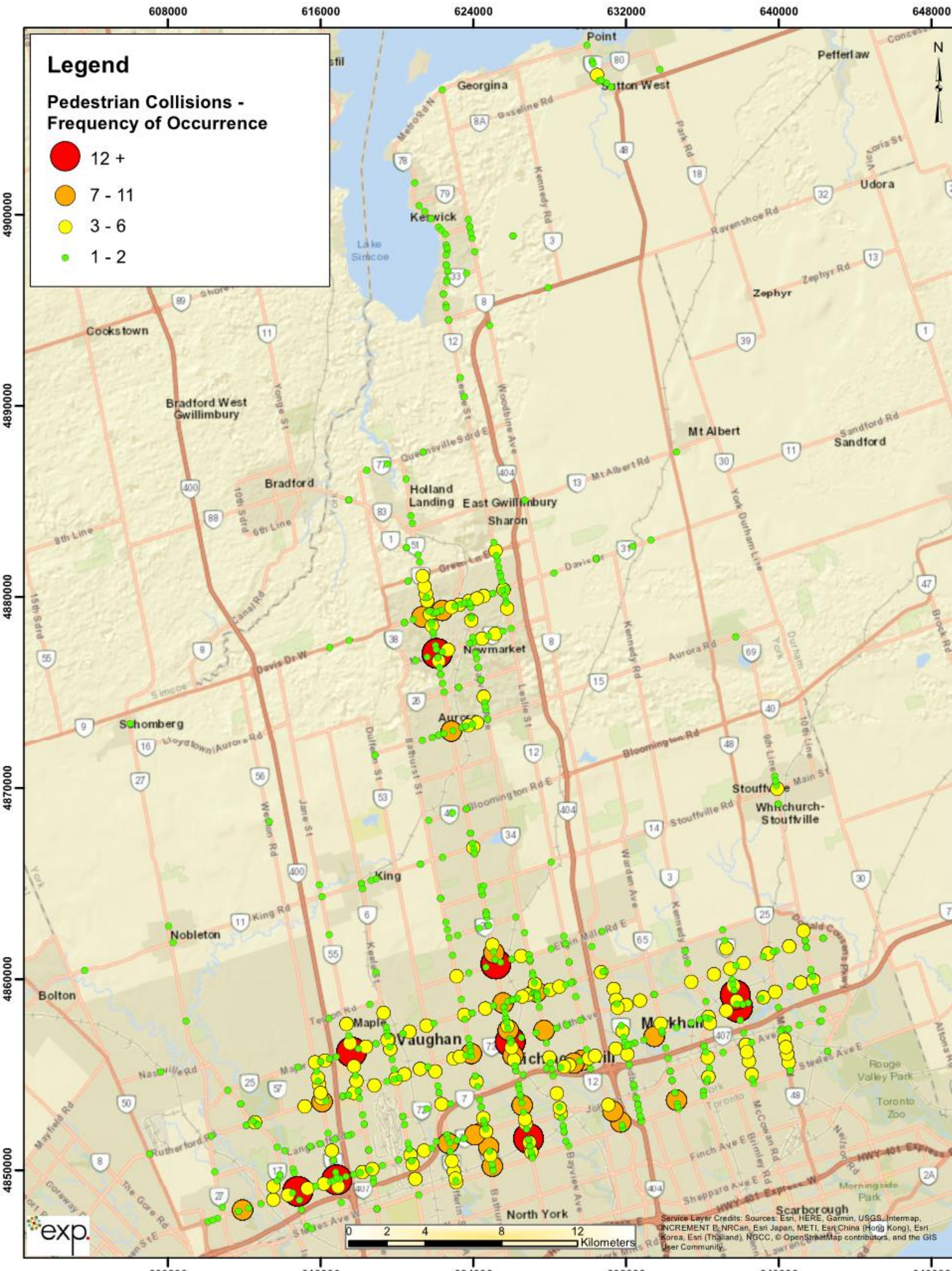


Figure 3 – Pedestrian Collision Frequency Map

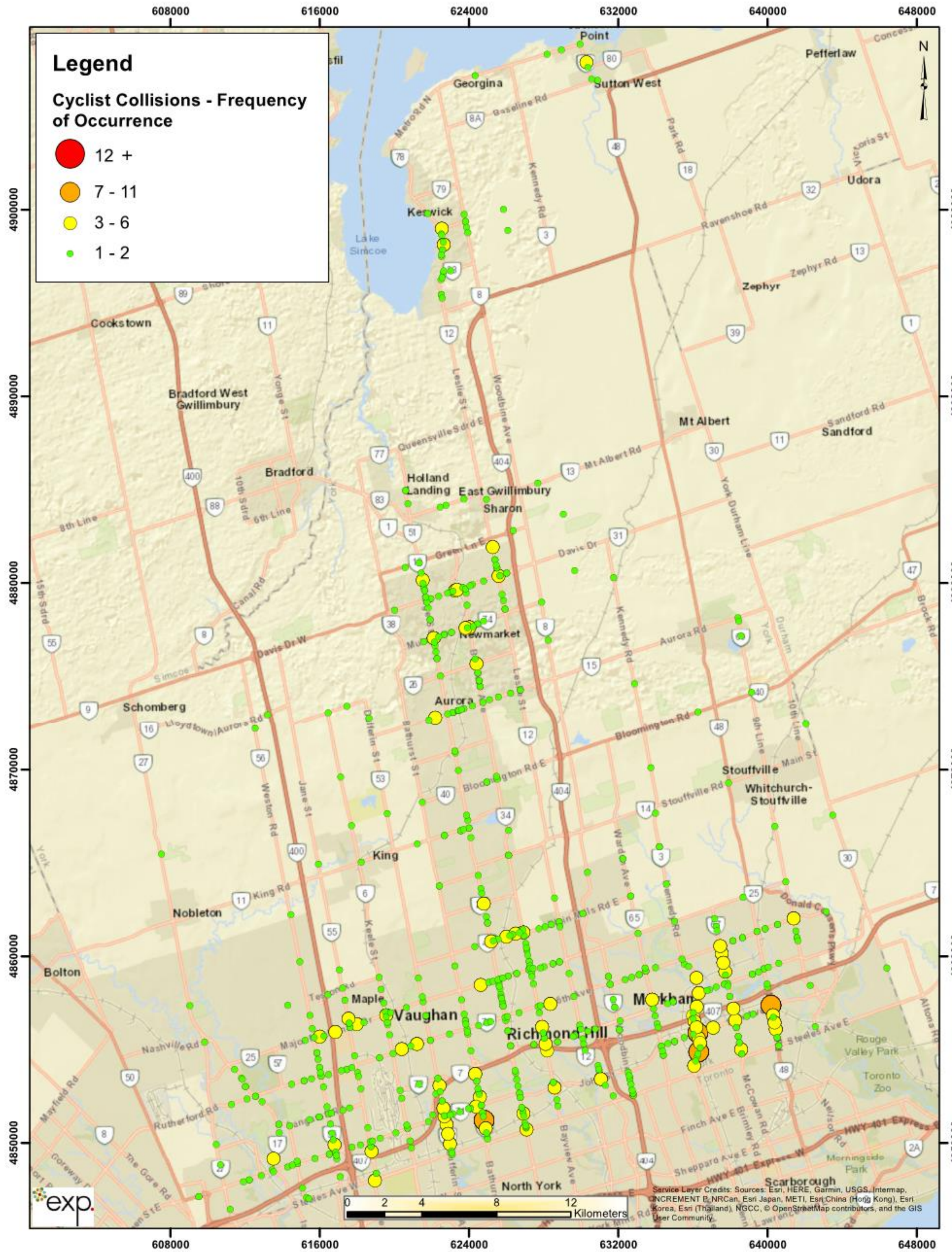


Figure 4 – Cyclist Collision Frequency Map

Combinations of Collision Characteristics

In addition to pure geographic mapping, further insight was determined by analyzing combinations of collision characteristics geospatially. Combinations and subsets were analyzed which reflected both the statistical analysis of the 10-year data set, as well as the annual traffic safety study conducted by the Region. Specifically, the following were analyzed:

- For pedestrian collisions:
    - Driver error with road location (intersection vs mid-block) and weather condition
    - Pedestrian age (specifically young adult) versus collision type
    - Road location (intersection vs mid-block) with light condition (day vs night) and vehicle maneuver
    - Traffic control condition with pedestrian action and number of lanes, for midblock collisions with pedestrians crossing only
- For cyclist collisions:
    - Cyclist action with traffic control type and number of lanes for mid-block collisions
    - Cyclist age (specifically young adult) versus collision type
    - Road location (intersection vs mid-block) with light condition (day vs night) and vehicle maneuver

Cross-Referencing with Geospatial Data

Geospatial data sets were cross-referenced to provide greater details on contributing factors to the collisions, the collision types and severity, the roadway geometric features, the high-risk user groups, the existing traffic control, and the human behaviors associated with the collisions.

These cross-referenced data sets also provide important information regarding potential countermeasure implementation. An example is the correlation between the location of off-road hiking and multi-use trails and midblock pedestrian collisions, shown in **Figure 5**—an identified goal in York Region's Transportation Master Plan is to improve the connectivity of the trail system. Similar geospatial analysis cross-referencing data sets involved demographic characteristic or linear facilities:

- Population density with all collisions
- Total traffic volumes with all collisions, subdivided by severity
- The presence of sidewalks with pedestrian collisions
- Bicycle facilities with cyclist collisions, subdivided by severity, location (intersection vs mid-block), posted speed and weather condition

Other analysis considered the proximity of collisions to specific features, for example:

- Bus stops with pedestrian collisions
- Pedestrian collisions mid-block and intersection with proximity to schools and hospitals

Some analyses had a null result. That is, there was no correlation found between the characteristic and the frequency of collisions. Others identified specific locations where certain safety improvements might be effective.

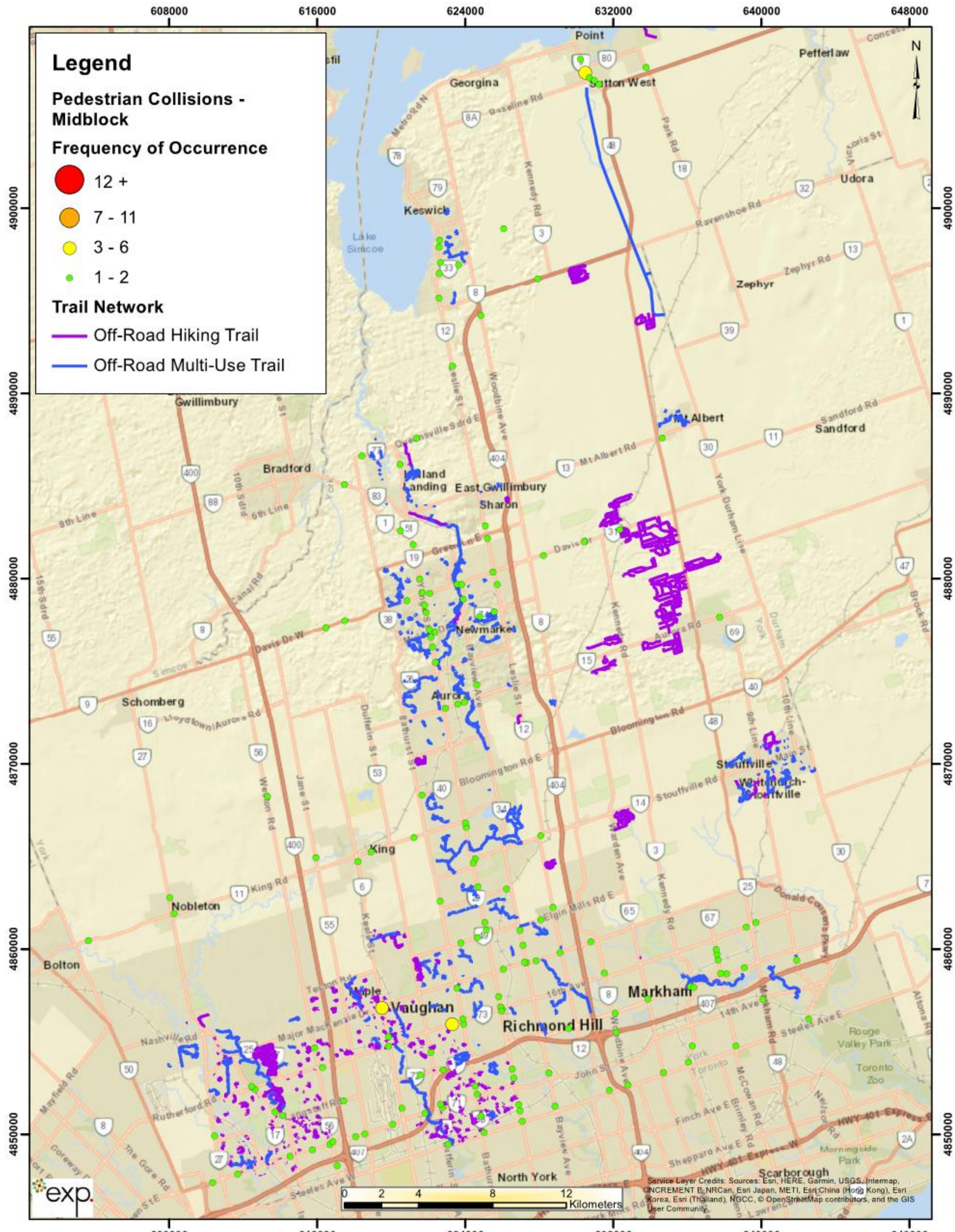


Figure 5 - Midblock Pedestrian Collisions Correlated to Off-Road Trail System

2.2 Observed Patterns

The analysis of 10 years of collision data, presented in the previous section, was synthesized to develop the following findings related to pedestrian and cyclist collisions. The findings are presented in decreasing order of significance.

Most pedestrian and cyclist collisions take place in urban areas.

More than 95% of pedestrian collisions and more than 90% of cyclist collisions occur in urban areas of York Region, likely due to the presence of more pedestrians, cyclists and transit users in these areas compared to rural areas of the Region.

Most collisions occur with turning vehicles at signalized intersections.

Approximately three quarters (75%) of pedestrian collisions occurred at signalized intersections. This finding is not necessarily typical; for example, only 10% of pedestrian collisions in the City of Toronto occur at a traffic signal[1]. 77% of pedestrian collisions at signalized intersections in York Region involved the vehicle making a turning movement—43% involved a left-turning vehicle and 34% involved a right-turning vehicle.

Similarly, approximately three-fifths (61%) of cyclist collisions occurred at signalized intersections, a finding which is again not necessarily typical; for example, only 6% of cyclist collisions in the City of Toronto occur at a traffic signal[2]. 73% of cyclist collisions at signalized intersections involved the motor vehicle making a turning movement—15% involved a left-turning vehicle and 59% involved a right-turning vehicle. These findings are represented in **Figure 6**.

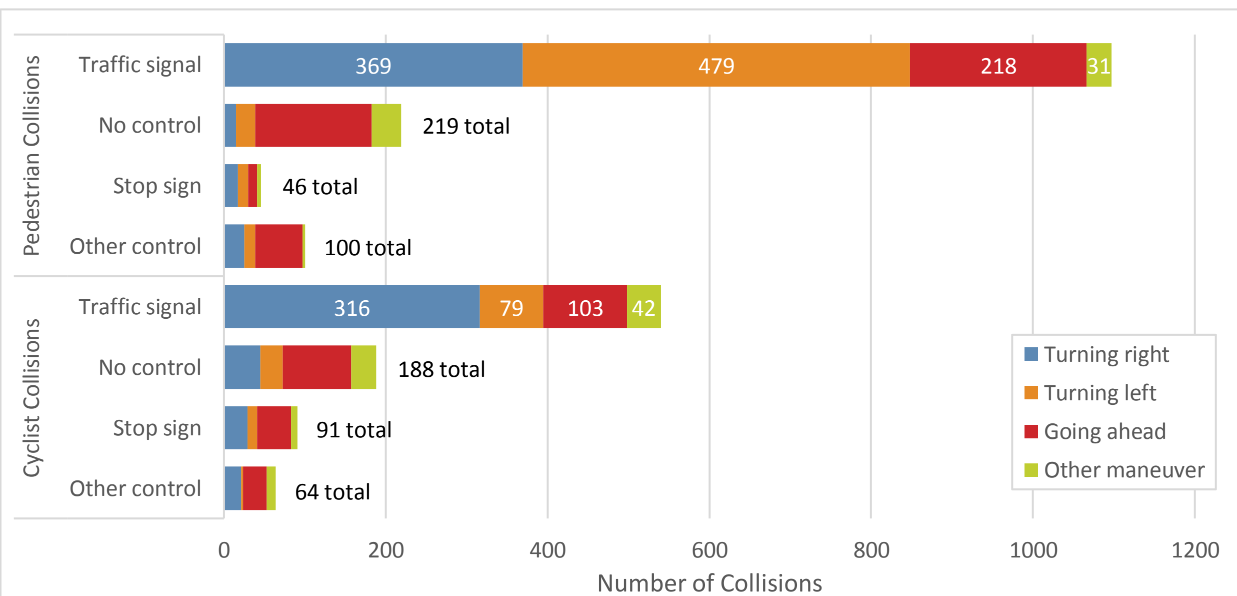


Figure 6 – Vehicle Maneuver in Pedestrian and Cyclist Collisions

[1] Toronto Public Health. Pedestrian and Cyclist Safety in Toronto. June 2015
[2] Ibid.

Right-turning vehicles pose a significant hazard to cyclists.

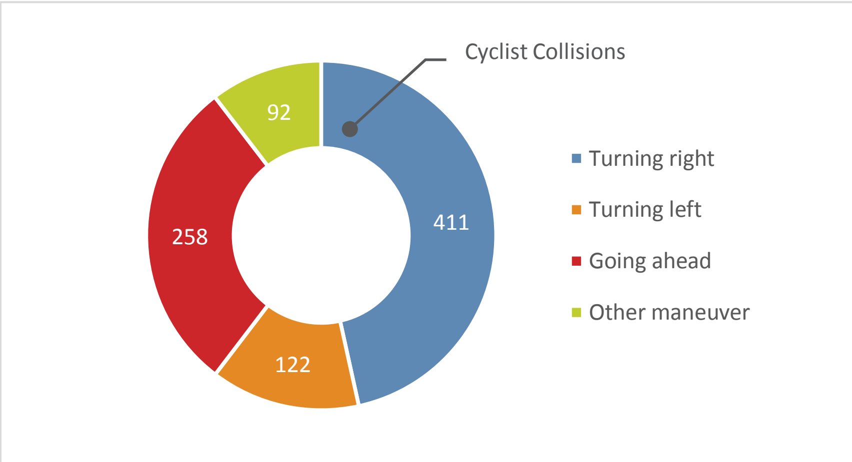


Figure 7 – Vehicle Maneuver in Cyclist Collisions

In nearly half (47%) of all collisions involving cyclists, the motor vehicle was turning right, while in only 14% of collisions the motor vehicle was turning left. This finding is represented in **Figure 7**. This is line with the pattern, but to a greater extreme, of a German study which found that 20% of cyclist collisions involved a turning vehicle, of which approximately 2/3 were turning right[3].

The driver of the motor vehicle was driving properly in 40% of all cyclist collisions, failed to yield the right-of-way in 31% of collisions, made an improper turn in 11% of collisions, made another error in 8% of collisions and was unknown in a further 10%. This wide distribution of driver action leads to the conclusion that public understanding of the assignment of right-of-way between cyclists and turning vehicles may be a concern.

Driver error accounts for most collisions with pedestrians and cyclists.

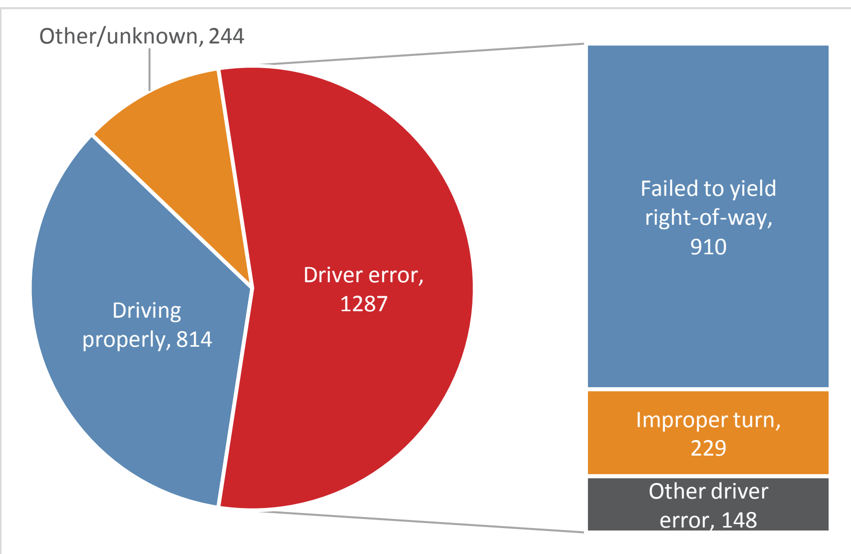


Figure 8 – Apparent Driver Action in All Pedestrian and Cyclist Collisions

Approximately 55% (1,287) of the 2,345 pedestrian and cyclist collisions analyzed were caused by driver error as shown in **Figure 8**. The most common driver error was failing to yield the right-of-way, followed by improper turns. The driver was driving properly in approximately 30% of collisions, and in approximately 10% of collisions the apparent driver action was listed as ‘other’ or was unknown.

[3] Richter & Sachs (Technische Universitaet Berlin, Dept. Of Road Planning and Operation). Turning accidents between cars and trucks and cyclists driving straight ahead. 2017

Approximately 58% of pedestrian collisions were caused by driver error—in these cases, pedestrians were typically crossing with the right-of-way (84% of pedestrian collisions where driver error was recorded). When the motorist was driving properly (32% of pedestrian collisions), the most common pedestrian action was crossing without right-of-way (46% of pedestrian collisions where the driver was driving properly), followed by running onto the roadway (12%). Approximately 50% of collisions involving cyclists were caused by driver error. These findings are represented in **Figure 9**.

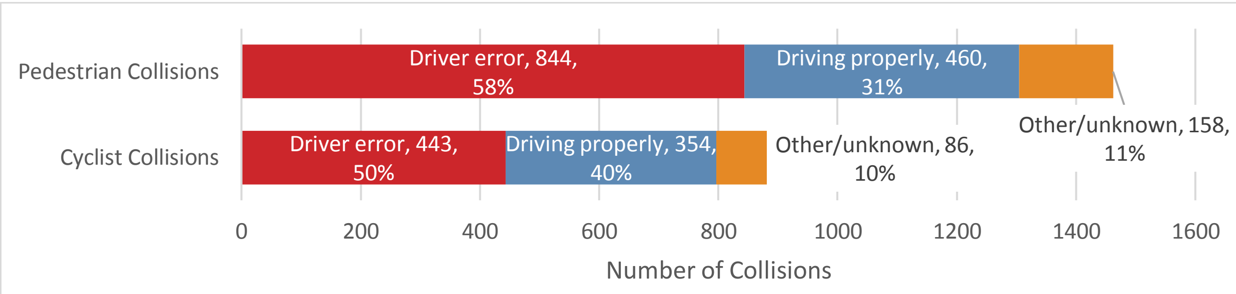


Figure 9 – Apparent Driver Action by Type of Collision

One possible reason for driver error in collisions is inattention of the driver. **Figure 10** shows that driver inattention (defined by both driver condition as inattentive and driver error in MVAR codes) has been increasing over the study period.

Extensive studies, such as the Virginia Tech Transportation Institute (VTTI)/ National Highway Safety Administration (NHSA) 100 car naturalistic driving study[4], have shown a strong correlation between distraction in the seconds prior to a crash occurring. This study, which monitored drivers' actions including eye movements 100% of the time for an entire year, found that inattention was involved in 90% of crashes and near-crashes. Reducing driver inattention has been a focus of road authorities and enforcement agencies as a result.

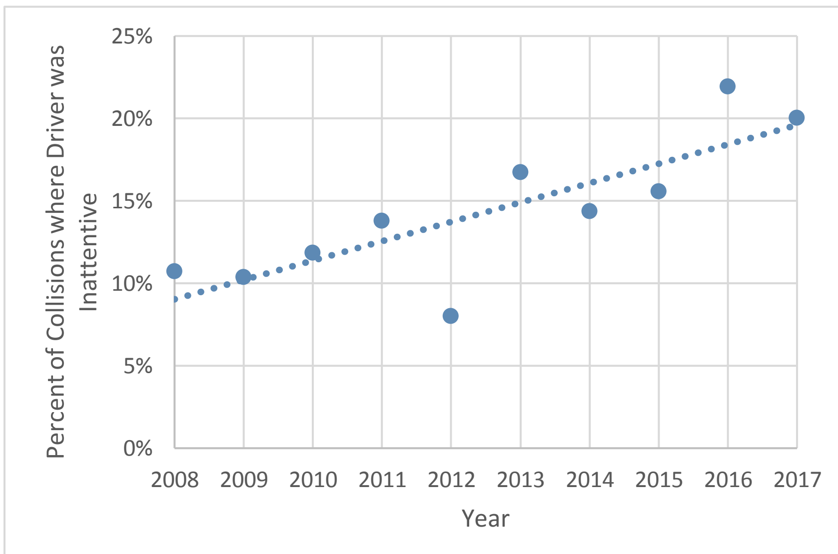


Figure 10 – Driver Inattentiveness in Pedestrian/Cyclist Collisions

[4] Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J., Ramsey, (2006) The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data DOT HS 810 594

Midblock collisions typically occur in locations without controlled crossings.

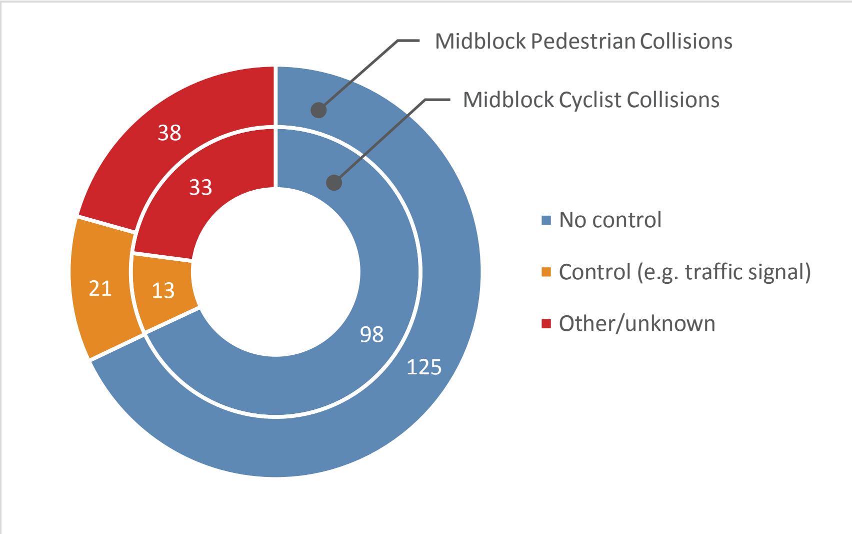


Figure 11 – Control Type in Midblock Collisions

Midblock pedestrian and cyclist collisions were found to be much less common than those at intersections (87% of pedestrian collisions and 84% of cyclist collisions occurred at intersections). However, where midblock collisions did occur, they were typically in locations without a controlled crossing: approximately two-thirds of midblock collisions involving both pedestrians and cyclists occurred in locations with no control (see **Figure 11**).

Young adults (20-29) and the elderly (60+) are disproportionately involved in collisions.

The involvement of pedestrians and cyclists in collisions over the past 10 years, by age group, was compared to the total daily number of walking and cycling trips originating in York Region for each age group, as shown in **Figures 12 and 13**. The total daily trips were derived from the 2016 Transportation Tomorrow Survey (TTS), an established source for origin-destination information across the Greater Golden Horseshoe. Pedestrian trips were derived by summing the 'walk' and 'transit excluding GO Rail' trip mode categories, since nearly all local transit trips involve walking.

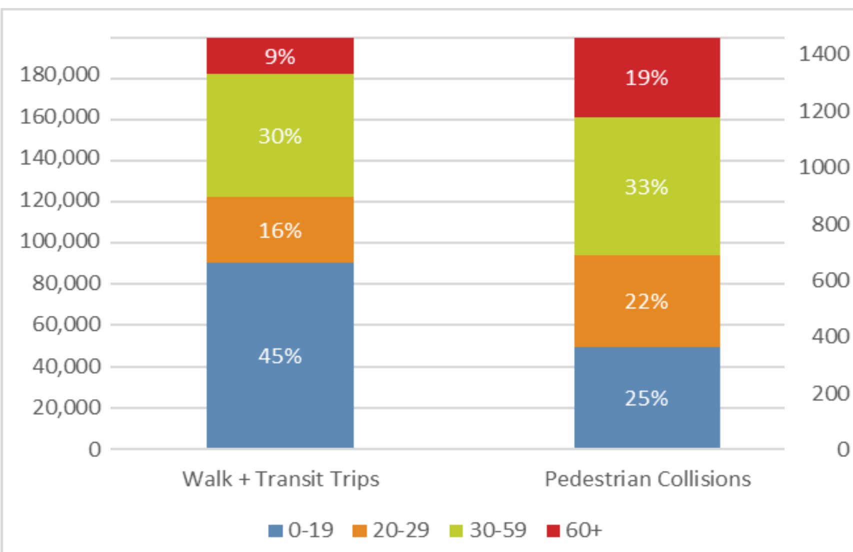


Figure 12 – Pedestrian Trips and Collisions by Age

Young adults, ages 20 to 29, were disproportionately more involved in collisions as pedestrians and as cyclists. The ratio of the proportion of collisions involving this age group to the proportion of total trips made by this age group is nearly 1.5 as pedestrians (i.e. 22% versus 16%) and more than 2.5 as cyclists, as shown in **Figure 14**. It is noted that 75% of young pedestrians involved in collisions at intersections were crossing with the right-of-way.

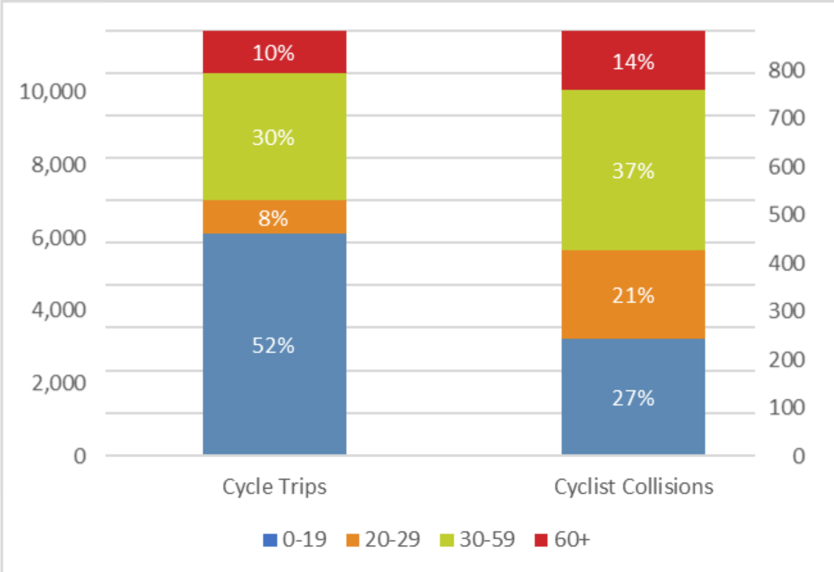


Figure 13 – Cyclist Trips and Collisions by Age

Elderly people, ages 60 and above, were also disproportionately more involved in collisions as pedestrians (ratio of the proportion of collisions involving this age group to the proportion of total trips made by this age group is more than 2.0) and as cyclists (about 1.4). However, it should be noted that the magnitude of collisions involving elderly pedestrians and cyclists is lower than in all other ranges, corresponding to a lower exposure (less total daily trips for walking and cycling modes).

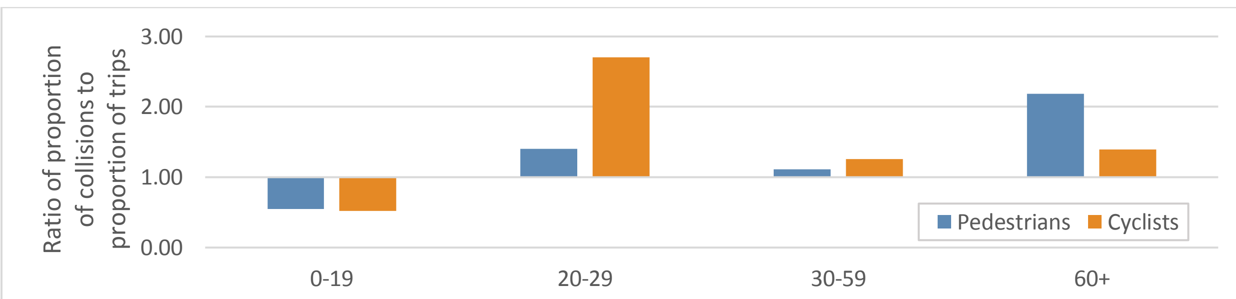


Figure 14 – Involvement in Collisions (Relative to Trips) by Age Group

Finally, it is observed that children and teenagers (0-19) make the most trips by both pedestrian and cycling modes (triple the daily pedestrian trips and six times the daily cycling trips of the 20-29 age group) but are proportionately less involved in collisions.

3 Safety Improvements

3.1 Industry Review of Potential Improvements

A transportation industry scan was conducted to determine if the major problem statements identified in York Region are comparable to general transportation trends throughout North America and the rest of the world. This scan also identified any innovative improvements that are currently being used in the industry to improve pedestrian and cyclist safety. Based on the trends identified in the statistical and geospatial analysis of pedestrian and cyclist collisions in York Region, industry review was to determine current research, trends and best practices in the following categories:

- Strategies and countermeasures to reduce pedestrian and cyclist collisions
- Innovations in safety applications for pedestrian and cyclist crossings
- Collisions involving vehicle turning maneuvers
- Collisions occurring at midblock locations
- Age of pedestrians and cyclists involved in collisions

Some identified measures, such as pedestrian countdown signals and longer pedestrian clearance times were not included in this analysis as they are already implemented on most or all of York Region roadways. Other measures, such as raised crosswalks or removal of on-street parking, were not included in this analysis as they are not applicable to York Region roadways which are mostly primary arterials without parking.

The safety measures were identified and evaluated using several sources, including guidelines and research reports. These sources include:

- Ontario Traffic Manual Book 15 (Pedestrian Crossing Treatments) and Book 18 (Cycling Facilities)—these guidelines are applicable standards in Ontario and provide best practice recommendations
- US Federal Highway Administration (FHWA) Pedestrian/Bicycle Safety Guide and Countermeasure Selection System—these guidelines include various statistics and case studies
- FHWA Crash Modification Factors (CMF) Clearinghouse—CMFs provide quantified estimates of crash reductions due to the implementation of various measures, based on compiled research. Not all identified factors have associated CMF factors researched.
- Various research reports published by the National Cooperative Highway Research Program (NCHRP) under the Transportation Research Board (TRB), including NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plans Vols. 5, 10, 12, 18 and 19

Short and medium term improvements are described below in detail. The long term measures of improving the network of pedestrian and cycling facilities are incorporated in the Region's Active Transportation Master Plan.

3.1.1 Short Term Improvements

Protect turning movement at intersections

Providing fully protected left-turn and/or right-turn phases at intersections reduces conflicts with pedestrians and cyclists by removing permitted turning phases (drivers are permitted to turn but must yield to oncoming vehicles and cyclists as well as crossing pedestrians). With the implementation of protected turning movements, turning vehicles and pedestrians are given exclusive right-of-way in sequence.

Benefits

- Reduces potential conflicts by removing permitted turning phases
- Shown to reduce overall crashes by up to 68%[5]

Impacts

- Additional phases may increase overall automobile delay at intersections

Recommended: Currently protect turning movements in York Region for motorist protection; should also be used at select locations to improve pedestrian and cyclist safety.

Restrict turning movements at intersections

Restricting left turns at intersections reduces conflicts with pedestrians and cyclists by removing permitted turning phases (drivers are permitted to turn but must yield to oncoming vehicles and cyclists as well as crossing pedestrians). Restricting right turns on red (RTOR) reduces conflicts with pedestrians who are crossing perpendicular to the vehicle direction.

Benefits

- Reduces potential conflicts by removing permitted turning phases
- Shown to reduce overall crashes by up to 8%[6]

Impacts

- Restricting turning movements altogether may result in unintended routes through neighborhoods
- Restricting RTOR may increase overall automobile delay at intersections

Recommended: Currently restrict turning movements in York Region for motorist protection and path control; should also be used at select locations to improve pedestrian and cyclist safety.

[5] FHWA Crash Modification Factors (CMF) Clearinghouse – www.cmfclearinghouse.org
[6] Ibid.

Leading pedestrian intervals

A leading pedestrian interval (LPI) gives pedestrians the opportunity to enter an intersection 3-7 seconds before vehicles are given a green indication. With this head start, pedestrians can better establish their presence in the crosswalk before vehicles have priority to turn left. They provide the following benefits: 60% reduction in pedestrians-vehicle collisions at intersections; increased visibility of crossing pedestrians; reduced conflicts between pedestrians and vehicles; increased likelihood of motorists yielding to pedestrian; and enhanced safety for pedestrians who may be slower to start into the intersection.

Benefits

- Allows pedestrians to establish presence and increases their visibility
- Have been shown to reduce pedestrian-vehicle collisions at intersections by up to 59%[7].

Impacts

- Increases overall automobile delay at intersections due to additional red time

Recommended: York Region has begun to pilot leading pedestrian intervals; should be further implemented at critical locations.

Warning signage

Signs which indicate to vehicles turning right that pedestrians and/or cyclists have the right-of-way within the intersection and must wait for the crosswalk to be clear.

Benefits

- May increase motorist awareness and understanding of right-of-way
- Increased visibility and awareness can reduce crashes by up to 40%[Error! Bookmark not defined.]

Impacts

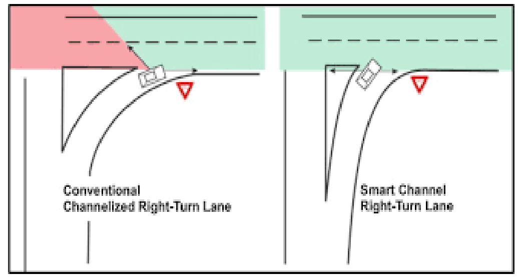
- Additional signage at intersections may cause oversaturation of driver attention

Recommended: Included in recent Canadian and Ontario industry guidelines; should be introduced at critical locations.

[7] FHWA Crash Modification Factors (CMF) Clearinghouse – www.cmfclearinghouse.org

3.1.2 Medium Term Improvements

Smart channels



Smart Channel alignment forces right-turning vehicles to slow to a near-stop as they approach and make their turns and places the pedestrian crossing directly in front of and perpendicular to the turning vehicles, increasing driver awareness. They also provide refuge islands separating the full-length pedestrian crossing into shorter segments.

Benefits

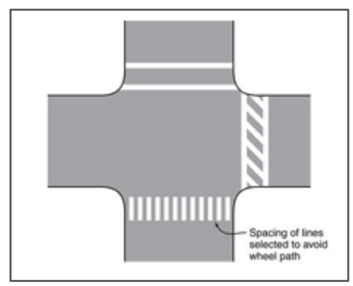
- Decreases speed of turning motorists
- Increases visibility of pedestrian crossing (perpendicular to turning vehicles)
- Also improves vehicle-vehicle visibility
- Shown to reduce crashes by up to 44%[8]

Impacts

- Pavement marking require regular maintenance (curbs must remain wider due to truck turning movements)
- Decreased vehicle speed may increase delay slightly for right-turning vehicles

Recommended: York Region's best practice is to remove channelized right turns entirely in construction in urban areas; where removal is not possible Smart Channel should be included in standard design, additionally should use pavement marking version in select locations as a trial.

Enhanced crosswalk pavement markings



High-visibility crosswalk markings, such as ladder markings, are an alternative to the typical parallel line markings. High-visibility crosswalks are recommended to be used in locations with high pedestrian and vehicle volume. Various studies have shown decreases in pedestrian-vehicle collisions[9]

Enhanced paving or colored paint can be used to further enhance the visibility of crosswalks in locations with high pedestrian volumes. York Region has implemented colored paving stone crosswalks along the Highway 7 BRT route.

Benefits

- Increases visibility of pedestrian crossing
- Shown to reduce crashes by 20% to 40%[8]

Impacts

- Pavement markings require regular maintenance

Recommended: Ladder crosswalk markings are used in York Region in all location where intersection geometry allows; should prioritize intersection improvements where current geometry precludes required direct crossings.

[8] FHWA Crash Modification Factors (CMF) Clearinghouse – www.cmfclearinghouse.org
[9] FHWA (2014) Evaluation of Pedestrian-Related Roadway Measures: A Summary of Available Research

Road diet

Road diets involve reducing the width of roadways as they approach intersections. They reduce the number of lanes pedestrians must cross and slow traffic on the approaches. One common road diet design in Ontario is to reduce a four-lane cross-section to three lanes (including two-way left turn lane) with bicycle lanes or a parking lane.

Benefits

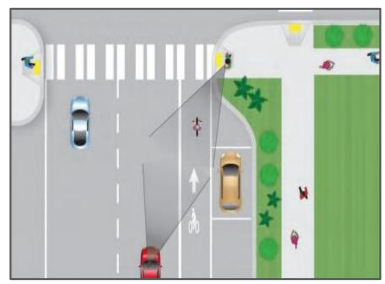
- Reduces width of pedestrian crossings, therefore reducing exposure to conflicts
- May decrease motorist speed due to narrower or fewer lanes
- Allows for introduction of dedicated cycling facilities

Impacts

- Fewer travel lanes may decrease automobile capacity of roadway (in some cases, such as four- to three-lane reduction with TWLTL, may allow for similar capacity)
- Additional pavement markings or landscaping features may require regular maintenance

Recommended: Road diets are used widely throughout GTA; should continue to look for implementation opportunities as part of resurfacing and reconstruction projects.

Curb extensions



Curb extensions (also known as bulb-outs) extend the sidewalk or curb line out into the parking lane and reduce the effective street width. This countermeasure improves pedestrian crossings by reducing the pedestrian crossing distance, reducing the time that pedestrians are in the street, visually and physically narrowing the roadway, and improving the ability of pedestrians and motorists to see each other.[10]

Benefits

- Reduces width of pedestrian crossings
- Increases visibility of pedestrian crossing
- May reduce motorist speeds due to narrower roadway and tighter curb radii

Impacts

- Capital cost of curb construction

Recommended/ Limited Applicability: Typically used on local and collector roads in high density urban areas; consider use but may have limited applicability on York Region roads.

[10] FHWA Pedestrian Safety Guide and Countermeasure Selection System – www.pedbikesafe.org

Reduce corner radius at intersections

Larger curb radii typically result in high-speed turning movements by motorists, which may increase the risk of pedestrians being struck by right-turning vehicles. Smaller radii can improve pedestrian safety by requiring motorists to reduce vehicle speed by making sharper turns and shortening pedestrian crossing distances which thereby improves signal timing. Also, the smaller radii provide larger pedestrian waiting areas at corners, improve sight distances, and allow for greater flexibility of curb ramp placement[10].

Benefits

- Reduces width of pedestrian crossings
- Reduces motorist speeds due to narrower roadway and tighter curb radii

Impacts

- Capital cost of curb construction
- May restrict some truck and emergency vehicle movements

Recommended: Reduced corner radii considered as part of all York Region intersection improvements; should continue to implement.

Bike boxes / cross-rides / green cycling areas

Bike boxes allow cyclists to have a safe and visible location to queue, ahead of motorists. In Ontario, cyclists and motorists are provided clear indication of these areas as they are painted bright green and contain bicycle pavement markings in them. A crossride is dedicated space at an intersection, identified by unique pavement markings, for cyclists to legally ride their bicycle through an intersection without dismounting. A crossride may appear alongside a pedestrian crosswalk as a separate facility or may be combined with a crosswalk to save space in some areas.

Benefits

- Increases motorist awareness and understanding of right-of-way at intersections on roads with dedicated cycling facilities
- Shown to reduce crashes by up to 39%[Error! Bookmark not defined.]

Impacts

- Increases complexity of pavement markings for motorists
- Requires regular maintenance

Recommended: Introduced within York Region (for example Hwy 7 bike boxes); should consider implementing on all designated York Region bicycle facilities.

Advance stop lines

Advance yield/stop line include the stop bar or "sharks' teeth" yield markings placed 6 to 15 meters in advance of a marked crosswalk to indicate where vehicles are required to stop or yield. This countermeasure discourages drivers from stopping too close to crosswalks and blocking other drivers' views of pedestrians and pedestrians' views of vehicles. Pedestrians can see if a vehicle is stopping or not stopping and can take evasive action. Studies have found that advance yield markings at midblock crossings can be particularly useful when combined with signs and beacons, such as the Pedestrian Hybrid Beacon or Rectangular Rapid-Flashing Beacon (RRFB)[11].

Benefits

- Increases visibility of pedestrian crossing
- Shown to reduce crashes by up to 25%[12]

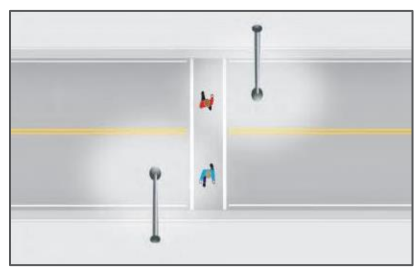
Impacts

- Additional pavement markings require regular maintenance

Recommended/ Limited Applicability: Advance yield line associated with new Pedestrian Crossovers only, which has limited potential use on Regional arterial roads; continue to use required advance stop line at mid-block pedestrian signals.

Enhanced lighting

Appropriate quality and placement of lighting can enhance an environment and increase comfort and safety. Pedestrians may assume that their ability to see oncoming headlights means motorists can see them at night; however, without sufficient lighting, motorists may not be able to see pedestrians in time to stop. A study sponsored by the FHWA found that 20 lx (a unit of illuminance) was necessary for motorists to detect a pedestrian in the crosswalk. To achieve 20 lx, the luminaire should be placed 3 m upstream of the crosswalk. This differs from traditional placement of luminaires over the actual intersection.[13]



Benefits

- Increases visibility of pedestrian crossing

Impacts

- Capital and maintenance costs of lighting

Recommended: York Region currently uses Transportation Association of Canada guidelines; as part of the LED upgrade program should consider installation of enhanced lighting at pedestrian crossings.

[11] FHWA Pedestrian Safety Guide and Countermeasure Selection System – www.pedbikesafe.org
[12] NCHRP Research Report 841: Development of Crash Modification Factors for uncontrolled Pedestrian Crossing Treatments
[13] FHWA Report No. FHWA-HRT-08-053 Informational Report on Lighting Design for Midblock Crosswalks (2008)

Pedestrian crossing islands

A pedestrian crossing island (or refuge area) is a raised island which can be implemented either at controlled crossing locations (e.g. between opposing traffic lanes at intersections or pedestrian crossovers) or at uncontrolled crossing locations (locations such as trail crossings where a controlled crossing is not warranted). These islands separate crossing pedestrians from motor vehicles and have been shown to reduce pedestrian collisions by up to 56%.

If implemented at an uncontrolled crossing location, the roadway characteristics, pedestrian exposure and geometry should be considered before providing a pedestrian crossing island and other physical components (e.g. signage) which designate the location as an uncontrolled crossing. The Ontario Traffic Manual (Book 15, Section 7) recommends implementing designated uncontrolled crossings only under the following conditions: the roadway should have a posted speed limit of 50 km/h or less; pedestrian and traffic volumes should not exceed the warrant thresholds for controlled crossing treatments; the roadway should have a maximum of two lanes in each direction; and the roadway should be classified as a collector or lower (i.e. the roadway should not be a major collector or arterial).

Benefits

- Reduces width of individual pedestrian crossing movements, therefore reducing exposure to conflicts

Impacts

- Capital cost of median island
- Increases width of roadway (potential property requirements) if no existing median

Recommended/ Limited Applicability: Pedestrian crossing islands are used in some lower or single tier GTA municipalities but not currently in York Region; should consider their use, however very few Regional roads will meet all requirements, so typically mid-block pedestrian signals should be installed instead.

Danish offset

Danish offsets are an enhanced form of pedestrian refuge islands which are offset on either side, providing a safe middle refuge and orienting pedestrians to face oncoming traffic as they cross the second leg. They also are more beneficial to those with mobility issues compared to standard pedestrian refuges. If implemented at an uncontrolled crossing location, the same conditions which apply to pedestrian crossings (OTM Book 15) apply to Danish offsets.

Benefits

- Reduces width of individual pedestrian crossing movements, therefore reducing exposure to conflicts

Impacts

- Capital cost of median island
- Increases width of roadway (potential property requirements) if no existing median

- Increases visibility between pedestrians and motorists

Recommended/ Limited Applicability: Danish offset crossings have had limited use in GTA municipalities but not currently in York Region; should consider their use, however very few Regional roads will meet all requirements, so typically mid-block pedestrian signals should be installed instead.

Controlled mid-block pedestrian crossings

One type of controlled pedestrian crossing is the pedestrian crossover, which allow pedestrians to cross the road where there are no traffic lights or stop signs. Motorists and cyclists must come to a complete stop when pedestrians indicate they want to cross the road at a crossover. All traffic must remain stopped until pedestrians reach the sidewalk on the opposite side of the road. These rules also apply to school crossings and other locations where a crossing guard is present. Another type of controlled pedestrian crossing (preferred in York Region to pedestrian crossovers) is an Intersection or Midblock Pedestrian Signal (MPS pictured), which function similarly to regular traffic signals where vehicles must stop when the indication is red.

Benefits

- Clearly assigns right-of-way between pedestrians and motorists at otherwise uncontrolled crossings
- Shown to reduce crashed by up to 29%[14].

Impacts

- Capital cost of traffic control (e.g. signals)
- Increases automobile delay

Recommended: York Region currently installs pedestrian traffic signals according to OTM Book 12 guidelines; should additionally review location requests for network connectivity and regular pedestrian crossing spacing.

[14] FHWA Crash Modification Factors (CMF) Clearinghouse – www.cmfclearinghouse.org

3.2 Rating of Potential Improvements

The safety improvements identified in the previous section were rated on their potential effectiveness for improving safety for the major observed collision patterns in York Region, as well as on their estimated cost and applicability on York Region roads. These ratings were combined to determine an overall recommendation rating for each measure. The methodology for rating each of these categories is described below and a summary of recommendations is shown in **Table 1**.

Effectiveness at Improving Safety for Targeted Collision Types

-	Not applicable
○	Less effective
◔	↑
◑	
◕	↓
●	More effective

Based on the major collision patterns identified in Section 2, four overarching types of collisions were identified to be targeted by potential safety improvement measures. These are:

1. Pedestrian collisions with turning vehicles at signalized intersections.
2. Cyclist collisions with turning vehicles at signalized intersections.
3. Collisions involving young adult pedestrians and cyclists (ages 20 to 29).
4. Collisions occurring at midblock locations with four or more lanes and no traffic control.

Each identified safety measure was rated for its potential effectiveness to improve safety for each of these four types of collisions. These ratings were based on an industry review of best practice and applicable research on the anticipated benefits and impacts of each measure, as outlined in Section 3.1.

Cost

○	More costly
◔	↑
◑	
◕	↓
●	Less costly

Each measure was rated based on its potential cost to implement. These ratings are based on the estimated typical installation of each measure. In general, measures which involve infrastructure changes (i.e. controlled midblock crossings) are anticipated to be costlier than those that do not (i.e. signage, pavement markings, etc.).

Applicability on York Region Roads

○	Not applicable
◑	Somewhat applicable
●	Applicable

Most roads under the jurisdiction of York Region are arterial roadways with four or more lanes. Some identified measures are not applicable to these types of roads, while some are possible but are generally not used.

Overall Recommendation Rating

○	Lower priority
◔	↑
◑	
◕	↓
●	Higher priority

The ratings for each of the categories listed above were combined to determine an overall recommendation for each identified measure specific to York Region conditions and collision patterns. Measures which have potential to improve safety for multiple collision types are generally recommended to be implemented at a higher priority.

Implementation time frame

A general time frame for implementation is identified for each type of improvement measure, based on the infrastructure or network modifications required. In general, measures which involve minor upgrades to signal timing, signage and/or pavement markings can be provided in a "short" time frame. Measures which involve moderate to substantial infrastructure upgrades (e.g. medians, new traffic signals, etc.) can be provided in a "medium" time frame. Network improvements can be provided in a "long" time frame.

Table 1 – Summary of Recommended Measures

Measure	**Effectiveness at Improving Safety for Targeted Collision Type**				**Cost Rating**	**Applicability on Regional Roads**	**Overall Recommendation Rating**	**Implementation Time Frame**
	1	**2**	**3**	**4**				
Protect turning movements at intersections	●	●	●	-	●	●	●	Short
Restrict turning movements at intersections	●	●	●	-	●	●	●	Short
Leading pedestrian intervals	◕	-	◕	-	●	●	◕	Short
Warning signage (i.e. turning traffic yield to pedestrians/cyclists)	◑	◑	◑	-	●	●	◕	Short
Education campaigns focused on distracted road users (pedestrians, cyclists and drivers)	◔	◔	◔	◔	◑	●	◑	Short
Smart Channels	◑	◑	◑	-	◑	●	◑	Medium
Enhanced (e.g. ladder) pavement markings at pedestrian crossings	◑	-	◑	-	◕	●	◑	Medium
Road diet to narrow lanes/ reduce speed	◔	◔	◔	◑	◑	●	◑	Medium
Curb extensions	◑	-	◑	◑	◑	◑	◑	Medium
Reduce corner radius at intersections	◑	◑	◑	-	◑	◑	◑	Medium
Bike boxes / cross-rides / green cycling areas	-	◑	◑	◑	◕	◑	◑	Medium
Improve pedestrian network connections	◑	-	◑	◑	◔	●	◑	Long
Advance stop lines	◔	◔	-	◑	◕	◑	◔	Medium
Enhanced lighting	◔	◔	◔	◔	◔	●	◔	Medium
Pedestrian crossing islands/ Danish offset	-	-	◑	◑	◑	◑	◔	Medium
Controlled mid-block crossings	-	-	-	◑	◔	●	◔	Medium
Improve cycling network connections (i.e. dedicated cycling facilities)	-	◑	◑	-	◔	●	◔	Long

4 Implementation and Prioritization

Safety data analysis revealed Region-wide patterns of collision characteristics to be addressed (Section 2). Potential safety improvements were identified by an industry review and rated by their anticipated effectiveness at addressing Region-specific collision patterns (Section 3). To guide the implementation of pedestrian and cyclist safety improvements in the Region, a prioritized index of specific locations to be further diagnosed and upgraded was developed.

In the long term, improved pedestrian and cycling facilities should be implemented systemically throughout the Region when new roads are built, or existing roads are reconstructed. Certain improvements, such as dedicated cycling facilities, should be implemented on a corridor or network basis. York Region's Pedestrian and Cycling Planning and Design Guidelines (2018) provide facility selection tools and design standards for this purpose.

4.1 Scope of Prioritization Index

4.1.1 Purpose

The purpose of the prioritization exercise is to identify specific locations where operational improvements have the greatest potential to improve pedestrian and cyclist safety. Considering Objective 3 of York Region's 2016 Transportation Master Plan to "*Integrate Active Transportation in Urban Areas*", a secondary goal is to increase active transportation mode share by improving pedestrian and cyclist comfort and accessibility in areas where there may be high potential active transportation demand but where the existing environment may be unwelcoming.

Based on the observed patterns of collision characteristics in York Region and the suite of identified potential improvement measures, the following parameters for prioritization were developed:

- Both pedestrian and cycling modes are addressed, since the most prominent collision patterns are shared (e.g. turning vehicles at signalized intersections) and several of the identified operational improvements have potential to improve safety for both modes (e.g. protecting or prohibiting turning movements).
- The prioritization exercise addresses signalized intersections only and uses variables which prioritize urban areas and intersections with a high proportion of turning volumes, since the safety analysis showed prominent patterns of collisions with these characteristics.

The recommended operational improvements are intended to be implemented throughout the Region, starting with the locations having the highest prioritization index. Each prioritized intersection will be reviewed for applicability, to understand site-specific problems and constraints, and to select and design which of the recommended safety measure be implemented. The systemic application will be validated at initial trial locations prior to proceeding. Safety benefits and operational impacts will be monitored and assessed pre and post implementation.

4.1.2 Methodology

The methodology for the prioritization index was based on the ActiveTrans Priority Tool Guidebook[15] published by the National Cooperative Highway Research Program (NCHRP). The methodology assigns each potential improvement location with a prioritization score by summing the weighted scores for several evaluation factors. Factors and factor weights were selected to prioritize locations which have potential to achieve the purpose set out in the previous section. Several related variables were analyzed to determine the score for each factor.

4.1.3 Factors

To achieve the objectives of the prioritization exercise, three factors were selected for analysis. These factors are relevant to York Region's goal to implement safety improvements at signalized intersections with the greatest potential to improve pedestrian and cyclist safety, especially in areas where there may be high potential to increase active transportation mode share but where the existing environment may be unwelcoming.

- **Safety** – Accounts for the risk of a pedestrian or bicyclist being involved in a collision. Safety is important because pedestrians and bicyclists are particularly vulnerable to being injured or killed when struck by a motor vehicle. In addition, concerns about safety can be a significant barrier to people choosing to walk and bicycle. The safety factor is evaluated in terms of reported pedestrian and bicycle crashes from both historical and predictive perspectives.

- **Demand** – Represents existing and potential pedestrian and bicycle activity levels. Demand is a key factor considering the goal to improve pedestrian and bicycle facilities where they will be most used. Existing pedestrian and bicycle volume measurements were used, in addition to an estimate of potential or 'latent' demand considering proximity to pedestrian and cyclist attractors and high-density land uses. An increasing body of evidence supports the concept of latent demand as a method to focus investments on areas with the greatest potential for multimodal trips, even if current levels of walking and bicycling trips are low.

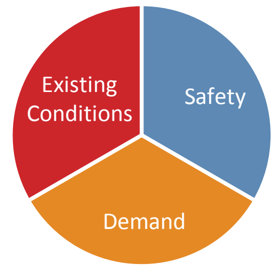
- **Existing Conditions** – Accounts for physical conditions that have an impact on pedestrian or bicycle safety, comfort, or demand, including the permanent physical road environment as well as travel behaviours that influence conditions for walking and cycling, such as traffic volumes and speed.

Each of the three factors was weighted equally in the prioritization formula, based on York Region policy and discussions with York Region staff. Each factor is given an arbitrary weight of 20 points, leading to a total score for each assessed location of 60 points (see **Table 2**).

[15] NCHRP Report 803: Pedestrian and Bicycle Transportation Along Existing Roads – ActiveTrans Priority Tool Guidebook ; Transportation Research Board; Washington DC; 2015

Table 2 – Intersection Prioritization Factor Weights

Factor	Weight
Safety	20
Demand	20
Existing Conditions	20
TOTAL SCORE OUT OF:	**60**



4.1.4 Variables

For each of the three analysis factors, several variables were selected to effectively represent the factor as described in the previous section. Each variable is scored out of five points. A brief description of each variable and its effective weighted contribution to the final score out of 60 is outlined in **Table 3**.

Table 3 – Intersection Prioritization Variables

Factor	Variable	Description	Score out of	% of factor	Factor weight	Effective variable weight
Safety	Observed collisions	Total collisions involving pedestrians and cyclists (10 years) based on MVAR data.	5	50%	20	10
	Potential for Safety Improvement (PSI)	Quantitative predictive measure of potential for increasing safety, using Safety Performance Functions (statistical analysis of collisions between all road users, considering various environmental factors).	5	50%		10
Demand	Existing pedestrian demand	Eight-hour pedestrian volume from most recent Turning Movement Counts at each intersection.	5	25%	20	5
	Proximity to transit	Scores are based on proximity to transit routes. Higher scores are given to intersections of routes and VIVA routes.	5	25%		5
	Proximity to attractors	Shopping centers within 500 m and schools within 800 m radius of intersection.	5	25%		5
	Average adjacent population density	Average population density within 800 m radius of intersection, based on 2016 census data.	5	25%		5

Existing Conditions	Traffic volume	Total eight-hour vehicle traffic from most recent Turning Movement Counts at each intersection.	5	25%	20	5
	Total turning traffic volume	Total eight-hour turning vehicle traffic from most recent Turning Movement Counts at each intersection.	5	25%		5
	Traffic speed	Average speed of approaching roads in km/h.	5	25%		5
	Number of travel lanes	Sum of travel lanes on all approaches.	5	25%		5
TOTAL SCORE OUT OF:					**60**	**60**

4.2 Prioritization

4.2.1 Variable Scoring

The safety, demand and existing conditions characteristics were evaluated for most signalized intersections in York Region[16]. The variables were scored using a percentile system (except for the transit variable) as outlined in **Table 4**. The percentile ranges are smaller for higher scores to increase sensitivity near the top of the ranked index.

Table 4 – Intersection Prioritization Scoring Criteria

Variable Score		0	1	2	3	4	5
Percentile (where applicable)		0%	40%	60%	75%	85%	95%
Safety	Collisions (10 years)	< 1	≥ 1	≥ 2	≥ 4	≥ 5	≥ 8
	PSI	< 1.00	≥ 1.00	≥ 6.14	≥ 16.41	≥ 31.08	≥ 79.06
Demand	Pedestrian Volume (8 hrs)	< 33	≥ 33	≥ 95	≥ 180	≥ 297	≥ 600
	Transit	no stops	N/A	one route	two routes	two routes, one VIVA	two routes, both VIVA
	Nearby Attractors	< 1	≥ 1	≥ 2	≥ 3	≥ 4	≥ 5
	Population Density	< 15.68	≥ 15.68	≥ 22.54	≥ 29.33	≥ 34.76	≥ 47.27
Existing Conditions	Vehicle Volume (8 hrs)	< 14,937	≥ 14,937	≥ 19,275	≥ 23,371	≥ 26,927	≥ 34,570
	Turning Volume (8 hrs)	< 2,829	≥ 2,829	≥ 4,044	≥ 5,877	≥ 8,174	≥ 10,482
	Average Approach Speed	< 55.0	≥ 55.0	≥ 56.7	≥ 60.0	≥ 63.3	≥ 70.0
	Total Approach Lanes	< 13	≥ 13	≥ 16	≥ 16	≥ 18	≥ 20

[16] Intersections with no available Turning Movement Count data were excluded from analysis.

4.2.2 Ranked Index

The scores for each variable were combined and weighted to determine the scores for each factor (safety, demand and existing conditions). The sum of the factor scores equates to the total weighted prioritization score (out of 60) for each intersection, with higher scores indicating higher priority for improvement. A ranked list of intersections with scores over 48 (80% of 60) or higher are included in **Table 5** and the full index of all signalized intersections is mapped in **Figure 15** and included as **Appendix A**.

Table 5 – Intersection Prioritization Index

Signalized Intersection	Variable Scores (all /5)										Factor Scores			Total Weighted Score (/60)
	Safety		Demand				Ex. Conditions							
	Collisions	PSI	Ped. Volume	Transit	Attractors	Pop. Density	Traffic Volume	Turning Volume	Speed	Approach Lanes	Safety (/20)	Demand (/20)	Ex. Conditions (/20)	
*Yonge Street & Carrville Road/ 16th Avenue **	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*4*	*0*	*5*	*20*	*20*	*14*	*54*
*Yonge Street & Mulock Drive **	*5*	*5*	*5*	*5*	*5*	*3*	*4*	*4*	*3*	*5*	*20*	*18*	*16*	*54*
Major Mackenzie Drive East & Bayview Avenue	**5**	**5**	**5**	**3**	**5**	**4**	**4**	**4**	**3**	**4**	**20**	**17**	**15**	**52**
*Highway 7 & Weston Road **	*5*	*5*	*5*	*5*	*3*	*0*	*5*	*5*	*4*	*5*	*20*	*13*	*19*	*52*
*Weston Road & Rutherford Road ***	*5*	*5*	*3*	*3*	*3*	*4*	*5*	*5*	*3*	*5*	*20*	*13*	*18*	*51*
*Highway 7 & Leslie Street **	4	5	5	5	5	0	5	4	4	5	*18*	*15*	*18*	*51*
*Yonge Street & Major Mackenzie Drive **	*5*	*5*	*5*	*5*	*5*	*4*	*4*	*3*	*0*	*4*	*20*	*19*	*11*	*50*
*Highway 7 & Pine Valley Drive **	*5*	*5*	*4*	*5*	*2*	*1*	*5*	*5*	*3*	*5*	*20*	*12*	*18*	*50*
*Yonge Street & Elgin Mills Road **	*5*	*5*	*5*	*5*	*4*	*3*	*4*	*4*	*1*	*3*	*20*	*17*	*12*	*49*
Yonge Street & Clark Avenue	**5**	**4**	**5**	**5**	**4**	**5**	**4**	**3**	**0**	**5**	**18**	**19**	**12**	**49**
Bathurst Street & Carrville Road/ Rutherford Road	**5**	**4**	**5**	**3**	**5**	**2**	**5**	**4**	**2**	**5**	**18**	**15**	**16**	**49**
Bathurst Street & Clark Avenue W	**5**	**4**	**5**	**3**	**4**	**4**	**5**	**4**	**1**	**4**	**18**	**16**	**14**	**48**

* *Excluded due to recent or imminent construction*
** *Excluded due to identified traffic operational impacts*

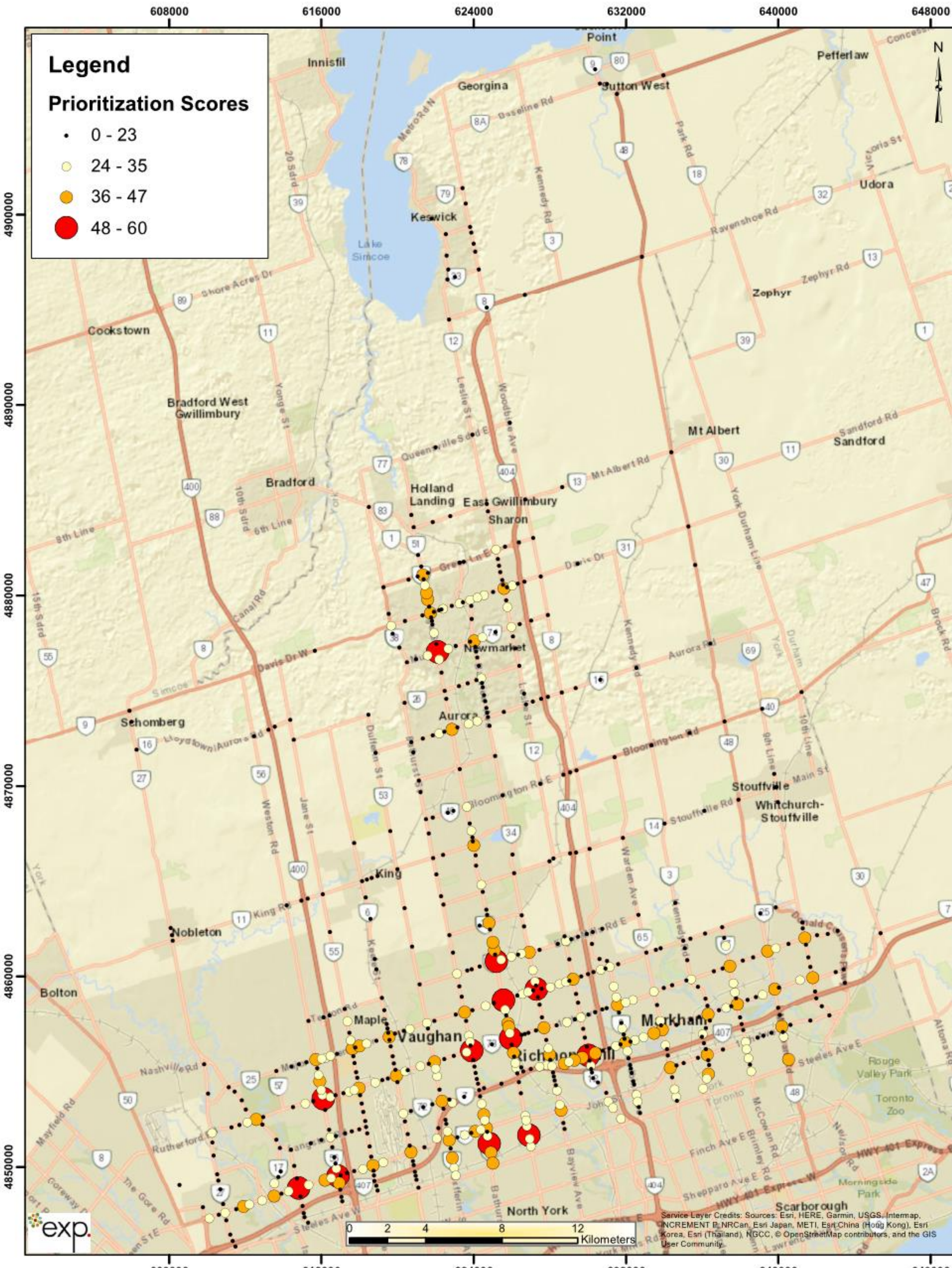


Figure 15 – Prioritization Index Map

4.3 Safety Improvement Trials at Priority Intersections

Intersections with prioritization scores of 48 or higher were selected for trials of safety improvements to be implemented and evaluated for future systemic implementation. The value 48 represents a natural break point in the data set, 80% of the maximum index and provides for a reasonable number of initial trial locations. These intersections are bolded in **Table 5**. Several intersections were eliminated from consideration as they were recently, are currently or are imminently undergoing construction and therefore not applicable for before/after analysis. Intersections were also identified which have the high potential for adverse operational impacts including neighbourhood traffic infiltration.

For each identified high-priority intersection, further diagnosis will be completed to understand site-specific problems, constraints and conditions, and to select and design safety improvements accordingly. This diagnosis will include:

- Analysis of pedestrian counts and turning movement counts to determine high-exposure conflicts
- Video conflict analysis to identify where and how conflicts occur
- Field observations to identify environmental, behavioural or other factors that may be influencing crashes and conflicts
- Detailed analysis of collision history to identify site-specific patterns or circumstances of collisions
- Operational analysis to define existing traffic conditions and potential impacts to conditions based on proposed improvements

Staff will monitor each intersection to evaluate the safety benefits and understand the corresponding impacts on vehicular traffic. Video conflict analysis and field observations from before and after implementation will be compared to determine what safety benefits have been realized, if any. Traffic operational impacts such as travel time increase, delay and queuing issues will also be evaluated. Based on the results, these operational measures will be considered for permanent installation as well as applicability at other locations.

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