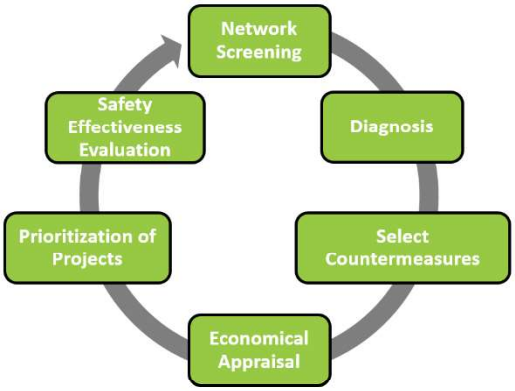
Executive Summary

Introduction

The road safety management process has the objectives of increasing the level of safety on municipal roads and reducing the cost of the road authority's liability. The City of Markham currently has a road safety strategy that is based upon the 5 pillars of Education (e.g., implementation of speed feedback advisory signs), Enforcement (e.g., speeding and stop compliance enforcement by police), Engineering (e.g., traffic calming and sidewalk network completion), Encouragement (e.g., supervised school crossing), and Evaluation (e.g., city-wide annual traffic data collection program). This strategy has been successful on many levels, allowing Markham to develop programs and policies to support road safety, and the continual reduction of collisions on City roads.



The Road Safety Management Process

In recent years, other jurisdictions have been adopting Vision Zero and Safe Systems approaches to road safety, including the Region of York. This coupled with an overall transportation culture change, shifting to promoting and supporting active modes and transit over motor vehicle travel, has motivated the City to undertake a traffic safety audit to refresh their road safety strategy. The objectives of this traffic safety audit included:

- Review collision data to assess municipal corridors and intersections;
- Prioritize locations based on severity and risk to road users;
- Identify potential traffic safety corrective measures; and
- Develop terms of reference for the future development of a comprehensive road safety strategies.

The review of collision data focuses on the assessment of the most recent five-year collision history of all intersections and road segments across the City to identify the underlying collision patterns (e.g., severity distribution), road user trends (e.g., involvement of vulnerable road users), environmental factors (e.g., road conditions), and spatial correlation (e.g., proximity to schools).

The prioritization of locations, also known as network screening, is an essential component of any effective safety management program and serves as a valuable tool in identifying and prioritizing collision "hot spots" across the City's network. The network screening process is conducted because diagnosing safety problems of the entire network on a site-by-site basis is cost prohibitive. Network screening provides a means through which resources are efficiently allocated to those sites which perform relatively poorly in terms of high collision history. To ensure that resources are spent on the sites with the highest potential for safety improvement, it is vital that a sound procedure be in place to screen the road network including intersections and road sections. In this project, the network screening was conducted to identify and prioritise locations with higher than expected prior collision history.

However, the network screening process is reactive in nature, as it relies on the occurrence of collisions to identify sites requiring safety intervention. While this approach is valuable to identify high-priority sites, it could ignore or downplay the importance of sites that experience a lower collision frequency,

but present risk factors that increase the potential for collisions. To address this limitation of the network screening process, a complementary systemic review of the City's road network was also conducted. This review entails the prioritization of City's facilities (i.e., intersections and road segments) based on environmental collision risk factors (roadway features having strong correlation with specific collision types). This approach supplements traditional site analysis and helps agencies broaden their traffic safety efforts by considering collision risk factors along with collision history when identifying where to make low-cost safety improvements.

The selection of countermeasures to address systemic risks is done through literature review to identify treatments that can eliminate or mitigate specific risk factors identified, followed by a screening for their effectiveness, applicability and feasibility in the City's context. Finally, a desktop review of the top ranked sites is conducted to identify which countermeasures may already be present, which ones may still be reasonably implemented, and which ones cannot be considered due to site limitations, generating a list of preliminary countermeasures, for each of the top ranked locations, for further evaluation prior to their implementation.

Considering the results of the above traffic safety assessments, Terms of Reference to develop a multi-year road safety implementation strategy / action plan were prepared to help the City of Markham engage a firm to complete the strategy.

The following sections describe the process and results associated with each of these study components.

Data Acquisition and Preparation

The data used in the traffic safety audit included collision records on City of Markham roads between January 2014 and December 2018, traffic volume data for the same period, and infrastructure data, including road segments and intersections and their physical (e.g. number of lanes, number of legs, etc.) and operational (e.g. speed limit, intersection control type, etc.) characteristics.

The data was reviewed for completeness and cleaned-up / supplemented as necessary. In particular, the systemic safety risk assessment requires detailed infrastructure data that is not typically available in a jurisdiction's traffic or infrastructure databases (for example, the presence of horizontal curves within a certain distance of an intersection or the presence of a median on a road segment). In these cases, the data was manually supplemented with the use of aerial imagery and/or Google Street View resources.

Traffic volume data was also reviewed for excessive growth between consecutive years. Sites showing changes in Annual Average Daily Traffic (AADT) greater than 15% from one year to the next were assessed whether there could be a reasonable justification for the large growth rate (for example, a new subdivision or new road section that could change traffic patterns). Sites for which a reasonable explanation for the large growth could not be identified had their AADTs adjusted to a more reasonable level by, for example, identifying unusually high or low counts that may have distorted the original growth rate and recalculating the growth rate based on more typical counts available.

Finally, a volume supplementation process was undertaken using an automated algorithm (followed by manual quality checks) to assign volumes to intersections and road segments for which no counts had been collected in the past. This process, in part, involved estimating volumes in some residential streets with simple surrounding road network (e.g. subdivisions) using trip generation rates from the Institute of Transportation Engineers.

At the end of the data processing, a total of 1,030 intersections and 2,035 road segments were defined to be within the scope of the network screening and systemic safety risk assessment, as summarized in the following table.

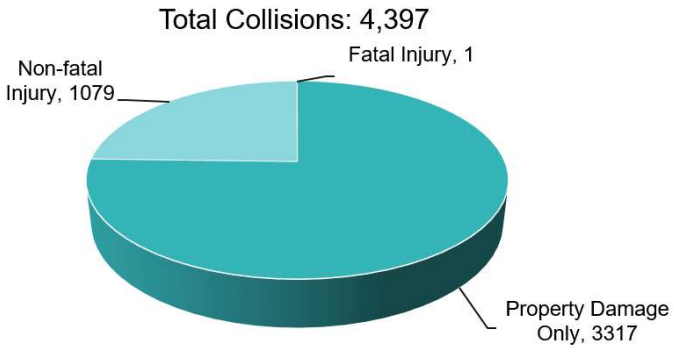
Number of Facilities Subject to Network Screening and Systemic Safety Review

Facility	Type	Number	
		Network Screening	Systemic Safety Review
Intersections	Signalized 4-leg Intersections	53	56
	Signalized 3-leg Intersections	27	30
	Unsignalized 4-leg Intersections	233	179
	Unsignalized 3-leg Intersections	717	476
	Total	**1,030**	**741**
Segments	Urban 2-lane Road Segments	1687	784
	Urban Multi-lane Road Segments	317	300
	Rural Road Segments	31	25
	Total	**2,035**	**1,109**

Review of Collision Data

Overall Collision Trends

A total of 4,397 collisions were reported on Markham roads between the years 2014 and 2018. 1,080 (24.5%) resulted in injuries, while 3,317 (75.5%) resulted in property damage only (PDO). Although the proportion of injury collisions is higher than the Provincial Average of 20.5%, it is slightly lower than the Regional average of 26.5%. Out of the 1,080 injury collisions, 37 (3.4%) resulted in major injuries,[1] one of which was a fatal pedestrian collision that occurred in 2015 at the intersection of Fieldside Street & Riverwalk Drive.



Collision Severity (2018 - 2018)

Intersection collisions correspond to 47% of total collisions and 63% of injury collisions. When broken down by number of legs and control type, 4-leg signalized intersections stand out, since they make up only 3% of all intersections in Markham but experience 37% of total collisions and 42% of injury

[1] Major injury is defined by hospital admission, including admission for observation. However, it excludes emergency room treatment with
out hospital admission.

collisions. To a lesser extent, 3-leg signalized intersection also stand out, being 2% of all intersections and experiencing 13% of collisions, as summarized in the following table.

Intersection injury collisions present an average decreasing rate of 2.2% per year.

Proportion of Intersections vs. Proportion of Collisions

Intersection Type	Facilities	Total Collisions	Injury Collisions
3-leg Two-way Stop	61%	22%	17%
4-leg Two-way Stop	16%	10%	10%
4-leg All-way Stop	8%	11%	11%
3-leg All-way Stop	7%	6%	5%
4-leg Signal	3%	**37%**	**42%**
3-leg Signal	2%	**13%**	**13%**
Others *	3%	1%	2%

** Roundabout, no control, 5-leg, etc.*

Road segment collisions correspond to 53% of total collisions and 37% of injury collisions. When broken down by area type, number of legs and speed limit, urban 4-lane road segments with 50 km/h speed limit stand out, since they make up only 3% of all road segments in Markham but experience 23% of total collisions and 32% of injury collisions. To a lesser extent, urban 2-lane road segments with 50 km/h speed limit also stand out, being 3% of all road segmetns and experiencing 12% of total collisions and 14% of injury collisions.

Road segment injury collisions present an average growth rate of 5.9% per year.

Proportion of Road Segments vs. Proportion of Collisions

Road Segment Type	Facilities	Total Collisions	Injury Collisions
Urban 2-lane 40 km/h	91%	56%	37%
Urban 2-lane 50 km/h	3%	**12%**	**14%**
Urban 4-lane 50 km/h	3%	**23%**	**32%**
Urban 4-lane 40 km/h	1%	**3%**	**6%**
Rural 2-lane 60 km/h	< 1%	**4%**	**6%**
Urban 4-lane 60 km/h	< 1%	**2%**	**3%**
Others	2%	< 1%	2%

Compared to other municipalities in Ontario, Markham presents the lowest annual rates of collisions per 100,000 population. While Markham presents 267 total collisions/year/100,000 people and 66 injury collisions/year/100,000 people, other municipalities reviewed (Burlington, Oakville, London, Hamilton, Brampton and Ottawa) range between 608 and 2,033 total collisions/year/100,000 people, and between 70 and 325 injury collisions/year/100,000 people. However, although Markham presents a proportion of injury collisions over total collisions (24.6%) slightly lower than York Region (24.6%), it has the highest proportion of injury collisions compared to other lower- or single-tier municipalities (11.5% to 21.0%).

Markham's pedestrian collision rate (11.7 pedestrian collisions/year/100,000 people) is relatively similar to those of Burlington and Oakville, which have populations lower than Markham's, and considerably lower than London, Hamilton, Brampton and Ottawa, which have populations higher than Markham's. For cyclist collisions, Markham's rate (6.7 cyclist collisions/year/100,000 people) is considerably lower than all other municipalities compared (which range between 10.6 and 33.0 cyclist collisions/year/ 100,000 people).

All compared municipalities have approximately half of total collisions occurring at intersections. For injury collisions, the proportion of collisions occurring at intersection increases by approximately 10 to 15 percent points for most compared municipalities. The proportion of collisions occurring at York Region intersections is considerably higher than Markham and all other compared municipalities, as 3 out of 4 both total and injury collisions at York Region occur at intersections. This is likely due to the higher volumes – and, consequently, higher potential for conflicts – at Regional intersections.

Road User Trends

There were 7,470 motor vehicle drivers involved in collisions in Markham between 2014 and 2018, 1,828 of which were involved in injury collisions. There were 208 pedestrians and 115 cyclists involved in collisions, most of which (199 and 100, respectively) were involved in injury collisions. Additionally, 39 motorcyclists and 170 truck drivers were involved in collisions (26 and 29 of which, respectively, were involved in injury collisions). There were also 567 users that were identified as "others", or that were not identified. However, only 10 of these users were involved in injury collisions.

The main findings from the collision history review relating to road user trends were the following:

- Injury collisions involving aggressive driving show a slight reduction trend between 2014 and 2017, with a spike in 2018;
- Injury collisions involving distracted or impaired driving show no clear trend in Markham;
- Pedestrian injury collisions present an increasing trend between 2014 and 2018 (although 2018 could be a spike not representative of a long-term trend);
- Pedestrian injury collisions present higher frequencies during winter months. Further analysis, involving the cross referencing of month and time of day, suggests higher frequencies of pedestrian collisions during periods of lower natural light;
- In the majority of pedestrian collisions, the pedestrian was reported to be crossing with the right-of-way, while the driver failed to yield the right-of-way to the pedestrian;
- Cyclist injury collisions present a decreasing trend between 2015 and 2018; and
- A consistent increasing trend in cyclist injury collisions is observed between the months of April and October, with a sudden reduction through the Winter months. This is expected due to the reduced use of bicycles during Winter.

Environmental Trends

The main findings from the collision history review relating to environmental trends were the following:

- 30% of all collisions in Markham occurred during non-daylight periods (i.e. dark, dusk and dawn combined), which is slightly higher than the Provincial average of up to 28%;
- Wet surface collisions in Markham (16%) are within the Provincial range of 14% to 16%, and lower than the Regional range of 18% to 20%;
- Winter surface collisions in Markham (11%) are lower than the Provincial average range of 12% to 18%, but higher than the Regional average of 8%;

- 41% of pedestrian collisions occurred during non-daylight periods;
- 39% of wet surface collisions occurred during non-daylight periods; and
- 45% of winter surface collisions occurred during non-daylight periods.

Spatial Trends

The main findings from the collision history review relating to spatial trends were the following:

- The Top 3 intersection with the highest collision frequencies are:
  - Esna Park Drive @ Rodick Road/Alden Road (42 total and 17 injury collisions);
  - Denison Street @ Brimley Road (39 total and 18 injury collisions); and
  - Enterprise Boulevard @ Birchmount Road (35 total and 7 injury collisions);
- The Top 3 road segments with the highest collision frequencies are:
  - Enterprise Boulevard between Birchmount Road and Rivis Road (31 total and 4 injury collisions);
  - Markham Road between Edward Jeffreys Avenue & Main Street Markham (27 total and 12 injury collisions); and
  - Esna Park Drive between Woodbine Avenue & Alden Road (24 total and 15 injury collisions);
- The main collision clusters identified in Markham are:
  - Denison Street between Woodbine Avenue and Markham Road; and
  - Main Street Markham between Highway 7 and Major Mackenzie Drive;
- Collision clusters were also identified near the following points of interest:
  - Franklin Street Public School;
  - Middlefield Collegiate Institute;
  - Pierre Elliott Trudeau High School;
  - Unionville High School;
  - Markville Secondary School;
  - School Zone at John Street between John Stocks Way and Woodbine Avenue;
  - School Zone at Esna Park Drive between Woodbine Avenue and Rodick Road;
  - Mount Joy Community Centre;
  - Senior facilities in the area near the intersection of Markham Road & Bullock Drive/Parkway Avenue;
  - Places of worship in the area near the intersection of Markham Road & Bullock Drive/Parkway Avenue;
  - Places of worship in the area near the intersection of McCowan Road & Denison Street (pedestrian collisions);
  - Markham GO and Mount Joy GO Stations; and
  - YRT Routes along John Street, Denison Street and Markham Road.

Network Screening

Purpose

Identifying sites that require investigation for safety treatments is the first step taken by a transportation agency as an essential part of its road safety strategy. In the absence of any objective

approach, identifying road sites with the greatest potential for safety improvements at the network level is often impossible. This is mainly because results of safety improvements in one road group (road segments or intersections with similar physical and traffic characteristics) are not directly comparable to the others. Hence, there is a need to establish a quantitative traffic safety approach in order to identify problematic sites and rank the candidate projects.

To ensure that resources are primarily spent on the sites with the highest potential for safety improvements, it is vital that a sound procedure be in place to screen the road network. This procedure will properly identify and rank black spots for diagnosis and treatment purposes. A black spot or a site with high potential for safety improvements exhibits an expected collision frequency that is significantly higher than typical potential values for a group of similar sites.

Safety Performance Functions

The expected collision frequency is estimated with the use of Safety Performance Functions (SPFs), which are mathematical equations which relate the number and type of collisions at a site to traffic volume and road characteristics. They are developed for each facility type and different collision types, based on local historical collision data. For City of Markham, SPFs were developed for each facility type and collision severity type, including fatal and injury collisions as well as property damage only (PDO) collisions, using traffic volume and collision data between the years 2014 and 2018. SPFs were developed for the following facility types:

Intersections:

- Signalized 4-leg intersections;
- Signalized 3-leg intersections;
- Unsignalized 4-leg intersections; and
- Unsignalized 4-leg intersections.

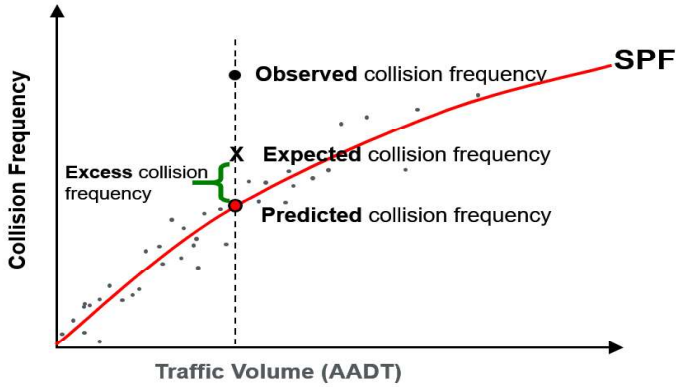
Road Segments:

- Urban 2-lane road segments;
- Urban multi-lane road segments; and
- Rural road segments.

Potential for Safety Improvement

The network screening process establishes a priority system to rank the road segments and intersections based on their Potential for Safety Improvement (PSI). In other words, this system ranks different sites according to where the safety of road users could potentially see the greatest increase. The Empirical Bayes (EB) method is used to estimate the long-term safety performance of each site. The long-term safety performance of each site is compared with its peers (i.e. other sites with similar geometric, traffic, and environment characteristics). If the safety performance of the subject site is worse than the average safety of its peers (i.e. average predicted number of collisions obtained from SPFs) then the subject site has a potential for safety improvement. This is illustrated in the figure below, where the predicted collision frequency is the average collision frequency for certain site characteristics and the expected collision frequency is the expected long-term safety performance of a specific site, calculated based on weight factors for the observed and predicted collision frequencies. The PSI is the excess collision frequency, or the difference between expected and predicted collisions.

Safety Performance Function and Potential for Safety Improvement



Site Rankings

Using the Empirical Bayes methodology, different facilities were ranked and prioritised based on their Potential for Safety Improvement (PSI). The following tables summarize the Top 10 intersections and road segments, ranked based on their The PSI value. In these tables, the PSI Value is expressed in Equivalent Property Damage Only (EPDO) collisions, which applies higher weights to injury collisions based on their societal costs.

Network Screening Top 10 Intersections

Rank	Intersection	PSI Value
1	Brimley Rd @ Denison St	34.68
2	Alden Rd / Esna Park Dr @ Rodick Rd / Esna Park Dr	23.58
3	Denison St @ Featherstone Ave	19.80
4	Denison St @ Middlefield Rd	19.26
5	Castlemore Ave @ Hwy 48	18.97
6	Denison St @ Hood Rd	18.43
7	Denison St @ Hillcroft Dr	14.58
8	Birchmount Rd @ Enterprise Blvd	11.98
9	Brimley Rd @ Wilclay Ave/Winston Rd	10.52
10	Apple Creek Blvd/Town Centre Blvd @ Hollingham Rd	10.33

Network Screening Top 10 Road Segments

Rank	Road Segment	PSI Value
1	Markham Rd btwn Main St Markham North & Edward Jeffreys Ave	23.33
2	Esna Park Dr btwn John St & Alden Rd	21.19
3	Enterprise Blvd btwn Birchmount Rd & Rivis Rd	13.29
4	Doncaster Ave btwn Meadowview Ave & Henderson Ave	10.99
5	John St btwn Nolan Crt & Woodbine Ave	9.94
6	Bullock Dr btwn Laidlaw Blvd & McCowan Rd	8.43
7	Rodick Rd btwn Riviera Dr & Esna Park Dr	6.16
8	Markham Rd btwn Castlemore Ave & Major Mackenzie Dr E	5.99
9	Bullock Dr btwn Jug Lane & Laidlaw Blvd	4.62
10	Denison St btwn Victoria Park Ave & Don Park Rd	4.24

Systemic Safety Review

Purpose

To address the limitation of the network screening process, which relies on the occurrence of collisions to identify sites requiring safety intervention, a complementary systemic review of the City's road network was also conducted. This review entails the prioritization of City's facilities (i.e., intersections and road segments) based on environmental collision risk factors (roadway features having strong correlation with specific collision types). This approach is proactive in nature, as it identifies sites with higher risk of collisions even before they occur. It supplements traditional site analysis and helps agencies broaden their traffic safety efforts by considering collision risk factors along with collision history when identifying where to make low-cost safety improvements for City-wide implementation.

Identification and Evaluation of Risk Factors

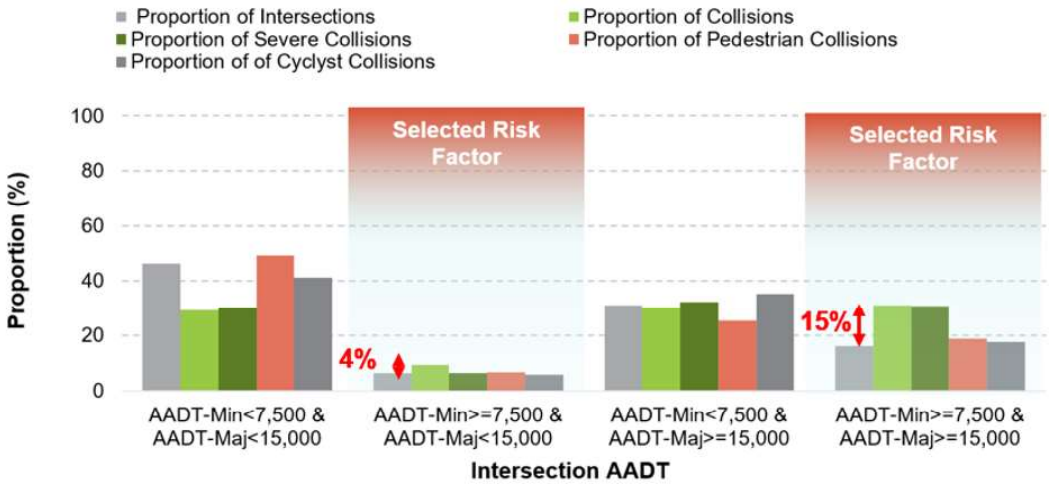
Identifying risk factors requires detailed information from infrastructure datasets. Determining Initial characteristics that should be considered for the analysis depends on several factors including their potential contribution to focus collision types as well the ability to quickly gather them for all study facilities. AASHTO Highway Safety Manual (HSM) and the FHWA Collision Modification Factor (CMF) Clearinghouse are two reliable sources for information on the relationship between risk factors and collision types. The potential risk factors listed in the table below were determined and further gathered after reviewing these two references.

Potential Risk Factors for Intersections	Potential Risk Factors for Road Segments
• Intersection Type (i.e. Cross vs. T) • Traffic Control (i.e., Traffic Signal vs. Stop Sign) • Area Type (Urban or Rural) • All-way vs. Two-way Stop Control • # of driveways within 50 m of the intersection	• Geo ID (A unique road segment ID in TES) • Description of the road segment (i.e., street name) • Owner • Number of Lanes • Length of Segment

Potential Risk Factors for Intersections	Potential Risk Factors for Road Segments
• Presence of sidewalks on one or two of the intersecting roadways • # of bus stops within 50 m of the intersection • Presence of horizontal curves within 200 m of the intersection • Presence of vertical curves within 200 metres of the intersection • Presence of at-grade railway crossings within 200 m of the intersection • Distance to other intersections within 200 m • Presence of commercial land use • Intersection skew • Divided road on one or two of the roadways • Presence of left-turn and/or right-turn lanes on one or two of the intersecting roadways • Presence of street lighting • Number of lanes on the major road	• Area Type • Speed Limit • Presence of sidewalks on one or both sides of the roadway • Presence of bus stops • Presence of two-way left-turn lane • Presence of horizontal curve • Presence of vertical curve • Presence of at-grade railway crossing • Presence of shoulder on one or both sides of the roadway • Presence of median • Presence of bicycle lanes • Presence of street lighting

After potential risk factors were identified, they were assessed to determine if the characteristics exhibit a relationship to future collision potential. Only those that positively demonstrate a relationship were selected as risk factors. The following figure exemplifies the evaluation of traffic volumes (AADT) at signalized intersections.

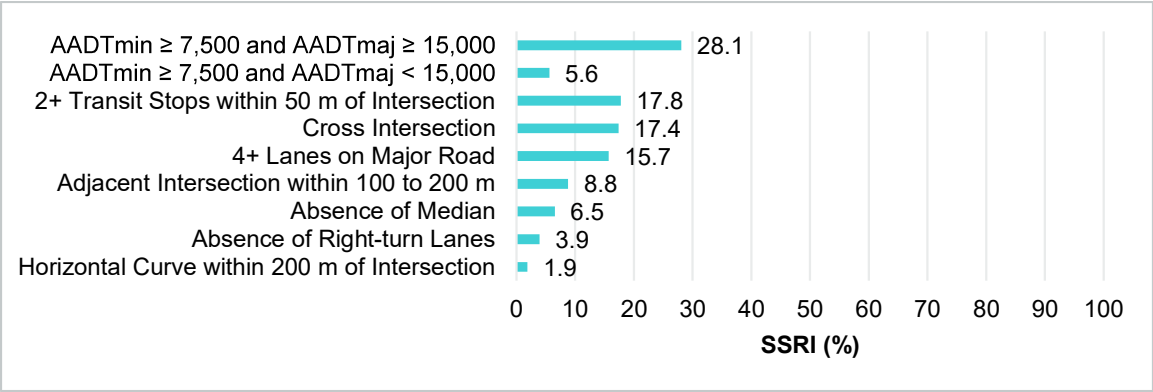
Example of Risk Factor Evaluation – AADT



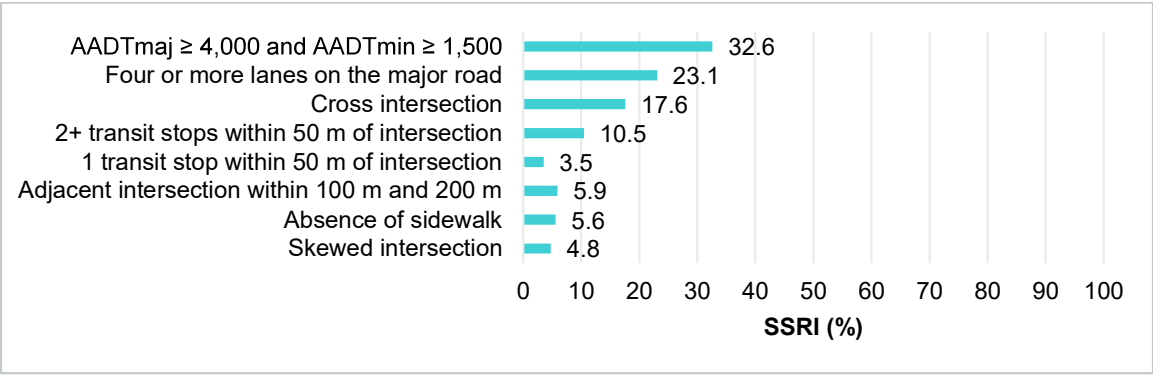
The figure shows that intersections with minor road AADT of 7,500 vehicles or more and major road AADT of less then 15,000 vehicles present 4 percent points more collisions than intersections with these volume levels. This difference is of 15 percent points at intersections with minor road AADT of 7,500 vehicles and major road AADT of 15,000 vehicles or more. This allows assigning magnitudes to different risk factors, including different levels of a specific risk factor. The following graphs show the selected risk

factors and their magnitudes, normalized so that a site presenting all risk factors at their highest level would have a total Systemic Safety Risk Index (SSRI) of 100.

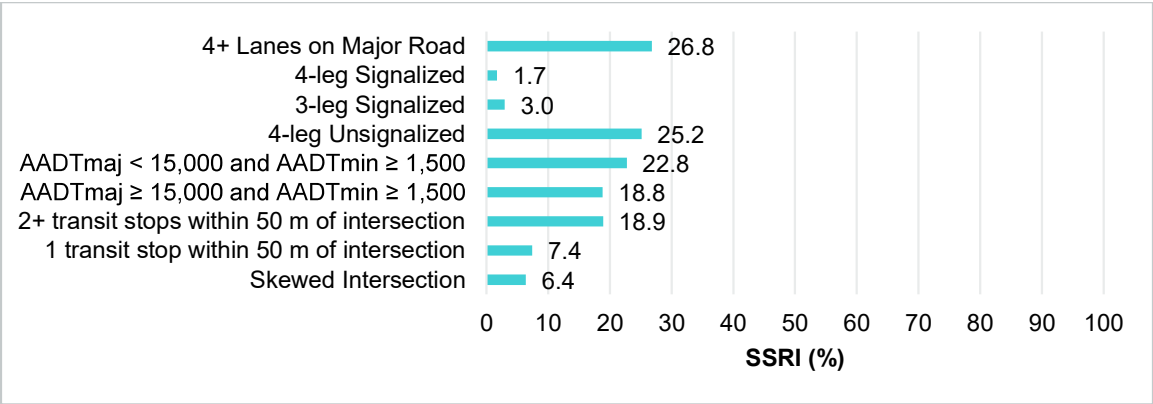
Selected Risk Factors for Signalized Intersections – All Road Users



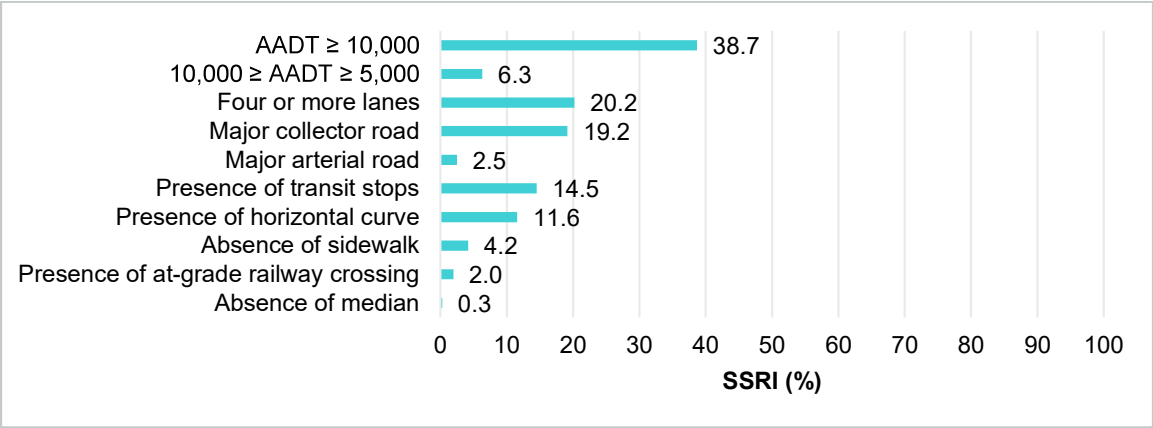
Selected Risk Factors for Unsignalized Intersections – All Road Users



Selected Risk Factors for All Intersections – Pedestrians and Cyclists



Selected Risk Factors for Road Segments – All Road Users



Systemic Safety Screening

The systemic safety risk assessment consists of adding up the scores of all risk factors present at each intersection under review and comparing the scores of all intersections so they can be ranked from highest to lowest risk. As an example, the signalized intersection of Alden Road & 14th Avenue / Hood Road presents the following characteristics and risk factor scores:

- Major road AADT of 21,700 vehicles and minor road AADT of 8,429 vehicles (Score: 28.1);
- 2 transit stops within 50 metres (Score: 17.8);
- Cross intersection (Score: 17.4);
- 4 lanes on the major road (Score: 15.7);
- No adjacent intersections within 100 to 200 metres (Score: 0.0);
- No medians (Score: 6.5);
- No dedicated right-turn lane (Score: 3.9); and
- Horizontal curve present within 200 metres (Score: 1.9).

By adding up all risk factor scores, the total Systemic Safety Risk Index of this intersection is 91.2, which is the 8th highest score among signalized intersections.

The following tables summarize the top ranked sites from the Systemic Safety Review. The tables include the ranking obtained by each site in the network screening, which shows that many sites that rank high for the presence of risk factors ranked very low in the network screening. This highlights the complementary nature of the two methodologies.

Top Ranked Sites – Systemic Safety Review of Signalized Intersections (All Road Users)

Rank	Intersection	SSRI	Network Screening Rank
1	Hollingham Rd/John Button Blvd @ Rodick Rd	100	340
1	Apple Creek Blvd @ Rodick Rd	100	61
1	Castlemore Ave @ Hwy 48	100	6

Rank	Intersection	SSRI	Network Screening Rank
4	Denison St @ Hood Rd	98.1	7
4	Brimley Rd @ Denison St	98.1	1
6	Bullock Dr/Parkway Ave @ Main St Markham North	94.2	19
7	Bur Oak Ave @ Hwy 48	91.6	30
8	14th Ave/Hood Rd @ Alden Rd	91.2	340
8	Birchmount Rd @ Denison St	91.2	13
10	Alden Rd / Esna Park Dr @ Rodick Rd / Esna Park Dr	80.7	2

Top Ranked Sites – Systemic Safety Review of Unsignalized Intersections (All Road Users)

Rank	Intersection	SSRI	Network Screening Rank
1	Macrill Rd/Rachel Cres @ Rodick Rd	83.7	340
1	Birchmount Rd @ Citizen Crt/Royal Crest Crt	83.7	70
1	Bur Oak Ave @ The Bridle Walk	83.7	64
1	Carlton Rd @ Central Park Dr/Halterwood Cir	83.7	43
1	Bur Oak Ave @ Country Ridge Rd/Fred McLaren Blvd	83.7	340
1	Bur Oak Ave @ Williamson Rd	83.7	40
1	Bur Oak Ave @ Cornell Park Ave	83.7	73
8	Bur Oak Ave @ Church St	82.7	145
9	Carlton Rd @ Loring Cres/Waterbridge Lane	79.2	189
10	Forester Cres/Rachel Cres @ Rodick Rd	76.8	340
10	Alfred Paterson Dr @ Bur Oak Ave	76.8	53

Top Ranked Sites – Systemic Safety Review of All Intersections (Pedestrians and Cyclists)

Rank	Intersection	SSRI	Network Screening Rank
1	Glen Cameron Rd/Proctor Ave @ Henderson Ave	100	340
1	Calvert Rd @ Rodick Rd	100	340
3	Clegg Rd @ South Town Centre Blvd	93.6	58

Rank	Intersection	SSRI	Network Screening Rank
3	Birchmount Rd @ Enterprise Blvd	93.6	9
3	Main St Unionville @ Unionville Gate	93.6	83
3	Bur Oak Ave @ Stonebridge Dr	93.6	126
3	Bur Oak Ave @ Roy Rainey Ave	93.6	47
3	Denison St @ Hillcroft Dr	93.6	8
3	Bur Oak Ave @ Mingay Ave	93.6	79
3	Coppard Ave @ Denison St	93.6	26
3	Denison St @ Featherstone Ave	93.6	4
3	Denison St @ Middlefield Rd	93.6	5
3	9th Line @ Rouge Bank Dr	93.6	340
3	Birchmount Rd @ Rougeside Prom	93.6	340

Top Ranked Sites – Systemic Safety Review of Road Segments (All Road Users)

Rank	Road Segment	SSRI	Network Screening Rank
1	Alden Rd btwn McPherson St & 14th Ave	93.9	525
1	Apple Creek Blvd btwn Corby Rd & Glencove Dr	93.9	94
1	Birchmount Rd btwn Risebrough Circt & 14th Ave	93.9	47
1	Birchmount Rd btwn Enterprise Blvd & Rougeside Prom	93.9	525
1	Brimley Rd btwn Steeles Ave E & Winston Rd	93.9	45
1	Bullock Dr btwn Austin Dr & McCowan Rd	93.9	525
1	Bullock Dr btwn Laidlaw Blvd & McCowan Rd	93.9	6
1	Denison St btwn Warden Ave & Kennedy Rd	93.9	160
1	Denison St btwn Mallory Ave & Townley Ave	93.9	525
1	Denison St btwn Woodbine Ave & Don Park Rd	93.9	69
1	Denison St btwn Red Sea Way & Middlefield Rd	93.9	188
1	Denison St btwn Fonda Rd & Coleluke Lane	93.9	525
1	Esna Park Dr btwn John St & Denison St	93.9	2
1	John St btwn Bayview Fairways Dr & John Stocks Way	93.9	15
1	Middlefield Rd btwn Steeles Ave E & Denison St	93.9	17

Rank	Road Segment	SSRI	Network Screening Rank
1	Enterprise Blvd btwn Rivis Rd & Main St Unionville	93.9	167

Selection of Countermeasures

A literature review was conducted to determine potential countermeasures which are applicable to the top-priority sites from the systemic safety review. The main sources of countermeasures reviewed include:

- NCHRP Report 500 – Volume 4: A Guide for Addressing Head-on Collisions (2003);
- NCHRP Report 500 – Volume 6: A Guide for Addressing Run-off-road Collisions (2003);
- NCHRP Report 500 – Volume 5: A Guide for Addressing Unsignalized Intersection Collisions (2003);
- NCHRP Report 500 – Volume 12: A Guide for Addressing Signalized Intersection Collisions (2004);
- NCHRP Report 500 – Volume 18: A Guide for Addressing Collisions Involving Bicycles (2008);
- NCHRP Research Report 893 – Systemic Pedestrian Safety Analysis (2018);
- FHWA Safety Evaluation of Advance Street Name Signs (2009);
- FHWA Safety Evaluation of Flashing Beacons at Stop-Controlled Intersections (2008); and
- FHWA CMF Clearinghouse.

The selection of countermeasures typically focuses on low-cost, highly effective treatments to be considered for implementation at candidate sites. The first step in this process was to assemble a comprehensive list of countermeasures associated with the selected collision and facility types. The countermeasures were then screened for their effectiveness (for example, by reviewing collision modification factors, when available), applicability (for example, consistency with the jurisdiction's policies and practices) and feasibility (for example, realigning an approach to an intersection due to a horizontal curve and limited sight distance to the intersecting road is very costly and is only practical under very specific circumstances). It was also important to ensure that the selected countermeasures were appropriate to eliminate or mitigate the systemic risk factors to ensure consistency throughout the systemic process.

After the countermeasures were screened and a short list was defined, a desktop review of the top ranked sites was conducted to identify which countermeasures may already be present, which ones may still be reasonably implemented, and which ones cannot be considered due to site limitations. For example, additional lanes or medians were not included as a potential countermeasure at intersections with limited right-of-way. It is important to note that these countermeasures are still preliminary, and their adequacy and applicability should be further evaluated (e.g. operational analysis of fully protected left-turn phase should be conducted to ensure it does not create unreasonable adverse operational effects; available right-of-way for installing medians and/or right-turn lanes should be assessed in more detail; etc.). Furthermore, closer investigation may result in the identification of additional countermeasures. The following tables identify potential systemic countermeasures that can be considered for each of the top ranked sites.

Potential Systemic Countermeasures – Signalized Intersections (All Road Users)

Systemic Countermeasures for All Road Users at Signalized Intersections	Fully Protected Left-turn Phase	Right-turn On Red Prohibition	Dedicated Right-turn Lanes on Major Road	Intersection Approach Median	Signal Visibility Improvements	Smart Channel (with PXO)	Clear Sight Triangles	Advance Street Name Signs	Enhanced Advance Street Name Signs	High Visibility Crosswalk	Leading Pedestrian Interval (LPI) [2]	Longer Pedestrian Phase	Coloured Pavement at Conflict Areas	Bike Box	Bicycle Signal / Leading Bicycle Interval (LBI)
Hollingham Rd/John Button Blvd @ Rodick Rd	X	X	X	X	X			X			X	X		X	
Apple Creek Blvd @ Rodick Rd	X	X	X	X	X		X	X				X		X	
Castlemore Ave @ Hwy 48	X	X	X		X			X			X	X		X	X
Denison St @ Hood Rd	X	X	X	X	X		X	X			X	X		X	
Brimley Rd @ Denison St	X	X			X						X	X		X	
Bullock Dr/Parkway Ave @ Main St Markham N	X	X			X			X		X	X	X		X	
Bur Oak Ave @ Hwy 48	X	X			X			X				X		X	
14th Ave/Hood Rd @ Alden Rd	X	X	X	X	X			X			X	X		X	
Birchmount Rd @ Denison St	X	X	X	X	X			X						X	
Alden Rd @ Rodick Rd / Esna Park Dr	X	X				X		X				X	X	X	X

[2] If fully protected left-turn phase is not implemented.

Potential Systemic Countermeasures – Unsignalized Intersections (All Road Users)

Systemic Countermeasures for All Road Users at Unsignalized Intersections	Systemic Signing and Marking Improvements	Enhance approach signage/markings	All-way Stop	Single-lane Roundabout	Left-turn lane on major road	Turn restrictions	Clear sight triangles	Provide Intersection Illumination	Restrict Parking on Intersection Approaches	Create gaps using adjacent signals	Flashing beacons on Stop sign or overhead	High Visibility Crosswalk	Crosswalk One Minor ApproachES
Macrill Rd/Rachel Cres @ Rodick Rd	X												
Birchmount Rd @ Citizen Crt/Royal Crest Crt		X								X			
Bur Oak Ave @ The Bridle Walk	X											X	
Carlton Rd @ Central Park Dr/Halterwood Cir	X												
Bur Oak Ave @ Country Ridge Rd/Fred McLaren Blvd	X							X				X	
Bur Oak Ave @ Williamson Rd	X												
Bur Oak Ave @ Cornell Park Ave													
Bur Oak Ave @ Church St	X											X	
Carlton Rd @ Loring Cres/Waterbridge Lane	X												X
Forester Cres/Rachel Cres @ Rodick Rd	X	X								X			X

Potential Systemic Countermeasures – All Intersections (Pedestrians and Cyclists)

Systemic Countermeasures for Pedestrians and Cyclists at All Intersections	High Visibility Crosswalk	Crosswalk on One Minor Approach	Leading Pedestrian Interval	Longer Pedestrian Phase	Crossride	Coloured Pavement at Conflict Areas	Bike Box	Bicycle Signal / Leading Bicycle Interval	Systemic Signing/Marking Improvements	Right-turn On Red Prohibition	Signal Visibility Improvements	Fully Protected Left-turn Phase	All-way Stop	Intersection Illumination
Glen Cameron Rd/Proctor Ave @ Henderson Ave			X	X						X	X			
Calvert Rd @ Rodick Rd			X	X			X			X	X			
Clegg Rd @ South Town Centre Blvd			X	X		X		X		X				
Birchmount Rd @ Enterprise Blvd				X		X	X	X		X	X	X		
Main St Unionville @ Unionville Gate			X	X			X	X		X	X	X		
Bur Oak Ave @ Stonebridge Dr			X	X			X			X	X			
Bur Oak Ave @ Roy Rainey Ave			X	X			X			X	X			
Denison St @ Hillcroft Dr			X	X			X			X	X			
Bur Oak Ave @ Mingay Ave			X	X			X			X	X			
Coppard Ave @ Denison St			X	X			X			X	X			
Denison St @ Featherstone Ave			X	X			X			X	X			
Denison St @ Middlefield Rd			X	X			X			X	X			
9th Line @ Rouge Bank Dr				X		X	X	X		X		X		

Systemic Countermeasures for Pedestrians and Cyclists at All Intersections	High Visibility Crosswalk	Crosswalk on One Minor Approach	Leading Pedestrian Interval	Longer Pedestrian Phase	Crossride	Coloured Pavement at Conflict Areas	Bike Box	Bicycle Signal / Leading Bicycle Interval	Systemic Signing/Marking Improvements	Right-turn On Red Prohibition	Signal Visibility Improvements	Fully Protected Left-turn Phase	All-way Stop	Intersection Illumination
Birchmount Rd @ Rougeside Prom			X	X				X		X	X			

Potential Systemic Countermeasures – Road Segments (All Road Users)

Systemic Countermeasures for All Road Users at Road Segments	Buffer Median	Traffic Calming [3]	Peripheral Transverse Bars	Speed Feedback Signs	Sidewalks	Illumination	MPS or PXO [4]	Shoulder Rumble Strips	Centre Line Rumble Strips
Alden Rd btwn McPherson St & 14th Ave		X		X			X		
Apple Creek Blvd btwn Corby Rd & Glencove Dr	X	X		X			X		

[3] Vertical Centre Line Treatment.
[4] At locations with pedestrian desire lines.

Systemic Countermeasures for All Road Users at Road Segments	Buffer Median	Traffic Calming [3]	Peripheral Transverse Bars	Speed Feedback Signs	Sidewalks	Illumination	MPS or PXO [4]	Shoulder Rumble Strips	Centre Line Rumble Strips
Birchmount Rd btwn Risebrough Circt & 14th Ave	X	X		X			X		
Birchmount Rd btwn Enterprise Blvd & Rougeside Prom	X	X		X	X				
Brimley Rd btwn Steeles Ave E & Winston Rd	No corrective measure from the list of potential systemic countermeasures is identified.								
Bullock Dr btwn Austin Dr & McCowan Rd	X	X		X					
Bullock Dr btwn Laidlaw Blvd & McCowan Rd	X	X		X					
Denison St btwn Warden Ave & Kennedy Rd		X		X			X		
Denison St btwn Mallory Ave & Townley Ave		X		X			X		
Denison St btwn Woodbine Ave & Don Park Rd	X	X							
Denison St btwn Red Sea Way & Middlefield Rd	No corrective measure from the list of potential systemic countermeasures is identified.								
Denison St btwn Fonda Rd & Coleluke Lane		X		X			X		
Esna Park Dr btwn John St & Denison St		X		X			X		
John St btwn Bayview Fairways Dr & John Stocks Way	X	X		X					
Middlefield Rd btwn Steeles Ave E & Denison St		X		X			X		
Enterprise Blvd btwn Rivis Rd & Main St Unionville		X		X			X		

Terms of Reference for Development of Action Plan

Following the completion of the Traffic Safety Audit, the next step to refresh Markham's road safety strategy is to develop an action plan. The retention of a qualified consultant through a Request for Proposals (RFP) process is recommended to help the City in the development of this action plan. To this effect, Terms of Reference were established outlining the requirements of the action plan, including the following main components:

- **Coalition Building Plan**, including developing a list of stakeholders and a communications and public engagement plan;
- **Data Collection and Update of Collision Analysis**, based on most recent 5-year collision data for the purpose of assessing collision patterns, trends, and over-represented collision types;
- **Environmental Scan**, including a needs assessment based on the current state of relevant road safety initiatives, strategies, and legislation at the federal, provincial, and/or municipal levels, and on information obtained from the coalition building plan;
- **Development of measurable goal and vision/mission statements,** aligned with any relevant City/Regional policies, programs and/or capital/operational/official plans;
- **Identification of Emphasis Areas,** using the results of the road safety data review and public consultation sessions. Examples of emphasis areas include pedestrians, cyclists, seniors, school zones, vulnerable users, speeding, aggressive driving, distracted driving, intersections, etc.;
- **Public Engagement,** to obtain public opinion about the perception of safety in the City, the areas requiring improvement, and their knowledge of the rules of the road and dangerous behaviours;
- **Development of Road Safety Action, Evaluation and Monitoring Plans,** aiming to improve overall traffic safety and to support the goal and vision adopted for the City's roads. The Plan will include annual safety targets toward the goal and will identify a series of countermeasures for each selected emphasis area; and
- **Development of Policy Papers** including standardized procedures and guidance relating to the following operational and safety programs:
  - Safety Management Program;
  - Road Safety Audits (RSA) and In-service Road Safety Reviews (ISRSR);
  - Safety Performance Measures;
  - Speed Management and Physical Traffic Calming;
  - Speed Limit Methodology;
  - Traffic Signal Warrant Analysis;
  - All-way Stop Warrant Analysis;
  - PXO Warrant Analysis;
  - Sight Distance;
  - Protected and Protected/Permissive Left-Turn Phasing;
  - Signal Phasing for Dual Left-Turn Phases;
  - Signal Timing;
  - Corridor Optimization Reviews; and
  - Fatal Collision Investigations.

The estimated cost to develop the City's traffic safety action plan is approximately $250,000, of which includes approximately $80,000 reserved for the development of the 14 policy papers.