

# Bicycle-Motor Vehicle Collision Locations in the City of Toronto



Prepared For: David Tomlinson, City of Toronto

Submitted By: Sarah Guarino  
Baorong Du  
Oksana Kutna

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## **Executive Summary**

Cycling is a practical and efficient mode of personal transportation with many environmental, economic, social and health benefits. However, cycling, as with any activity is not free of risk especially when sharing the road with motorized vehicles. This study addresses the Toronto Bicycle/Motor-Vehicle Collision Study's (2003) recommendation for additional geographic information through a detailed analysis of bicycle/vehicle collisions reported to the police for the years 1995-2003. Through GIS analysis areas, where accidents occur most frequently (hot spots) are defined.

The general characteristics of accidents in the study were examined and a literature review was conducted to assess potential analytical approaches. Drawing on the methodologies described in the literature review, these methods were adapted to our data and additional procedures were developed to meet our needs. Variables were tested for clustering using spatial autocorrelation, from the basis of these results, a density surface approach was selected. This density surface was used to generate the 'hot spots' where accidents were occurring most frequently and then accidents were related to this layer.

Our density analysis resulted in the identification of 93 'hot spot' areas where accidents were occurring more frequently. The density technique applied in this exercise has proven to be useful in identifying where accidents are occurring most frequently. Analysis and comparison of accident characteristics in hot spots as a group was not found to be useful as this analysis mainly found trends that were present in all accidents. Further study of the identified hot spot areas is needed to identify the local factors that are causing the higher concentration of accidents.

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## **Introduction**

Cycling is a practical and efficient mode of personal transportation with many environmental, economic, social and health benefits. However, cycling, as with any activity is not free of risk especially when sharing the road with motorized vehicles. In 1999 the City of Toronto conducted a survey to measure the state of cycling in the city and to provide a benchmark for cycling behaviour and attitudes.

This study found that cycling is a significant activity in the city with approximately sixty percent of households owning a bicycle and approximately forty eight percent of the population over 15 participating in either recreational or utilitarian cycling. Recreational cycling can be defined as cycling for the purpose of fitness or leisure while utilitarian cycling is cycling for transportation such as to school, work or for running errands. It was found that approximately eleven percent of the population rides their bicycles to work or school on a daily basis and most of these utilitarian trips occur in the city core (City of Toronto Bike Plan). After commuting distance, safety is the most frequently cited reason for not using a bicycle for utilitarian purposes.

In the City of Toronto, bicycle use is highly concentrated in the city centre, and not surprisingly, the pattern of bicycle collisions mirrors this pattern of cycling use with more collisions occurring in the city centre and on highly trafficked routes. According to the City of Toronto's Bike Plan, cyclists are only involved in two percent of all reported vehicle collisions, however they account for seven percent of injuries and five percent of fatalities. It is estimated that more than eighty percent of bicycle collisions are unreported and nearly half of cyclist injuries are not reported to the police (Strutts and Hunter, 1998).

In addition to the Bike Plan, there have been a several studies on accident collisions in the city, including a Coroner's review of cycling fatalities and most notably, the Toronto Bicycle/Motor-Vehicle Collision Study (2003). This study analyzed collisions between motor-vehicles and cyclists for the years 1997-1998. One of the 'next steps' proposed in this study was a further geographic analysis of collisions from a greater number of years in order to "pin-point specific sites where unusually high numbers of collisions tend to occur".

Our study will address the recommendation for additional geographic information through a detailed analysis of bicycle/vehicle collisions reported to the police for the years 1995-2003. General characteristics and trends of these collisions will first be examined in order to establish an understanding of the accident characteristics. A review of previous studies is then presented to determine the best methods and approaches to use in determining where accidents most frequently occur. Through GIS analysis areas, where accidents occur most frequently (hot spots) are defined. The defined hot spots and subsequent analysis of the characteristics of the accidents occurring in these locations provide a base from which the city can target safety improvement measures.

## Bicycle Collision Characteristics

Before analyzing the distribution of bicycle collisions, it is useful to understand the nature and characteristics of the collisions being examined. The data in this study is based on a database of 11,219 collisions that were reported to the police from 1995 to 2003. The data provided includes 18 attribute variables, as well as latitude and longitude coordinates for each record. Accident attributes include the accident date, time, age of cyclist, impact type, injuries sustained, traffic control and road surface conditions. These attributes are available in Appendix A.

On average, there were 1,247 bicycle/motor-vehicle collisions annually for the 9-year study period. **Figure 1** illustrates the locations of all the reported collisions. This map shows that accidents are highly concentrated in the downtown core and accidents occur less in the outer suburban neighbourhoods. A simple density calculation confirms this visual concentration visible in Figure 1. In the downtown core there are 6.4 collisions per km<sup>2</sup>, and when the entire city is considered, the density drops to 1.9 collisions per km<sup>2</sup>.



**Figure 1 - All Reported Collisions 1995-2003**

When the number of collisions occurring per annum is examined, the number of collisions per year is fairly consistent with a relatively small annual variation. **Table 1** lists the number of collisions per year. The highest number of collisions occurred in 1998 and the lowest number of collisions reported was in 1996.

Year	Number of Collisions
1995	1240
1996	1098
1997	1291
1998	1340
1999	1187
2000	1266
2001	1309
2002	1290
2003	1198

**Table 1 - Annual Number of Reported Collisions**

When analyzed by month, the distribution of collisions is skewed with collisions occurring more frequently during the summer months (June to September). Nearly 60% of all reported collisions occurred during the period from June to September. The fewest collisions occurred during the winter months from December to March, with a total 7.4% of collisions. The lowest number of collisions occurred in January with only 2% of reported collisions in this month. Histograms displaying the frequency of collisions by year, month, hour, age, injury type, impact type, traffic control and road surface conditions are shown in Appendix B.

The time of day in which collisions occur also exhibited a strong skewness with collisions occurring most frequently during the evening rush hour between 3 and 7 pm. A secondary increase in frequency also occurs during the 8 am hour. Collisions are most likely to occur between 8 am and 8 pm. From 9 pm to 4 am collisions occur less frequently with the fewest number of collisions occurring between midnight and five am.

The age of cyclists involved in collisions is also an important factor to note. Cyclists between the ages of 20 and 38 were most frequently involved in collisions, followed by the age groups: 12 to 18, 41 to 60, 5 to 11. The injury related statistics are quite positive with less than one percent (0.2%) of collisions resulting in fatality and a low percentage (3.5%) of injuries resulting in major injuries. More than 96% of collisions result in no, minor or minimal injuries.

Collision impact types vary greatly however an 'Angle' impact occurs most frequently, accounting for nearly a third of all collisions. A turning action seems to be one of the most common factors in the collisions under consideration with 82.7% of collisions being angle, side wipe, and turning movement. Traffic control has a different pattern related to bicycle collisions. 50.6% of collisions are happening where there is no traffic control, and 46.4% at traffic and stop signs. It is particularly interesting that no bicycle collisions occurred in school guard zones, school bus zones, and at traffic gates. Around yield sign, police control, and traffic control the collision rate is also quite low.

Road surface condition demonstrated an extreme frequency distribution. 90.2% bicycle collisions occurred on a dry road surface, 8.9% in wet road conditions. Only 0.9% occurred in other road surface conditions, such as snow, slush, etc. With the characteristics of the data set under study established a literature review was conducted in order to determine the best approach to analyzing the data.

## Literature Review

Methods and technologies in bicycle accident studies can be divided into two categories - statistical analysis and geographical exploration. Most research on human behaviour, facilities, and environment make use of such statistical methods. Julia B Edwards performed a tabular data comparison to find out the pattern of bicycle accidents related to weather factors in England and Wales. Lisa Hall et. al. performed ANOVA tests for categorical variables in facility study in Ottawa and Toronto. Yinhai Wang et al used negative binomial regression models to estimate the risk of collisions between bicycles and motor vehicles at intersections with traffic signals.

However, in most cases, the statistics are not isolated, and are instead combined with spatial analyses, particularly with GIS. The advent of GIS greatly extends the scope of application of statistical methods. Lisa Hall et al make use of route trace with ArcInfo Network analysis components in GIS to establish the cycling route and analysis while Benoit Flahaut et al apply local spatial autocorrelation and kernel methods for identifying black zones.

Studies in bicycle accidents are limited by data available and analysis techniques. Methodology in bicycle accident research is quite exploratory, and often limited to specific sample areas. Spatial statistics, such as spatial autocorrelation, kernel method, negative binomial models, disaggregate analysis and proximity analysis not directly related to geographical locations.

The primary source of data regarding bicycle accidents is from police stations and hospitals, ie. the data only includes the reported records. Thus a problem of representation arises. Unreported accidents are not included in these statistics (Lisa Hall,

Ottawa-Carleton commuter cyclist on- and off-road incident rates). The severity of bicycle accidents, however, may be overestimated. This is because records from police and hospital may be more serious than those that are unreported, when in fact fatalities comprise only a small proportion in bicycle accidents

Despite this limitation in data, research on bicycle accidents remains valuable. Such research includes the prevention of cyclist injuries and fatalities so as to improve the safety of cyclists (Yinhai Wang, Nancy L. Nihan), and the creation of a model to predict the accidents in transportation planning (K. Geurts, G. Wets). The study of the relationship between the severity of physical injuries and crash types, to study the safety issues related to cycling recreation activities (Lisa Hall); to develop safe cycling products such as helmets (Australia scholars), and to promote cycling as a viable replacement for private motor vehicles in considering the sustainability of economy and environment (Christopher A Kennedy). No matter what purpose the researchers or organizations focus on, they are all concentrating on exploring cycling accident patterns and the factors that cause them.

In such a study, researchers generally focus on factors such as human behaviour, facilities, and environmental conditions. Human behaviour relates to age, sex, skills, physical fatigue, and cycling habits contributing to safety (Australia, New Zealand). Facilities relate to the types of cycling surface and their design— intersections, sharing the road with motor vehicles, sidewalks, and isolated cycling paths (Japan intersection study, Lisa's facilities studies). Environmental conditions relate to weather, time of day, and light conditions (Toronto BMV collision study, England weather factor study).

City of Toronto conducted a number of research initiatives on cycling collisions including the bicycle fatality study “Cycling in Toronto - Coroner's Report” led by W.J. Lucas et al from 1986 to 1998, Lisa Hall’s analysis of Toronto bicycle commuter safety rates in 1999, and the BMV Collision Study conducted by the City of Toronto’s Transportation Services Division in 2003. The statistical approach is adopted in the BMV collision study and Lucas’s fatality study, while GIS in Lisa’s facility study.

In terms of limitations specific to accident studies in Toronto, Lisa’s analysis is limited by the data, which is from surveying, but does not include official police and hospital records. Another drawback in her study is that the focus on the safety of cycling facilities such as isolating paths which generally go through city parks, is somewhat incongruous with the fact that bicycle accidents happen mainly on the street network of the city. Lucas’ research is on fatalities of bicycle accidents which would inevitably have some biases in underestimation or overestimation of bicycle accidents (discounting injuries or potential threat, for example).

What was concluded as a result of this literature review is that there has not been any studies conducted that apply GIS analysis to a collision data set as large as the database used in this study. Previous studies have been limited to specific road segments or a limited amount of sample data. Therefore a different approach from previous research was selected and is outlined in the methods section.

## Methods

Drawing on the methodologies described in the literature review, our approach was to adapt these methods to our data and develop additional procedures to meet our needs. Bicycle-Motor Vehicle collisions were analyzed in terms of their spatial locations as well as their characteristics using GIS software, SPSS and Excel statistical packages.

### Data preparation

Collision data was received in two formats, a dbf table and a series of excel spreadsheets. The dbf table was a single file for accidents from 1998 to 2003 and contained the attributes listed in Appendix A. Three separate excel spreadsheets were received for accidents in 1995, 1996 and 1997 respectively. In order to create a single database for the accidents from 1995 to 2003, several data formatting and compatibility issues had to be resolved. The major difference between the 1995-1997 data and the 1998-2003 data was the format for the accident dates. In order to overcome the date differences, excel was used to convert the single date columns into three separate columns one for the day of the week, one for the month and one for the year. Figure 2 illustrates the changes that were made to the date formats

1995-1997 Date	1998-2003 Date	Combined date format		
		DAY	MONTH	YEAR
950323	1/7/1998	1	03	1995
		23	07	1998

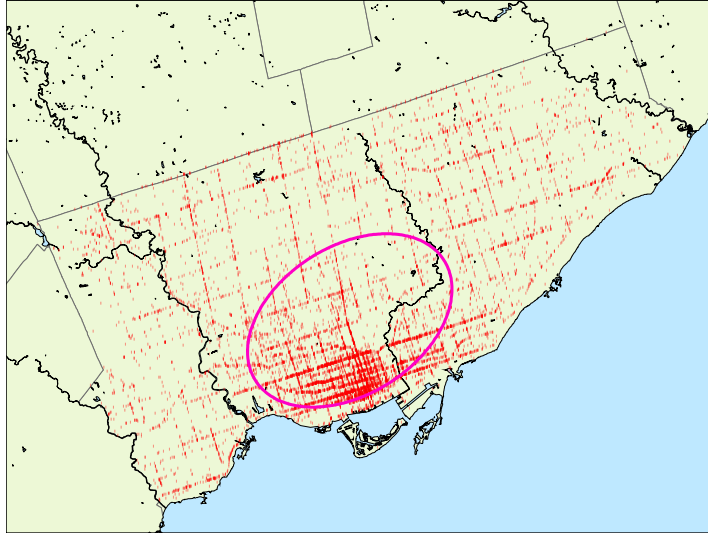
Figure 2-Date Format Conversion

With formatting issues resolved, the three excel files were converted to dbf format and were combined with the existing 1998-2003 into a single database. This database of 11,219 accidents was then imported into ArcMap and the latitude and longitude coordinates were used to create a point for each of the accidents in the database. A total of 11178 accidents were located, 40 accidents were not included in the analysis because they did not have latitude and longitude coordinates and 1 accident was removed from the analysis because the coordinates placed the accident outside of the city of Toronto.

Before analysis could begin, the data was converted into a shapefile, then variables were tested for clustering using spatial autocorrelation in order to determine our analysis approach.

### Spatial Patterns of Bicycle Accidents

An understanding of the geographical orientation and dispersion of bicycle accidents was achieved by calculating a standard deviational ellipse representing the distribution and directional bias of the accident locations across the city. The standard deviational ellipse was preferred over the standard distance circle technique as accident locations depend on a shape of a road and will not always form a circular shape (Lee and Wong, 2001). It can be seen that accidents distribution is “stretched” in west-east direction and have so-called “directional bias” that corresponds with the City of Toronto’s Bike Plan (Figure 3).



**Figure 3-**Standard Deviational Ellipse

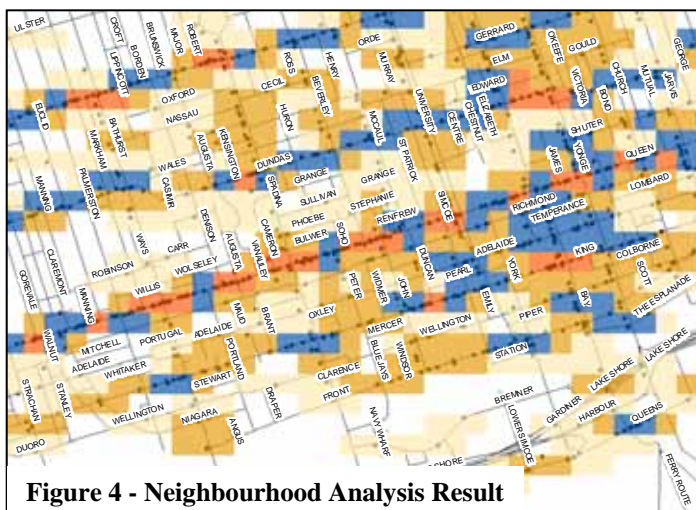
It was also important to test to see if the accident characteristics had a clustered or random distribution in order to establish the type of analysis approach. Spatial autocorrelation is used in statistical analysis and the theoretical basis of it is that similar values of a variable tend to cluster spatially and dissimilar values tend to disperse. The Moran (1948) coefficient (MC) is a measure of spatial autocorrelation that could be global or local. Moran's coefficient ranges from -1 to +1. If a coefficient is close to +1 it indicates that similar numeric values tend to cluster (positive spatial autocorrelation); if a coefficient moves toward -1 it shows that dissimilar values tend to group together (negative spatial autocorrelation), and in the case of a coefficient close to  $-(1/N-1)$  the numeric values are located haphazardly. There is no distinction between high or low values clustering.

Spatial autocorrelation analysis included injury, impact type, road surface condition, and traffic control. Variable attributes were coded into dummy variables in order to allow for this analysis. For road surface conditions only the two most common attributes, wet and dry were considered.

Our analysis indicated that the attributes did not exhibit spatial clustering. The only attribute that did experience some clustering was traffic control type. As a result of this absence of attribute clustering, it was determined that our analysis would examine all accidents to determine areas where accidents were occurring more frequently, rather than examining for clusters or concentrated areas based on different accident characteristics (Appendix C).

### Density Calculation

In order to determine where in the city accidents were occurring most frequently a point density surface of accident locations was created using the Spatial Analyst extension of ArcGIS. We chose to perform a simple point density as opposed to a kernel density. Simple density type was preferred over a kernel density as we were interested in a concentration of phenomena per a unit area and in the case of a Kernel density a smoothly curved surface is created that is fitted over each data point (ArcGIS Help).



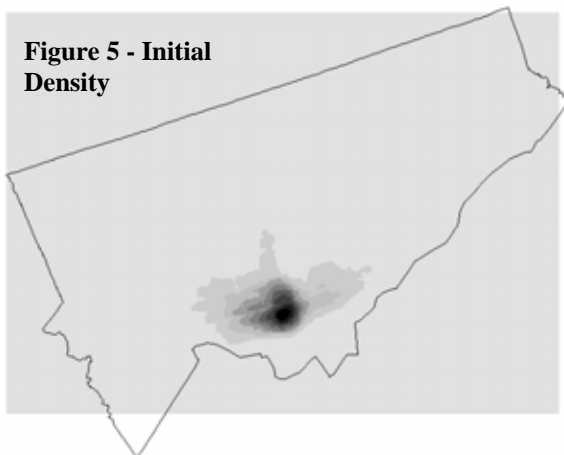
A neighbourhood surface was also considered as it lets determination of the shape of a neighbourhood and summarizes the number of ‘neighbouring’ points that fall inside of a specified area. However, neighbourhood analysis options

do not allow a specification of the angle of a neighbourhood orientation as illustrated in **Figure 4**. As together with a spatial bias presented in a data we had to take into

consideration the spatial orientation of the roads network, it was decided to apply a point density analysis instead of a neighbourhood option. When calculating the density surface several options had to be determined such as the output cell size, neighbourhood size and the search radius. With a bigger neighbourhood more points are included in the calculation but since the number of points is divided by the neighbourhood size the net result is not that different. Search radius effects the visual representation of the output as choice of a bigger neighbourhood results in a more generalized output raster (ArcGIS Help). Smaller cell size of an output raster will produce a more ‘detailed’ picture of the density. However, if too small of an output cell size is chosen the computer can ‘fail’ to produce a final output.

The following parameters were selected for the density calculations: Areal units – Square Kilometre, output cell size X,Y (10,10) (map units – meters). Search radii of 30, 40, and 50 kilometres were tested, however the 40km search radius was chosen as it produced the best visual output. The initial result of the density calculation clearly showed the concentration of accidents in the downtown core (Appendix E).

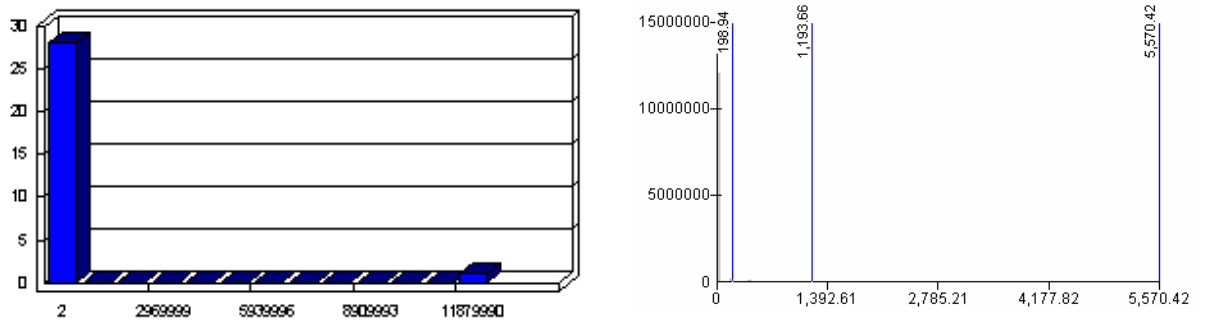
The initial density surface ranged from 0 to 557 accidents per square kilometre



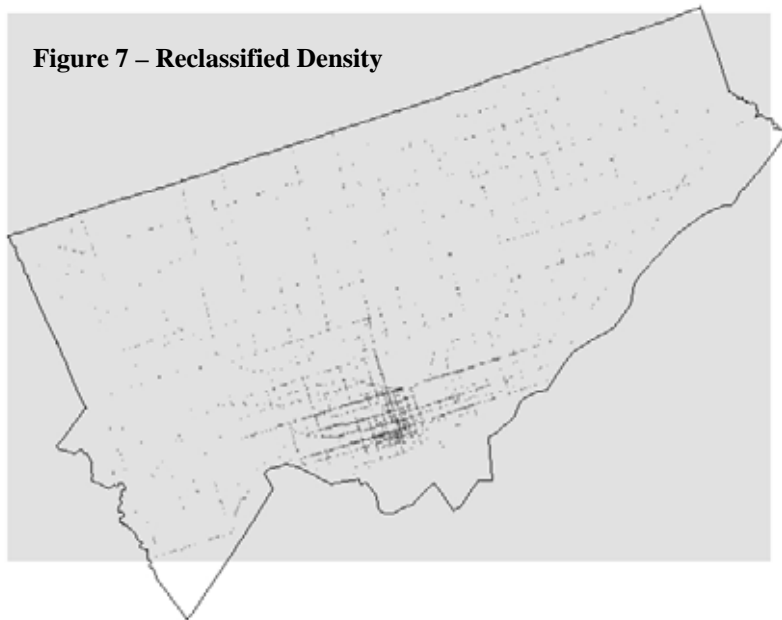
and was reclassified in order to display more localized concentrations of the accidents across the entire surface. By default the density surface was displayed with nine equal interval classes, which produces the result in **Figure 5**.

The “Natural Breaks” classification method captures trend presented in a natural distribution of the data and for this reason it was selected. Based on the histogram of the density surface, it was reclassified into three classes: 0-198.94; 198.95-1,193.66 and 1,193.67-5,570.42.

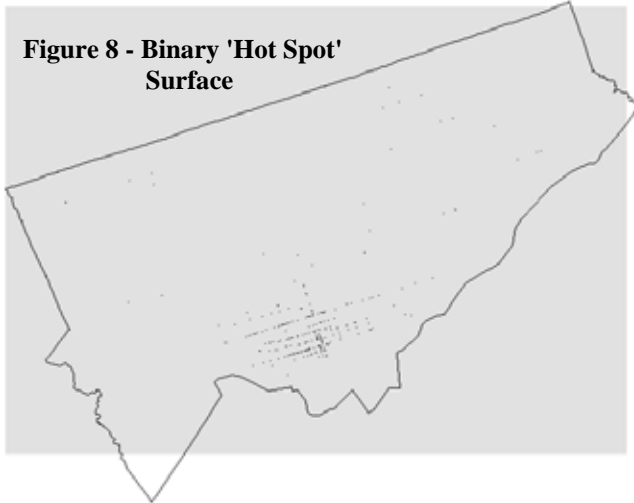
**Figure 6** shows the histogram of density values and the subsequent reclassification into three classes. The result of the density surface reclassification can be seen in **Figure 7**.



**Figure 6 - Density Histogram and Classification Values**



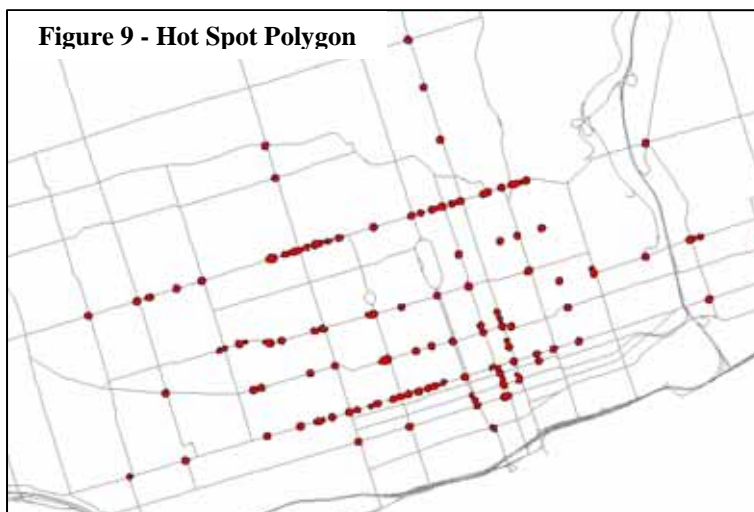
## Hot Spot Creation



Hot spots were defined as areas with the highest concentration of bicycle collisions. The highest density class from the reclassified density surface was used to designate 'hot spots'. The reclassified density surface was classified into a binary raster with

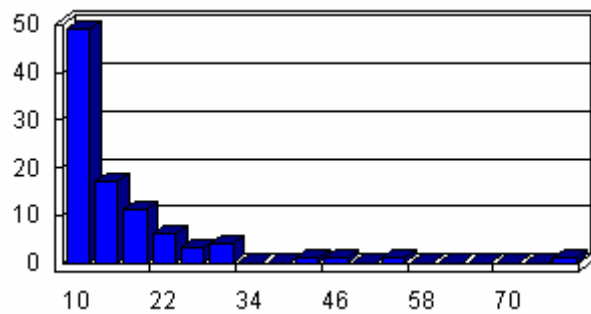
a value of '1' for the high density areas and '0' for all other areas. The resultant binary raster can be seen in **Figure 8**. The hot spots from the raster surface were then converted into a vector polygon layer for further analysis.

The resulting shapefile consisted of 337 polygons and after some cleaning of the data and removal of extraneous polygons the final result was 93 hot spots (**Figure 9**). As this layer did not contain any information regarding the accidents in these locations, some further processing was required.



In order to get information about the number of accident points within a “hot spot” area a “hot spot” shapefile was spatially joined with an initial data set of 1995-2003 collision locations. This resulted in the addition of a “count” attribute being added to the polygon layer representing number of accidents for each particular “hot spot”.

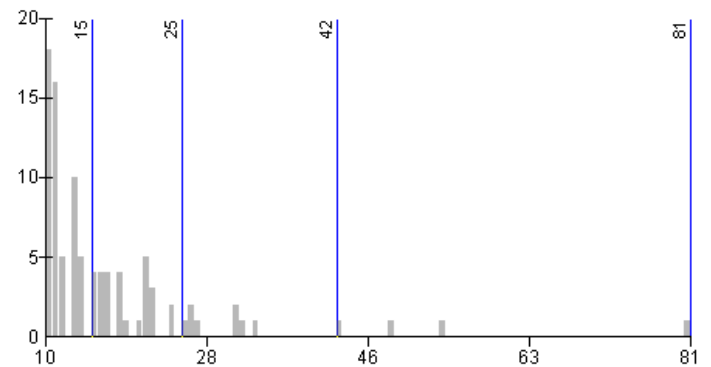
The histogram of the accident count within each hot spot revealed that the number of collisions in each hot spot varied greatly (**Figure 10**).



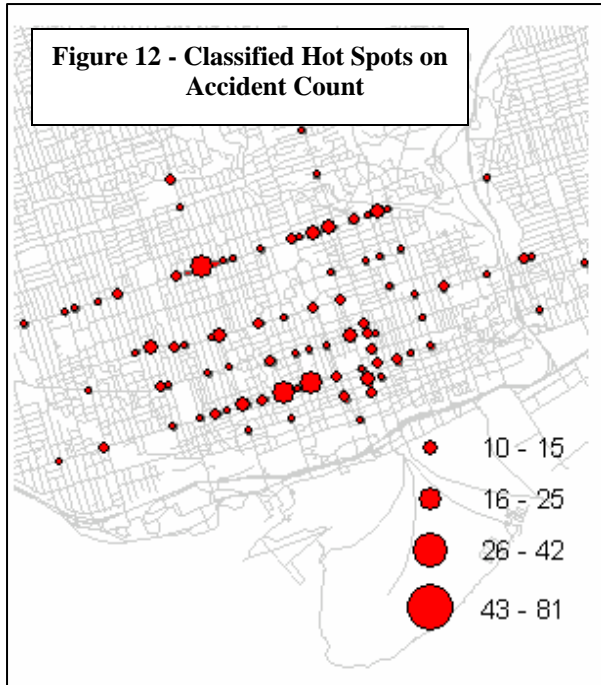
**Figure 10 - Histogram of Accident Counts within Hot Spots**

Because the number of collisions varied, the hot spots were further categorized on the basis of this count value. Four classes were distinguished from the natural distribution of the data and were depicted using “Natural Breaks” classification method (**Figure 11**).

**Figure 2 - Hot Spot Classification**



First “hot spot” class included 3 areas with 43-81 collisions happened during 1995-2003 period; second “hot spot” class covered 8 areas with 26-42 collisions occurred within later period; third class shown 25 regions with 16-25 accidents and fourth class introduces 58 areas with 10-15 bicycle accidents recorded during 1995-2003 period (Figure 12).



In order to obtain attribute information for accident points that fall within each hot spot, the initial shapefile of 1995-2003 accident locations was clipped on the basis of the hot spot in which the accident was located. Attribute characteristics of a total “hot spot” area and separate HS classes were analysed in SPSS and Excel using descriptive statistics.

## **Results and Analysis**

Our density analysis resulted in the identification of 93 ‘hot spot’ areas where accidents were occurring more frequently. For ease of analysis the ‘hot spots’ were grouped into four classes based on the number of accidents that occurred within the hot spot. First the hot spots are described as a whole. Then differences between hot spot classes are highlighted and general characteristics of all ‘hot spots’ are compared to those accidents not included in hot spots. Accidents that occurred outside of the hot spot areas have been classified as ‘cold spot’ accidents. 1,654 accidents were classified in hot spots and 9,523 in cold spots, accounting for respectively 15.1% and 84.9% of total 11,219 bicycle collisions in Toronto from 1995 to 2003. At the end of this section the hot spots with the highest numbers of collisions are described in more detail. Formal maps of accident locations as well as accident hot spots are located in Appendix E.

### Hot Spot Accidents

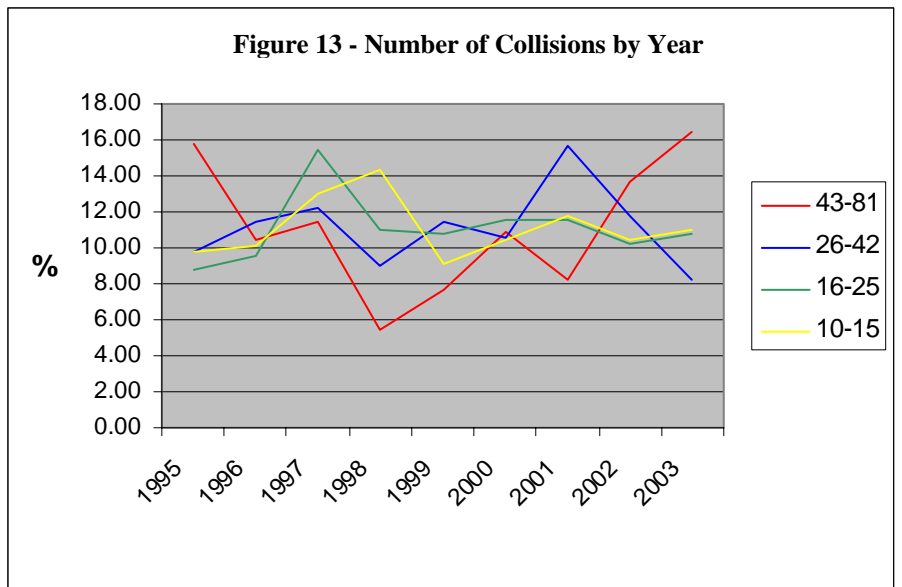
“Hot spot” areas included 1654 accidents (14.7 % of all accidents). The years 1997 and 2001 stand out with the highest number of accidents happening during those periods. As what was found with the analysis of all accidents, collisions were considerably more frequent during summer months: June, July and August. The beginning of the day (9-10 am), lunch time (2-3 pm) and the evening rush hour (5-6 pm) where the periods with the most frequent accident occurrences.

Traffic signals, “stop” signs and road segments without traffic controlling devices are the most dangerous places for cyclists (205, 647 and 676 accidents accordingly).

Cyclists between 23-33 years of age were most frequently involved in collisions. Most cyclists were not damaged or obtained minor injures (372 and 88 accidents respectively). Road conditions did not show any particular influence in collisions as road conditions were mostly dry (1168 accidents). Frequency distributions for all these variables are available in Appendix D, and when compared to the distributions presented in Appendix A one can see that the distributions are very similar.

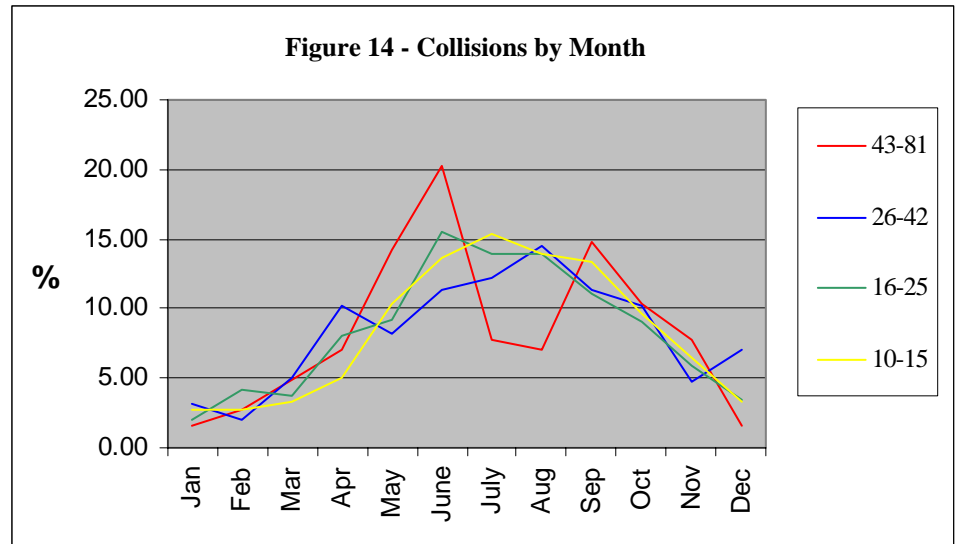
When these accident variables are compared on the basis of hot spot class variations between the classes become evident, and trends that are not seen when looking at all accidents can be visualized. The two ‘lower’ HS classes depict very similar patterns concerning their attribute characteristics and for this reason they can be discussed as a stand along group and will be characterized together (1215 accidents; 73.5% of all “HS area” accidents).

The years 1997 and 1998 were periods of the highest number of accidents during 1995-2003 and later the number of accidents significantly decreased. However, from 2001 onwards there is a large



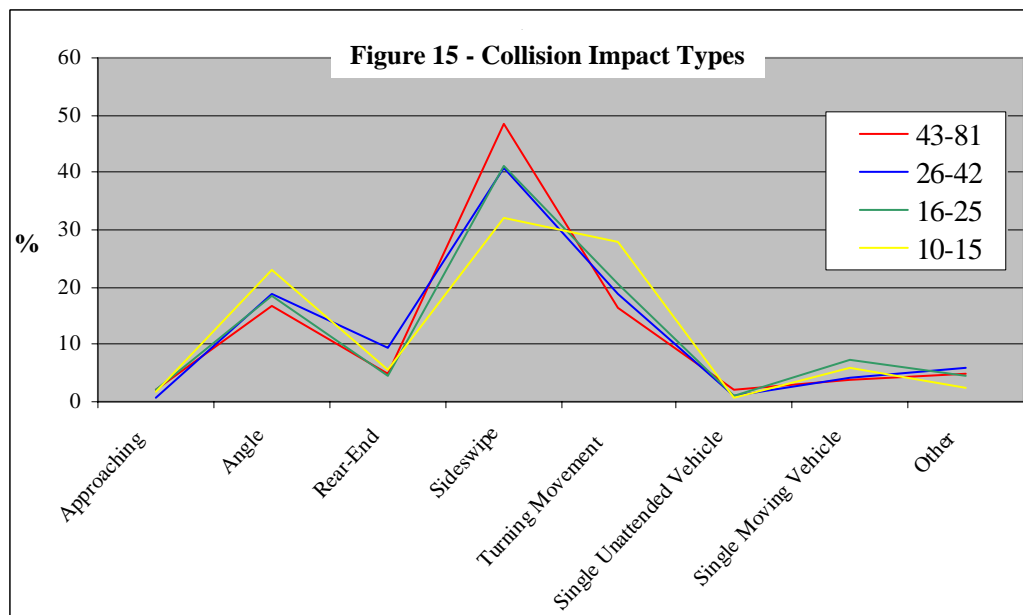
increase in accidents for the highest (43-81) hot spot class and a smaller increasing trend with the lower two classes (figure 13).

June, July, August and September are months of the most frequent bicycle collision occurrence, with the highest number of accidents in June and



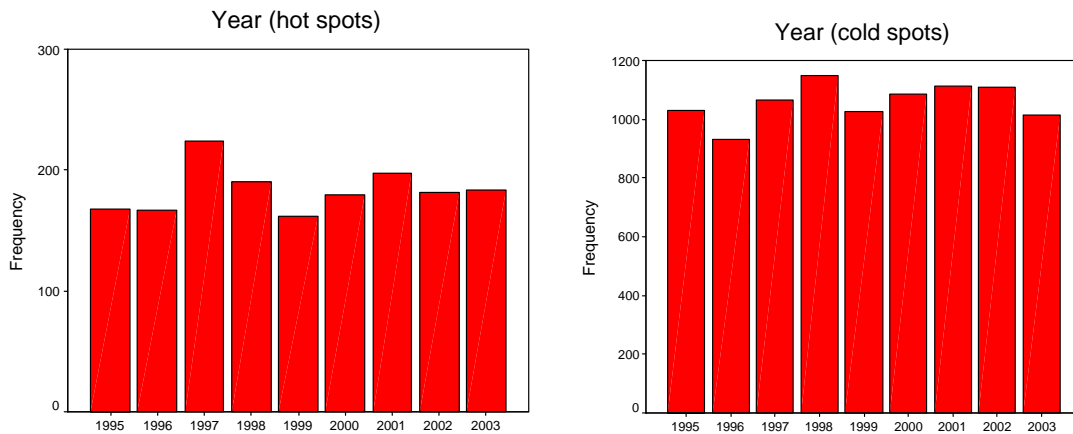
July. Here again the lowest three classes follow the same general trend. The highest class differs with a drop in accident frequency in July and August (Figure 14).

For other variables such as traffic control, age, road surface conditions and impact type there was virtually no variations in frequency between the hot spot classes. A graph comparing the frequency of various impact types is shown in **Figure 15** as an example of the similarities between the hot spot classes for this variable. All four classes follow the same general pattern.

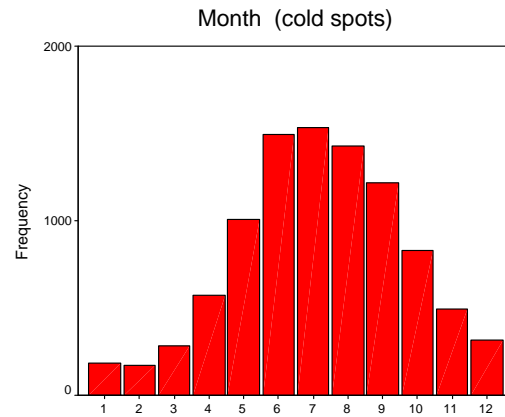
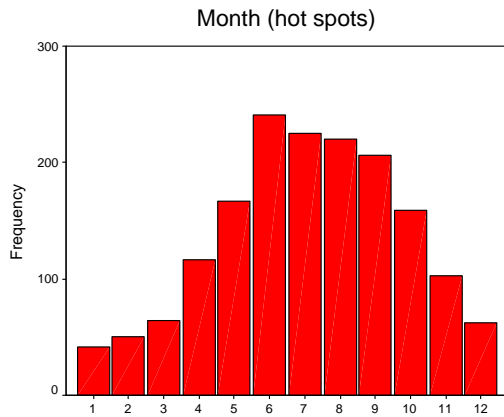


### Comparison to cool spots

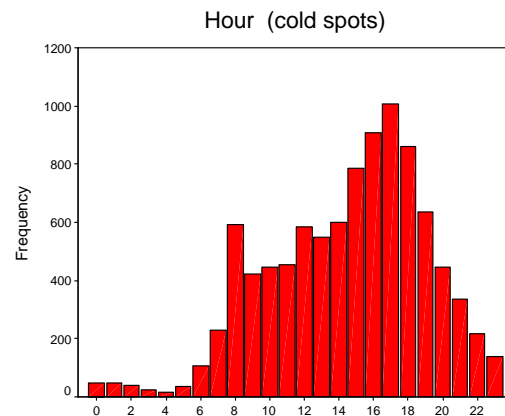
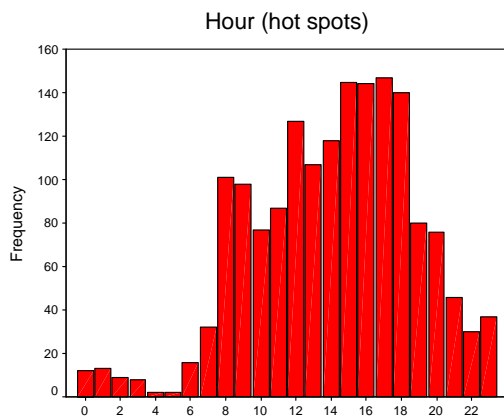
A comparison of attributes between hot spots and cold spots are given by comparing bar charts and frequency statistics. Temporal attributes, year, month, and hour are consistent between hot spots and cold spots with some minor variation. In hot spots, the greatest number of bicycle collisions occurred in 1997, followed by 2001 and 1998. The lowest number of collisions occurred in 1999. However, in cold spots, the highest bicycle collisions occurred in 1998, followed by 2001 and 2002. The lowest number of collisions occurred in 1996, however these variations are not significant enough to be considered different.



Collisions classified by month demonstrated a similar pattern between hot spots and cold spots with the exception of the peak month. In hot spots, the peak month occurred in June while in cold spots it occurred in July. However, the general trend of accidents occurring most frequently in the summer months is consistent.

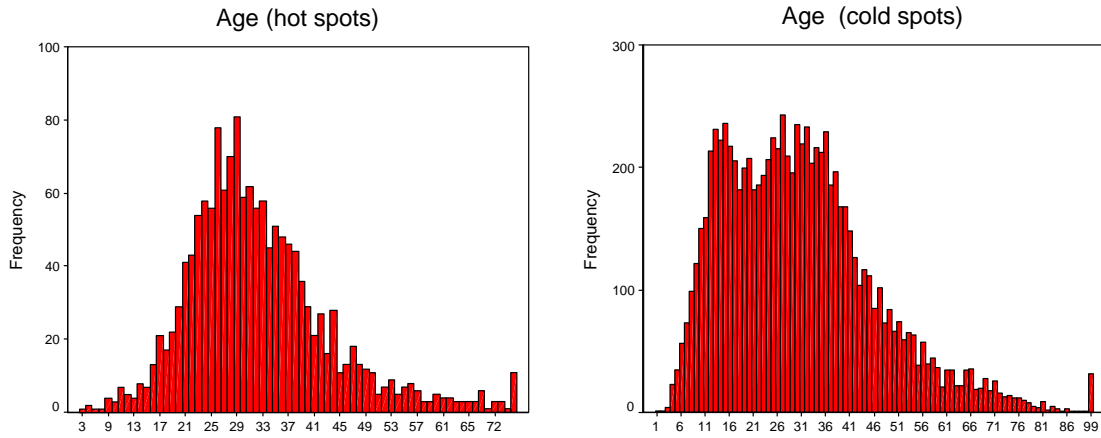


Collisions classified by hour indicate that hot spots had more notable peaks than in cold spots. In hot spots there are three ‘peaks’ in frequency, the time between 8 am and 9 am, noon (12 am), and the period between 3 pm and 6 pm. Compared to hot spots, cold spots did not show a peak at noon, but did show the similar patterns with hot spots in other two peaks. Time from 3 pm to 6 pm is the period of highest collisions occurred in a day, followed by time from 8 am to 9 am. Both hot spots and cold spots have lowest collision occurrence during the night (including dawn) from 9 pm to 6 am.

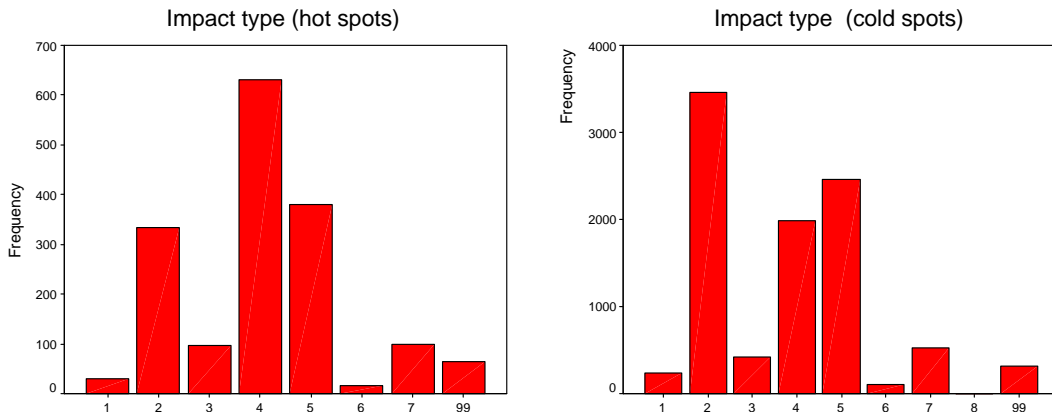


The age groups of cyclists within hot spots showed a narrower range than cool spots. The age groups within which the highest number of collisions in cold spots,

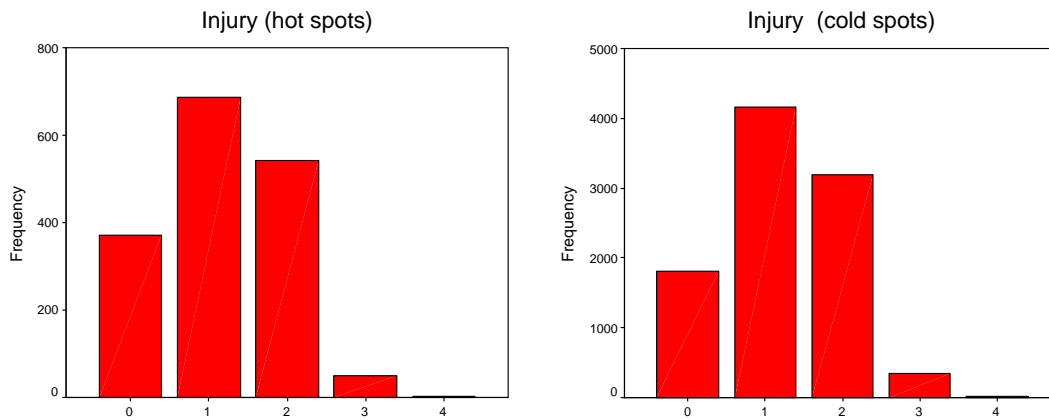
however, have a wider range from age 12 to 38, in which age group between 18 to 25 is interestingly lower than its adjacent age groups –age 12 to 18, and age 26 to 38.



Impact types between hot spots and cold spots demonstrated a different pattern among type 2 (angle), type 4 (sideswipe), and type 5 (turning movement). In hot spots, the most frequent impact type occurring is the sideswipe, followed by turning movement, and angle. In cold spots, however, the most frequent impact type is the angle, followed by turning movement and sideswipe. However, when these three impact types are put together, they account for a similar contribution to total collisions, 81.4% in hot spots and 82.9% in cold spots.



Injury and road surface condition attributes showed no difference between hot spots and cold spots with virtually identical frequency distributions. The similarities in distribution can be seen with the injury distribution as an example.

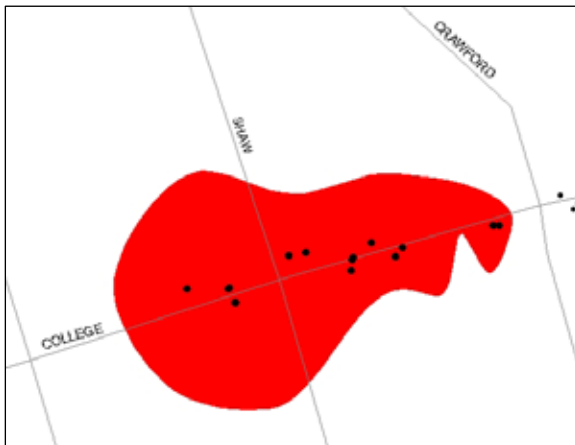


Bicycle collision attributes between hot spots and cold spots showed an overall similarity in time distributions (year, month, hour) except in some distributions. Cyclists in hot spots have a narrower range of age groups. The impact type of bicycle collisions between hot spots and cold spots demonstrated some difference among angle, sideswipe, and turning movement types. In hot spots, sideswipe is the type occurred most frequently while in cold spots, angle is the type occurring most frequently. Injury and road surface conditions do not exhibit significant differences between hot spots and cold spots. With the similarities between all accidents and those accidents inside and outside of the hot spot areas established, a more detailed description of hot spots with the highest numbers of collisions will follow.

### Detailed description of 'Hot Spots'

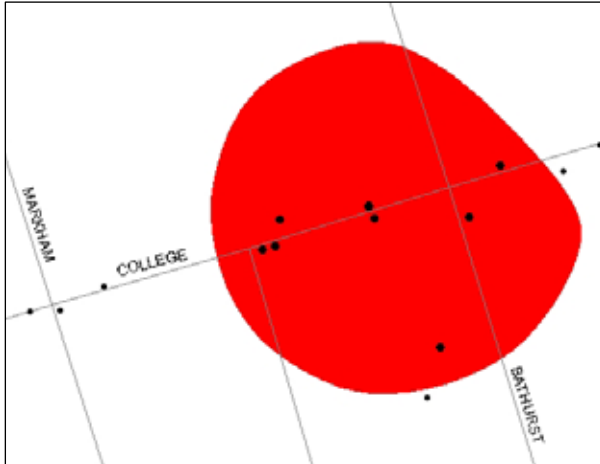
A more detailed analysis of the collision characteristics of eleven hot spots which contain the highest number of collisions is presented in this section. These hotspots are areas where twenty-six or more accidents have occurred within the study period. They are categorized by the intersection. Appendix F contains the full list of all 93 hot spots and the name of the intersection or street segment where it is located.

#### *College and Shaw*



At the intersection of College and Shaw, total of twenty-six accidents occurred from 1995-2001. These accidents occurred more frequently during the months of October (8 accidents) and June (6 accidents). These accidents occurred mainly between 4 and 5 pm however there is also a slight increase in accidents at 8am and 12pm. The median age for cyclists involved in collisions at this location is 26. Wet road conditions were present in only 11% of accidents, in all other cases the conditions were dry or unknown. Approximately 43% of these accidents involved minor injuries, 7% were major and no fatalities occurred in this area. 43% of these accidents occurred at the stop sign traffic control.

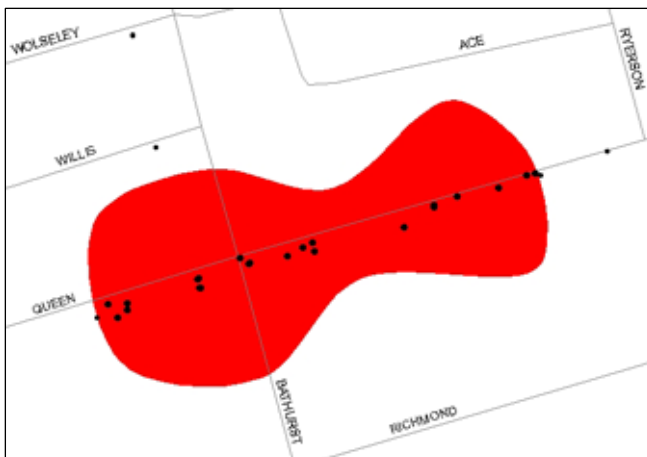
### *College and Bathurst*



At the intersection of College and Bathurst, twenty-seven accidents occurred from 1995-2003 with the most accidents occurring in 1999 (6 accidents) and 2001(6 accidents). Accidents at this location occurred throughout the day between 10 am and 6

pm. This may be because this area is used frequently by students going to classes throughout the day as opposed to cyclists on their way to work. The traffic control involved in 60% of these accidents was a traffic signal. The most common impact types was pedestrian crossover (30%), police control (26%) and stop sign (25%). The mean age of cyclists involved in collisions at this intersection is 27 and dry road conditions were present with 92% of these accidents. The types of injuries at this location were primarily minor with no fatalities. No injury was reported in 26% of accidents, minimal injury in 33% of cases and minor injury in 37% of cases. Fewer than 4% of these collisions resulted in a major cyclist injury.

### *Queen and Bathurst*



A total of 34 accidents occurred at the intersection of Queen and Bathurst between 1996 and 2003, 23% of these accidents occurred during 2002. The majority of

accidents occurred during the summer months and accidents occurred most frequently during the early evening, 20% of accidents occurred during the 5 o'clock hour. Just over 29% of the accidents in this area occurred where there was no traffic control. This may indicate that the area approaching the intersection rather than the intersection itself is where safety should be examined. It should also be noted that the accidents at this intersection occurred solely along Queen Street. The most common type of impact at this intersection was a sideswipe (52%). The mean age of cyclist involved in collisions at this intersection was 28. Approximately 50% of collisions at this intersection resulted in minimal cyclist injuries, however there was one fatal accident in this area. A dry road surface was involved in 80% of accidents in this 'hot spot'.

### *Bay and Dundas*



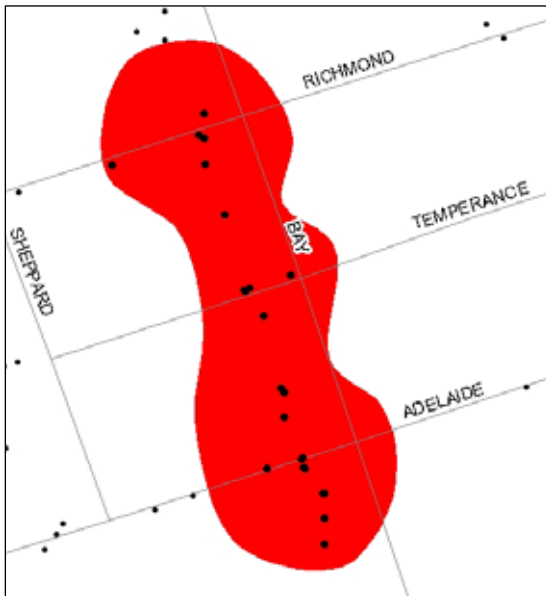
Thirty one accidents occurred within the area of Bay and Dundas between 1995 and 2003. Accidents at this intersection occurred consistently throughout the year with a slightly higher frequency throughout the month of August but no drop in accident frequency during the winter months. The morning hours of 9-11 am were when the most accidents

occurred. Traffic control measures in the zone where accidents occurred more frequently were the stop sign at Bay and Edward and locations where there was no traffic control.

The most common impact types were sideswipe (25%) and turning movement (32%), the

angle impact type was also present in 22% of accidents. The mean age of cyclists involved in collisions at this intersection is 24 which is surprising as this is much younger than in the other 'hot spots' and perhaps would be an age you would expect in an area close to a university where students are cycling. Accidents at this intersection were either minimal (61%) or minor (23%). No serious or fatal accidents occurred in this area. As with the other hot spots, the most prevalent road conditions were 'dry'.

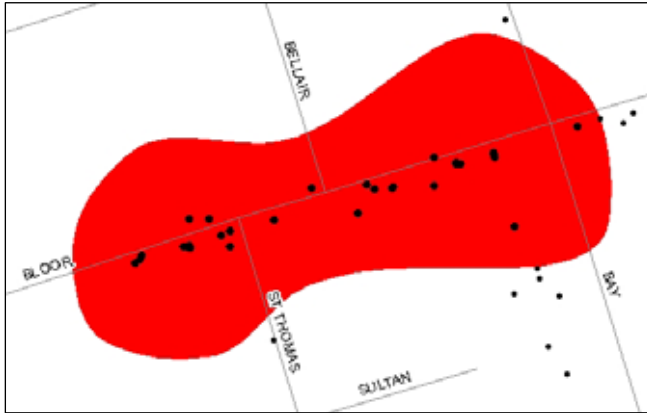
*Bay St. from Richmond to Adelaide*



Between 1995 and 2003, a total of 31 accidents occurred along Bay St. between Richmond and Adelaide. Accidents at this intersection occurred throughout the year with a higher frequency in the months of July-August and surprisingly February-April. There is a slight increase in accident frequency during the 9am hour and a significant increase in accidents between

noon and 1pm, and another small increase during the evening rush hour from 4-6pm. A traffic signal control was involved in 35% of the accidents while 45% of accidents occurred with no traffic control. The most common impact type was a sideswipe (40%), the mean age of cyclists involved in collisions was 24 and dry surface conditions were the most common. Injuries were either minimal or minor with no major or fatal accidents in this region.

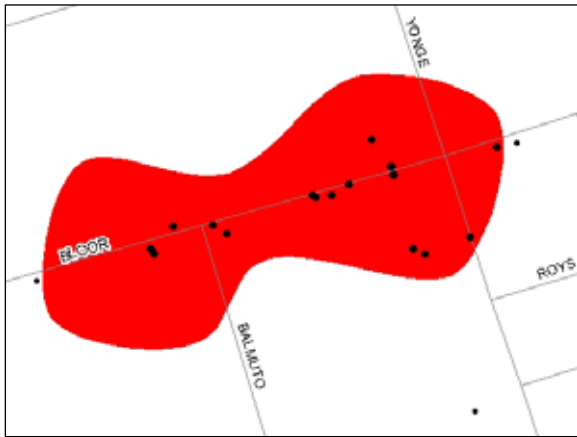
*Bloor and Bay*



Between the years of 1995 and 2003, a total of 42 accidents were recorded at this intersection. The majority of these accidents occurred during the summer and early fall, and accidents occurred most frequently between the hours of two and five in the

afternoon. No traffic control were involved in the majority (64%) of these accidents, approximately 20% of accidents occurred at a traffic signal. The most common impact type for accidents in this intersection was sideswipe. The mean age of cyclist involved in collisions in this area was 27. Dry surface conditions were most common and most accidents resulted in minimal, minor or no injury. There were two major cyclist injuries in this area.

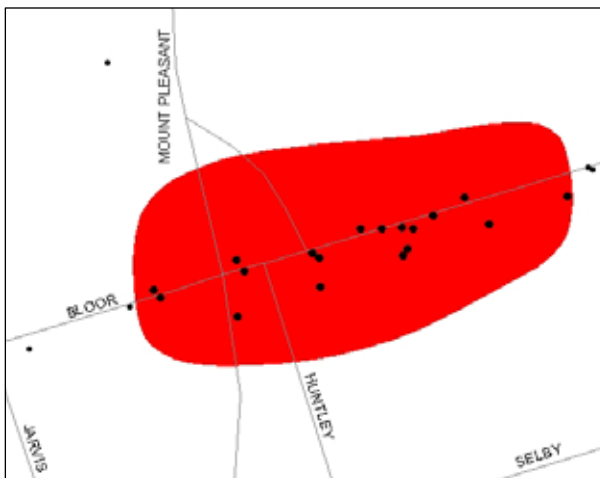
### *Bloor and Yonge*



During the period of 1995-2003 a total of 35 accidents occurred in the area along Bloor from Yonge to Balmuto. Accidents occurred throughout the year however, small spikes in frequency occurred in April, August and October. Accidents occurred throughout the day in this area

with small increases in frequency at 10am, noon, 4pm and 6pm. Just under half of these accidents occurred at a traffic control, and one third occurred in areas without traffic control. The most common impact types for accidents in this 'hot spot' was sideswipe (40%), turning (25%) and rear-end (20%). The mean age of cyclists was 31. Dry road conditions were the most prevalent. Minimal or no injury were reported most frequently and there were few minor and only one major injury reported.

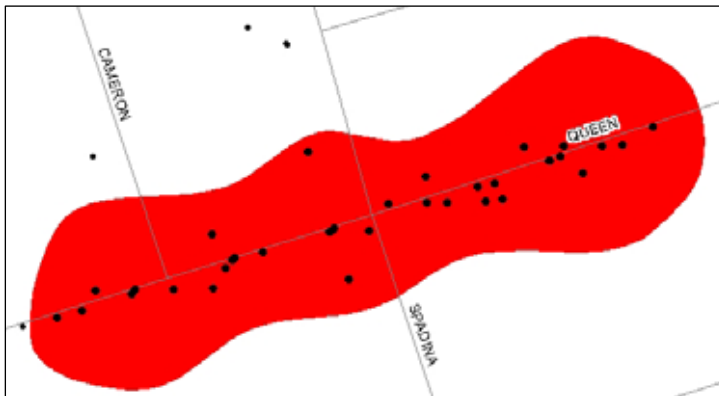
### *Bloor and Mount Pleasant*



Twenty-eight accidents occurred within the vicinity of Bloor and Mount Pleasant from 1995 to 2003. The number of accidents per month in this area is fairly consistent with a slight increase during the summer months. Accidents in this area occurred

throughout the day with a slight increase from 4-6pm. More than three quarters of the accidents in this area occurred where there was no traffic control. The most common impact types were sideswipe or turning movement. The mean age of cyclists involved in collisions at this intersection is 28. Dry road surface conditions were the most common. Injuries in this area were minor, minimal or none.

### *Queen and Spadina*



A total of fifty four accidents occurred in this 'hot spot' between the years 1995-2003. The majority of these accidents occurred during the summer months and took place during

the afternoon between 3 and 6 pm. Just over half of these accidents (51%) occurred where a traffic control was absent while 31% occurred at a traffic signal. More than half of the accidents in this area were a sideswipe impact type and an angle impact was a factor in 13% of accidents. The mean age of cyclists involved in accidents in this area was 28. The most prevalent road surface condition was dry. Most accidents in this area were minor or minimal however, there were three major accidents in this area during the period under study.

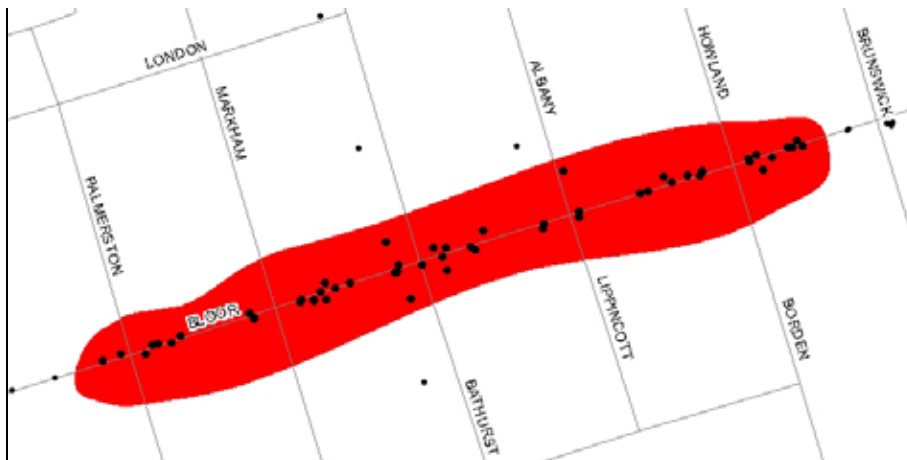
*Queen and Beverly*



From 1995-2003, 48 accidents were reported to the police in the area along Queen St. from McCaul to Beverly. Most accidents in this area occurred during June-July or October between noon and 5pm.

No traffic control was involved in most of the accidents and sideswipe and angle were the most common impact types. The mean age of cyclists was 31. Dry conditions were the most common road surface condition. Most injuries were minimal or none however there were some minor and four major injuries in this area.

*Bloor between Palmerston Ave. and Brunswick Ave.*



The Area of Bloor St. between Palmerston and Brunswick Ave. exhibited the highest number of accidents in the City. Between 1995 and 2003, 81 accidents occurred. Accidents in this area have increased in recent years with 13 accidents happening in 2002 and 2003 respectively as opposed to previous years where an average of 8 or fewer accidents occurred annually. Most of the accidents in this area occurred during the warmer months, especially May-June and September-October. Most accidents occurred during the afternoon hours with the peak time being 3-5pm. Most accidents occurred where there were no traffic controls and just under 20% occurred at a traffic signal. As with many of the other 'hot spot' regions, the sideswipe was the most common type of impact with turning and angle being the second and third most common respectively. The mean age of cyclists in collisions in this region is 28. Injuries in this area were all either minor (40%) or less severe. Road surface conditions were dry in nearly 80% of these accidents, in other cases conditions were not reported or were wet (7%).

## **Conclusions**

The comparison between hot spots and all accidents as well as the comparison between hot spots and cool spots did not show many significant differences between the different groups of accidents. The comparison of variables within different hot spot classes or individual hot spots however did result in some differences being discovered. This indicates is that accident characteristics are localized to the particular area in which they occur. The differences that were found between hot spots and cool spots may be related to the location of the hot spots rather than the density of the accidents in these areas. Hot spots were generally located in the downtown core which is predominantly used by utilitarian cyclists whereas the cool spots capture both utilitarian and recreational cyclists. The differences between cyclist groups would explain the variation in hour, age, month, and impact type. The narrower range in which hot spot accidents occur can be explained by the to-and-from work trips of utilitarian cyclists and the wider time range in which recreational cyclists. The differences in age are most likely a result of this same reason, recreational cyclists have a wider age range while utilitarian cyclists are generally restricted to working age people, aged 20-50.

When examining individual hot spots, differences between accident attributes within each hot spot are more prominent than examining accidents as a whole. This is most likely due to localized influences. It is interesting to note, however that the majority of hot spots, even when examined individually did not differ much from the general characteristics of all accidents. The attributes of age, injury, impact type month and time of day remained the most consistent. Yearly trends were not the same from hot spot to

hot spot. The number of annual accidents varied greatly and some areas had accidents in all years while others did not. The intersection of College and Shaw is a unique hot spot as no accidents occurred after 2001.

The density technique applied in this exercise has proven to be useful in identifying where accidents are occurring most frequently. Further study of the identified hot spot areas is needed to identify the local factors that are causing the higher concentration of accidents. In most cases however, higher accident density may simply be a result of higher traffic and cyclist volume. In this instance the use of cyclist counts would have been useful to determine if this was the case.

Analysis and comparison of accident characteristics in hot spots as a group was not found to be useful in distinguishing as this analysis mainly found trends that were present in all accidents. A study of these characteristics is useful for identifying and targeting safety improvements and education on a broader scale.

## Recommendations

- Further study of the intersections and road segments identified as 'hot spots' is recommended in order to determine safety improvement measures. Additional variables should also be considered to enhance the analysis such as traffic volume and flow.
- An investigation of the worst areas for cyclist collisions should be studied in correlation with the most dangerous intersections for motor vehicle accidents.
- The analysis of accident locations can be enhanced by locating accidents to the road network rather than using (x,y) coordinates. When accidents are related to the road network many new analysis techniques become possible.
- The use of specialized accident analysis software should also be considered. An example of such an application is the Highway Safety Information System (HSIS) developed by the Turner-Fairbank Highway Research Centre at the U.S. Department of Transportation.
- Conduct further investigation into safety improvement measures currently in place in the City of Toronto, such as bicycle lanes, and their role in the prevention of collisions.

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