REGION OF PEEL – COMMODITY FLOW AND NETWORK ANALYSIS

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1 Introduction

The Region of Peel is a significant freight hub for Canada and a strategic location for national freight distribution. An estimated $1.8 billion worth of commodities travel to, from and through Peel every day making goods movement a pillar of the regional economy. The Region of Peel is currently undergoing a goods movement planning effort, which includes development of a short term five year strategic plan and development of a long term plan.

A component of the long term plan is the identification and assessment of supply chains of importance to the Region by commodity. The rise of online shopping or e-commerce, has forced retailers to seriously reconsider their logistics and distribution of their products. While brick and mortar stores are not disappearing, the need to rapidly deliver goods to both individual homes and stores for pick-up in response to online shopping necessitates a reappraisal of supply chain dynamics. As a result of the changing nature of last mile deliveries, technological changes, and decentralization of distribution, it is important for planning agencies to understand how the commodities of importance move through their jurisdiction.

The commodity flow and network analysis completed for the long term plan allows Peel to understand the industries and commodities of greatest importance to the Region in terms of value and tonnage. Commodity attributes are identified using Ministry of Transportation Ontario (MTO) Commercial Vehicle Survey (CVS) data. The CVS data is used to identify the value, tonnage, and origin-destination of commodities. The movement of goods is modelled using the MTO Greater Golden Horseshoe Version 4 (GGHM V4) model in the 2011 base year and the forecast 2031 horizon year.

The output of this analysis provides an understanding of how specific commodities move through the Region and the location of current and future congestion. It also provides an understanding of how industries interact with the Regional road network and how their supply chains function. Using this information, Peel can make future investments to benefit goods moving industries, the Region and nation.

2 Region of Peel – Attributes and National Significance

The Region of Peel has established itself as an important marketplace for goods moving industries, driven by a well-established transportation network and proximity to the largest economic center in Canada. Not only do the Region's goods movement functions serve the Greater Toronto Area, many companies choose to locate in Peel and in turn serve national markets, demonstrating the national importance of the Region. Peel Region is situated in the west-central portion of the Greater Toronto Hamilton Area (GTHA) and

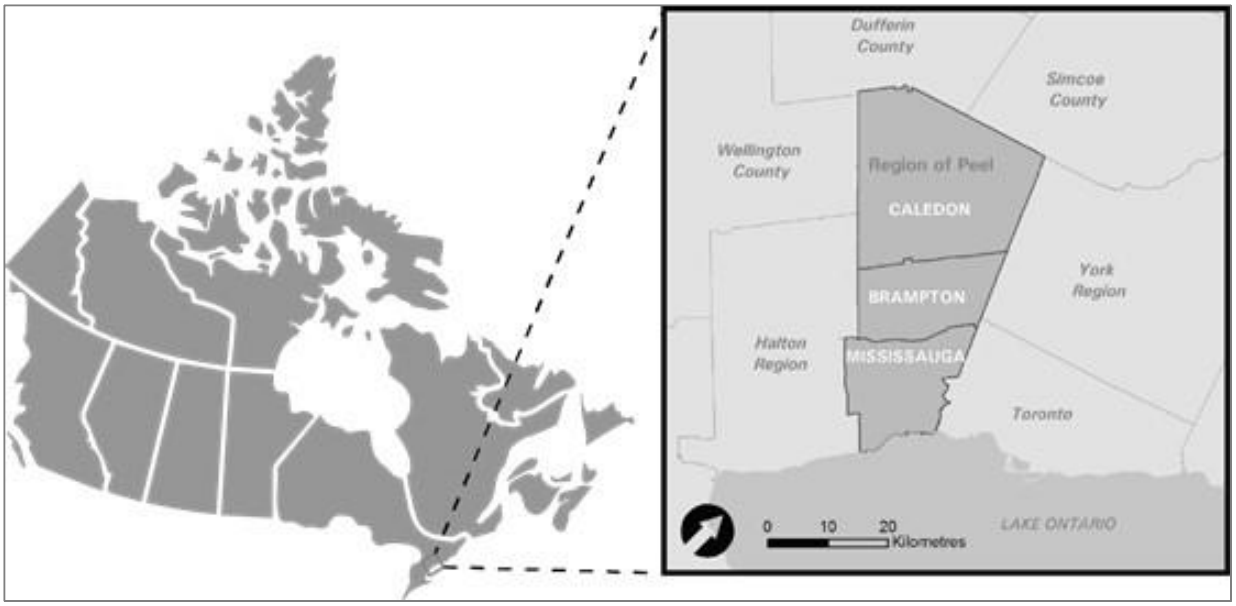


Figure 1. Location of the Region of Peel in the GTHA and Rest of Canada

borders the City of Toronto as shown in Figure 1. Peel is situated at the junction of some of North America's most important east-west and north-south trade routes. In the past 20 years, Peel's location on major trade corridors, the availability of appropriately zoned and priced land, access to a skilled workforce, and proximity to major markets in the GTHA and beyond have led to strong growth in the number of manufacturing, warehousing and goods movement-related businesses locating in the region. Important elements of the goods movement network include: the densest network of 400-series highways in the GTHA, Canada's largest international airport (Pearson), and mainline tracks and facilities for Canada's two major railroads, including the CN Brampton Intermodal Terminal and, adjacent to Peel, the CP Vaughan Intermodal Terminal.

The performance of the transportation system is a priority issue for both residents and employers in Peel. Traffic and congestion is a top concern for both residents and businesses. In 2008, it was estimated that congestion cost $845 million to commuters in the Region of Peel.[i] The increasing congestion affects the reliability and predictability of moving goods within and through Peel, and, therefore, threatens Peel's economic competitiveness. Alleviating traffic congestion and moving goods more efficiently are top priorities for the goods movement industry.

The fluidity and operating conditions of Peel roads have a direct impact on the vitality and competitiveness of the local and national economy. In 2012, there were an estimated 16.3 million truck trips that had either an origin or destination in Peel, according to MTO's CVS data. Trucks are estimated to contribute to 286 million kilometers of travel on Peel's roads, on average 17.5 kilometers per trip. The CVS suggests trucks carried over $312 billion CAD in cargo in 2012 to, from, and within the Peel Region.

3 Analysis

This section describes the analysis used to select and assess the key commodity groups moving through the Region of Peel in terms of commodity flow and network analysis.

3.1 Selection of Key Commodity and Industry Groups

Top commodities originating and delivered to Region of Peel were identified based on MTO CVS data. The CVS data was collected in 2012 and provides a detailed understanding of commercial vehicle travel to, from and within Ontario. The highest prevalence of intra-Ontario trucks can be seen within the Greater Golden Horseshoe, with 18% of truck trips in Ontario originating from Region of Peel. Nearly a quarter of total commodity value for truck trips originating in Ontario has a trip origin in Region of Peel.

For the purposes of this study, MTO prepared a subset of the CVS data which provides commercial vehicle travel to, from and within Peel. Route data was collected at survey locations throughout the Region, including 400-series highways, major arterials, and Pearson International Airport. Survey location data from the CN Brampton and CP Vaughan intermodal terminals was not provided by MTO and as a result not included in the analysis.

The CVS data provides commodity value and tonnage by Standard Classification of Transported Goods (SCTG) code. Total value of commodities originated and delivered to Peel is important in determining which supply chains to assess. Commodity value provides an indication of the economic impact (output, GDP, jobs, and taxes) which can be attributed to each commodity group. Commodity value is estimated based on the weight of the cargo and the average value of goods per-kilogram which is provided by Statistics Canada. Total commodity tonnage is also an important value in determining which supply chains to assess. Total tonnage is important due to the impact this tonnage has on the road network infrastructure which can be measured using the Equivalent Single Axle Loading (ESAL).

Ten commodities were selected for further supply chain assessment. Eight of these top ten commodities were selected based on highest value, while two commodities were selected based on highest tonnage (gravel and waste/scrap). The top ten commodities for assessment are provided in Table 1.

Table 1. Top 10 Commodities for Supply-Chain Assessment, by SCTG

SCTG	Commodity Group	Value (Millions CAD)
21	Pharmaceuticals	21,813
43 and 46	Mixed freight	19,112
35	Electronics	18,301
36	Motorized vehicles	12,085
7	Other foodstuffs	11,535
34	Machinery	9,327
23	Chemical prods.	7,921
12	Gravel	4,756
41	Waste/scrap	2,520

Source: MTO Commercial Vehicle Survey

3.2 Conversion of Commodities to Industries

To draw a more direct relationship between industries in Peel and commodity flows, an analysis was performed to develop a correspondence between SCTG commodity grouping and North American Industry Classification System (NAICS) industry groupings. Linking commodities to industries can be done at two levels: the propensity of industries to ship certain commodities and the proportion of industries shipping certain commodities. The relationship between SCTG commodity groupings and NAICS industry groups is not an exact analysis and requires some manual identification of which industries are most applicable to commodity type based on the propensity for industries to ship and the proportion of industries shipping certain commodities. Industries of importance were interviewed to understand how their supply chains function through the Region. Industries were identified based on the NAICS industry groups and using Region of Peel employment survey data to assess the top employers by number of employees for each industry group.

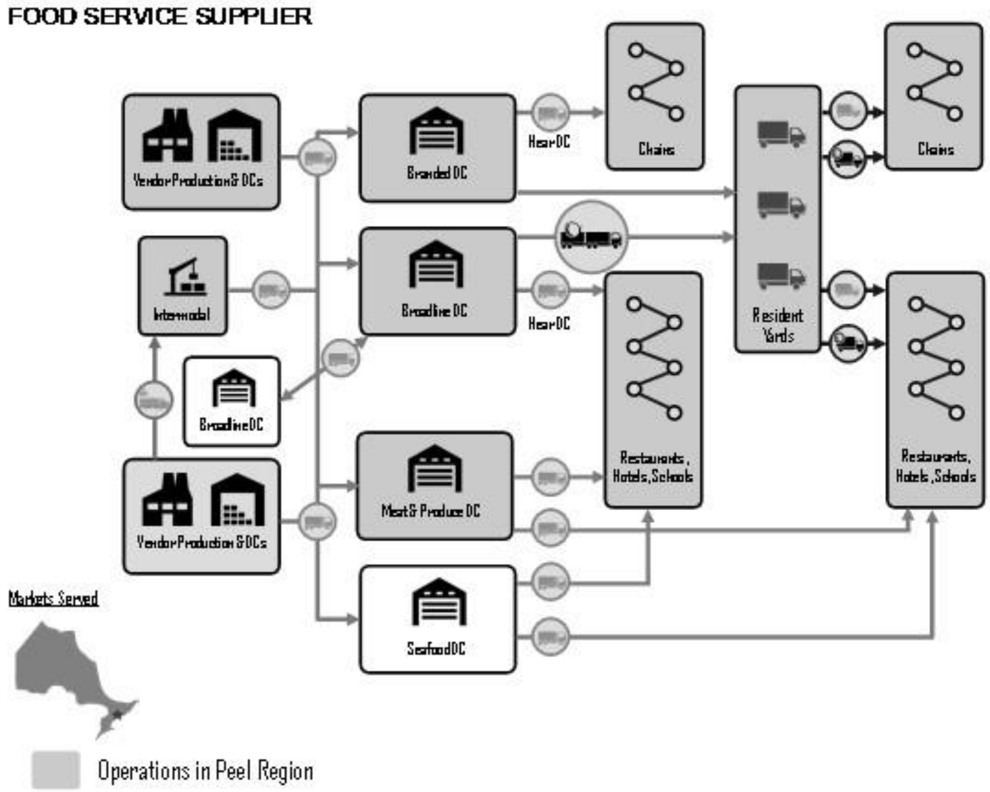


Figure 2. Example Supply Chain Flowchart Illustration

The interview topics generally included discussion of: operations, geography, goods moved, volumes, transportation modes, performance and trends and risks. For each industry, supply chain illustrations were developed to understand diagrammatically how the supply chains work step-by-step as shown in Figure 2. These supply chain illustrations are based on best practice and accompanied by an account of network performance which allows for an understanding of issues for public planners.[ii]

3.3 MTO GGHM Model – Attributes and Use

The GGHM V4 model is the fourth generation of the MTO's flagship passenger travel demand model, developed by WSP. The V4 is a significant update with its activity-based framework, advanced transit modelling tools, and 24-hour modelling capabilities. The V4 also includes a microsimulated urban truck tour model that like the passenger component is a 24-hour model and uses GPS truck processed data to establish dwell time, trip length frequency, and tour distributions for sampling.

In the context of the Region of Peel study, the GGHM V4 model was used to establish existing network levels of service and for analyzing commodity flows by trucks, tonnage, and dollar value. The attributes from the GGHM V4 model's network in conjunction with observed truck/auto collision data from 2010 to 2014 was also used to estimate a logistic regression model to estimate the probability of a truck/auto collision across the network.

For future conditions analysis, the GGHM V4 model was used to develop forecast year (2031) network levels of service to model and visualize forecasted commodity flows and probabilistic collision patterns. Details on the specific use of the V4 are noted in Section 3.4.

3.4 Supply Chain Modelling Using the GGHM

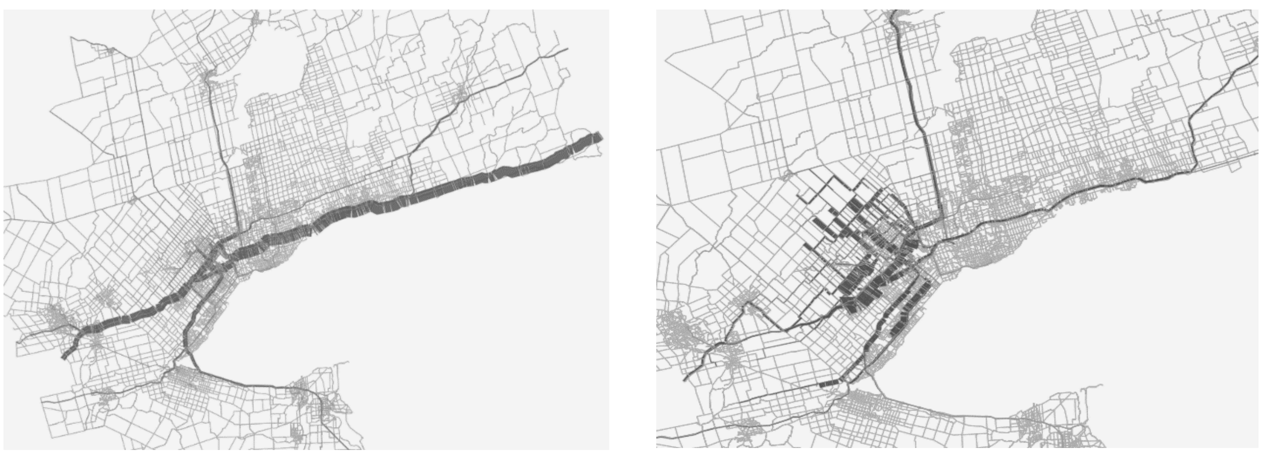
Supply chain modelling, with respect to the Peel Commodity Flow Analysis was focused around answering the following questions:

- What are the primary corridors of travel for the key commodities?
- What sort of delay are these commodities facing under congested conditions?
- Are there network hot spots w.r.t. to accident potential that these commodity groups face?

To answer the above questions, we used the 2012 CVS processed data and the GGHM V4 model's network to understand route choice of commodities under different network stress or levels of service, also called fluidity analysis. This analysis was completed for the 10 major SCTG2 commodity groups noted in Table 2. The fluidity analysis was complemented with a probabilistic truck/car collision model using observed data from 2010-2015 and the GGHM V4's network characteristics.

3.4.1 Primary Corridors of Travel

Figure 3 shows aggregated annual tonnage flows across the GGHM's V4 network using the AM peak hour congested times for route choice. Shown below are annual tons for SCTG2-43 (Mixed Freight) and SCTG2-12 (Gravel and Stone). These two commodity groups were chosen as they are very spatially diverse in terms of their origin-destination patterns and consequently route choice. The Mixed Freight group is primarily focused along the major highways, such as Highway 401, Highway 400 etc., with very long trip movements. The Gravel and Stone commodity group on the other hand has more of a local economic flavor and consequently shorter trip flows.



SCTG2-43 **SCTG2-1**

Figure 3. Annual Tons by SCTG2-43 (Mixed Freight) and SCTG2-12 (Gravel and Stone)

3.4.2 Commodity Delay

Commodity delay was estimated using a measure called the travel time index (TTI), which is a ratio of congested time over free flow time. This definition was modified for the purposes of this analysis by replacing the free flow time with LOS D time, as we believed LOS D times were a better representation of expected travel metrics in an urban area of this scale.

Figure 4 below shows the travel time index (TTI) for each of the 10 commodities (Mixed Freight is a combination of SCTG2 43 and SCTG2 46) under level of service (LOS) D conditions. Disaggregated data i.e. individual commodity movements in the 2012 CVS, were used to generate the violin plot. The plot shows the minimum, mean, and maximum LOS D TTI values and the probability density of the data at different LOS D TTI values. Similar analysis was also undertaken using Free Flow TTI values, but it was meant more for visualization rather than analytical reasons.

Specifically, the LOS D TTI values were calculated by dividing the congested times between an observed commodity origin-destination pair to the LOS D network travel times for the pair in question. Thus a TTI value is always greater than 1.0 and represents the extra time (percentage) needed to complete a trip. The data shown below represents 2012 conditions and was developed in the following manner:

- The 2012 CVS data was geocoded by map matching the latitude and longitude coordinates of each CVS record to the GGHM V4 model's traffic analysis zones (TAZ);
- Congested travel times between TAZ pairs were derived from the GGHM V4 model 2011 AM peak hour assignment;
- The LOS D travel times for each TAZ pair were developed by overwriting the congested link times in the network by a computed value that represents traffic conditions under LOS D operations. This was done only for those links that had congested times greater than the computed LOS D link times, while the remaining links were allowed to carry forward their AM peak hour "congested" times; and,

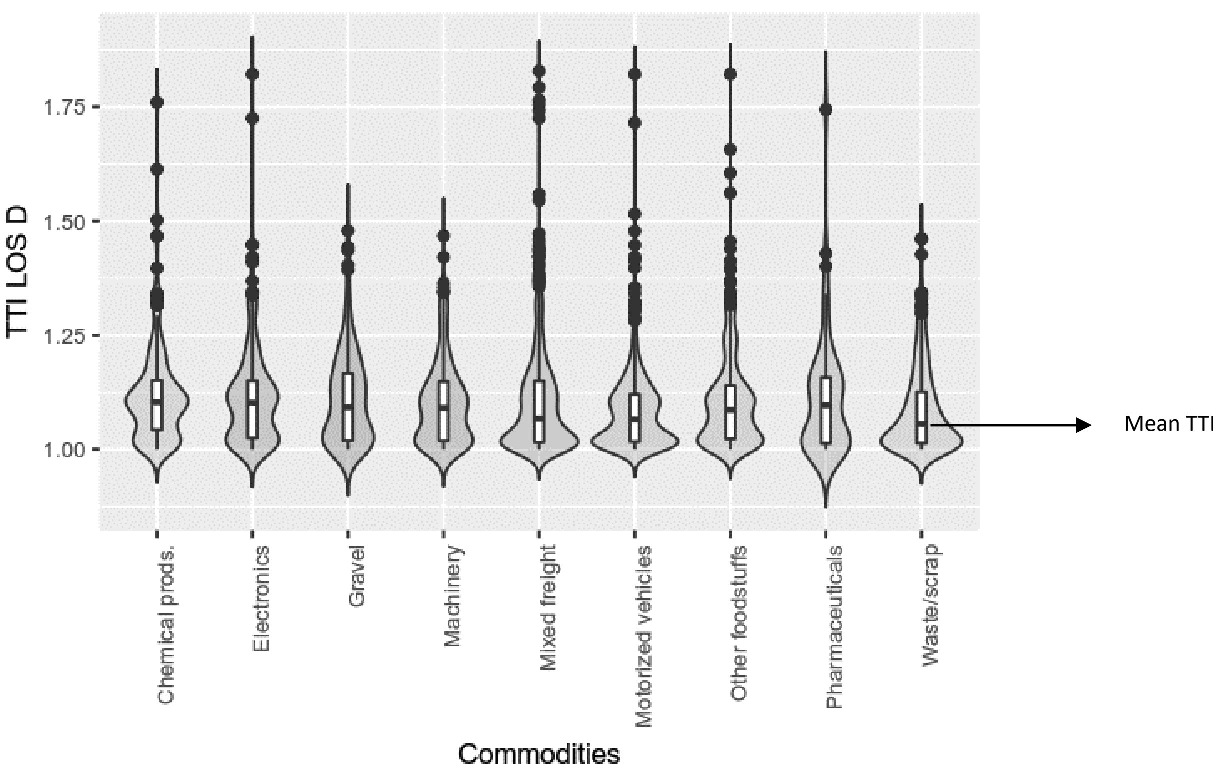


Figure 4. Travel Time Index for Congested vs. LOS D

Of the 10 commodity groups, the Gravel, Machinery, and Waste/Scrap CVS observations (trips) experienced the lowest spread between minimum and maximum TTI values under LOS D conditions. The remaining commodity groups saw a significant spread in the minimum and maximum TTI values, with some trips witnessing a value greater than 1.75. Minimizing the spread in TTI greatly improves the value of reliability, which is an extremely important consideration for freight movement.

The violin plot used disaggregated 2012 CVS data, which was unfiltered for any outliers. Another measure of TTI was obtained by calculating an average LOS D TTI (summed across all trips within a commodity group), which is shown in Table 2. The travel times were calculated using the GGHM V4 model's AM peak hour network.

Table 2. Network Travel Times by Commodity (minutes)

SCTG	Commodity Group	LOS D Time	Congested Time	LOS D TTI
21	Pharmaceuticals	4,823	5,356	1.11
43 and 46	Mixed freight	90,704	99,040	1.09
35	Electronics	20,194	22,451	1.11
36	Motorized vehicles	37,663	40,889	1.09
7	Other foodstuffs	48,486	53,765	1.11
34	Machinery	22,366	24,637	1.10
23	Chemical prods.	20,309	22,638	1.11
12	Gravel	7,237	8,201	1.13
41	Waste/scrap	18,865	20,482	1.09

3.4.3 Hotspots and Commodity Flows

Hotspots in a network can take on a number of forms, including but not limited to capacity constraints identified by links with high volume to capacity ratios and links or corridors with a high propensity of collisions, amongst others. During the process of the project, we used the GGHM V4 model to identify 2011 capacity constraints in the network, which were overlaid on the commodity flows by tonnes, values, and truck trips to isolate critical corridors and/or links in the system.

Additionally, a probabilistic (logistic regression) truck-auto collision model was built in *R* to estimate a link's propensity of a truck-auto collision. The data from the Peel accident database was first geocoded to the GGHM V4 model's network and then mined to facilitate the development of the collision model. Some of the salient features of the data are noted below. Figure 4 shows truck-auto collision frequency from 2011

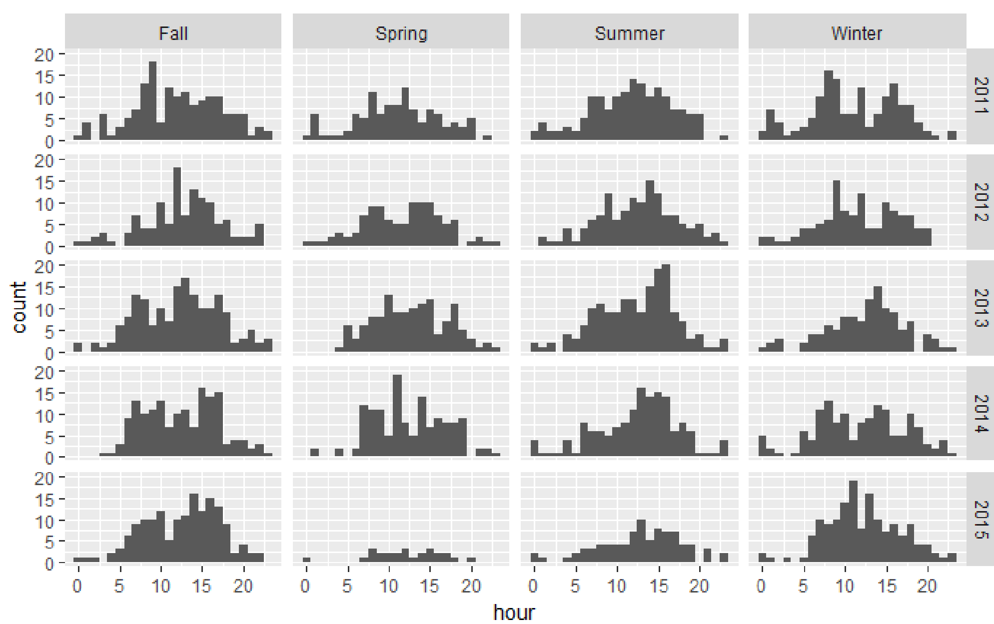
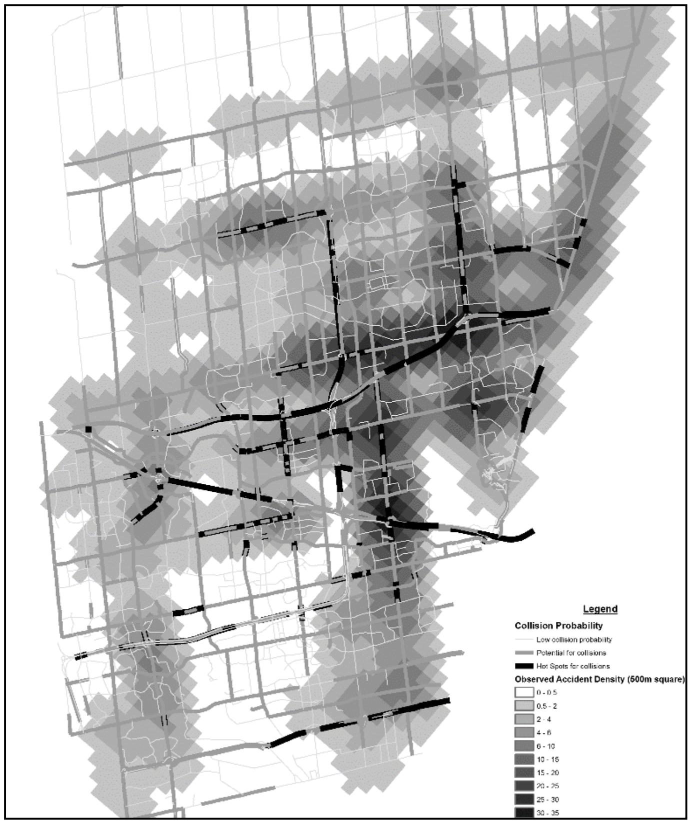


Figure 4. Truck-Auto Collision Frequency (2010-2014)

to 2014 categorized by season. Figure 5 shows the results from the collision model overlaid with a density plot of observed collisions in the network. Similar to the capacity constraint analysis, commodity flows by trips, value, and tonnage were overlapped with this link propensity.



4 Conclusions

This type of commodity flow and network analysis allows planners to understand the industries and commodities of greatest importance to their jurisdiction in terms of value and tonnage. Value provides an understanding of the economic importance of the road network, where value can be seen as a proxy for economic output. Tonnage provides an understanding of the potential for wear and tear on roadways and future public expenditures for maintenance. The output of this analysis provides an understanding of how specific commodities move through a region and the location of current and future congestion and safety concerns. This analysis allows planners to begin the process of making infrastructure investment decisions which support goods movement based on locations which have the greatest impact on the economy, state of good repair and safety. In cases where jurisdictions have defined strategic goods movement networks, this type of analysis can model how these networks are used by goods moving industries, and understand where in the supply chain these network issues pose the greatest problems and work with industry to try and solve them.

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[i] HDR (December 2008). Costs of Road Congestion in the Greater Toronto and Hamilton Area: Impact and Cost Benefit Analysis of the Metrolinx Draft Regional Transportation Plan.

[ii] National Cooperative Freight Research Program (2012). Guidebook for Understanding Urban Goods Movement. Report 14.