HIGH OCCUPANCY TOLL LANES: HOT OR NOT[1]

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Introduction

The High Occupancy Toll (HOT) lane is a new strategy implemented by the Ontario Government's Ministry of Transportation to manage the transport of goods and people across the central region[i]. The HOT strategy adopted by the government is an adjustment to the current successful operation of High Occupancy Vehicle (HOV) lane. The HOV lane was first implemented in December 2005 on Highways 403 and 404 and there are currently 48.5 kilometers of HOV lanes spread across the 403, 404 and the Queen Elizabeth Way (QEW) (Tuen, 2016). TheHOV lane was created to reduce traffic congestion and improve the overall operation of the system by promoting carpooling and transit (Government of Ontario, Ministry of Transportation, 2016). The HOV lane ensures this by allowing drivers with two or more occupants the ability to use a separate lane dedicated for carpooling. The General Purpose Lanes (GPL), on the other hand, allow any user, independent of the number of passengers in the car, to drive in these lanes and accounts for most of the capacity along Central Region's road network.

The HOT lane is an extension of the HOV lane, where individuals can exploit the HOV lane for a specified price, regardless of vehicle occupancy level. The reason for its implementation is attributed to the fact that individuals would be willing to pay for a less congested lane and benefit from faster travel times, while also reducing the number of vehicles in the GPL. This is believed to be a means of reducing congestion and carbon emissions within the network (Government of Ontario, Ministry of Transportation, 2016).

However, there is no empirical evidence to support such a claim. Therefore, this paper investigates the impact of the newly implemented HOT Lane on the Queen Elizabeth Way (QEW). In particular, we have analysed the current Level of Service (LoS) on the QEW for both HOV lanes and GPLs to investigate the impacts that a HOT policy might have on the traffic flow.

Towards that end, firstly, we reviewed the best practices of HOT and HOV lanes policy implementation to understand their operations. Secondly, using data from Central Region's Fourth Line and QEW, we have analyzed the LoS of the QEW for a weekday operation prior to and after the HOT policy implementation. Lastly, based on the results, we recommend different policies to maximize the utilization of the HOT/HOV lanes while promoting care sharing.

Review of Best Practice

On May 3rd, 2008 Washington State converted an HOV lane to a HOT lane on the State Route 167. This initiative was created to utilize unused space within the HOV lane as well as to deal with congestion faced within the GPL. In regard to tolling, Washington utilizes a Good to Go pass that allows users to indicate when they are carpooling or driving alone within the HOT lane. This strategy differs from that of Ontario's as the price is variable with time and is dependant upon the traffic congestion experienced.

[1] 54th Annual Meetings of the *Canadian Transportation Research Forum*, May 26 - 29, 2019 at Vancouver, British Columbia

Over the three-year analysis period, tolls were seen to be as high as 9.00 USD for the 10-mile commute (SR 167 HOT Lanes). This system, however, follows an honesty system where users activate their pass based on how many occupants are within the car. With the variable pricing method, maintaining an acceptable Level of Service within the HOT lane at all times, even during peak demands, is possible due to the ability to deter drivers, during times of higher congestion, by increasing the fee to use the lane. However, just as easily, in times of lower levels of congestion, the price can be reduced allowing for more users to use the lane. This allows for more users to be able to use the HOT lane while also ensuring a proper LoS at all times.

Throughout a three-year analysis period, by the Washington State Department of Transportation, it was determined the HOT pilot was a complete success as it did not impact the travel times experienced by pre-existing HOV users, while also managing to reduce travel times within the GPL. The State claims that this was accomplished due to the varying price method, as the higher prices were an effective way to deter drivers from using the HOT lane in times of higher congestion.

In 1998, to deal with the extreme congestion, Houston's Transportation Department implemented a 13-mile HOT lane on IH-10, also known as Katy Freeway. The highway "*... is considered one of the most congested stretches of freeway in Texas…Designed to carry 79,200 vehicles per day, the Katy Freeway now carries over 207,000 vehicles per day*" (Chapter 7 Current Hot Lane Experience). IH-10 has only one HOT lane for both directions and is separated by a median. The direction of flow in the HOT lane is dependent on the travel demand and handles inbound traffic in the morning and outbound at night.

Both the IH-10 and QEW have an increasing number of vehicles utilizing the road each year, while also having limited space to expand. The knowledge that can be gained from this project is the ability to change the HOV 2+ to an HOV 3+. Due to the high demands on the network, Houston officials opted to allow cars with three occupants the ability to utilize the HOT lane for free while charging a fee to those with only two. This was implemented under the assumption thatif an HOV of 2+ was allowed, the LoS within this lane would be relatively lower and the benefits of utilizing this lane would be negligible.

Methodology

One must first understand the current performance of the highway network before understanding how the implementation of a HOT lane would impact it. It could be argued that the most comprehensive way to determine the current performance of the corridor selected is to complete a Level of Service assessment. This is the best practiced way to determine the capacity of a network, based upon the Highway Capacity Manual's capacity guidelines. This would also allow for the prediction of future corridor performance based on the transfer of drivers from the GPL to the HOV lane, due to the HOT implementation, and to what extent it would impact the current Level of Service.

However, some assumptions were made throughout the paper. That said, all assumptions are grounded on solid theoretical foundations. First, bottleneck effects are not considered in calculating the highway Level of Service. This paper is not based upon extreme cases were many lanes merge together. Assumptions were also made for calculating the Level of Service. Lastly, the LoS analyses were conducted for weekdays only as it was assumed that the HOT permits are purchased to decrease travel times to and from work.

Level of Service (LoS)

Level of Service is an important metric used to evaluate the performance of a road. Level of Service is a qualitative means for rating the traffic conditions experienced by the users (American Highway Capacity Manual, 2010). The method for estimating the LoS used in this paper is prescribed within the American Highway Capacity Manual. It divides traffic conditions into a diminishing scale, A through F, where A represents free flow conditions where vehicles can manoeuvre freely, while F represents when demand exceeds capacity causing stop and go traffic.

The LoS for the selected road segments is illustrated using a heat-map tool to better depict the current densities experienced on the road network. This map represents Level of Service by colours on a chart, where the darker colour indicates a low Level of Service and lighter colours mean high Level of Service. This was created to allow for the ease of understanding of when the lowest Level of Service occurs and to confirm if this is in line with current theory.

Density

Density in transportation is defined as the number of vehicles within one mile and is used to determine the level of service. Based upon the equation for density it can be foreseen that if volume increases and speed decreases the density, in turn, would rise, which as stated above would decrease the level of service for the network. To determine the density of the highway network first the volume and speeds must be recorded.

Volume

Volume in transportation is defined as the number of vehicles passing a given location over a fixed amount of time (American Highway Capacity Manual, 2010). This can be recorded in several different ways including radar detection, loop detection or visual inspection. In this paper, we utilize loop detection data provided by the Central Region, Traffic Office of Ontario’s Ministry of Transportation. The data is collected from Ford Drive to Guelph Line.

This data is used to calculate the adjusted volume for the density formula. Adjusted volume (Vp) can be calculated using the following formula:

$$Vp = \frac{V}{PHF*N*Fhv*Fp} \qquad \text{Eq. (1)}$$

The data analysis involved several data adjustments and thus some assumptions were made. Firstly, due to LoS being calculated for each lane, the N (number of lanes) value was set to equal to 1 for all calculations. This is to preserve consistency since the LoS of the HOV lane is an independent lane and likewise, the General-Purpose Lane can be subdivided into single lanes. Secondly, the adjustment factor for the familiarity of users was estimated to be 95 percent or 0.95 for all lanes. This adjustment assumed that drivers who are less experienced on the roadway will use the network less effectively. Thirdly the heavy vehicle factor was determined through the equation specified from the American Highway Capacity Manual 2010, to be 0.9345, as it was assumed that 10% of vehicles using the network were heavy vehicles, for all GPL lanes. A heavy vehicle factor of 1 was assumed for the HOV lane as no heavy vehicles are allowed within this lane. Finally, the peak hour factor generally follows the following formula:

$$PHF = \frac{V}{v15*4} \qquad \text{Eq. (2)}$$

Where V is the volume per hour and V15 is the maximum volume experienced within 15 minutes.

The peak adjustment factor (PHF) is used to account for variations in traffic flow over time. Equation 3 is used if 15-minute intervals are recorded since the data used by the author was based on hourly information a new equation was derived.

$$PHF = \frac{V1+V2}{\frac{Max(V1,V2)}{2}*4} \qquad \text{Eq. (3)}$$

Equation (3) also adjusts for variations in traffic flow but it utilised information known by the author. The $\frac{Max(V1,V2)}{2}$ represents the maximum 30-minute volume experienced by the network within a given two-hour period. It is for this reason that the density and Level of Service analysis for this report was completed in two-hour periods.

Speed

As with the volume, the speed was also determined by data from the loop detectors. Due to the density calculations being completed for two-hour intervals, the speeds were averaged over two-hour intervals and converted to miles per hour as per the formulas specifications.

HOT Capacity

Once the pre-HOT Level of Service analysis was completed for each individual lane, a projection of future events is created. Three different cases weredeveloped for each direction to mimic worst, best, and average cases of traffic congestion during peak hours as seen in Tables 2 and 3. These scenarios follow several key assumptions. Firstly, the number of permits to be sold was determined based upon the work week peak demands. It was assumed most users who purchased a permit would use this permit to cope with peak hour congestion. Secondly, the LoS within the HOV lane before the HOT implementation was to be unchanged, meaning that users that currently use the HOV lane will not notice a difference in the HOV LoS upon HOT implementation and therefore continue to use this lane. Finally, three different trip distributions were used in each case to determine the number of permits that could be sold given the percentage of permit users travelling in each direction within the specified hours. These percentages were selected to be 100%, 50% and 25% to mimic different trip distribution. A 100% allocation represents a situation when all permits are used at the same time in the same direction. A 50% allocation represents a situation where half of all permit users utilize the HOT lane within the specified time in the specified direction. Finally, a 25% allocation represents one-quarter of all permits using the HOT lane within the hours specified.

Table 1: Toronto Bound Simulations

	Scenario 1 Min LoS	Scenario 2 Ave LoS	Scenario 3 Max LoS
Assumptions	Users use permit during the week's highest peak hours.	Users use permit between 6 a.m. and 8 a.m. Monday to Friday.	Users use permit between 6 a.m. and 10 a.m.
Time of Use for HOT permits.	The lowest LoS. (Monday 6 a.m.- 8 a.m.)	6-8 a.m.	6-10 a.m.

Table 2: Fort Erie Bound Simulations

	Scenario 1 Min LoS	Scenario 2 Ave LoS	Scenario 3 Max LoS
Time of use	All users use permit during the week's highest peak hours.	User use permit between 4 p.m. and 6 p.m.	User use permit between 2 p.m. and 8 p.m.
Time of Use for the HOT permits	The lowest LoS. (Friday 4 p.m.-6 p.m.)	4-6 p.m.	2-8 p.m.

With these cases created, the future densities were projected. To determine future densities and LoS several equations were created, which utilized the principles of density explained within the 2010 American Highway Capacity Manual.

$$Thedensityavailableforsale = LT - DensityofHOV \qquad \text{Eq. (4)}$$

Where LT is the limiting density, highest density within a LoS range, to stay within the same LoS during peak hours.

$$Permitstobesold/hr = Thedensityavailableforsalex\ 10.25\ miles \qquad \text{Eq. (5)}$$

$$TotalPermitstobesold = Permitstobesold/hrx\ 2\ hrs \qquad \text{Eq. (6)}$$

From equation 4, the density available for sale was evenly distributed into the GPL to determine how the GPL densities would react. For example:If the HOV had a density available for sale equal to 6, a density of 2 from each GPL was taken from the GPL and added to the HOV lane density, to determine the future projection of LoS for all lanes.

Results

The densities of the QEW and Fourth Line were calculated for a four-month period in the Toronto Bound direction and a six-month period in the Fort Erie Bound direction. From this, the week of February 1st, 2016 was chosen to be represented in this report as it was a good representation of how density varied with time in both directions.Once the LoS for each direction was determined, based upon pre-HOT conditions, Heat Maps were also created. These maps were created to illustrate how density varied with time in a simple way.

Figure 1: Toronto Bound Density

Date	Lane	Time (00-24) hr 0:00-2:00	2:00-4:00	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
2016-02-01 Monday	HOV Density	1	0	9	21	15	8	8	11	17	8	4	2
	GPL 1 Density	3	2	31	48	40	32	28	33	44	26	15	10
	GPL 2 Density	3	3	19	32	27	21	19	22	29	18	12	9
	GPL 3 Density	3	4	20	37	37	27	28	30	36	24	15	10
	GPL 4 Density	0	0	1	6	7	6	4	4	6	3	1	1
2016-02-02 Tuesday	HOV Density	0	0	9	20	16	7	8	10	16	8	4	2
	GPL 1 Density	2	2	30	48	45	28	28	35	44	28	16	11
	GPL 2 Density	4	3	18	31	31	19	20	22	29	19	13	9
	GPL 3 Density	4	4	19	36	39	26	29	29	37	26	16	11
	GPL 4 Density	0	0	2	5	8	4	5	4	6	4	2	1
2016-02-03 Wednesday	HOV Density	1	0	9	19	15	10	8	9	15	10	5	2
	GPL 1 Density	3	1	30	46	41	34	29	34	42	30	17	11
	GPL 2 Density	4	3	18	31	28	21	19	21	27	20	13	9
	GPL 3 Density	4	4	19	37	36	29	29	30	36	28	17	11
	GPL 4 Density	0	0	2	5	7	5	4	5	5	4	1	1
2016-02-04 Thursday	HOV Density	0	0	7	18	14	9	8	11	17	8	5	3
	GPL 1 Density	2	2	28	43	40	33	30	35	42	27	17	11
	GPL 2 Density	4	3	16	28	26	21	21	23	27	19	14	10
	GPL 3 Density	5	4	18	34	33	29	30	31	35	27	17	10
	GPL 4 Density	0	0	1	5	7	5	4	4	5	4	2	1
2016-02-04 Friday	HOV Density	1	0	7	19	14	11	12	16	19	14	7	4
	GPL 1 Density	3	2	28	43	39	34	32	40	39	29	19	12
	GPL 2 Density	4	3	17	29	25	22	22	24	25	20	13	10
	GPL 3 Density	5	4	18	33	35	32	33	34	34	26	16	11
	GPL 4 Density	0	0	1	5	7	4	4	4	5	3	1	1
Legend		A	D<11	B	11<D <18	C	18<D <26	D	26<D <35	E	35<D <45	F	D>45

Within Figure 1, Toronto Bound LoS Snapshot, it is seen that the highest densities and lowest LoS are experienced between the hours of 6 a.m. and 10 a.m. It was also noted that General Purpose Lane 1 experienced the worst LOS on all days. From this information, it was understood that the HOT would be most beneficial between the hours of 6 a.m. and 10 a.m. In particular, Monday morning, as this was determined to be the limiting factor for Case 1 as it already experiences a density of at 21 pcu/mile. It is also important to note that a p.m. peak is also noticed from 4 to 6 p.m. but does not experience densities as high as those experienced within the morning rush, so the morning rush so, therefore, it was determined that the morning peak should be the basis for the scenarios.

Figure 2: Fort Erie Bound Density

Date	Lane	Time (00-24) hr											
		0:00-2:00	2:00-4:00	4:00-6:00	6:00-8:00	8:00-10:00	10:00-12:00	12:00-14:00	14:00-16:00	16:00-18:00	18:00-20:00	20:00-22:00	22:00-24:00
2016-02-02 Monday	HOV Density	1	0	1	7	7	7	8	14	17	11	5	3
	GPL 1 Density	4	2	6	35	37	26	30	38	39	36	19	11
	GPL 2 Density	6	3	9	30	32	27	30	33	36	33	20	14
	GPL 3 Density	4	3	8	28	30	24	26	29	36	32	17	10
2016-02-02 Tuesday	HOV Density	1	1	1	6	6	6	8	17	17	12	5	3
	GPL 1 Density	4	3	5	34	35	24	30	39	38	35	21	13
	GPL 2 Density	7	6	10	31	32	26	30	35	35	32	23	14
	GPL 3 Density	5	4	9	26	29	23	26	34	36	33	18	12
2016-02-03 Wednesday	HOV Density	2	1	1	6	8	7	9	18	18	14	5	4
	GPL 1 Density	7	3	6	33	35	27	31	41	40	37	23	13
	GPL 2 Density	10	5	10	29	30	29	31	36	38	33	23	16
	GPL 3 Density	6	4	7	26	29	25	26	35	38	34	20	11
2016-02-04 Thursday	HOV Density	1	1	1	5	8	7	9	18	19	12	6	4
	GPL 1 Density	5	3	6	32	38	27	32	41	43	35	23	15
	GPL 2 Density	7	6	9	29	33	27	30	36	40	31	24	16
	GPL 3 Density	6	5	8	25	31	25	28	36	43	32	20	12
2016-02-05 Friday	HOV Density	1	1	1	7	7	9	12	20	21	15	10	6
	GPL 1 Density	6	3	5	35	37	29	38	42	37	34	23	15
	GPL 2 Density	8	6	10	31	32	30	34	37	34	31	22	18
	GPL 3 Density	6	5	8	27	30	27	30	33	34	29	18	13
Legend		A	D<11	B	11<D <18	C	18<D <26	D	26<D <35	E	35<D <45	F	D>45

From Figure 2, Fort Erie Bound LoS Snapshot, the highest workday densities and lowest LoS are experienced between 2 p.m. to 6 p.m. Once again, the GPL 1 experienced the worst LoS within the system. The worst LoS experienced within the HOV lane was determined to be on Friday from 4-6 p.m. with a density of 21 pcu/mile and was determined to be the limiting factor for Case 1 in this direction.

Projections

In addition to the LoS analysis and heat map creation the correlation of densities between lanes was conducted to see how the density of the GPL affected the density within the HOV lane:

Table 3: Correlation Factors for Toronto Bound Traffic

	Correlation Factor
HOV toGPl 1	0.962
HOV to GPl 2	0.968
HOV to GPl 3	0.931
HOV to GPl 4	0.870

Table 4: Correlation Factors for Fort Erie Bound Traffic

	Correlation Factor
HOV To GPL 1	0.871
HOV To GPL 2	0.874
HOV To GPL 3	0.906

Figure 3: Toronto Bound Cases

	Case 1 (Pre-HOT)	**Post HOT Conditions**
HOV	21	26
GPL 1	48	47
GPL 2	32	31
GPL 3	37	35
	Case 2 (Pre-HOT)	**Post HOT Conditions**
HOV	19	26
GPL 1	46	43
GPL 2	30	28
GPL 3	35	33
	Case 3(Pre-HOT)	**Post HOT Conditions**
HOV	17	26
GPL 1	43	40
GPL 2	29	26
GPL 3	36	33

Figure 4: Fort Erie Bound Cases

	Case 1(Pre-Hot)	**Post HOTConditions**
HOV	21	26
GPL 1	37	35
GPL 2	34	32
GPL 3	34	32
	Case 2(Pre-Hot)	**Post HOT Conditions**
HOV	18	26
GPL 1	40	37
GPL 2	36	34
GPL 3	37	35
	Case 3 (Pre-Hot)	**Post HOT Conditions**
HOV	16	26
GPL 1	38	35
GPL 2	35	31
GPL 3	34	31

Utilizing the knowledge gained from the heat maps and understanding the high correlation between lanes, the projections were determined. Seeing that there is a high correlation between the HOV lane and GP lanes the assumptions made is held. The cases described in tables 1 and 2 were created and their results can be seen within figures3 and 4.

From Figures 3and 4 it can be seen that with the LoS held constant in the HOV lane it is possible to improve the LOS within the GPL during peak hours, while also having excess capacity to distribute over off-peak hours. The Post HOT conditions are shown in Figures 3 and 4 represent peak hour conditions, but for 50% and 25% trip distributions, there is an additional capacity to be shared within the GPL during non-peak hours. It is to be noted that Case 1, which mimicked the worst-case scenario, allowed for the least number of permits to be sold, while Case 3 a better scenario allowed for more permits to be sold in both cases.

Traffic condition and LoS

From the correlation factors presented in Tables 3&4there is indeed a high correlation between the LoS of GP and HOV lanes. This means, that as the density in the General-Purpose lane increases so does the density in the HOV lane. This can be explained by the added benefit when one decides to use the HOV lane. As it can be seen at any given time, the HOV provides a better Level of Service compared to those experienced in GP lanes, and thus offers reduced travel times. This relation, however, was not seen to be linear. It was seen that there was an increase in HOV users when capacity in the GP lane was significantly worse than that of the HOV lane. This is consistent with the findings of Tuen (2016) in the HOV Violation study. "*…the number of violations is directly proportional to the free flow of traffic. When the general-purpose lanes are at capacity and the HOV lanes are in free flow conditions, the violations increase significantly.*" (Tuen, 2016). This information was later used to assist with the case projections. Knowing that the HOV to GP Lanes had a high correlation it confirmed the assumption that cars could be shifted from the GPL to the HOT lane.

With the addition of the new users in the HOV lane due to the HOT implementation, the density of this lane will increase. The question that needed to be answered was: to what degree could theaddition of new users be tolerated within the HOV lane, and to what extent wouldit improve the Level of Service within the GPL?Seeing as the goal of the HOT lane is to "*Promote behaviour change by encouraging people to form carpools, help to manage congestion, provide more choice to travellers*" (High Occupancy Toll (HOT) Lanes) at a minimum, the addition of the HOT users should not reduce the current Level of Service experienced by pre-existing HOV users. That being stated, to reduce congestion within the GPL it was deemed acceptable to increase the density within the HOV to 26 pcu/mile, the top end of level of service C, a level of service the HOV users have become accustomed to. This acceptable increase was then the basis for the scenarios seen in figures 3 and 4.

HOT Effectiveness

Several different cases were created to determine future LoS due to HOT implementation. For example, within figure 3:

> Case 1 Toronto Bound, the current density on Monday was determined to be 21 pcu/mile. From this, there is a space for 5 vehicles per mile per hour before a new LoS is experienced. Seeing as there is 16.5 km of HOT lane implemented on the QEW or 10.25 miles, the HOT lane can accommodate a total of 51 vehicles per hour. Since the time window of study is over two hours the HOT can accommodate a total of 102 new vehicles, or HOT permits, within the peak hours. Now, this is understood to be an extreme case, and highly unlikely, where all permit holders would all use the HOT permit between 6 a.m. and 8 a.m. on Monday morning to go to Toronto.

Due to this, it has been determined that a safe and reasonable assumption is to average Cases 2 at 25% for both directions. Case 2 was chosen, for both directions, as it can be seen that it is during these hours, 6 to 8 a.m.for Toronto Bound and 4 to 6 p.m. for Fort Erie bound, that the HOT is most limited in its capacity to accept new users and therefore these times should dictate the number of permits to be sold. The percentage of HOT permits using the HOT during these peak times were determined in the following fashion:

> An assumption that 50% of permit holders would be using the HOT lane for each direction was made.Seeing as the a.m. peak for Toronto Bound and p.m. peak for Fort Erie bound were determined to be limiting factors, only two out of the four movements were considered limiting factors. Based upon this it can be seen that $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$ and therefore the 25% distribution was selected. Utilizing these assumptions, a total of 591 permits could be sold.

From this determined number of permits to be sold, it can be seen from Figures 2 and 3 that the LoS within the HOT lane will be on average level C, except for hours of highest peak demand, while also improving the LoS in the GPL to D. Therefore, the HOT will help the transportation system in Ontario, improving the General-Purpose lanes' travel times, while having a minimal impact on current HOV users. That being stated the traditional method of selling permits is limited, and times of lower than anticipated LoS on the HOV will occur, as such other HOT projects were researched to see if any other methods were better suited for Ontario.

Conclusions

The purpose of this paper was to determine the extent to which the implementation of a HOT lane would impact transportation in Ontario's Central Region. Using the 2010 American Highway Capacity Manual the Level of Service for the network's performance, pre-HOT conditions, was derived. With this information, heat maps were created to illustrate how density varied with time to allow for a thorough understanding of when peak demands occurred. Through the analysis of the heat maps, the pre-HOT LoS of the General-Purpose lanes and HOV lane were determined to be, on average, levels E and C accordingly. Once the heat maps were analysed three different cases became apparent for each direction, which were created to understand potential impacts on density due to the addition of HOT users to the HOV lane. From the three cases created, it is suggested that a maximum of 591 permits should be sold. This number was determined based upon the conclusion that 25% of permit holders were to use the HOT corridor Toronto bound between 6 and 8 a.m., and 25% of permit users were to use permits Fort Erie Bound Between 4 and 6 p.m. If the 591 permits were to be adopted the impacts would include an average LoS of C within the HOT lane, while the GPL would be improved to level D, under average peak hour demands. This solution was however not seen to be the best option for Ontario as it was shown that during the week's highest peak demand, this number would not be accommodated within the system. Instead, it is suggested that a variable pricing method be used as it would allow for the variation of the number of HOT users due to real-time traffic data rather than a weekly average that is less capable of dealing with high and low traffic extremes.

This paper was created with limited access to comprehensive traffic data for 15-minute intervals. Due to the hourly volume and speed data used, hourly density and LoS analysis could not be completed and therefore two-hour intervals were created instead. This being stated, the methodology used in this report can be readily adapted to accommodate 15-minute traffic data and could be implemented atdifferent locations. It is suggested that if this research were to be duplicated that multiple locations be reviewed to understand bottleneck affects as well as the impact of the traffic distribution on the network that was not discussed within this report.

In conclusion, the HOT implementation would impact transportation in Ontario by enhancing the average Level of Service within the General-Purpose lanes to level D while maintaining a Level of Service of C within the HOT lane, during peak weekday hours. However, the method of selling a predetermined number of permits was seen to have its limitations, especially during times of very high and low demands. Therefore, it is concluded that Ontario should further its research in the implementation of variable pricing methods on the HOT lane to accommodate more users, which would, in turn, increase the LOS within the GPL, without jeopardizing the Level of Service within the HOT lane.

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[i] The Government of Ontario's Ministry of Transportation has subdivided the responsibilities of highway management to five different regions across Ontario. They are Central Region, East Region, Northeast Region, Northwest Region, and West Region.