UNIVERSITY OF WATERLOO
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Evaluation of Travel Time Prediction Algorithm and Measurement Using Bluetooth Signals

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The title of this report, "Evaluation of Travel Time Prediction Algorithm and Measurement Using Bluetooth Signals" was prepared as my 2A Work Report for the City of Toronto, Traffic Management Center. This is my second work report. The purpose of this report is to test the accuracies of results from various travel time methodologies and to implement the most desirable one.

The City of Toronto, Traffic Management Center (TMC), Urban Traffic Control Systems (UTCS) is responsible for traffic signal operation and freeway management.

UTCS includes Road Emergency Services Communications Unit (RESCU), which is responsible for incident detection and provides update traffic information on freeways. I was employed in RESCU, which is managed by Simon Foo; a Senior Engineer who supervises the RESCU operation and conducts research related to transportation systems and technologies.

This report was written entirely by me and has not received any previous academic credit at this or any other institution. I would like to thank Mr. Simon Foo for proofreading my report and providing me with valuable advice and resources. I would like to thank Mr. Eamonn Doherty for the assistance of programming code development in C#. I received no other assistance.

Sincerely,

Hao Xiang Qian
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Executive Summary

Travel Time (TT) prediction and measurement methodologies need to be evaluated to determine their accuracy, reliability and practicality. The goal is to display TT on the Changeable Message Sign (CMS) to the desired destination on the Don Valley Parkway in Toronto, Ontario.

The actual TT data are created by using the Closed Circuit Television (CCTV) cameras to monitor a vehicle on freeway by recording the arrival time at each camera location (1). This is one way to accurately measure TT for a vehicle trip, and uses TT data (as the "ground truth"). The time period for the "ground truth" data measurement is during morning peak period (6am to 10am) on June 9 and 10, 2009.

Distance over average vehicle speed formula is used to calculate the TT algorithm (2). As for the TT measurement with Bluetooth signals, each Bluetooth mobile phone device is detected with arrival times recorded at two locations, and the TT is the time difference (3).

During the evaluation phase, the data from both experiments are compared with the actual data. Analysis of the results is included such as the percentage errors. In the end, the algorithm data show more accurate results than the Bluetooth TT measurement with low percentage errors, and thus, the travel time prediction algorithm is more reliable.

1.0 Background

The City of Toronto, Traffic Management Center designs, maintains, manages and operates urban transportation system with one of the units called Urban Traffic Control Systems (UTCS). UTCS is responsible for operating traffic signals and managing freeways in the city which are operated by a sub unit known as Road Emergency Services Communications Unit (RESCU) (4). It manages freeway traffic flow on the Gardiner Expressway, the Don Valley Parkway and Allen Road and provides central dispatch functions.

RESCU detects freeway traffic incidents, collects traffic data and provides up-to-date traffic information via email, fax, changeable message signs (CMS) and websites. RESCU also monitors traffic on freeways using Closed Circuit Television (CCTV) cameras. Vehicle Detector Stations (VDS) use loop sensors to detect vehicles and receive traffic information such as traffic speed, traffic volume and road occupancy (4).

A website called Transnomis provides a map of the city to display real-time traffic information such as static images from CCTV cameras, vehicle speed, VDS status, and traffic signal status(4). The locations of the RESCU equipment such as CCTV cameras, VDS loop stations and CMS are marked on the map as well. Transnomis contains all the collected raw and graphical traffic data from the VDS. The data is updated every 20 seconds.

2.0 Introduction

Travel time (TT) information can help travelers to decide when to travel and which route to take. Travel time measurement and prediction are difficult to implement because of inaccuracy of results. To determine TT on freeways, there are various factors to consider such as driver's behaviour, traffic incidents, traffic volume, and weather. The objective of this report is to evaluate a simple TT prediction algorithm and a leading-edge TT measurement methodology on the Don Valley Parkway (DVP). Data used includes both directions (northbound and southbound) from June 9 and 10 during the morning peak hours (6 am to 10 am). These two data sets are compared to the "ground truth" TT.

In order to measure the "ground truth" TT, the experiment used Closed Circuit Television (CCTV) cameras to monitor a specific vehicle and record the arrival time at each location. TT is the difference of arrival times at the start and end point. The selected TT prediction algorithm uses a simple formula to calculate the TT, travel distance divided by the average vehicle speed. Lastly, TT measurement methodology based on Bluetooth technology is evaluated. It involves deploying a Bluetooth device called BluFax at two specific locations to detect Bluetooth signals from mobile phone users. The arrival times are recorded, and the time difference is the TT. More detail analysis of each experiment is provided. Finally, the evaluation of each experiment is shown to determine the accuracy of results.

3.0 "Ground Truth" Travel Time Measurement

The "ground truth" travel time data or the actual travel time data are verified with other travel time results gathered from various algorithms and methodologies. One appropriate "ground truth" travel time measuring methodology on a freeway is by using cameras to monitor a vehicle and record the time when the vehicle passes through each location and then calculate the time differences. A section on a freeway between two consecutive camera locations is called a zone. A zone travel time can be determined as:

Zone Travel Time = TFinal – TInitial;

Where TFinal is the arrival time of zone's second camera location, and TInitial is the arrival time of zone's first camera location.

Also, the total travel time from the beginning of the trip to a particular location can be determined as:

Total Travel Time = T2 – T1;

Where T2 is the arrival time of a particular location, and T1 is the departure time of a trip.

3.1 Experiment Procedure

The Don Valley Parkway has a total of 15 Closed Circuit Television (CCTV) camera poles mounted at various locations along the freeway. See figure 1 for camera location on the DVP. During each trip, a specific truck was selected to record arrival times at each camera. The location was then displayed on a monitor. Trucks were selected because they are easier to identify on the monitor. After gathering the arrival times at all locations, zone travel times and accumulated total travel times could be calculated.
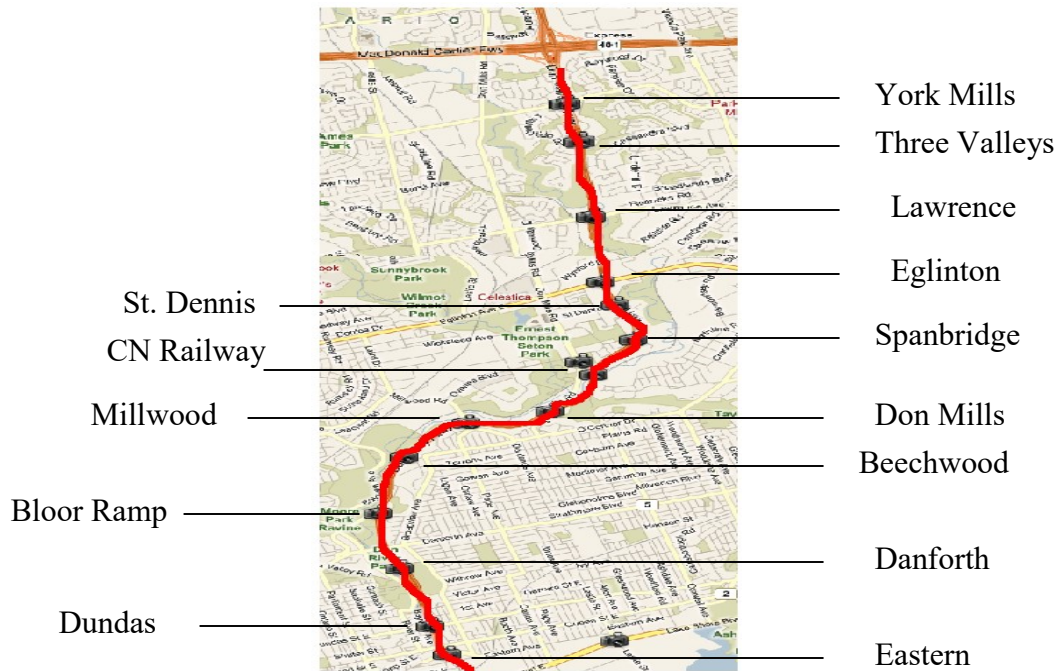
Figure 1. Camera Locations on DVP (Red)

3.2 Experiment Result

The experiment took two days from 6:00am to 10:00am on June 9 and 10, 2009 with distinct departure times. The weather conditions on both days were sunny. There was one incident that occurred southbound resulting in one lane closure. It was near Millwood starting around 7:45am until 8:45am on June 9. A sample of a complete trip data is shown below.

DVP Northbound June 10 2009					
Location/Intersection	Camera Number	Exact Location on Camera	Time (AM)	Zone Travel Time (Seconds)	Total Travel Time (Seconds)
Eastern Avenue	65	Bridge	9:16:32	-	-
Dundas Street	66	Bridge	9:16:58	26	26
Danforth Avenue	67	End Screen	9:17:49	51	77
Bloor Ramp	68	Off Ramp	9:18:47	58	135
Beechwood Drive	69	CMS	9:19:30	43	178
Millwood Road	70	Bridge	9:20:10	40	218
Don Mills Road	71	Bridge	9:20:49	39	257
CN Railway	73	End Screen	9:21:31	42	299
Spanbridge Road	74	Bridge	9:22:02	31	330
St. Dennis Drive	75	End Screen	9:22:27	25	355
Eglinton Avenue	76	On Ramp	9:23:04	37	392
CP Railway	77	On Ramp	9:24:29	85	477
Lawrence Avenue	78	Off Ramp	9:25:25	56	533
Three Valley	79	CMS	9:26:15	50	583
York Mills Avenue	80	Bridge	9:27:08	53	636

Table 1. Data for A Single Trip

The exact location indicates the time recorded when trucks passed through a particular spot. For each camera, an exact location was selected by the experimenter. All exact locations must be consistent in every trip experiment and cannot be changed to another location. Zone travel time represents the total time traveled from the previous camera's exact location to the current camera's exact location. Zone travel time is non-accumulative from the beginning of the trip. Total travel time is accumulated time calculated from the beginning of the trip to the current camera's exact location.

The above example was a truck travelling a complete trip (from Eastern Avenue to York Mills Avenue). In some cases, trucks could exit before reaching the end of the DVP. In this case, another truck starting at the location where the first truck existed was selected and monitored. An example is shown below

DVP Southbound - June 10, 2009					
Location/Intersection	Camera Number	Exact Location	Time (AM)	Zone Travel Time (Seconds)	Total Travel Time (Seconds)
York Mills Avenue	80	Bridge	7:16:26	-	-
Three Valley	79	CMS	7:17:36	70	70
Lawrence Avenue	78	Off Ramp	7:18:33	57	127
CP Railway	77	End Screen	7:20:12	39	166
Eglinton Avenue	76	Eglington Aveue	7:20:59	47	213
St. Dennis Drive	75	On Screen	7:21:26	27	240
Spanbridge Road	74	Bridge	7:21:48	22	262
CN Railway	73	On Screen	7:22:15	27	289
Don Mills Road	71	Bridge	7:22:57	42	331

DVP Southbound - June 10, 2009					
Location/Intersection	Camera Number	Exact Location	Time	Zone Travel Time (Seconds)	Total Travel Time (Seconds)
Don Mills Road	71	Bridge	7:27:27	-	-
Millwood Road	70	Bridge	7:28:30	63	63
Beechwood Drive	69	CMS	7:29:05	35	98
Bloor Ramp	68	Off Ramp	7:30:30	55	153
Danforth Avenue	67	On Screen	7:31:22	52	205
Dundas Avenue	66	Bridge	7:32:10	48	253
Eastern Avenue	65	Bridge	7:32:26	16	269

Table 2. Data in Non-complete Trips

The tables above are two non-completed trips with both TT calculated. Other non-completed trips with different origins and destinations were recorded. The total travel time starts at zero in the second table and does not accumulate from the first one.

The "ground truth" or actual data collection were used to compare with the TT prediction algorithm and the measurement methodology for evaluation and verification.

3.3 Experiment Errors and Further Improvement

There were numerous non-completed trips due to trucks exiting before reaching the final destination. In order to record TT with all complete trips, a truck or vehicle traveling beside the truck should be selected to continue for time recording until it reaches the final destination. There may be minor inaccuracy of recording the arrival times in the experiment. Arrival time may be recorded one or two seconds before or after a truck passing through the exact location.

4.0 Travel Time Prediction Algorithm

The goal was to forecast TT by calculating TT in each zone and the total travel time for each trip on the DVP northbound and southbound.

4.1 Algorithm Development

The mathematical formula used in this algorithm is

Travel Time = Distance / Average Speed;

There are two types of results to find in the algorithm, zone travel time and total travel time. To calculate the zone travel time, the distance of the zone and average speed within the zone were needed first. On the DVP, in zone n, the travel time would be

$T_n = S_n / V_n$;

T_n is the travel time in zone n, V_n is the average speed within zone n, S_n is the distance of zone n.

To calculate the total travel time at the final location of zone n with the starting trip at the initial location of zone number 1, the following formula was applied.

$$\sum_{i=1}^{n} (S_i / V_i);$$

S is the distance of the zone, V is the average speed in the zone and i is the current zone number. The Google Map Distance Calculator was used to estimate the zone distance (5). Vehicle Detector Station (VDS) detected the average vehicle speed for each 20 second interval. The average vehicle speed data can be found on the Transnomis website. Since there are only 11 VDS loops along each direction on the DVP, some of the zones share the same VDS. Each zone's average speed was identified from the VDS closest to the zone (particularly VDS closest

to the starting location of the zone). The time for each average speed was based on the arrival

time of trucks from the camera monitoring experiment. A sample data table of a trip's travel time

is shown below.

DVP Northbound Travel Time Comparison on June 9, 2009 @ 7:58:35 am									
Location	VDS ID	Distance (m)	Average Speed(m/s)	Travel Time(s)	Total Travel Time(s)	Actual Zone Travel Time(s)	Actual Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	18.61	-	-	-	-	-	-
Dundas	ds0020dnd	602	30.56	19.70	**19.70**	**25**	**25**	**-21.20**	**-21.20**
Danforth	ds0020dnd	1128	26.49	42.58	**62.28**	**44**	**69**	**-3.22**	**-9.74**
Bloor	ds0050dnd	1362	27.62	49.31	**111.59**	**51**	**120**	**-3.31**	**-7.01**
Beechwood	ds0050dnd	1177	25.44	46.27	**157.86**	**61**	**181**	**-24.15**	**-12.79**
Millwood	ds0050dnd	866	26.97	32.11	**189.97**	**15**	**196**	**114.07**	**-3.08**
Don Mills	ds0080dnd	1055	27.72	38.06	**228.03**	**39**	**235**	**-2.41**	**-2.97**
CN Railway	ds0080dnd	958	27.77	34.50	**262.53**	**41**	**276**	**-15.86**	**-4.88**
Spanbridge	dn0090dnd	838	28.09	29.83	**292.36**	**33**	**309**	**-9.60**	**-5.39**
St. Dennis	dn0100dnd	795	12.03	66.08	**358.44**	**39**	**348**	**69.45**	**3.00**
Eglinton	dn0110dnd	475	4.34	109.45	**467.89**	**107**	**455**	**2.29**	**2.83**
CP Rail	dn0115dnd	835	6.73	124.07	**591.96**	**176**	**631**	**-29.50**	**-6.19**
Lawrence	dn0130dnd	989	15.14	65.32	**657.28**	**69**	**700**	**-5.33**	**-6.10**
Three Valleys	dn0140dnd	1401	12.69	110.40	**767.69**	**64**	**764**	**72.50**	**0.48**
York Mills	dn0145dnd	724	19.44	37.24	**804.93**	**74**	**838**	**-49.67**	**-3.95**
							Average	**6.72**	**-5.50**

Table 3. Travel Time Comparison for a Complete Trip at DVP Northbound

4.2 Results

All the trips' departure times must coincide with the actual data to make an exact comparison.

For the table above, each row's arrival location represents the final location of each zone.

Dundas Street represents the final location of zone number 1 going northbound on DVP. The

VDS ID numbers were listed beside their respective zones, and the average vehicle speeds were

obtained from the VDS detectors with their specified ID numbers. Then, the zone TT and total

TT could be calculated with the distance and average speed parameters. Finally, the actual zone

TT and actual total TT data were listed beside the TT algorithm data. Please refer to the appendix

which contains all TT algorithm data tables on the DVP in both directions between 6am to 10am, June 9 and 10, 2009.

4.3 Evaluation

For the second last column, the zone TT percentage error was defined as

((actual zone TT – zone TT) / actual TT) * 100%;

For the last column, the total TT percentage error was defined as

((actual total TT – total TT) / actual total TT) * 100%;

The average zone percentage error and total percentage error in each trip were calculated and listed at the bottom right corner of the table. They are shown in four graphs (in two opposite directions and on two separate days) below.
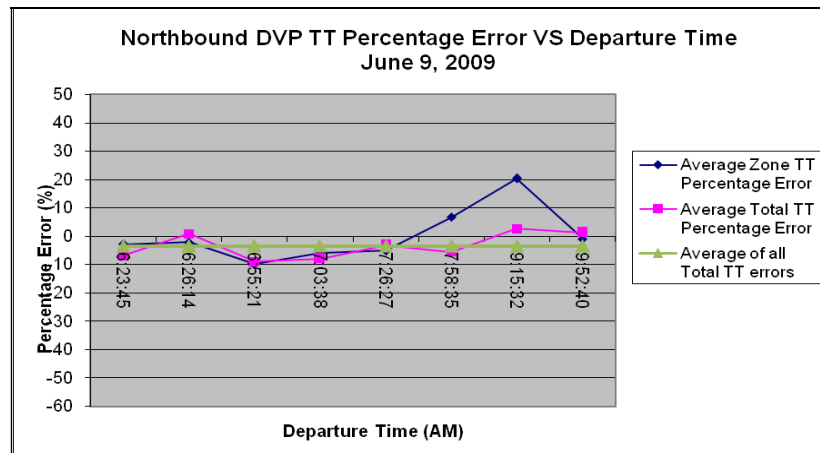
Figure 2. Average Zone and Total TT Percentage Errors for Each Trip

From the above graph, the lines appear in both positive and negative regions with the highest average zone TT percentage error, 20.39 % at departure time, 9:15:32am, and lowest average zone TT percentage error, -8.92 % at departure time, 6:55:21am. The highest average total TT percentage error is 2.6% at departure time, 9:15:32am, and lowest average total TT percentage error is -8.92% at departure time, 6:55:21am. Most of the two types of absolute average

percentage errors per trip are under 10% with 3 out of 8 trips' average total TT absolute average percentage errors under 5%. The average of all total TT error is a negative percentage, indicating that the actual TT is lower than predicted.
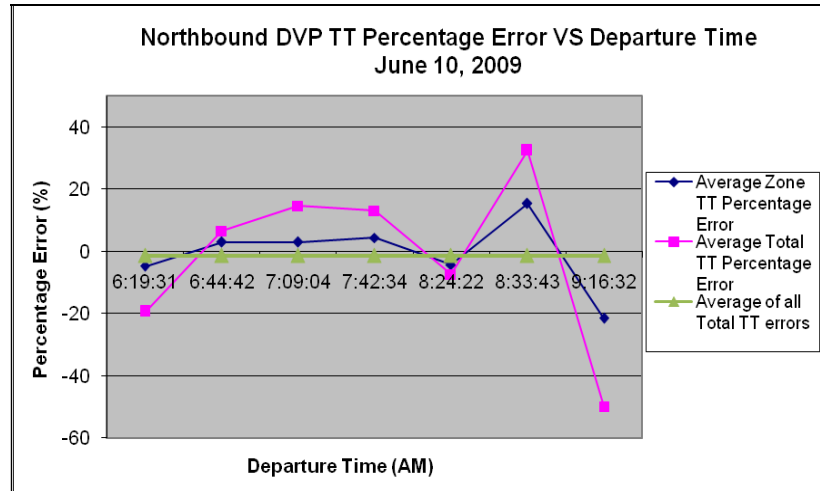
Figure 3. Average Zone and Total TT Percentage Errors for each trip

In the graph above, the amplitudes of the average total TT percentage errors are bigger, unlike the first graph. Trips at departure times 8:33:43am and 9:16:32am have bigger percentage errors in both positive and negative regions with the highest average zone TT percentage error, 15.42% and lowest, -21.61%. The highest average total TT percentage error is 32.5% and lowest is -49.93%.
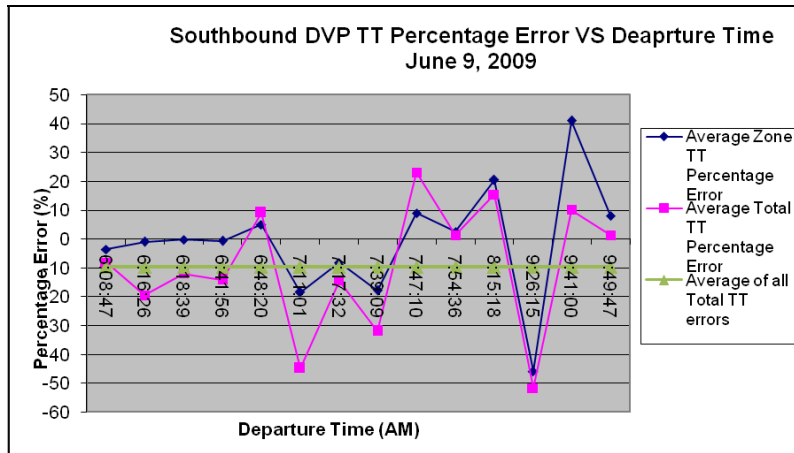
Figure 4. Average Zone and Total TT Percentage Errors for each trip

There seems to be more trips and departure times. Much of the TT data recorded was for non-complete trips. For trips departure at 6:08:47am to 6:48:20am, the absolute average percentage errors are low. For trips departure at 7:11:01am to 8:15:18am, the absolute average percentage errors are medium. Percentage errors are high for trips from 9:26:15am to 9:49:47am. The incident that happened at departure time 8:15:18am had medium impact on percentage errors; given the average zone TT percentage error is 20.43% and average total TT percentage error is 15.33%.
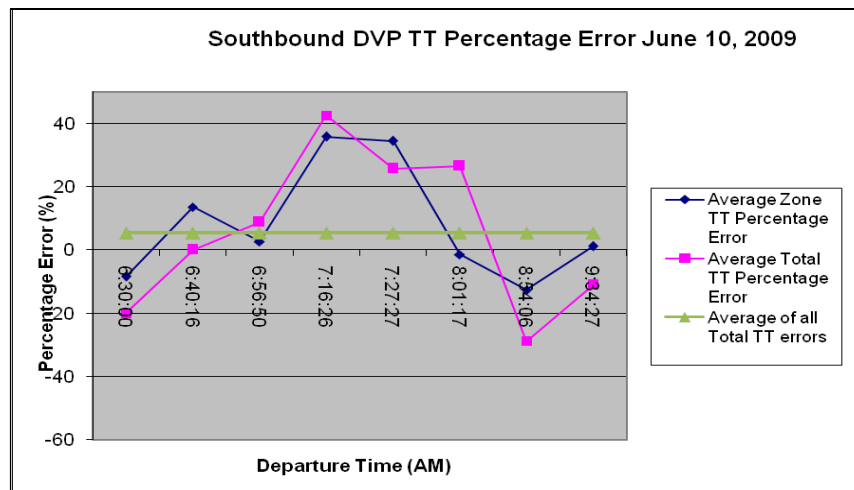
Figure 5. Zone and Total TT Percentage Errors for each trip

The highest percentage errors occur at departure time 7:16:26am to 8:01:17am.

In general, the absolute average percentage errors are low between departure times 6am to 7am. There are few exceptions with low absolute average percentage errors when trips start between 7am to 9:30am. The average zone TT percentage errors are slightly higher than the average total TT percentage errors due to shorter travel distance measured. Almost all the absolute percentage errors are below 40%. Most absolute percentage errors are below 10% with trips starting between 6am to 7am and 20% to 30% with trips starting between 7am to 9:30am. Overall, southbound DVP results have higher absolute average percentage errors than northbound DVP. Tables for the above four graphs are included in the appendix.

There are other comparison graphs between the TT algorithm data and actual data. Four graphs (each graph for one travel direction on one day) of absolute average zone and total TT percentage errors at each location are posted in the appendix. Also, four graphs of absolute total TT percentage errors at the final destination versus trip's departure time are shown in the appendix.

The overall trend for the other comparison graphs is no different than the first set of graphs (average percentage errors per trip). Low percentage errors exist between departure times 6am to 7am, with higher percentage errors from 7am to 9:30am due to higher traffic congestion (higher traffic volume). Also, the algorithm testing to predict TT seems accurate and reliable in less congested traffic and free-flowing traffic conditions, but inaccurate and unreliable during high congestion due to high percentage errors.

4.4 Further Improvement

In this algorithm, two parameters, zone distance and average vehicle speed are measured from Google Distance Calculator and Vehicle Detector Stations. Both measurements create possible errors and can affect final TT results. The exact spot on the camera could not be precisely measured on Google Distance Calculator website. The distance could be off by a few meters. Further improvement to obtain a precise measurement would be to measure the zone distance from one exact location to another using leading-edge technology (laser, computer software etc). The most inaccurate measurement in this algorithm is probably the average vehicle speed within each zone. Due to insufficient VDS coverage, some VDS only detected a portion of the zone's vehicle speed. This gave inaccurate average speeds which can affect the TT results. With more VDS deployed on DVP (preferably one VDS per each zone), the TT results should be more accurate with the "ground truth" data.

5.0 Travel Time Measurement using Bluetooth Technology

Bluetooth is a technology used to interconnect electronic devices such as cell phones, computer and radio wirelessly in short range (6). An example would be connecting wireless Bluetooth headset with a mobile phone.

A device called BluFax created by the Traffax Inc. is capable to detect mobile phones with Bluetooth signals on a freeway. The Bluetooth protocol uses a Media Access Control (MAC) address to identify Bluetooth device (7). The BluFax device is able to detect the MAC address of the Bluetooth signal on an electronic device (mobile phone for example) in a vehicle. Then, the time of arrival would be obtained and stored in a removable memory card. There is about one vehicle with Bluetooth signal in the mobile phone per 20 vehicles. A BluFax device can detect traffic on both directions of a freeway since the cover range of Bluetooth has a radius of 100 meters (8). The data would transfer to a Blustats Analysis Software which could perform graphical display for the data collected. By having two BluFax devices deploy at two locations on a freeway, the analysis software could statistically summarize the travel time between the two locations in five minute intervals (7). Pictures of the BluFax device are shown below.

Figure 6. Left: BluFax device exterior design
Figure 7. Right: BluFax device interior design

Photo Credit:
Photograph. Toronto. *Traffax Inc.* Web. 2009. <http://www.traffaxinc.com/content/products>.

Blufax is only able to identify MAC addresses, and MAC addresses are not associate with any user account or vehicle information (9). Thus, privacy concern is minimized compared to other methods of detecting traffic information such the camera monitoring and license plate matching.

5.1 Deployment and Measurement Procedure

The deployment of the device was convenient. It could be placed at the base of a sign post or guard rail, and it could be mounted on a pole. TPA North America Inc. used the BluFax device to collect traffic information 24 hours a day from June 8 to 11, 2009 on DVP between Beechwood Drive to York Mills Avenue. In the experiment, the BluFax devices were deployed at southbound Beechwood Drive, 1.75 meters above the roadway and on the road surface beside a pole at York Mills Avenue (9). Pictures are shown below.

Figure 8. Left: BluFax mounted 1.75 meters above roadway at Beechwood Drive
Figure 9. Right: BluFax mounted level with road at York Mills Avenue

Photo Credit
2009. Photograph. Don Valley Parkway, Toronto. *DVP Bluefax Report*. Toronto: TPA NA, 2009. 1-2. Print.

A portion of the raw data with MAC addresses and arrival times which the BluFax device detected at each location is displayed in the appendix.

5.2 Travel Time Calculation

All the Bluetooth signals IDs and arrival times are included in the raw data (input files) at both locations. An algorithm, coded in C# language, simply matched all the Bluetooth IDs from the two locations, and calculated their arrival time differences to obtain the TT. Finally, four output files were created with one file indicating one day in one trip direction. Each file includes the matched Bluetooth IDs and the TT. A sample of some of the trips' TT outputs and the programmed code are included in the appendix.

5.3 Results

The TT between 6am to 10am on June 9 and 10, 2009 are shown below.

DVP Northbound - June 9, 2009 (Beechwood to York Mills)		
Departure Time	Bluetooth ID	Bluetooth TT (s)
6:24:12	1D28536CC5	331
7:03:05	54F213729	700
7:49:05	2106E24E45	614
9:12:55	54F694D82	291
9:48:02	21D288DF07	273
DVP Northbound - June 10, 2009 (Beechwood to York Mills)		
Departure Time	Bluetooth ID	Bluetooth TT (s)
6:20:27	136CF5664F	329
6:47:36	1D2869356C	477
7:11:11	167443E9F5	705
7:43:05	54F593D8E	817
9:16:03	21864CA1CE	299
DVP Southbound - June 9, 2009 (York Mills to Beechwood)		
Departure Time	Bluetooth ID	Bluetooth TT (s)
8:15:26	E9F6C1CA1	1324
DVP Southbound - June 10, 2009 (York Mills to Beechwood)		
Departure Time	Bluetooth ID	Bluetooth TT (s)
6:30:00	213EE6FA9A	474
6:56:50	21FED0F048	848
8:01:17	F86D42663	783
8:54:06	23F1007C85	588
9:34:27	237A6BEA3D	331

Table 4. Sample TT data collected using Bluetooth signals

Notice the trip locations are between York Mills Avenue and Beechwood Drive. The trip's

departure time from Bluetooth signal may not be exactly the same as the departure time from the

actual data observed on cameras. However, the departure time is close enough for comparison.

5.4 Evaluation

The comparison tables between the TT measurement using camera monitoring and Bluetooth

signal as well as TT prediction algorithm data is displayed in the appendix. The total TT per each

trip obtained from Bluetooth signal measurement, TT prediction algorithm and camera monitoring measurement are displayed below in graphs.
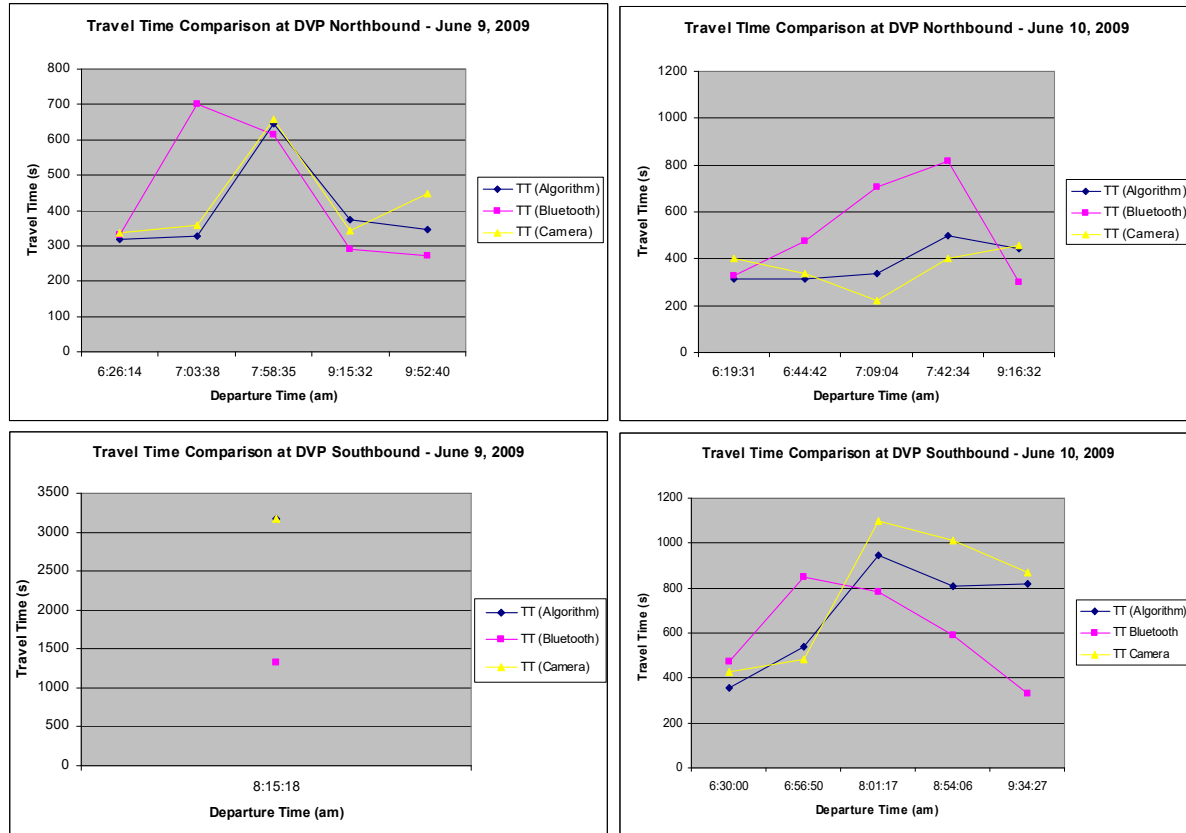
Figure 10. TT Measurements and Prediction Results Comparison

According to the graphs, most of the total TT collected from the BluFax device has significant differences between actual data and TT prediction algorithm. Trips with departure times before 7am have similar TT for all three data. TT measurement using Bluetooth and TT prediction algorithm absolute percentage errors in comparison with the actual data are displayed in table below.

DVP Northbound – June 9 2009 Departure Time	Algorithm Absolute Percentage Error (%)	Bluetooth Absolute Percentage Error (%)
6:26:14	5.55	1.78
7:03:38	8.81	94.99
7:58:35	1.51	6.54
9:15:32	9.26	15.16
9:52:40	22.48	39.06
Average	**9.52**	**31.51**
DVP Northbound – June 10 2009 Departure Time	Algorithm Absolute Percentage Error (%)	Bluetooth Absolute Percentage Error (%)
6:19:31	22.14	18.36
6:44:42	6.96	42.39
7:09:04	50.26	216.14
7:42:34	24.38	103.74
9:16:32	2.90	34.72
Average	**21.33**	**83.07**
DVP Southbound – June 9 2009 Departure Time	Algorithm Absolute Percentage Error (%)	Bluetooth Absolute Percentage Error (%)
8:15:18	0.09	58.25
Average	**0.09**	**58.25**
DVP Southbound – June 9 2009 Departure Time	Algorithm Absolute Percentage Error (%)	Bluetooth Absolute Percentage Error (%)
6:30:00	16.53	11.01
6:56:50	10.94	74.85
8:01:17	13.82	28.62
8:54:06	20.34	42.01
9:34:27	5.83	62.00
Average	**13.49**	**43.70**

Table 5. Absolute Percentage Errors Comparison

The highest absolute average percentage error per each trip from Bluetooth detection is 83.07%, and the algorithm has 21.33%. The lowest absolute average percentage error per each trip from Bluetooth detection is 31.51%, and the algorithm has 0.09%.

6.0 Conclusion

Based on the TT prediction algorithm and TT measurement methodology using the BluFax device, the algorithm predicted more accurate TT than measured by Bluetooth signals within the morning peak hours (6am – 10 am) on June 9 and 10, 2009. The absolute average percentage error for the algorithm prediction along northbound DVP on June 9 is 9.52%, and on June 10 is 21.33%, along southbound DVP on June 9 is 0.09%, and on June 10 is 13.49%. The absolute average percentage error for the Bluetooth signal measurement along northbound DVP on June 9 is 31.51%, and on June 10 is 83.07%, along southbound on June 9 is 58.25%, and on June 10 is 43.7%. Thus, the overall absolute average percentage error for the prediction algorithm is 11.11% and for the Bluetooth signal measurement is 54.13%.

Although Bluetooth-based TT measurement is a good idea, we are unable to validate this methodology in this experiment. The reason for the error is unknown.

For a further and more detailed evaluation of the TT prediction algorithm and Bluetooth measuring methodology, more data experiments could be carried out. More testing periods (especially during the afternoon-peak) and improvements to the experiment may be needed to allow for better understanding of the TT prediction and measurement strategies.

7.0 Recommendations

- Continue further experiments on TT prediction algorithm with more precise distance and average vehicle speed measurements.

- Conduct more TT experiment with Bluetooth signals to further evaluate the accuracy of the data.

- Identify new TT measurement and prediction methodologies.

- Evaluate the data from TT experiments to find the most accurate data and desirable outcome.

- The TT methodology with the most desirable outcome should be implemented, and the TT should be displayed on the CMS on the DVP.

Reference

(1) Foo, Simon, personal communication, June 8, 2009.

(2) Foo, Simon, personal communication, July 8, 2009.

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(4) *MANUAL FOR CO-OP STUDENTS*. Issue brief. Toronto: City of Toronto RESCU, Transportation Services, 2008. Print.

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Appendix A – Travel Time Prediction Algorithm

DVP Northbound Travel Time Comparison on June 9, 2009 @ 6:23:45 am

Location	VDS ID	Distance (m)	Average Speed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	28.96	0.00	**0.00**	0	0	0.00	0.00
Dundas	ds0020dnd	602	29.44	20.45	**20.45**	24	24	-14.80	-14.80
Danforth	ds0020dnd	1128	21.53	52.39	**72.84**	48	72	9.15	1.17
							Average	-2.82	-6.82

DVP Northbound Travel Time Comparison on June 9, 2009 @ 6:26:14 am

Location	VDS ID	Distance (m)	Average Speed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	28.33	0.00	**0.00**	0	0	0.00	0.00
Dundas	ds0020dnd	602	23.75	25.35	**25.35**	25	25	1.39	1.39
Danforth	ds0020dnd	1128	22.72	49.65	**75.00**	36	61	37.91	22.94
Bloor	ds0050dnd	1362	27.78	49.03	**124.02**	55	116	-10.86	6.92
Beechwood	ds0050dnd	1177	27.66	42.55	**166.58**	46	162	-7.49	2.82
Millwood	ds0050dnd	866	27.96	30.97	**197.55**	35	197	-11.51	0.28
Don Mills	ds0080dnd	1055	27.84	37.90	**235.44**	37	234	2.42	0.62
CN Railway	ds0080dnd	958	29.22	32.79	**268.23**	42	276	-21.94	-2.82
Spanbridge	dn0090dnd	838	29.05	28.85	**297.08**	28	304	3.02	-2.28
St. Dennis	dn0100dnd	795	30.14	26.38	**323.45**	25	329	5.51	-1.69
Eglinton	dn0110dnd	475	28.81	16.49	**339.94**	31	360	-46.82	-5.57
CP Rail	dn0115dnd	835	25.15	33.20	**373.14**	30	390	10.67	-4.32
Lawrence	dn0130dnd	989	29.03	34.07	**407.21**	30	420	13.56	-3.05
Three Valleys	dn0140dnd	1401	28.06	49.93	**457.14**	41	461	21.78	-0.84
York Mills	dn0145dnd	724	26.11	27.73	**484.87**	38	499	-27.03	-2.83
							Average	-2.10	0.83

DVP

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Northbound Travel Time Comparison on June 9, 2009 @ 6:55:21 am

Location	VDS ID	Distance (m)	Average Speed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	26.94	0.00	**0.00**	0	0	**0.00**	**0.00**
Dundas	ds0020dnd	602	28.19	21.36	**21.36**	23	23	**-7.15**	**-7.15**
Danforth	ds0020dnd	1128	29.31	38.49	**59.84**	44	67	**-12.53**	**-10.69**
							Average	**-9.84**	**-8.92**

DVP Northbound Travel Time Comparison on June 9, 2009 @ 7:03:38 am

Location	VDS ID	Distance (m)	Average Speed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Bloor	ds0050dnd	0	29.03	0	**0**	0	0	**0.00**	**0.00**
Beechwood	ds0050dnd	1177	30.66	38.39	**38.39**	40	40	**-4.03**	**-4.03**
Millwood	ds0050dnd	866	28.23	30.68	**69.07**	38	78	**-19.27**	**-11.45**
Don Mills	ds0080dnd	1055	31.4	33.60	**102.66**	33	111	**1.81**	**-7.51**
CN Railway	ds0080dnd	958	30.11	31.82	**134.48**	41	152	**-22.40**	**-11.53**
Spanbridge	dn0090dnd	838	26.7	31.39	**165.87**	28	180	**12.09**	**-7.85**
St. Dennis	dn0100dnd	795	27.66	28.74	**194.61**	25	205	**14.97**	**-5.07**
Eglinton	dn0110dnd	475	28.39	16.73	**211.34**	33	238	**-49.30**	**-11.20**
CP Rail	dn0115dnd	835	26.03	32.08	**243.42**	28	266	**14.57**	**-8.49**
Lawrence	dn0130dnd	989	26.91	36.75	**280.17**	30	296	**22.51**	**-5.35**
Three Valleys	dn0140dnd	1401	24.89	56.29	**336.46**	65	361	**-13.40**	**-6.80**
York Mills	dn0145dnd	724	24.72	29.29	**365.75**	38	399	**-22.93**	**-8.33**
							Average	**-5.94**	**-7.96**

DVP Northbound

Travel Time Comparison on June 9, 2009 @ 7:26:27 am

Location	VDS ID	Distance (m)	Average Speed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	18.61	0.00	**0.00**	**0**	**0**	**0.00**	**0.00**
Dundas	ds0020dnd	602	24.23	24.85	**24.85**	**27**	**27**	**-7.98**	**-7.98**
Danforth	ds0020dnd	1128	23.43	48.14	**72.99**	**47**	**74**	**2.43**	**-1.37**
Bloor	ds0050dnd	1362	25.51	53.39	**126.38**	**56**	**130**	**-4.66**	**-2.79**
Beechwood	ds0050dnd	1177	27.91	42.17	**168.55**	**43**	**173**	**-1.93**	**-2.57**
Millwood	ds0050dnd	866	28.55	30.33	**198.88**	**27**	**200**	**12.34**	**-0.56**
Don Mills	ds0080dnd	1055	26.29	40.13	**239.01**	**41**	**241**	**-2.12**	**-0.82**
CN Railway	ds0080dnd	958	28.53	33.58	**272.59**	**43**	**284**	**-21.91**	**-4.02**
Spanbridge	dn0090dnd	838	27.19	30.82	**303.41**	**32**	**316**	**-3.69**	**-3.98**
St. Dennis	dn0100dnd	795	28.21	28.18	**331.59**	**26**	**342**	**8.39**	**-3.04**
Eglinton	dn0110dnd	475	26.66	17.82	**349.41**	**26**	**368**	**-31.47**	**-5.05**
							Average	**-5.06**	**-3.22**

DVP Northbound Travel Time Comparison on June 9, 2009 @ 7:33:30 am

Location	VDS ID	Distance (m)	Average Speed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eglinton	dn0110dnd	0		0.00	**0.00**	**0**	**0**	**0.00**	**0.00**
CP Rail	dn0115dnd	835	25.94	32.19	**32.19**	**47**	**47**	**-31.51**	**-31.51**
Lawrence	dn0130dnd	989	12.95	76.37	**108.56**	**38**	**85**	**100.98**	**27.72**
Three Valleys	dn0140dnd	1401	20.42	68.61	**177.17**	**60**	**145**	**14.35**	**22.19**
York Mills	dn0145dnd	724	18.89	38.33	**215.50**	**54**	**199**	**-29.02**	**8.29**
							Average	**13.70**	**6.67**

DVP Northbound Travel

Time Comparison on June 9, 2009 @ 7:58:35 am

Location	VDS ID	Distance (m)	Average Speed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	18.61	0.00	**0.00**	**0**	**0**	**0.00**	**0.00**
Dundas	ds0020dnd	602	30.56	19.70	**19.70**	**25**	**25**	**-21.20**	**-21.20**
Danforth	ds0020dnd	1128	26.49	42.58	**62.28**	**44**	**69**	**-3.22**	**-9.74**
Bloor	ds0050dnd	1362	27.62	49.31	**111.59**	**51**	**120**	**-3.31**	**-7.01**
Beechwood	ds0050dnd	1177	25.44	46.27	**157.86**	**61**	**181**	**-24.15**	**-12.79**
Millwood	ds0050dnd	866	26.97	32.11	**189.97**	**15**	**196**	**114.07**	**-3.08**
Don Mills	ds0080dnd	1055	27.72	38.06	**228.03**	**39**	**235**	**-2.41**	**-2.97**
CN Railway	ds0080dnd	958	27.77	34.50	**262.53**	**41**	**276**	**-15.86**	**-4.88**
Spanbridge	dn0090dnd	838	28.09	29.83	**292.36**	**33**	**309**	**-9.60**	**-5.39**
St. Dennis	dn0100dnd	795	12.03	66.08	**358.44**	**39**	**348**	**69.45**	**3.00**
Eglinton	dn0110dnd	475	4.34	109.45	**467.89**	**107**	**455**	**2.29**	**2.83**
CP Rail	dn0115dnd	835	6.73	124.07	**591.96**	**176**	**631**	**-29.50**	**-6.19**
Lawrence	dn0130dnd	989	15.14	65.32	**657.28**	**69**	**700**	**-5.33**	**-6.10**
Three Valleys	dn0140dnd	1401	12.69	110.40	**767.69**	**64**	**764**	**72.50**	**0.48**
York Mills	dn0145dnd	724	19.44	37.24	**804.93**	**74**	**838**	**-49.67**	**-3.95**
							Average	6.72	-5.50

DVP Northbound Travel Time Comparison on June 9, 2009 @ 9:15:32 am

Location	VDS ID	Distance (m)	Average Speed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	26.39	0.00	**0.00**	**0**	**0**	**0.00**	**0.00**
Dundas	ds0020dnd	602	20.65	29.15	**29.15**	**24**	**24**	**21.47**	**21.47**
Danforth	ds0020dnd	1128	24.96	45.19	**74.34**	**47**	**71**	**-3.85**	**4.71**
Bloor	ds0050dnd	1362	28.28	48.16	**122.51**	**48**	**119**	**0.34**	**2.95**
Beechwood	ds0050dnd	1177	29.44	39.98	**162.49**	**39**	**158**	**2.51**	**2.84**
Millwood	ds0050dnd	866	26.06	33.23	**195.72**	**33**	**191**	**0.70**	**2.47**
Don Mills	ds0080dnd	1055	28.99	36.39	**232.11**	**38**	**229**	**-4.23**	**1.36**
CN Railway	ds0080dnd	958	29.2	32.81	**264.92**	**38**	**267**	**-13.66**	**-0.78**
Spanbridge	dn0090dnd	838	30.42	27.55	**292.46**	**57**	**324**	**-51.67**	**-9.73**
St. Dennis	dn0100dnd	795	26.71	29.76	**322.23**	**11**	**335**	**170.58**	**-3.81**
Eglinton	dn0110dnd	475	26.58	17.87	**340.10**	**13**	**348**	**37.47**	**-2.27**
CP Rail	dn0115dnd	835	26.17	31.91	**372.01**	**31**	**379**	**2.93**	**-1.85**
Lawrence	dn0130dnd	989	24.9	39.72	**411.72**	**21**	**400**	**89.14**	**2.93**
Three Valleys	dn0140dnd	1401	15.14	92.54	**504.26**	**63**	**463**	**46.88**	**8.91**
York Mills	dn0145dnd	724	21.94	33.00	**537.26**	**38**	**501**	**-13.16**	**7.24**
							Average	20.39	2.60

DVP Northbound Travel Time Comparison on June 9, 2009 @ 9:52:40 am

Location	VDS ID	Distance (m)	Average Speed	Travel Time (s)	Total Travel	Actual Travel	Total Travel	Zone TT	Total TT

			(m/s)		Time (s)	Time (s)	Time (s)	Error (%)	Error (%)
Eastern	ds0010dnr	0	29.81	0.00	**0.00**	**0**	**0**	0.00	0.00
Dundas	ds0020dnd	602	30.99	19.43	**19.43**	**22**	**22**	-11.70	-11.70
Danforth	ds0020dnd	1128	24.44	46.15	**65.58**	**46**	**68**	0.33	-3.56
Bloor	ds0050dnd	1362	25.11	54.24	**119.82**	**40**	**108**	35.60	10.95
Beechwood	ds0050dnd	1177	26.48	44.45	**164.27**	**40**	**148**	11.12	10.99
Millwood	ds0050dnd	866	26.07	33.22	**197.49**	**33**	**181**	0.66	9.11
Don Mills	ds0080dnd	1055	27.75	38.02	**235.51**	**39**	**220**	-2.52	7.05
CN Railway	ds0080dnd	958	28.27	33.89	**269.39**	**45**	**265**	-24.69	1.66
Spanbridge	dn0090dnd	838	26.39	31.75	**301.15**	**32**	**297**	-0.77	1.40
St. Dennis	dn0100dnd	795	28.81	27.59	**328.74**	**25**	**322**	10.38	2.09
Eglinton	dn0110dnd	475	27.62	17.20	**345.94**	**31**	**353**	-44.52	-2.00
CP Rail	dn0115dnd	835	25.86	32.29	**378.23**	**28**	**381**	15.32	-0.73
Lawrence	dn0130dnd	989	23.22	42.59	**420.82**	**29**	**410**	46.87	2.64
Three Valleys	dn0140dnd	1401	23.75	58.99	**479.81**	**46**	**456**	28.24	5.22
York Mills	dn0145dnd	724	22.81	31.74	**511.55**	**140**	**596**	-77.33	-14.17
							Average	-0.93	1.35

NorthBound DVP Travel Time Estimation-June 10 departuring @ 6:19:31 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)		Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	23.78	**0.00**	0.00	0	0	0.00	0.00
Dundas	ds0020dnd	602	29.44	**20.45**	20.45	25	25	-18.21	-18.21
Danforth	ds0020dnd	1128	28.52	**39.55**	60.00	52	77	-16.17	-22.08
Bloor	ds0050dnd	1362	26.94	**50.56**	110.56	60	137	-6.89	-19.30
Beechwood	ds0050dnd	1177	28.33	**41.55**	152.10	45	182	-1.90	-16.43
Millwood	ds0050dnd	866	27.83	**31.12**	183.22	41	223	-4.43	-17.84
Don Mills	ds0080dnd	1055	29.50	**35.76**	218.98	44	267	-3.09	-17.98
CN Railway	ds0080dnd	958	29.67	**32.29**	251.27	46	313	-4.38	-19.72
Spanbridge	dn0090dnd	838	29.44	**28.46**	279.74	35	348	-1.88	-19.62
St. Dennis	dn0100dnd	795	30.28	**26.25**	305.99	31	379	-1.25	-19.26
Eglinton	dn0110dnd	475	29.07	**16.34**	322.33	27	406	-2.63	-20.61
CP Rail	dn0115dnd	835	24.96	**33.45**	355.78	45	451	-2.56	-21.11
Lawrence	dn0130dnd	989	28.43	**34.79**	390.57	38	489	-0.66	-20.13
Three Valleys	dn0140dnd	1401	28.07	**49.91**	440.48	49	538	0.17	-18.13
York Mills	dn0145dnd	724	28.53	**25.38**	465.86	47	585	-3.70	-20.37
							Average	-4.83	-19.34

NorthBound DVP Travel Time Estimation-June 10 departuring @ 6:44:42 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)

Location	VDS ID #	Distance (m)	Average Speed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	22.99	0.00	0.00	0	0	0.00	0.00
Dundas	ds0020dnd	602	22.45	26.82	26.82	21	21	27.69	27.69
Danforth	ds0020dnd	1128	25.56	44.13	70.95	31	52	25.25	36.44
Bloor	ds0050dnd	1362	28.71	47.44	118.39	48	100	-0.56	18.39
Beechwood	ds0050dnd	1177	30.1	39.10	157.49	41	141	-1.35	11.69
Millwood	ds0050dnd	866	30.28	28.60	186.09	36	177	-4.18	5.14
Don Mills CN Railway	ds0080dnd	1055	30.12	35.03	221.12	39	216	-1.84	2.37
Spanbridge	ds0080dnd dn0090dnd	958	32.17	29.78	250.90	38	254	-3.24	-1.22
	dn0100dnd	838	28.61	29.29	280.19	29	283	0.10	-0.99
St. Dennis	dn0110dnd	795	27.25	29.17	309.36	24	307	1.69	0.77
Eglinton	dn0115dnd	475	31.28	15.19	324.55	20	327	-1.47	-0.75
CP Rail	dn0130dnd	835	27.42	30.45	355.00	40	367	-2.60	-3.27
Lawrence	dn0140dnd	989	27.94	35.40	390.39	34	401	0.35	-2.64
Three Valleys	dn0145dnd	1401	27.12	51.66	442.05	40	441	2.64	0.24
York Mills		724	26.68	27.14	469.19	35	476	-1.65	-1.43
							Average	2.92	6.60

NorthBound DVP Travel Time Estimation-June 10 departuring @ 7:09:04 am

Location	VDS ID #	Distance (m)	Average Speed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	22.5	0.00	0.00	0	0	0.00	0.00
Dundas	ds0020dnd	602	23.72	25.38	25.38	27	27	-6.00	-6.00
Danforth	ds0020dnd	1128	24.33	46.36	71.74	44	71	3.33	1.04
Bloor	ds0050dnd	1362	27.59	49.37	121.11	48	119	1.15	1.77
Beechwood	ds0050dnd	1177	26.3	44.75	165.86	41	160	2.35	3.66
Millwood	ds0050dnd	866	26.3	32.93	198.79	27	187	3.17	6.30
Don Mills CN Railway	ds0080dnd	1055	28.77	36.67	235.46	23	210	6.51	12.12
Spanbridge	ds0080dnd dn0090dnd	958	30.35	31.57	267.02	22	232	4.12	15.10
	dn0100dnd	838	27.23	30.77	297.80	16	248	5.96	20.08
St. Dennis	dn0110dnd	795	29.11	27.31	325.11	16	264	4.28	23.15
Eglinton	dn0115dnd	475	27.87	17.04	342.15	23	287	-2.08	19.22
CP Rail	dn0130dnd	835	26.51	31.50	373.65	23	310	2.74	20.53
Lawrence	dn0140dnd	989	27.12	36.47	410.12	21	331	4.67	23.90
Three Valleys	dn0145dnd	1401	23.73	59.04	469.16	23	354	10.18	32.53
York Mills		724	22.78	31.78	500.94	29	383	0.73	30.79
							Average	2.94	14.59

NorthBound DVP Travel Time Estimation-June 10

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departuring @ 7:42:34 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	23.06	0.00	0.00	0	0	0.00	0.00
Dundas	ds0020dnd	602	22.69	26.53	26.53	21	21	26.34	26.34
Danforth	ds0020dnd	1128	21.53	52.39	78.92	45	66	11.20	19.58
Bloor	ds0050dnd	1362	26.69	51.03	129.95	54	120	-2.47	8.29
Beechwood	ds0050dnd	1177	27.03	43.54	173.50	43	163	0.33	6.44
Millwood	ds0050dnd	866	26.62	32.53	206.03	33	196	-0.24	5.12
Don Mills	ds0080dnd	1055	27.03	39.03	245.06	41	237	-0.83	3.40
CN Railway	ds0080dnd	958	28.25	33.91	278.97	41	278	-2.55	0.35
Spanbridge	dn0090dnd	838	27.23	30.77	309.75	30	308	0.25	0.57
St. Dennis	dn0100dnd	795	13.28	59.86	369.61	28	336	9.48	10.00
Eglinton	dn0110dnd	475	14.06	33.78	403.40	38	374	-1.13	7.86
CP Rail	dn0115dnd	835	9	92.78	496.17	20	394	18.47	25.93
Lawrence	dn0130dnd	989	16.01	61.77	557.95	50	444	2.65	25.66
Three Valleys	dn0140dnd	1401	21.12	66.34	624.28	56	500	2.07	24.86
York Mills	dn0145dnd	724	15.09	47.98	672.26	64	564	-2.84	19.20
							Average	4.34	13.11

NorthBound DVP Travel Time Estimation-June 10 departuring @ 8:24:22 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	23.33	0.00	0.00	0	0	0.00	0.00
Dundas	ds0020dnd	602	30	20.07	20.07	25	25	-19.73	-19.73
Danforth	ds0020dnd	1128	23.42	48.16	68.23	46	71	3.05	-3.90
Bloor	ds0050dnd	1362	27.32	49.85	118.08	52	123	-1.75	-4.00
Beechwood	ds0050dnd	1177	28.36	41.50	159.59	40	163	0.92	-2.09
							Average	-4.38	-7.43

NorthBound DVP Travel Time Estimation-June 10 departuri

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Beechwood	ds0050dnd	0	27.76	**0.00**	**0.00**	**0**	**0**	**0.00**	**0.00**
Millwood	ds0050dnd	866	27	**32.07**	**32.07**	**31**	**31**	**3.46**	**3.46**
Don Mills CN	ds0080dnd	1055	13.1	**80.53**	**112.61**	**40**	**71**	**57.09**	**58.60**
Railway	ds0080dnd dn0090dnd	958	28.87	**33.18**	**145.79**	**37**	**108**	**-3.53**	**34.99**
Spanbridge e	dn0100dnd	838	7.78	**107.71**	**253.50**	**81**	**189**	**14.13**	**34.13**
St. Dennis	d	795	9.93	**80.06**	**333.56**	**65**	**254**	**5.93**	**31.32**
							Average	**15.42**	**32.50**

NorthBound DVP Travel Time Estimation-June 10 departuring @ 8:43:06 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
St. Dennis	dn0100dnd	0		**0.00**	**0.00**	**0**	**0**	**0.00**	**0.00**
Eglinton	dn0110dnd	475	9.91	**47.93**	**47.93**	**105**	**105**	**-54.35**	**-54.35**
CP Rail	dn0115dnd	835	10.17	**82.10**	**130.04**	**211**	**316**	**-40.79**	**-58.85**
Lawrence	dn0130dnd	989	15.69	**63.03**	**193.07**	**127**	**443**	**-14.44**	**-56.42**
Three Valleys	dn0140dnd	1401	10.5	**133.43**	**326.50**	**104**	**547**	**5.38**	**-40.31**
York Mills	dn0145dnd	724	16.39	**44.17**	**370.67**	**68**	**615**	**-3.87**	**-39.73**
							Average	**-21.61**	**-49.93**

NorthBound DVP Travel Time Estimation-June 10 departuring @ 9:16:32 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eastern	ds0010dnr	0	24.08	**0.00**	**0.00**	**0**	**0**	**0.00**	**0.00**
Dundas	ds0020dnd	602	22.92	**26.27**	**26.27**	**26**	**26**	**1.02**	**1.02**

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Danforth	ds0020dnd	1128	22.92	49.21	75.48	51	77	-2.32	-1.97
Bloor	ds0050dnd	1362	26.94	50.56	126.04	58	135	-5.51	-6.64
Beechwood	ds0050dnd	1177	25.59	45.99	172.03	43	178	1.68	-3.35
Millwood	ds0050dnd	866	28.92	29.94	201.98	40	218	-4.61	-7.35
Don Mills CN	ds0080dnd	1055	27.96	37.73	239.71	39	257	-0.49	-6.73
Railway	ds0080dnd	958	27.5	34.84	274.54	42	299	-2.40	-8.18
Spanbridge	dn0090dnd	838	26.51	31.61	306.16	31	330	0.19	-7.23
St. Dennis	dn0100dnd	795	26.73	29.74	335.90	25	355	1.34	-5.38
Eglinton	dn0110dnd	475	11.09	42.83	378.73	37	392	1.49	-3.39
CP Rail	dn0115dnd	835	12.5	66.80	445.53	85	477	-3.82	-6.60
Lawrence	dn0130dnd	989	15.42	64.14	509.67	56	533	1.53	-4.38
Three Valleys	dn0140dnd	1401	19.76	70.90	580.57	50	583	3.59	-0.42
York Mills	dn0145dnd	724	20	36.20	616.77	53	636	-2.64	-3.02
Average								-0.78	-4.54

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
York Mills	dn0145dsd	0	30.56	0.00	0.00	0	0	0.00	0.00
Three Valleys	dn0140dsd	724	30.28	23.91	23.91	40	40	-40.22	-40.22
Lawrence	dn0130dsd	1401	27.78	50.43	74.34	42	82	10.28	-9.34
CP Rail	dn0120dsd	989	26.39	37.48	111.82	25	107	11.66	4.50
Eglinton	dn0110dsd	835	27.77	30.07	141.89	36	143	-4.15	-0.78
St. Dennis	dn0100dsd	475	27.39	17.34	159.23	24	167	-3.99	-4.65
Spanbridge	dn0095dsd	795	27.91	28.48	187.71	19	186	5.10	0.92
Average								-3.55	-8.26

Southbound DVP Travel Time Estimation - June 9
Departuring @ 6:16:26 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
York Mills	dn0145dsd	0	24.14	0.00	0.00	0	0	0.00	0.00
Three Valleys	dn0140dsd	724	25.83	28.03	28.03	44	44	-36.30	-36.30
Lawrence	dn0130dsd	1401	26.06	53.76	81.79	40	84	34.40	-2.63
Average								-0.95	-19.46

Southbound DVP Travel Time Estimation - June 9
Departuring @ 6:18:39 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
York Mills	dn0145dsd	0	22.02	0.00	0.00	0	0	0.00	0.00
Three	dn0140dsd	724	22.78	31.78	31.78	45	45	-29.37	-29.37

Valleys

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Lawrence	dn0130dsd	1401	22.77	61.53	**93.31**	63	108	**-2.34**	**-13.60**
CP Rail	dn0120dsd	989	23.14	42.74	**136.05**	29	137	**47.38**	**-0.69**
Eglinton	dn0110dsd	835	22.77	36.67	**172.72**	44	181	**-16.66**	**-4.57**
							Average	**-0.25**	**-12.06**

Southbound DVP Travel Time Estimation - June 9
Departuring @ 6:41:56 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
York Mills	dn0145dsd	0	16.49	0.00	**0.00**	0	0	**0.00**	**0.00**
Three Valleys	dn0140dsd	724	16.67	43.43	**43.43**	54	54	**-19.57**	**-19.57**
Lawrence	dn0130dsd	1401	22.39	62.57	**106.00**	75	129	**-16.57**	**-17.83**
CP Rail	dn0120dsd	989	19.26	51.35	**157.35**	46	175	**11.63**	**-10.08**
Eglinton	dn0110dsd	835	25.13	33.23	**190.58**	60	235	**-44.62**	**-18.90**
St. Dennis	dn0100dsd	475	24.06	19.74	**210.32**	20	255	**-1.29**	**-17.52**
Spanbridge CN	dn0095dsd	795	26.45	30.06	**240.38**	22	277	**36.62**	**-13.22**
Railway	dn0090dsd	838	18.61	45.03	**285.41**	29	306	**55.27**	**-6.73**
Don Mills	ds0080dsd	958	25.89	37.00	**322.41**	51	357	**-27.45**	**-9.69**
							Average	**-0.75**	**-14.19**

Southbound DVP Travel Time Estimation - June 9
Departuring @ 6:48:20 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Don Mills	ds0080dsd	0		0.00	**0.00**	0	0	**0.00**	**0.00**
Millwood	ds0080dsd	1055	25.13	41.98	**41.98**	36	36	**16.62**	**16.62**
Beechwood	ds0080dsd	866	24.78	34.95	**76.93**	32	68	**9.21**	**13.13**
Bloor	ds0050dsd	1177	27.14	43.37	**120.30**	42	110	**3.26**	**9.36**
Danforth	ds0050dsd	1362	25.51	53.39	**173.69**	54	164	**-1.13**	**5.91**
Dundas	ds0020dsd	1128	25.83	43.67	**217.36**	43	207	**1.56**	**5.00**
Eastern	ds0020dsd	602	23.89	25.20	**242.56**	25	232	**0.80**	**4.55**
							Average	**5.05**	**9.09**

Southbound DVP Travel Time Estimation - June 9
Departuring @ 7:11:01 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
York Mills	dn0145dsd	0	8.89	0.00	**0.00**	0	0	**0.00**	**0.00**
Three Valleys	dn0140dsd	724	17.5	41.37	**41.37**	145	145	**-71.47**	**-71.47**

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Lawrence	dn0130dsd	1401	15.67	89.41	130.78	83	228	7.72	-42.64
CP Rail	dn0120dsd	989	18.78	52.66	183.44	47	275	12.05	-33.29
Eglinton	dn0110dsd	835	23.29	35.85	219.29	46	321	-22.06	-31.68
							Average	-18.44	-44.77

Southbound DVP Travel Time Estimation - June 9
Departuring @ 7:17:32 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eglinton	dn0110dsd	0		0.00	0.00	0	0	0.00	0.00
St. Dennis	dn0100dsd	475	23.01	20.64	20.64	33	33	-37.44	-37.44
Spanbridge CN	dn0095dsd	795	25.6	31.05	51.70	28	61	10.91	-15.25
Railway	dn0090dsd	838	27.5	30.47	82.17	36	97	-15.35	-15.29
Don Mills	ds0080dsd	958	25.58	37.45	119.62	39	136	-3.97	-12.04
Millwood	ds0080dsd	1055	24.24	43.52	163.14	47	183	-7.40	-10.85
Beechwood	ds0080dsd	866	25.2	34.37	197.51	46	229	-25.29	-13.75
Bloor	ds0050dsd	1177	24.93	47.21	244.72	49	278	-3.65	-11.97
Danforth	ds0050dsd	1362	25.58	53.24	297.97	56	334	-4.92	-10.79
Dundas	ds0020dsd	1128	23.89	47.22	345.18	43	377	9.81	-8.44
Eastern	ds0020dsd	602	26.39	22.81	367.99	24	401	-4.95	-8.23
							Average	-8.23	-14.41

Southbound DVP Travel Time Estimation - June 9
Departuring @ 7:39:09 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
York Mills	dn0145dsd	0	10.24	0.00	0.00	0	0	0.00	0.00
Three Valleys	dn0140dsd	724	16.67	43.43	43.43	99	99	-56.13	-56.13
Lawrence	dn0130dsd	1401	14.57	96.16	139.59	107	206	-10.13	-32.24
CP Rail	dn0120dsd	989	17.97	55.04	194.62	53	259	3.84	-24.86
Eglinton	dn0110dsd	835	23.94	34.88	229.50	41	300	-14.93	-23.50
St. Dennis	dn0100dsd	475	21.56	22.03	251.53	25	325	-11.87	-22.60
							Average	-17.85	-31.87

Southbound DVP Travel Time Estimation - June 9
Departuring @ 7:47:10 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
St. Dennis	dn0100dsd	475		0.00	0.00	0	0	0.00	0.00
Spanbridge CN	dn0095dsd	795	9.39	84.66	84.66	38	38	122.80	122.80
Railway	dn0090dsd	838	23.89	35.08	119.74	51	89	-31.22	34.54

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Don Mills	ds0080dsd	958	14.12	67.85	**187.59**	109	198	-37.76	-5.26
Millwood	ds0080dsd	1055	11.64	90.64	**278.22**	99	297	-8.45	-6.32
Beechwood	ds0080dsd	866	14.93	58.00	**336.23**	56	353	3.58	-4.75
Bloor	ds0050dsd	1177	27.14	43.37	**379.60**	38	391	14.13	-2.92
							Average	9.01	23.02

Southbound DVP Travel Time Estimation - June 9
Departuring @ 7:54:36 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Bloor	ds0050dsd	1177		0.00	**0.00**	0	0	0.00	0.00
Danforth	ds0050dsd	1362	25.67	53.06	**53.06**	53	53	0.11	0.11
Dundas	ds0020dsd	1128	25.28	44.62	**97.68**	43	96	3.77	1.75
Eastern	ds0020dsd	602	24.17	24.91	**122.59**	24	120	3.78	2.15
							Average	2.55	1.34

Southbound DVP Travel Time Estimation - June 9
Departuring @ 8:15:18 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
York Mills	dn0145dsd	0	9.17	0.00	**0.00**	0	0	0.00	0.00
Three Valleys	dn0140dsd	724	1.67	433.53	**433.53**	140	140	209.67	209.67
Lawrence	dn0130dsd	1401	3.61	388.09	**821.62**	472	612	-17.78	34.25
CP Rail	dn0120dsd	989	4.16	237.74	**1059.36**	295	907	-19.41	16.80
Eglinton	dn0110dsd	835	2.5	334.00	**1393.36**	603	1510	-44.61	-7.72
St. Dennis	dn0100dsd	475	3.33	142.64	**1536.00**	231	1741	-38.25	-11.77
Spanbridge	dn0095dsd	795	2.78	285.97	**1821.98**	232	1973	23.26	-7.65
CN Railway	dn0090dsd	838	2.5	335.20	**2157.18**	269	2242	24.61	-3.78
Don Mills	ds0080dsd	958	2.5	383.20	**2540.38**	438	2680	-12.51	-5.21
Millwood	ds0080dsd	1055	4.44	237.61	**2777.99**	357	3037	-33.44	-8.53
Beechwood	ds0080dsd	866	2.22	390.09	**3168.08**	134	3171	191.11	-0.09
Bloor	ds0050dsd	1177	27.54	42.74	**3210.82**	57	3228	-25.02	-0.53
Danforth	ds0050dsd	1362	27.78	49.03	**3259.84**	43	3271	14.02	-0.34
Dundas	ds0020dsd	1128	24.72	45.63	**3305.48**	44	3315	3.71	-0.29
Eastern	ds0020dsd	602	24.72	24.35	**3329.83**	22	3337	10.69	-0.21
							Average	20.43	15.33

Southbound DVP Travel Time Estimation - June 9
Departuring @ 9:26:15 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
York Mills	dn0145dsd	0	3.33	0.00	**0.00**	0	0	0.00	0.00
Three Valleys	dn0140dsd	724	4.44	163.06	**163.06**	390	390	-58.19	-58.19
Lawrence	dn0130dsd	1401	6.71	208.79	**371.86**	354	744	-41.02	-50.02
CP Rail	dn0120dsd	989	26.18	37.78	**409.63**	68	812	-44.45	-49.55

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eglinton	dn0110dsd	835	26.71	31.26	**440.89**	**52**	**864**	**-39.88**	**-48.97**
							Average	**-45.88**	**-51.68**

Southbound DVP Travel Time Estimation - June 9
Departuring @ 9:41:00 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Eglinton	dn0110dsd	835		0.00	**0.00**	**0**	**0**	**0.00**	**0.00**
St. Dennis	dn0100dsd	475	29.76	15.96	**15.96**	**89**	**89**	**-82.07**	**-82.07**
Spanbridge CN	dn0095dsd	795	16.09	49.41	**65.37**	**24**	**113**	**105.87**	**-42.15**
Railway	dn0090dsd	838	3.89	215.42	**280.79**	**52**	**165**	**314.28**	**70.18**
Don Mills	ds0080dsd	958	15.9	60.25	**341.05**	**66**	**231**	**-8.71**	**47.64**
Millwood	ds0080dsd	1055	13.18	80.05	**421.09**	**85**	**316**	**-5.83**	**33.26**
Beechwood	ds0080dsd	866	11.9	72.77	**493.86**	**67**	**383**	**8.62**	**28.95**
Bloor	ds0050dsd	1177	23.94	49.16	**543.03**	**90**	**473**	**-45.37**	**14.81**
							Average	**40.97**	**10.09**

Southbound DVP Travel Time Estimation - June 9
Departuring @ 9:49:47 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Error (%)	Total TT Error (%)
Bloor	ds0050dsd	1177	0	0.00	**0.00**	**0**	**0**	**0.00**	**0.00**
Danforth	ds0050dsd	1362	23.09	58.99	**58.99**	**54**	**54**	**9.23**	**9.23**
Dundas	ds0020dsd	1128	26.11	43.20	**102.19**	**49**	**103**	**11.83**	**-0.79**
Eastern	ds0020dsd	602	22.5	26.76	**128.94**	**30**	**133**	**10.81**	**-3.05**
							Average	**7.97**	**1.35**

Southbound DVP Travel Time Estimation - June 10 Departuring
@ 6:30:00 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Absolute Error (%)	Total TT Absolute Error (%)
York Mills Three	dn0145dsd	0	5.09	0.00	**0.00**	**0**	**0**	**0.00**	**0.00**
Valleys	dn0140dsd	724	21.67	**33.41**	**33.41**	**75**	**75**	**-55.45**	**-55.45**
Lawrence	dn0130dsd	1401	24.51	**57.16**	**90.57**	**43**	**118**	**32.93**	**-23.25**

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Absolute Error (%)	Total TT Absolute Error (%)
CP Rail	dn0120dsd	989	22.47	44.01	134.58	51	169	-13.70	-20.36
Eglinton	dn0110dsd	835	24.29	34.38	168.96	44	213	-21.87	-20.68
St. Dennis	dn0100dsd	475	25.37	18.72	187.68	30	243	-37.59	-22.76
Spanbridge CN	dn0095dsd	795	26.57	29.92	217.60	24	267	24.67	-18.50
Railway	dn0090dsd	838	12.36	67.80	285.40	32	299	111.87	-4.55
Don Mills	ds0080dsd	958	25.85	37.06	322.46	41	340	-9.61	-5.16
Millwood	ds0080dsd	55	28.03	1.96	324.43	49	389	-96.00	-16.60
Beechwood	ds0080dsd	866	27.06	32.00	356.43	38	427	-15.78	-16.53
Bloor	ds0050dsd	1177	26.84	43.85	400.28	50	477	-12.30	-16.08
							Average	-8.44	-19.99

Southbound DVP Travel Time Estimation - June 10 Departuring @ 6:40:16 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Absolute Error (%)	Total TT Absolute Error (%)
Bloor	ds0050dsd	1177	0	0.00	0.00	0	0	0.00	0.00
Danforth	ds0050dsd	1362	26.99	50.46	50.46	52	52	-2.96	-2.96
Dundas	ds0020dsd	1128	26.94	41.87	92.33	42	94	-0.31	-1.77
Eastern	ds0020dsd	602	26.11	23.06	115.39	16	110	44.10	4.90
							Average	13.61	0.06

Southbound DVP Travel Time Estimation - June 10 Departuring @ 6:56:50 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Absolute Error (%)	Total TT Absolute Error (%)
York Mills Three	dn0145dsd	0	17.12	0.00	0.00	0	0	0.00	0.00
Valleys	dn0140dsd	724	14.17	51.09	51.09	102	102	-49.91	-49.91
Lawrence	dn0130dsd	1401	7.78	180.08	231.17	62	164	190.45	40.96
CP Rail	dn0120dsd	989	19.44	50.87	282.05	74	238	-31.25	18.51
Eglinton	dn0110dsd	835	23.17	36.04	318.08	46	284	-21.66	12.00
St. Dennis	dn0100dsd	475	25	19.00	337.08	28	312	-32.14	8.04
Spanbridge CN	dn0095dsd	795	25.78	30.84	367.92				
Railway	dn0090dsd	838	14.17	59.14	427.06				
Don Mills	ds0080dsd	958	25.8	37.13	464.19		400		16.05
Millwood	ds0080dsd	1055	26.79	39.38	503.57	47	447	-16.21	12.66
Beechwood	ds0080dsd	866	25.12	34.47	538.05	38	485	-9.28	10.94
Bloor	ds0050dsd	1177	26.71	44.07	582.11	45	530	-2.08	9.83
Danforth	ds0050dsd	1362	25.08	54.31	636.42	50	580	8.61	9.73
Dundas	ds0020dsd	1128	25.83	43.67	680.09	45	625	-2.96	8.81
Eastern	ds0020dsd	602	26.11	23.06	703.15	24	649	-3.93	8.34
							Average	2.70	8.83

Southbound DVP Travel Time Estimation - June 10 Departuring @ 7:16:26 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Absolute Error (%)	Total TT Absolute Error (%)

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Absolute Error (%)	Total TT Absolute Error (%)
York Mills	dn0145dsd	0	18.33	0.00	0.00	0	0	0.00	0.00
Three Valleys	dn0140dsd	724	6.11	118.49	118.49	70	70	69.28	69.28
Lawrence	dn0130dsd	1401	10.28	136.28	254.78	57	127	139.09	100.61
CP Rail	dn0120dsd	989	17.5	56.51	311.29	99	226	-42.91	37.74
Eglinton	dn0110dsd	835	23.49	35.55	346.84	47	273	-24.37	27.05
St. Dennis	dn0100dsd	475	23.95	19.83	366.67	27	300	-26.54	22.22
Spanbridge	dn0095dsd	795	26.76	29.71	396.38	22	322	35.04	23.10
CN Railway	dn0090dsd	838	13.33	62.87	459.25	27	349	132.84	31.59
Don Mills	ds0080dsd	958	21.96	43.62	502.87	42	391	3.87	28.61
							Average	35.79	42.53

Southbound DVP Travel Time Estimation - June 10 Departuring @ 7:27:27 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Absolute Error (%)	Total TT Absolute Error (%)
Don Mills	ds0080dsd	958		0	0	0	0	0.00	0.00
Millwood	ds0080dsd	1055	11.11	94.96	94.96	63	63	50.73	50.73
Beechwood	ds0080dsd	866	16.04	53.99	148.95	120	183	55.01	18.61
Bloor	ds0050dsd	1177	24.74	47.57	196.52	85	268	44.03	26.67
Danforth	ds0050dsd	1362	24.44	55.73	252.25	52	320	7.17	21.17
Dundas	ds0020dsd	1128	26.11	43.20	295.45	48	368	10.00	19.71
Eastern	ds0020dsd	602	26.94	22.35	317.80	16	384	39.66	17.24
							Average	34.43	25.69

Southbound DVP Travel Time Estimation - June 10 Departuring @ 8:01:17 am

| Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Absolute Error (%)	Total TT Absolute Error (%)
York Mills	dn0145dsd	0	6.25	0.00	0.00	0	0	0.00	0.00
Three Valleys	dn0140dsd	724	12.5	57.92	57.92	149	149	-61.13	61.13
Lawrence	dn0130dsd	1401	10	140.10	198.02	161	310	-12.98	36.12
CP Rail	dn0120dsd	989	17.22	57.43	255.45	193	503	-70.24	49.21
Eglinton	dn0110dsd	835	5	167.00	422.45	85	588	96.47	28.15
St. Dennis	dn0100dsd	475	7.36	64.54	486.99	119	707	-45.77	31.12
Spanbridge	dn0095dsd	795	12.27	64.79	551.78	76	783	-14.75	29.53
CN Railway	dn0090dsd	838	11.94	70.18	621.97	78	861	-10.02	27.76
Don Mills	ds0080dsd	958	8.61	111.27	733.23	83	944	34.06	22.33
Millwood	ds0080dsd	1055	10.98	96.08	829.32	89	1033	7.96	19.72
Beechwood	ds0080dsd	866	7.46	116.09	945.40	64	1097	81.38	13.82
Bloor	ds0050dsd	1177	22.79	51.65	997.05	55	1152	-6.10	13.45
Danforth	ds0050dsd	1362	24.99	54.50	1051.55	61	1213	-10.65	13.31
Dundas	ds0020dsd	1128	24.72	45.63	1097.18	46	1259	-0.80	12.85
Eastern	ds0020dsd	602	25.83	23.31	1120.49	25	1284	-6.78	12.73
							Average	-1.38	26.52

Southbound DVP Travel Time Estimation - June 10 Departuring @ 8:54:06 am

| Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Absolute Error (%)	Total TT Absolute Error (%)
York Mills	dn0145dsd	0	3.61	0.00	0.00	0	0	0.00	0.00
Three Valleys	dn0140dsd	724	10	72.40	72.40	200	200	-63.80	-63.80
Lawrence	dn0130dsd	1401	11.72	119.54	191.94	158	358	-24.34	-46.39
CP Rail	dn0120dsd	989	17.22	57.43	249.37	86	444	-33.22	-43.84
Eglinton	dn0110dsd	835	5.56	150.18	399.55	85	529	76.68	-24.47
St. Dennis	dn0100dsd	475	11.12	42.72	442.27	90	619	-52.54	-28.55
Spanbridge	dn0095dsd	795	18.51	42.95	485.22	38	657	13.03	-26.15
CN Railway	dn0090dsd	838	16.67	50.27	535.49	61	718	-17.59	-25.42
Don Mills	ds0080dsd	958	8.61	111.27	646.75	122	840	-8.80	-23.01
Millwood	ds0080dsd	1055	12.7	83.07	729.82	100	940	-16.93	-22.36
Beechwood	ds0080dsd	866	11.11	77.95	807.77	74	1014	5.33	-20.34
Bloor	ds0050dsd	1177	22.88	51.44	859.21	70	1084	-26.51	-20.74
Danforth	ds0050dsd	1362	23.66	57.57	916.78	58	1142	-0.75	-19.72
Dundas	ds0020dsd	1128	28.61	39.43	956.21	49	1191	-19.54	-19.71
Eastern	ds0020dsd	602	25.28	23.81	980.02	26	1217	-8.41	-19.47
							Average	-12.67	-28.85

Southbound DVP Travel Time Estimation - June 10 Departuring @ 9:34:27 am

Location	VDS ID #	Distance (m)	AverageSpeed (m/s)	Travel Time (s)	Total Travel Time (s)	Actual Travel Time (s)	Total Travel Time (s)	Zone TT Absolute Error (%)	Total TT Absolute Error (%)
York Mills	dn0145dsd	0	7.5	0.00	0.00	0	0	0.00	0.00
Three Valleys	dn0140dsd	724	6.94	104.32	104.32	196	196	-46.77	-46.77
Lawrence	dn0130dsd	1401	13.73	102.04	206.36	90	286	13.38	-27.85
CP Rail	dn0120dsd	989	10.59	93.39	299.75	65	351	43.68	-14.60
Eglinton	dn0110dsd	835	8.79	94.99	394.75	75	426	26.66	-7.34
St. Dennis	dn0100dsd	475	10.83	43.86	438.61	81	507	-45.85	-13.49
Spanbridge	dn0095dsd	795	8.89	89.43	528.03	48	555	86.30	-4.86
CN Railway	dn0090dsd	838	6.67	125.64	653.67	66	621	90.36	5.26
Don Mills	ds0080dsd	958	16.29	58.81	712.48	98	719	-39.99	-0.91
Millwood	ds0080dsd	1055	18.89	55.85	768.33	73	792	-23.49	-2.99
Beechwood	ds0080dsd	866	16.69	51.89	820.22	79	871	-34.32	-5.83
Bloor	ds0050dsd	1177	25.86	45.51	865.73	86	957	-47.08	-9.54
Danforth	ds0050dsd	1362	24	56.75	922.48	63	1020	-9.92	-9.56
Dundas	ds0020dsd	1128	25.28	44.62	967.10	46	1066	-3.00	-9.28
Eastern	ds0020dsd	602	21.94	27.44	994.54	26	1092	5.53	-8.93
							Average	1.11	-11.19

Travel Time Algorithm Model
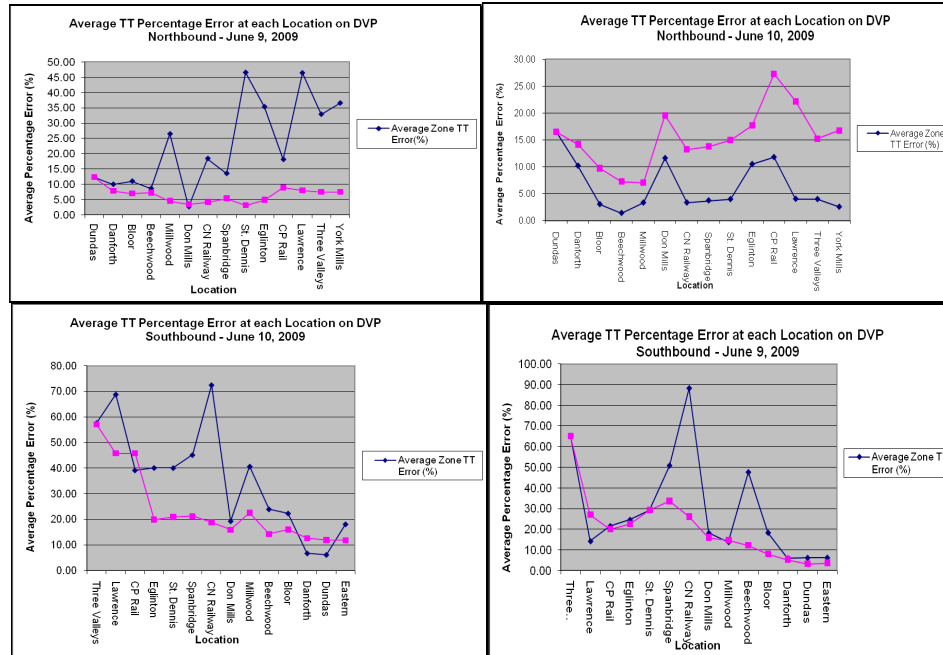
Average Absolute Percentage Errors at Each Location
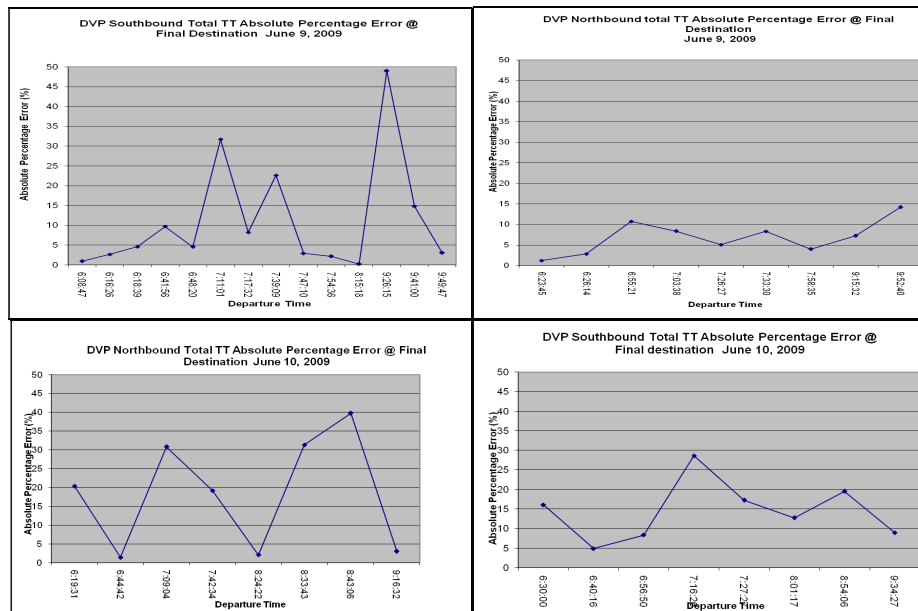
Absolute Percentage Error per trip at the Final Destinations

Appendix B – Travel Time Measurement using Bluetooth Signals

DVP Northbound - June 9, 2009

(Beechwood to York Mills)

Departure Time (am)	TT Algorithm (s)	TT Bluetooth (s)	Bluetooth ID	TT Camera (s)	Note	Algorithm Absolute Percentage Error (%)	Bluetooth Absolute Percentage Error (%)
6:26:14	318.29	331	1D28536CC5	**337**	Bluetooth departuring at 6:24:12	5.55	1.78
7:03:38	327.36	700	54F213729	359	Bluetooth departuring at 7:03:05	8.81	94.99
7:58:35	647.07	614	2106E24E45	657	Bluetooth departuring at 7:49:05	1.51	6.54
9:15:32	374.77	291	54F694D82	343	Bluetooth departuring at 9:12:55	9.26	15.16
9:52:40	347.28	273	21D288DF07	448	Bluetooth departuring at 9:48:02	22.48	39.06
					Average	**9.52**	**31.51**

DVP Northbound - June 10, 2009 (Beechwood to York Mills)

Departure Time (am)	TT Algorithm (s)	TT Bluetooth (s)	Bluetooth ID	TT Camera (s)	Note	Algorithm Absolute Percentage Error (%)	Bluetooth Absolute Percentage Error (%)
6:19:31	313.76	329	136CF5664F	403	Bluetooth Departure at 6:20:27	22.14	18.36
6:44:42	311.7	477	1D2869356C	335	Bluetooth Departure at 6:47:36	6.96	42.39
7:09:04	335.08	705	167443E9F5	223	Bluetooth Departure at 7:11:11	50.26	216.14
7:42:34	498.76	817	54F593D8E	401	Bluetooth Departure at 7:43:05	24.38	103.74
9:16:32	444.74	299	21864CA1CE	458	Bluetooth Departure at 9:16:03	2.90	34.72
					Average	**21.33**	**83.07**

**DVP Southbound - June 9, 2009 (York Mills to Beechwood)**

Departure Time (am)	TT Algorithm (s)	TT Bluetooth (s)	Bluetooth ID	TT Camera (s)	Note	Algorithm Absolute Percentage	Bluetooth Absolute Percentage

						Error (%)	Error (%)
8:15:18	3168.08	1324	E9F6C1CA1	3171	Bluetooth Departure at 8:15:26	0.09	58.25
					Average	**0.09**	**58.25**

DVP Southbound - June 10, 2009 (York Mills to Beechwood)

Departure Time (am)	TT Algorithm (s)	TT Bluetooth (s)	Bluetooth ID	TT Camera (s)	Note	Algorithm Absolute Percentage Error (%)	Bluetooth Absolute Percentage Error (%)
6:30:00	356.43	474	213EE6FA9A	427	Bluetooth Departure at 6:29:21	16.53	11.01
6:56:50	538.05	848	21FED0F048	485	Bluetooth Departure at 6:56:51	10.94	74.85
8:01:17	945.4	783	F86D42663	1097	Bluetooth Departure at 8:01:12	13.82	28.62
8:54:06	807.77	588	23F1007C85	1014	Bluetooth Departure at 8:54:18	20.34	42.01
9:34:27	820.22	331	237A6BEA3D	871	Bluetooth Departure at 9:34:23	5.83	62.00
					Average	**13.49**	**43.70**

Comparison Table with All Three Data
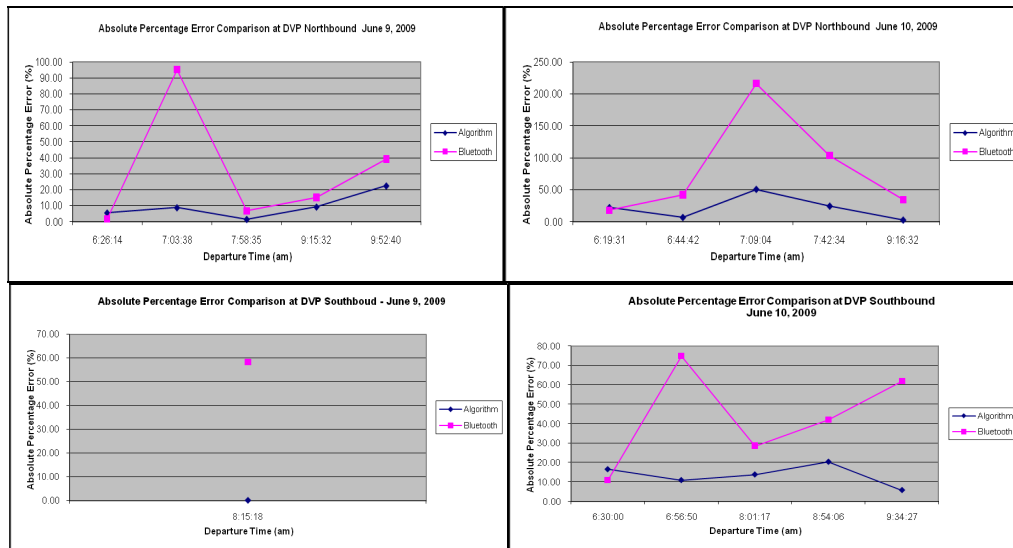
Absolute Percentage Errors for Algorithm and Bluetooth Data

Appendix C – Raw Data and Programmed Code

ID	IDNUM	YEAR	MONTH	DAY	HOUR	MIN	SEC	HITS	SPAN_MINUTES
213EE8A8A4	1.43E+11	2009	6	8	9	52	51	1	0
21FECCE348	1.46E+11	2009	6	8	9	52	51	1	0

1FCD97FE0E	1.37E+11	2009	6	8	9	52	55	1	0
54F651BA9	22806862761	2009	6	8	9	52	55	3	0.12
1A8AA513CC	1.14E+11	2009	6	8	9	53	7	1	0
1ADBB09A9A	1.15E+11	2009	6	8	9	53	7	1	0
21FEAA7F48	1.46E+11	2009	6	8	9	53	23	1	0
1CCCD6590A	1.24E+11	2009	6	8	9	53	23	1	0
1E4573517E	1.30E+11	2009	6	8	9	53	25	2	0.02
219E71B1E3	1.44E+11	2009	6	8	9	53	26	2	0.08
16B8305342	97579455298	2009	6	8	9	53	31	1	0
1D284B90F3	1.25E+11	2009	6	8	9	53	41	1	0
1EE2BE9A56	1.33E+11	2009	6	8	9	53	41	1	0
1016E8461D	69103797789	2009	6	8	9	53	47	1	0

A Portion of the Raw Data of Bluetooth Signals Detected from the BluFax Device

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.IO;

namespace ReadBluetoothData
{
    class Program
    {
        static void Main(string[] args)
        {

            // Read in both files data gathered by bluetooth device
            string[] allLines1 = File.ReadAllLines("P:\\HQIAN\\BlueTooth Detection Raw
Data\\STATION_DETECTIONS_FOR_C46_Beechwood-June 9, 6am - 10am.csv");
            string[] allLines2 = File.ReadAllLines("P:\\HQIAN\\BlueTooth Detection Raw
Data\\STATION_DETECTIONS_FOR_C4B_York Mills-June 9, 6am - 10am.csv");

            //Output files
            using (StreamWriter nbOut = new StreamWriter(@"P:\HQIAN\BlueTooth Detection Raw Data\Test Results(NB) - June
9.csv"))
            using (StreamWriter sbOut = new StreamWriter(@"P:\HQIAN\BlueTooth Detection Raw Data\Test Results(SB) - June
9.csv"))
            {


                // Store each data file in a dictionary with ID #s and Arrival Times
                Dictionary<long, List<DateTime>> data1 = new Dictionary<long, List<DateTime>>();
                Dictionary<long, List<DateTime>> data2 = new Dictionary<long, List<DateTime>>();

                // Call the file processing function
                ProcessFile(allLines1, data1);
                ProcessFile(allLines2, data2);

                long currentID;

                // Output data headers
```

```csharp
        sbOut.WriteLine("ID, Time Arriving @ York Mills, Time Arriving @ Beechwood, Travel Time");
        nbOut.WriteLine("ID, Time Arriving @ Beechwood, Time Arriving @ York Mills, Travel Time");


        // Find the identical ID #s in both files
        foreach (KeyValuePair<long, List<DateTime>> entry in data1)
        {
            currentID = entry.Key;

            //Skip if data2 does not have current ID
            if (!data2.ContainsKey(currentID))
                continue;

            //Compare times
            for (int i = 0; i < entry.Value.Count && i < data2[currentID].Count; i++)
            {
                if (data2[currentID][i] < entry.Value[i]) //Going Southbound
                {
                    TimeSpan difference = entry.Value[i] - data2[currentID][i];
                    // Display the southbound(SB) data results on excel
                    sbOut.WriteLine("{0},{1},{2},{3}", currentID, data2[currentID][i], entry.Value[i], difference);
                }

                if (entry.Value[i] < data2[currentID][i]) //Going Northbound
                {

                    TimeSpan difference = data2[currentID][i] - entry.Value[i];
                    // Display the northbound(NB) data results on excel
                    nbOut.WriteLine("{0}, {1}, {2}, {3}", currentID, entry.Value[i], data2[currentID][i], difference);
                }
            }
        }
    }

}

private static void ProcessFile(string[] allLines, Dictionary<long, List<DateTime>> data)
{
    foreach (string line in allLines) // Display the bluetooth data file - June 9, from 6am-10am
    {
        string[] columns = line.Split(',');

        long id = 0;                // Read in ID #s
        try
        {
            id = Convert.ToInt64(columns[0], 16);
        }
        catch
        {
            Console.WriteLine("Cannot read: " + columns[0]);
            continue;
        }

        int year = Convert.ToInt32(columns[2]);
        int month = Convert.ToInt32(columns[3]);
        int day = Convert.ToInt32(columns[4]);
        int hour = Convert.ToInt32(columns[5]);
        int minute = Convert.ToInt32(columns[6]);
        int second = Convert.ToInt32(columns[7]);

        if (second == 60)
        {
```

```
        second = 0;
        minute++;
      }

    DateTime datetime = new DateTime(year, month, day, hour, minute, second); //Call the Standard DateTime Function

    Console.WriteLine(id + " - " + datetime.ToString());          // Read in the data
    if (!data.ContainsKey(id))
      data.Add(id, new List<DateTime>());
    data[id].Add(datetime);
    }
   }
  }
}
```

The programming code which performs searching of the identical Bluetooth IDs from the two locations, and the arrival time and travel time data are shown on the output files.

DVP Southbound - June 10, 2009

Bluetooth ID	Time Arriving @ York Mills	Time Arriving @ Beechwood	Travel Time(h:m:s)
22804294826	6:00:26 AM	6:06:32 AM	0:06:06
108702000000	6:00:16 AM	6:06:38 AM	0:06:22
134940000000	6:00:21 AM	6:06:48 AM	0:06:27
102651000000	6:00:41 AM	6:06:50 AM	0:06:09
80843855580	6:00:46 AM	6:07:02 AM	0:06:16
106391000000	6:01:19 AM	6:07:31 AM	0:06:12
130014000000	6:01:19 AM	6:07:34 AM	0:06:15
143066000000	6:00:57 AM	6:07:07 AM	0:06:10
22807167966	6:01:23 AM	6:07:34 AM	0:06:11
152384000000	6:01:53 AM	6:08:17 AM	0:06:24
123012000000	6:02:22 AM	6:08:17 AM	0:05:55
113638000000	6:02:32 AM	6:08:39 AM	0:06:07
136966000000	6:02:58 AM	6:08:44 AM	0:05:46
146009000000	6:03:07 AM	6:08:59 AM	0:05:52

A Sample Output File