

MIDTOWN IN MOTION

ACTIVE TRAFFIC MANAGEMENT

TECHNICAL MEMORANDUM # 1: DATA COMPARING PRE-EXISTING AND TEST BASELINE SIGNAL CONTROL

Feb 9, 2011

The objective of the overall project is to improve traffic flow in a designated zone of Manhattan by the use of active traffic management, namely from 2nd to 6th Avenues and 59th Street to 42nd Street.

As part of that effort, a set of traffic signal plans were developed and tested, to provide a baseline for the active traffic management, if the underlying premise were accepted and if the field results justified their use. Their implementation was concurrent with the period in which the newly-installed detectors (RTMS¹ and ETC readers) were providing real-time data feeds to the Traffic Management Center (TMC) and a data base was being built as the detectors came on line.

This technical memorandum presents initial results from the data feeds, under both the pre-existing and candidate baseline plans. The data collection reported herein occurred in December of 2010 and January of 2011. Data collection and analysis continues, covering a broader area as the detectors come on line.

The memorandum addresses five major topics:

- Travel time maps as obtained from the ETC readers that cover segments of Lexington and 3rd Avenues, and cross street segments at 57th, 49th, and 42nd Streets;
- Travel time maps as obtained from GPS-based travel time runs on Lexington, 3rd, and 2nd Avenues and on a number of the cross streets between them;
- Displays of the same GPS-based data in a time-space format, to highlight the area in which stops occur and speeds are atypical;
- The relation between travel time in one eastbound link on 57th Street monitored by the EZPass transponders and the flow and occupancy observed for thru movement in the immediate upstream block;
- The data from both the ETC readers and the RTMS detectors at one location (3rd Avenue, between 44th and 45th Streets) visited on Jan 31, 2011 for the purpose of qualitatively assessing the meaning of "occupancy" data in terms of traffic operations, congestion, and control.

It must be emphasized that the phase of building and comprehending the data base is on-going: the network of detectors is providing more real-time data than ever available heretofore; more detectors

¹ A glossary at the end of the memorandum defines terms.

are coming on line each week, so the expanse is growing; more sources are being tapped, including the taxi travel time data for each past month; the use of the data for generally-perceived performance measures and for control purposes. Further, all data efforts were supplemented with extensive field inspections, to identify operational issues and provide reality checks.

1. Executive Overview: Findings and Observations

The principal observations and findings to date are:

- 1) There is considerable variability in both traffic demand and capacity in the zone, with a number of apparent underlying causes:
 - Daily patterns that differ over the week and from week to week;
 - Weather, limiting capacity and affecting demand;
 - Incidents, also limiting capacity at points within the zone or exit points (e.g. the QBB) or entry paths (again, the QBB as an example);
 - Recurring operational issues, such as concentrations of deliveries and double-parking, that affect capacity;
 - Random operational issues, of the same sort;
 - Re-routing that occurs due to all of the above;
- 2) This variability in and of itself documents the potential for active traffic management, which is designed to address traffic control changes on two levels: LEVEL 1, the selection of plans to match the existing situation, over an hour or more, including the use of metering and queue management; LEVEL 2, the adjustment of the allocation of green time (i.e. "splits") between competing demands at select critical intersections;
- 3) While the variability makes a decisive comparison difficult, it is clear that the candidate baseline plans do add travel time to the arterials even while providing queue management (qualitatively), typically one additional stop within the zone;
- 4) The candidate baseline plans were to
 - Provide the opportunity for queue clearance on the arterials, by advancing the start of green from a typical 6-7 second forward progression to a near-simultaneous setting, thereby allowing for clearing existing queues as well as providing queue management and avoiding spillback in heavier flows;
 - Provide greater mobility east-west while managing queues and providing good service north-south. Only two east-west blocks are affected to date (between Lexington & 3rd, and 3rd and 2nd) by this goal, and the data does not provide evidence that a significant improvement took place. Moreover, the dialog led to a re-affirmation of the emphasis on arterial priority;
- 5) The test of the candidate baseline plans did lead to identifying key locations at which queue management has value, and can/should be part of the underlying signal plans. Locations are:
 - (a) 2nd Avenue from 63rd Street to 59th Street, where traffic entering QBB fills in the available the storage;
 - (b) 2nd Avenue from 38th Street to 36th Street, where traffic entering QMT occasionally spills back ;

- (c) 3rd Avenue from 40th Street to 42nd Street, where heavy turning traffic at 42nd Street constrains capacity of through traffic;
 - (d) 3rd Avenue from 56th Street to 59th Street, where two right turn lanes towards QBB dominate operations²;
 - (e) Lexington Avenue from 63rd Street to 59th Street, where traffic going to QBB impedes through traffic ;
 - (f) Lexington Avenue from 45th Street to 42nd Street, where curbside activities such as taxi pick-up and drop-off near Marriot Hotel take away travel lanes.
- 6) Above all, the variability in patterns actually observed do confirm the value of having a number of LEVEL 1 plans at the ready, for use in active traffic management, as cited in #2;
 - 7) The ETC readers provide exceptional sample sizes, more than ever available by other means, and an excellent base for characterizing multi-block segments of trips. Based upon work with the ETC data for this memorandum²,
 - a. The scatter of the data reflects interrupted trips (short term elective stops, perhaps, or other causes) as well as regular in-motion travel, and the data has to be culled for the in-motion characterization;
 - b. The data reveals clusters that correspond to bands of vehicles that are not stopped, stopped once, and so forth. The percent of vehicles in each cluster is an enticing metric, and its use has to be pondered upon;
 - c. For comparative purposes, and recognizing that not all vehicles have ETC readers, the data also provides some insight into relative flow rates;
 - d. The number of samples is higher than otherwise obtainable for travel times;
 - 8) The RTMS readers provide insight into developing traffic problems by using occupancy and flow rates in combination. Occupancy in turn implies queues, and should be thought of in these terms. Because they are point measures, they can be used for a variety of analysis periods, although very long periods would tend to “average out” important details;
 - 9) For both the RTMS and ETC data, the smoothing of the data can allow trends to be detected that will allow LEVEL 1 decisions to be made, balancing the need to see the details with the desire to avoid false alarms due to short term fluctuations;
 - 10) The spatial pattern of occupancy will be commented upon in a later memorandum, after more RTMS detectors are on-line;
 - 11) Some of the field observations deserve attention and discussion, including (a) the mid-day concentration of delivery and other vehicles in certain locations, (b) the possible value in changing the order of phases at a limited number of locations.

The results show a general pattern in which the travel times on both the arterials and cross streets are greater under the candidate baseline plans, although there are days and periods in which they are lower or the same. Unfortunately, the weather in the two periods is not comparable: the “after” period was

² NYCDOT is also conducting its own analyses, and there is a dialog.

marked by more adverse weather days (snow, rain) that left residues that affected parking, lane availability, and travel generally – even on the days used for analysis. Thus, the conundrum is resolving the role of weather-related capacity reductions vis-à-vis the traffic signal plans in the results.

As of February 5, 2011, the pre-existing plans are in effect, so that additional data can give insights into this conundrum. But in terms of overall lessons learned, a summary would be: (a) variability in traffic demand and capacity in the zone and its environs indicates that active traffic management has potential, with multiple LEVEL 1 plans; (b) the emphasis on servicing the arterials is a keystone; (c) the LEVEL 1 plans have to use queue management and metering selectively, in concert with progression.

The results to date are being used to modify plans being developed.

2. Detectors and the Data Collection Periods

The zone of interest extends from 2nd to 6th Avenues and from 59th Street to 42nd Street, inclusive, and is shown in yellow highlight in Figure 1. Control is to be exercised within the zone, and in the two areas north and south of the zone; these are shown in light blue shading in Figure 1.

Figure 1 also shows the extent of two simulation tools that were constructed in other projects, and are to be available for use as the present work progresses. The area shown by the heavy dashed black border was modeled as part of the MPT evaluations and refinements related to the Third Water Tunnel work near the QBB and to part of the Second Avenue Subway work. The area shown by the darker blue shading indicates an extensive area for which the simulator is being finalized, under different work being done for NYCDOT.

The zone and its periphery are being instrumented extensively with both RTMS units and ETC readers, as shown in Figure 2. The RTMS detectors collect occupancy and flow for each lane, at the various points indicated. The ETC readers collect travel times along the segments indicated, for all vehicles that have EZPass transponders and traverse the specific segment.

As of February 8, 2011, the implementation of the RTMS is:

		As of Feb 8, 2011
As Planned		109
Installed	Total	61
	<i>Configured</i>	46
	<i>Being Finalized</i>	15
To be Installed		48

Note: Of the 46 configured detectors, 24 are providing data.

The full installation is scheduled to be completed by the end of February 2011. ETC readers are scheduled for installation on Madison Avenue at 42nd, 49th, and 57th Streets.

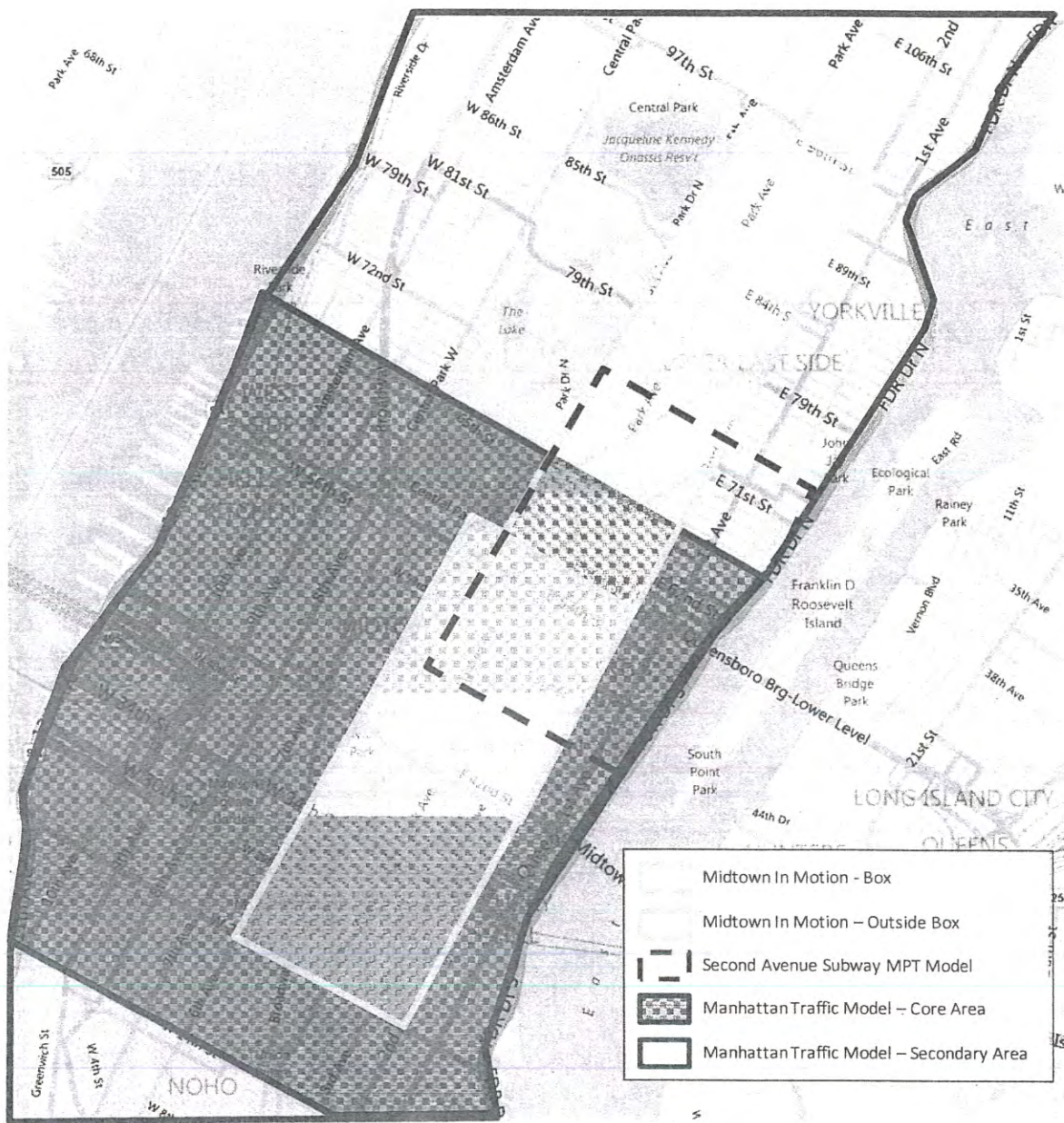


Figure 1: The Midtown-in-Motion Zone, and Related Information

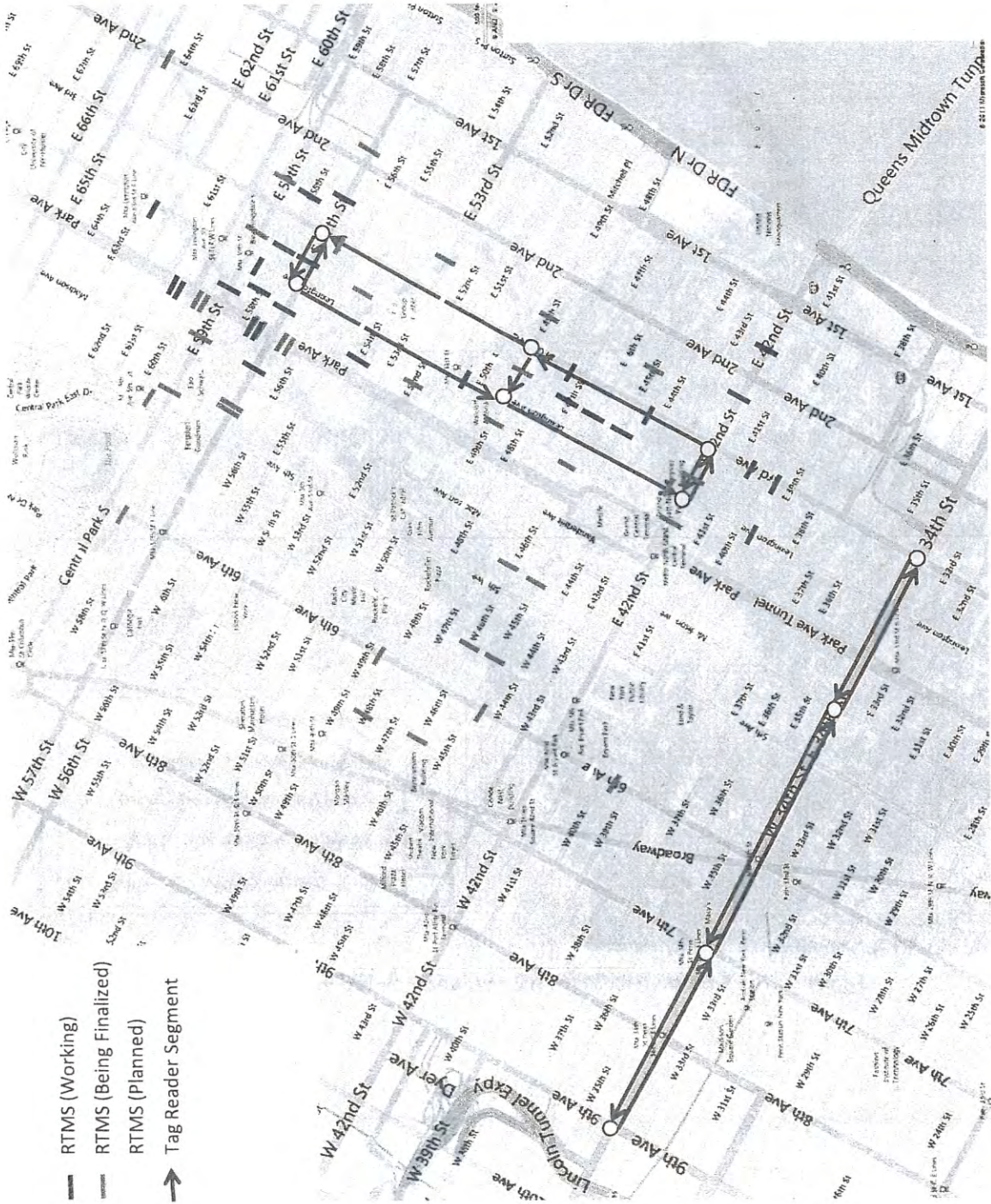


Figure 2: Some of the Detectors Addressing Flow, Occupancy, and Travel Time

Table 1 summarizes the general conditions affecting the traffic observations from January 1 to February 4 of 2011 (snow, rain, fog, incidents), the availability of detector information, and the traffic signal control in effect. The word "available" does not indicate that all of the detectors implemented as of January 31st (see page 4) were in use; many of the RTMS detectors came on-line during the period covered in Table 1.

Table 1: Summary of Control, Data, and Events (December 1-February 7, 2011) Affecting the Zone

	12/1	12/2	12/3	12/4	12/5	12/6	12/7	12/8	12/9	12/10	12/11	12/12	12/13	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/21	12/22	12/23	12/24	12/25	12/26	12/27	12/28	12/29	12/30	12/31	
	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	
RTMS Data	Available																															
Control	Existing																															
ETC Data																						Available										
GPS Data							X	X	X					X	X	X	X															
Weather	F, R													F, R, R, S	S																F, S	F, S
Accidents																																
Holiday																									X	X						X

	1/1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1/10	1/11	1/12	1/13	1/14	1/15	1/16	1/17	1/18	1/19	1/20	1/21	1/22	1/23	1/24	1/25	1/26	1/27	1/28	1/29	1/30	1/31
	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon
RTMS Data	Available																														
Control	Existing															Base Plans															
ETC Data	Available																														
GPS Data					X						X			X		X			X	X											
Weather		F, R					F, S	S				F, S	F, S						R, S	R		F, S					F, S	F, S			
Accidents																				X	X										
Holiday	X															X															

	2/1	2/2	2/3	2/4	2/5	2/6	2/7	2/8	2/9	2/10	2/11	2/12	2/13	2/14	2/15	2/16	2/17	2/18	2/19	2/20	2/21	2/22	2/23	2/24	2/25	2/26	2/27	2/28	
	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	
RTMS Data	Available																												
Control	Base Plans							Pre-Existing																					
ETC Data	Available																												
GPS Data								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Weather	R, S	R, S		R	R			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Accidents								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Holiday								*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

R = Rain S = Snow F = Fog * = Future Dates

Based upon the information in Table 1, thirteen (13) pairs were selected in the before-after analyses, as shown in Table 2. The pairing was done by day of week. A total of 7 "before" and 7 "after" days were available. (Some supplemental analysis was done that included February 4th, a Friday).

Table 2: Pairing of Dates for Analysis

		After							
		18-Jan	21-Jan	23-Jan	24-Jan	25-Jan	30-Jan	31-Jan	
Before	28-Dec	Tue	✓				✓		
	2-Jan	Sun			✓			✓	
	3-Jan	Mon				✓		✓	
	4-Jan	Tue	✓				✓		
	9-Jan	Sun			✓			✓	
	10-Jan	Mon				✓		✓	
	14-Jan	Fri		✓					
				2	1	2	2	2	2

3. Travel Time Maps from ETC Reader Data

Figure 3 shows data from the travel time readers for a section along Lexington Avenue, based upon work at NYCDOT. The data is being analyzed internally for insights, such as the clusters shown in Figure 3 that show patterns of vehicles that are delayed more than others (the higher values tend to be isolated cases of extended stops at the option of the vehicle operator).

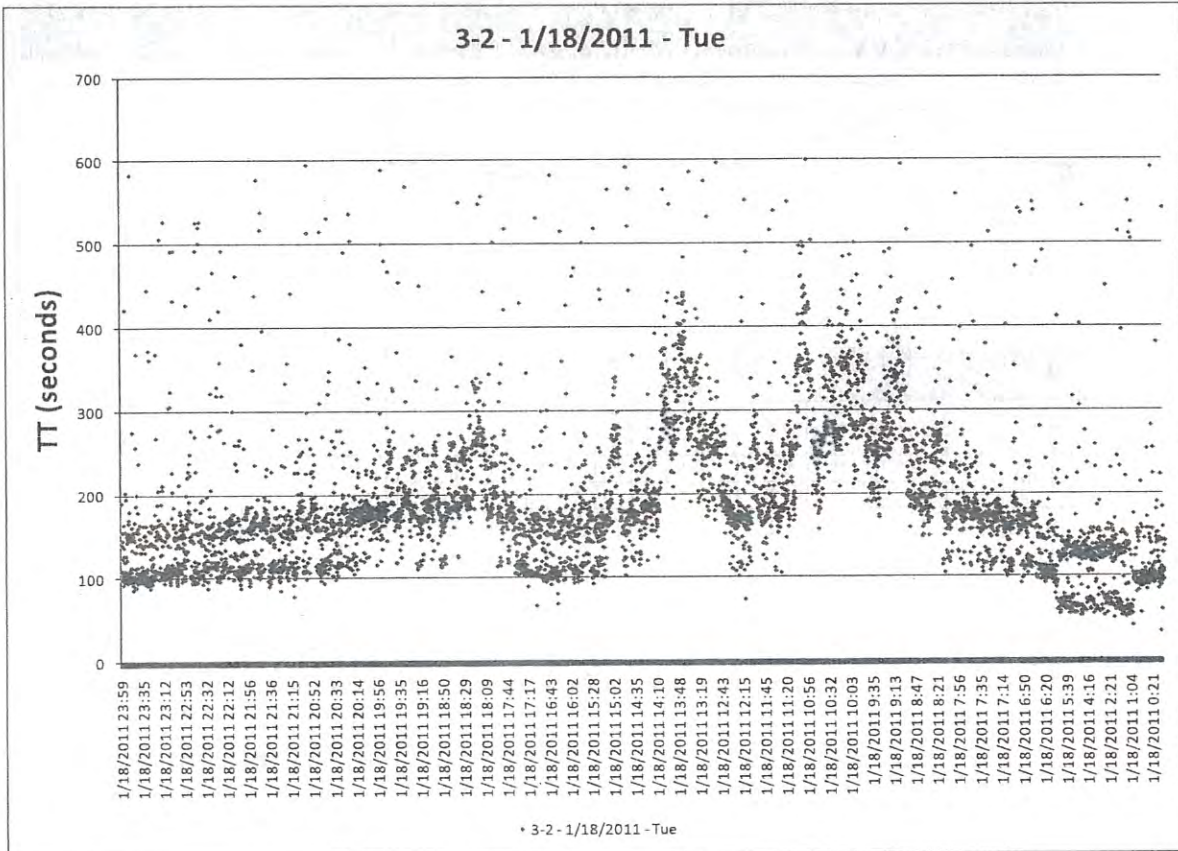
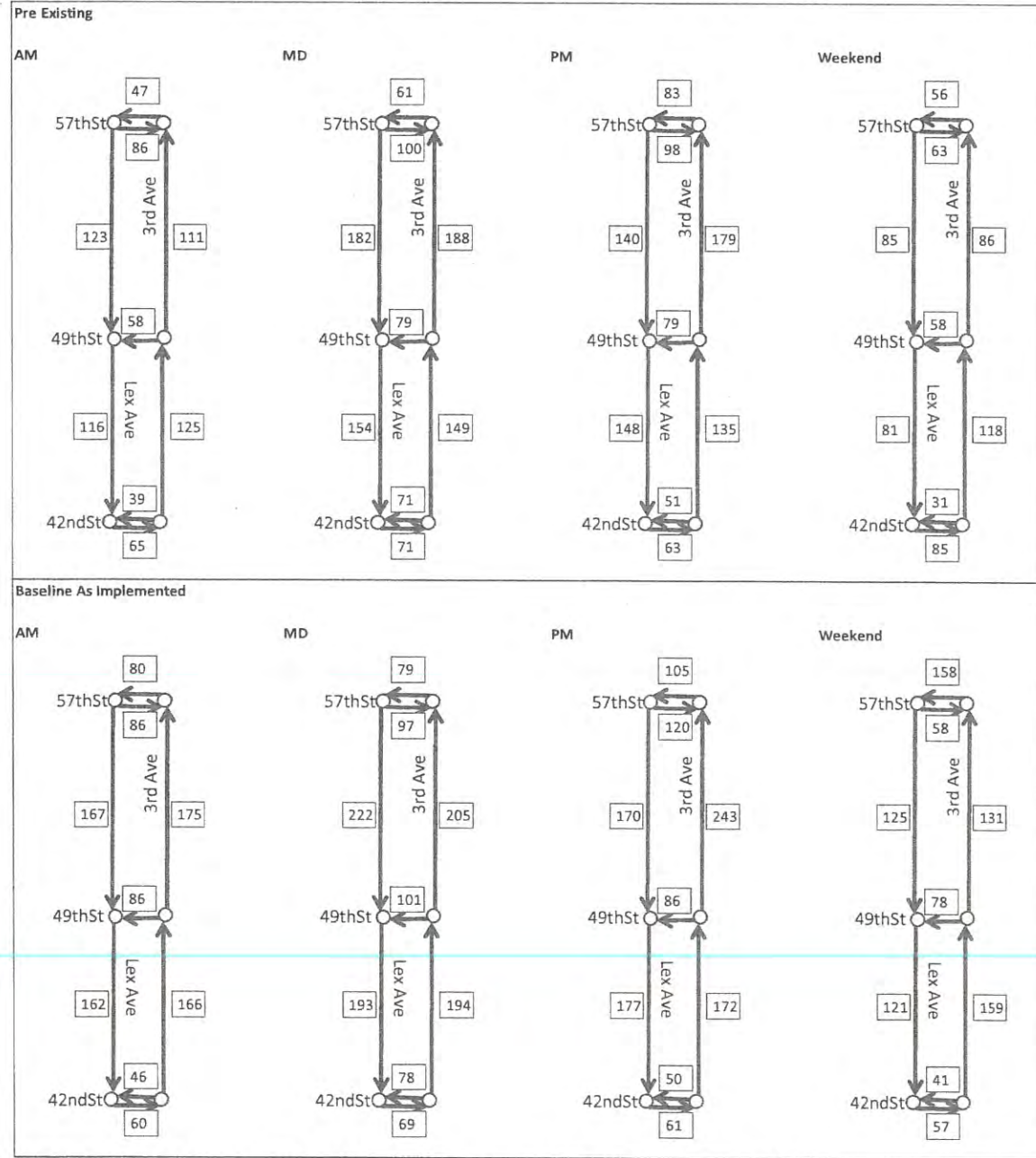


Figure 3: Sample of Individual Travel Times, from NYCDOT

a) Overall Pattern

Refer to Table 3, which shows average travel time on the segments covered within the zone by the ETC readers, for 3 times of day on the weekdays and one time covering all day on the weekend, for the two traffic control plans. All data above 400 seconds was eliminated, so that drivers who chose to dwell in the segment were not considered in the averages. Appendix A contains additional detail, including displays of the travel times in the format of Figure 3.

Table 3: Representative ETC-based Travel Times (seconds)

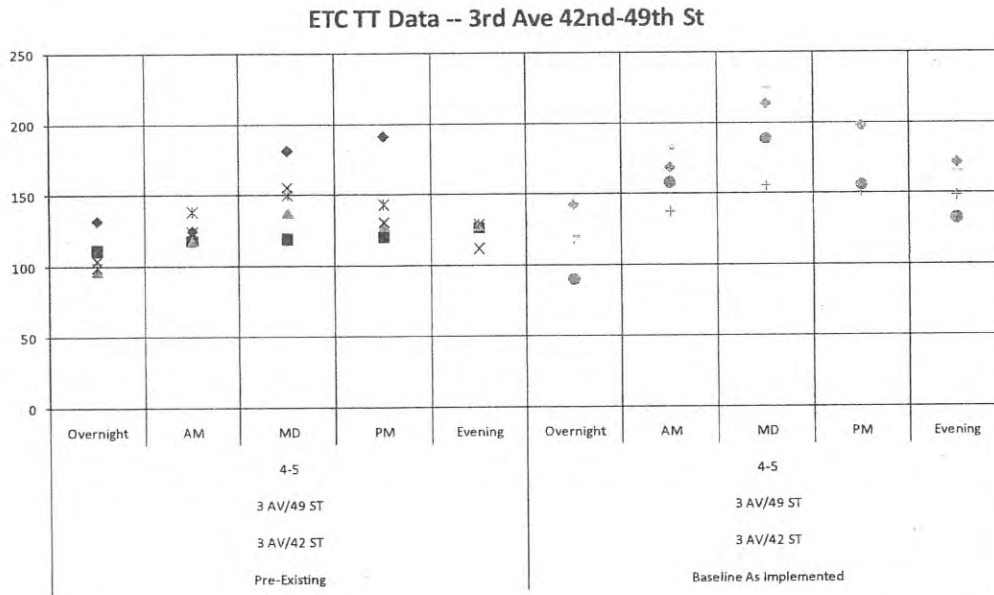
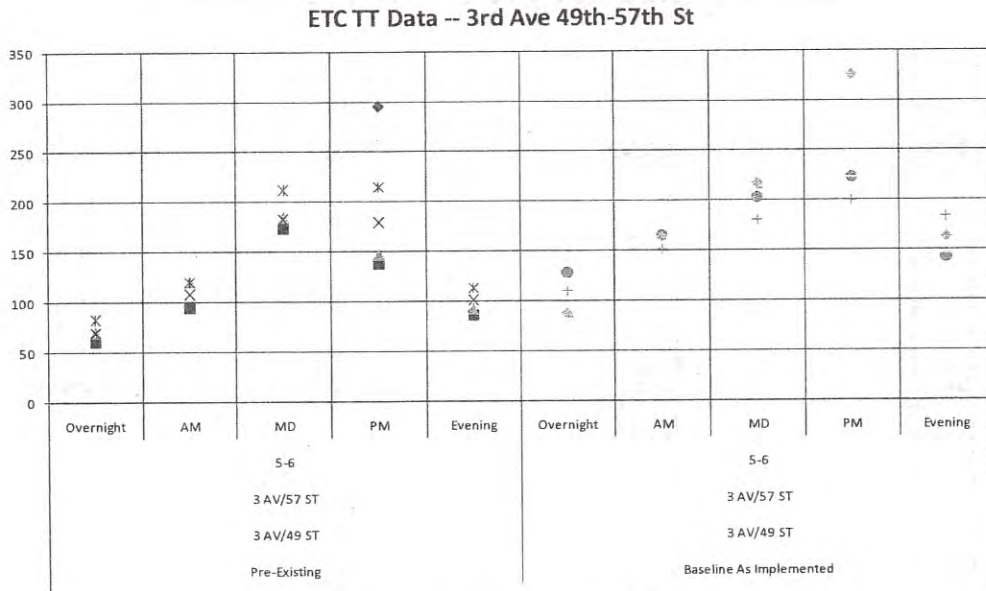


Note: AM=5AM to 10AM, MD=11AM to 2PM, PM=2PM to 8PM, Weekend=All day

Table 3 depicts a situation in which the baseline as implemented results in greater average travel times on the arterials, with the cross street blocks covered also generally being higher.

The variability in travel times on each segment is considerable, within both the "before" and "after" periods. For instance, see Table 4 for an illustrative display of the scatter along 3rd Avenue for the weekday periods.

Table 4: Scatter of Average Travel Times by Segment, Along 3rd Avenue



The question of whether occupancies are affected beneficially is addressed in a later section, to the extent that the available detectors allow. For instance, in terms of queue management, it would be

interesting if there were fewer vehicles when stops occur. This could lead to a situation in which drivers experience greater travel times but shorter queues, dispersed.

Table 3 has to be viewed in the context of both variability and the possibility that the weather factor (i.e. capacity reduction) is skewing the results. Further insights into the latter may be obtained when (and if) comparable conditions exist (e.g. Feb 7-10, for instance) with the pre-existing plans in effect.

Notwithstanding these factors, an apt summary (cited on page 4) remains:

- a) Variability in traffic demand and capacity in the zone and its environs is a reality, for which active traffic management has potential, with multiple LEVEL 1 plans;
- b) The emphasis on servicing the arterials is a keystone;
- c) The LEVEL 1 control plans have to use queue management and metering *selectively, in concert with progression* (emphasis added).

b) Further Commentary on Variability

To further consider the variability of travel times from day to day, vis-à-vis effect of control, consider Figure 4, for 3rd Avenue from 49th to 57th Streets:

- It is the “after” day (Feb 4th) that shows a lower concentration of travel times from 11am to 4pm;
- The “before” day (Jan 14th) shows a lower concentration of travel times from 8am to 11am and again from 6pm to the end of the day;
- From 4pm to 8pm, both show extended travel times, with the “after” data showing better (i.e. lower) distinct clusters.

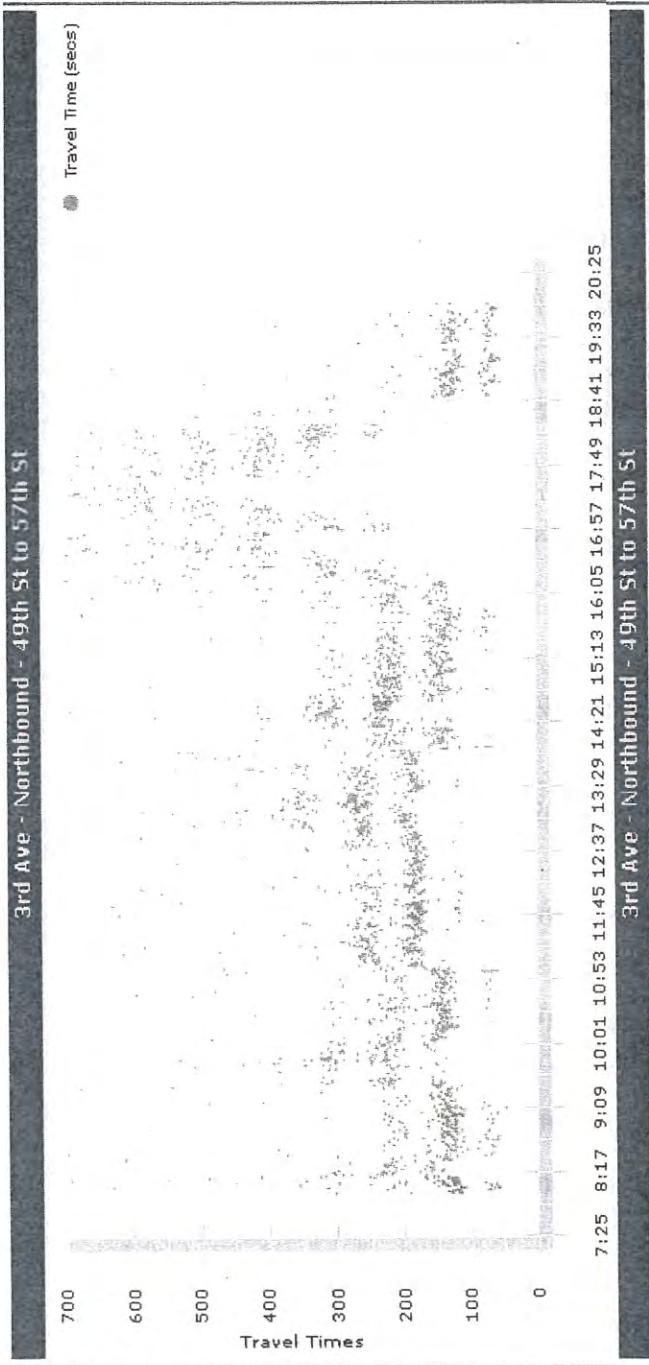
Figure 5 shows the same segment from 8pm on the Friday to 8am on the Saturday:

- From 8pm on Friday to 2am on Saturday, and again from 6am to 8am on Saturday, the “before” day has lower travel times (in terms of clusters);
- From 2am to 6pm on Saturday, both days have the same low clusters but the “after” day has a second cluster which could be interpreted as less good.

But for the overnight period, both “before” and “after” plans use forward progression, although the “after” or baseline plan slows the progression more and tightens the green time (allowing more ped times), knowledge transferred from another project for NYCDOT.

Figure 6 shows another segment --- 3rd Avenue, from 42nd to 49th Streets --- for a full 24 hours on the two Fridays just cited (Jan 14th and Feb 4th). The overall pattern shows variations throughout the 24 hours, in terms of which clustered pattern is better.

a) Jan 14, 2011



b) Feb 4, 2011

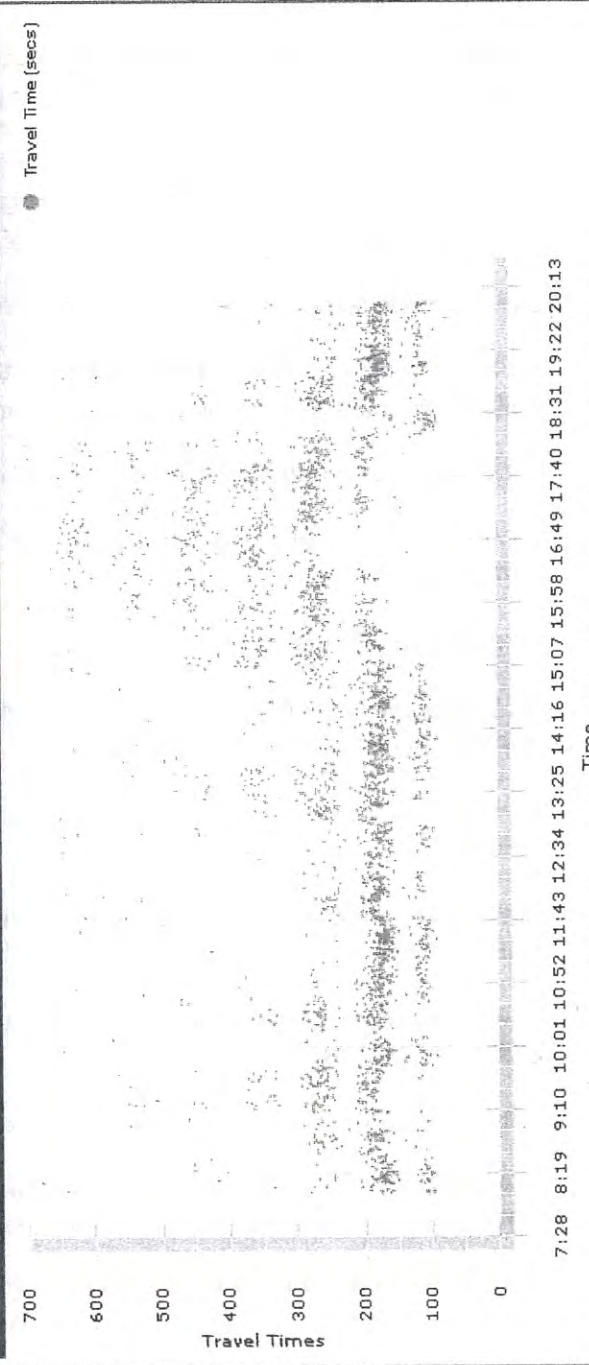
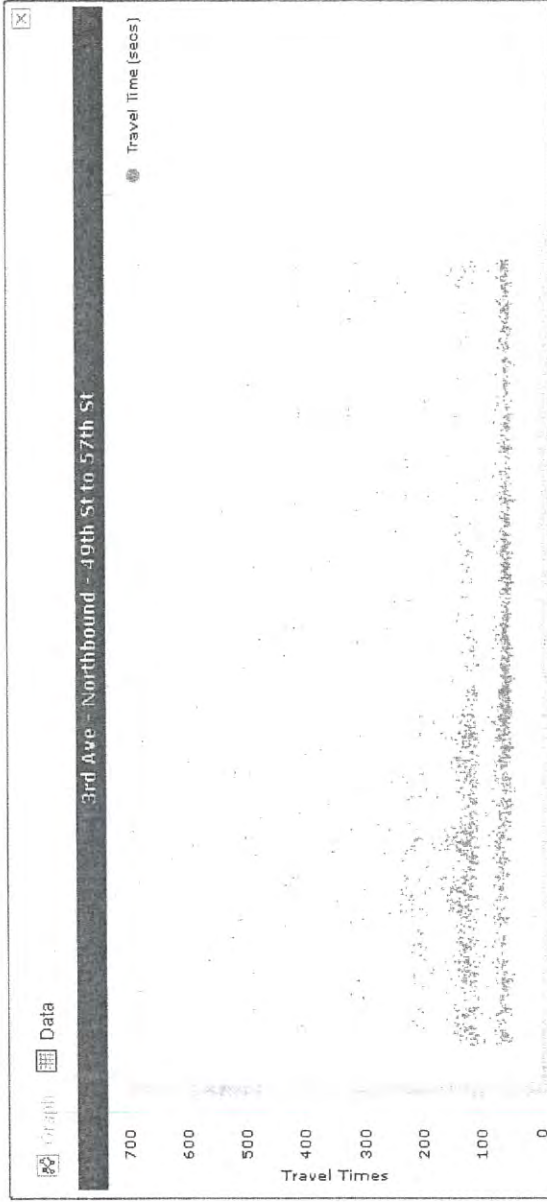


Figure 4: Comparison of Travel Time Profile for Two Fridays, with Different Signal Plans, 8am to 8pm

a) Jan 14-15, 2011



3rd Avenue NB, 49th to 57th Streets (both)

b) Feb 4-5, 2011

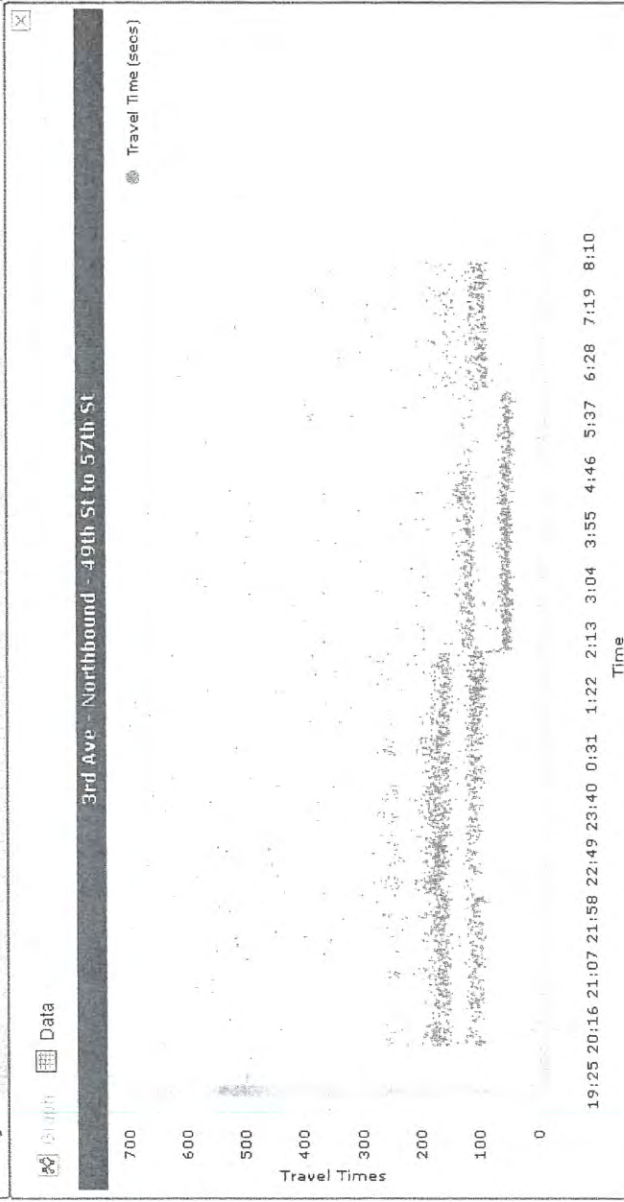
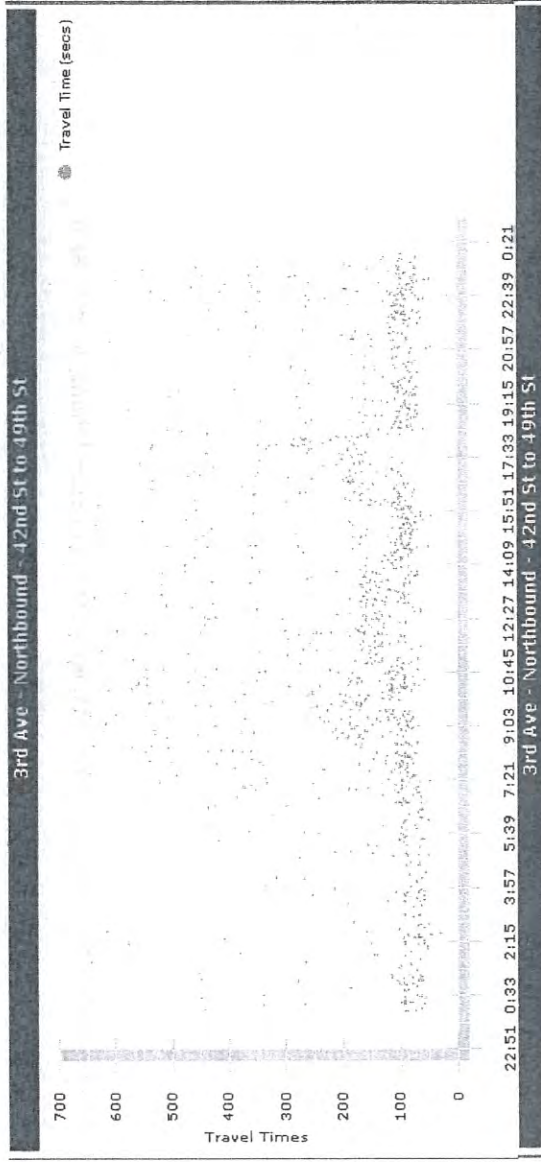


Figure 5: Comparison of Travel Time Profile for Two Friday Overnights, with Different Signal Plans, 8pm to 8am

a) Jan 14, 2011



3rd Avenue NB, 42nd to 49th Streets (both)

b) Feb 4, 2011

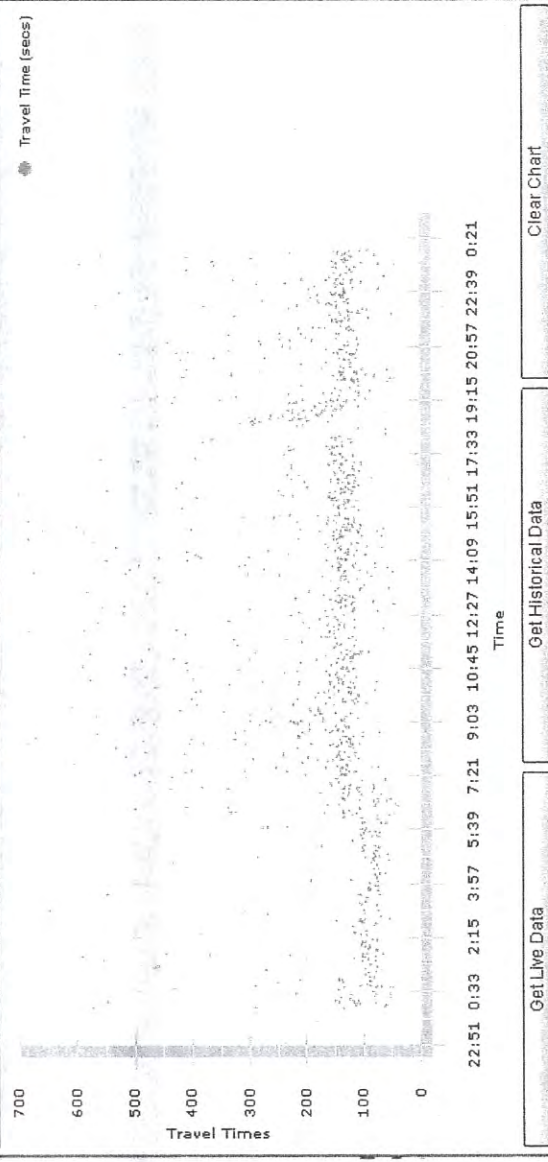


Figure 6: Comparison of Travel Time Profile for Two Friday Overnights, with Different Signal Plans, 24 Hours, Another Segment

b) Further Commentary on Occupancy

Figure 7 illustrates the flow and occupancy at one location (3rd Avenue, between 44th and 45th Streets, Lane 2). While not decisive, it does show a situation of very comparable flows (black lines, solid for “before” date and dashed for “after” date) that have notably different occupancies (red lines, with the same solid-dashed convention).

Even with the sizable data base available, it is challenging to find exactly comparable situations, to isolate single factors. But the hypothesis of queue management settings being helpful is more plausible with such cases, when identified. As the RTMS network grows and is fully implemented, a considerable data base will become available, to inform control decisions. The same is true of the ETC network.

Appendix B contains additional summaries of RTMS-based data.

4. Travel Time Maps from GPS-based Travel Time Runs

Figure 8 shows the path of a GPS-equipped test vehicle, as it drives up and down arterials in the area of the zone of interest. The dots are sample locations taken at fixed intervals, so that well-spaced dots indicate good travel times (i.e. better speeds). Conversely, tightly spaced dots indicate slow movement, delay, and congestion.

There was a systematic plan developed for having GPS-based travel times taken along the arterials and cross streets for both the “before” and “after” condition, with the arterial runs encompassing streets well north and south of the zone of interest.

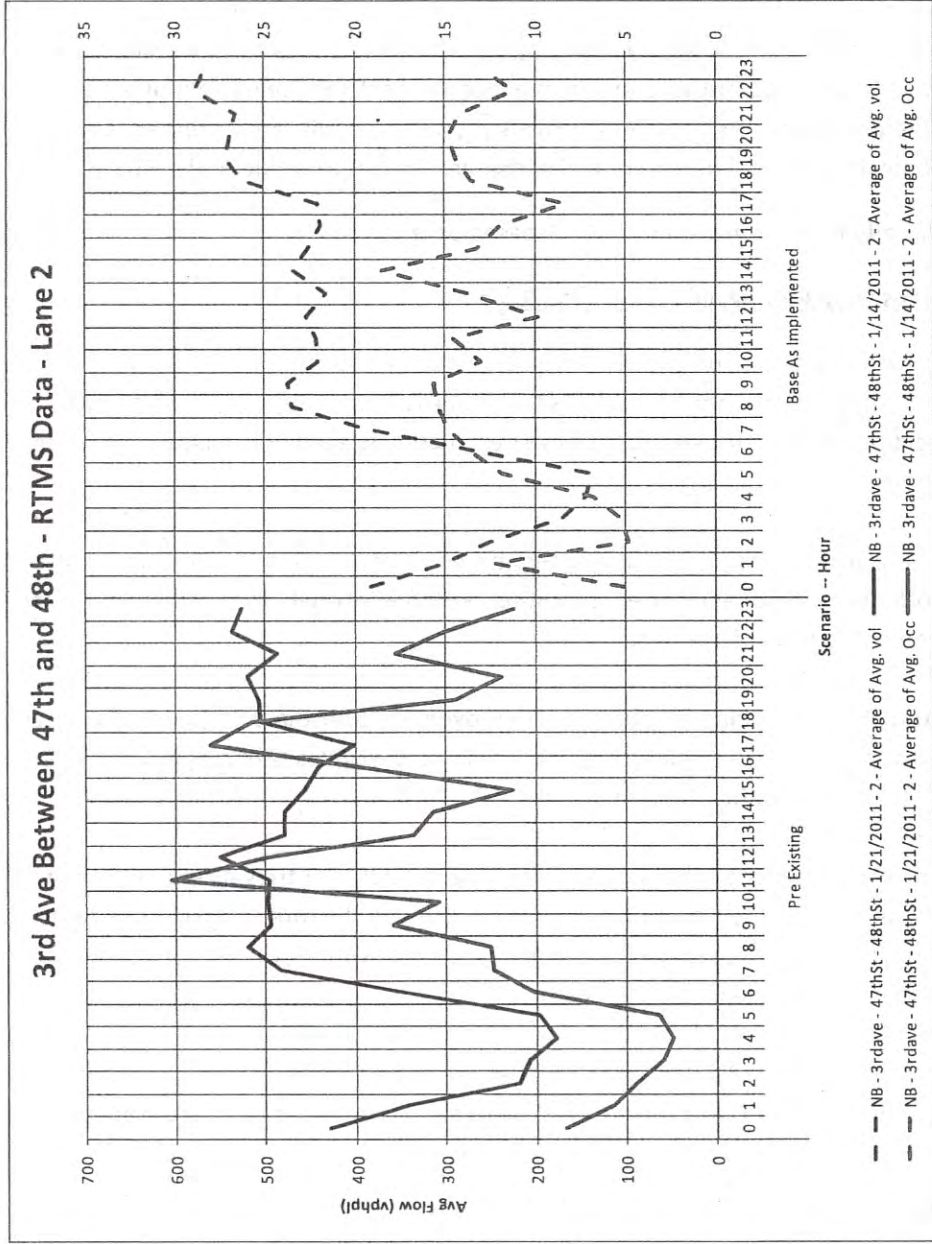
The GPS-based automated recording is a substantial improvement over the older, manual transcription methods, but still suffers from the sample size problem: the test vehicles take a significant amount of time to traverse their routes, limiting the sample sizes.

Appendix C contains a summary of the data effort, including the detail of trips by segments along the routes travelled. Table 5 shows the travel times *within the zone* on the three arterials of interest at this time. Data from Jan 19th and 20th is shown for completeness, but with a strike-through, because of incidents that disrupted travel time in the area.

Travel time summaries are becoming available from the taxi origin-destination trips, through NYCDOT. This will add considerably to the number of samples, but (a) this is only one type of vehicle, and (b) only trip durations are available, from origin to destination of the trip.

5. Time-Space Displays of GPS-based Travel Time Runs

Figure 9 shows the time-space trajectories of the test vehicles along Lexington Avenue for weekday mornings (6am to 10am). “Before” runs are shown in shades of red. “After” runs are shown in shades of



Note: Dates are Jan 14th and 21st, Lane 2, from data available at the time of this report

Figure 7: RTMS Occupancy and Flow Data on 34th Street between 44th and 45th Streets, Lane 2

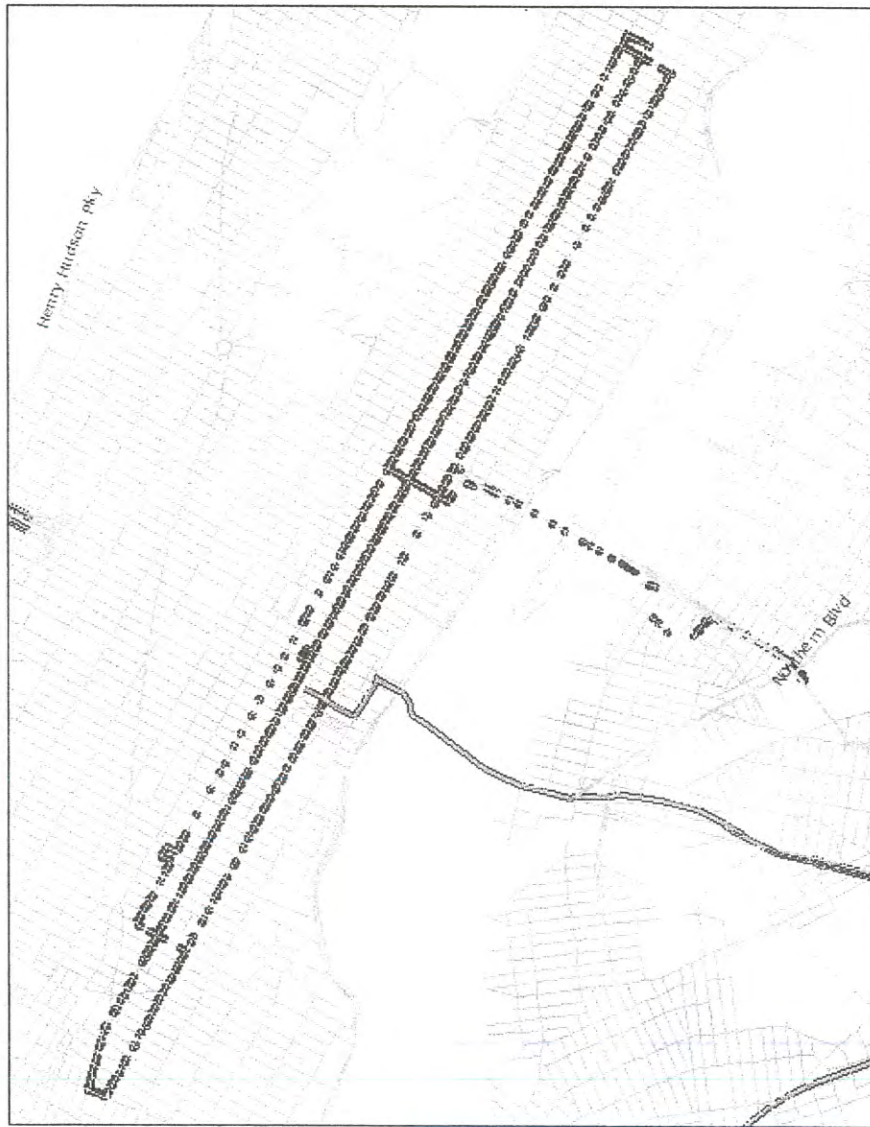


Figure 8: Trajectory of Test Vehicle with GPS-based Travel Time

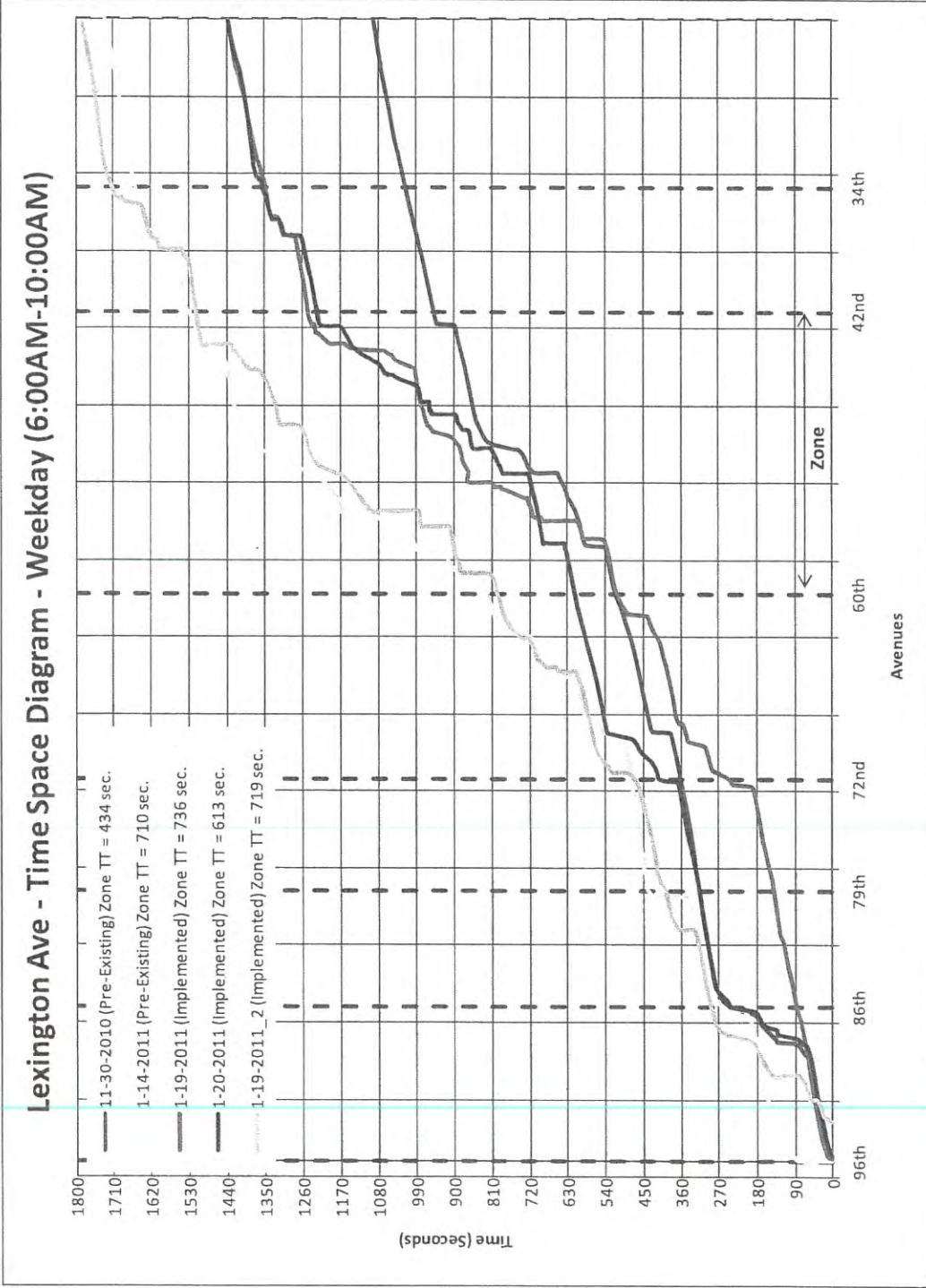
Table 5: Representative GPS-based Travel Times (seconds)

	AM		MID-DAY		PM	
	Pre-Existing	Baseline	Pre-Existing	Baseline	Pre-Existing	Baseline
2nd Avenue	268	347		444	372	249
		362		290		
		439		406		
Lexington Ave	434	607	389	996	398	524
	710	736	529	472		
		613	448	773		
		719				
3rd Avenue	380	279	565	279	115	565
	272	1097	442	535	219	896
	264	371	760	374		715
		343		448		993
		1096				

	FROM	TO
AM	6AM	10AM
MID-DAY	10AM	2PM
PM	2PM	7PM

All table entries in **seconds**.

Note: The observations crossed out were collected on days that had incidents reported on the QBB



Note: "Before" runs are shown in shades of red. "After" runs are shown in shades of blue.

Figure 9: Illustrative Time-Space Diagrams Along Lexington Avenue, Weekday Mornings

blue. The display is best read by following a vehicle in time (vertical axis)³, and observing that stops or delays show little or no forward (spatial) progress. At any point in space (along the horizontal axis), the greater times indicate the slower trips.

Figure 9 contains another illustration of the great variability that is inherent in the data: the “best time” through the zone --- and the overall arterial --- is a “before” run that is unusually efficient; the two “poorest times” are very close, with one representing “before” and the other “after”.

Appendix C contains additional time-space diagrams, with attention to the arterials.

6. Relation of Occupancy & Travel Time, in One Location

A question that was raised was the relation of occupancy data and travel time data, namely whether they reinforce each other and whether the patterns are as one would expect.

To that end, one location was selected at which the ETC readers measure a single block (most of the readers are spaced 6-8 blocks from each other) and the RTMS detector measures the thru traffic feeding that block. This was eastbound on 57th Street, east of Park Avenue:

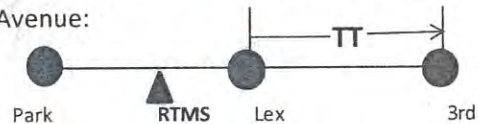


Figure 10 shows the travel time data and the occupancy data, each by 3-minute averages (see the blue scatter of data points). Only data with travel times less than 400 seconds were used in the averages.

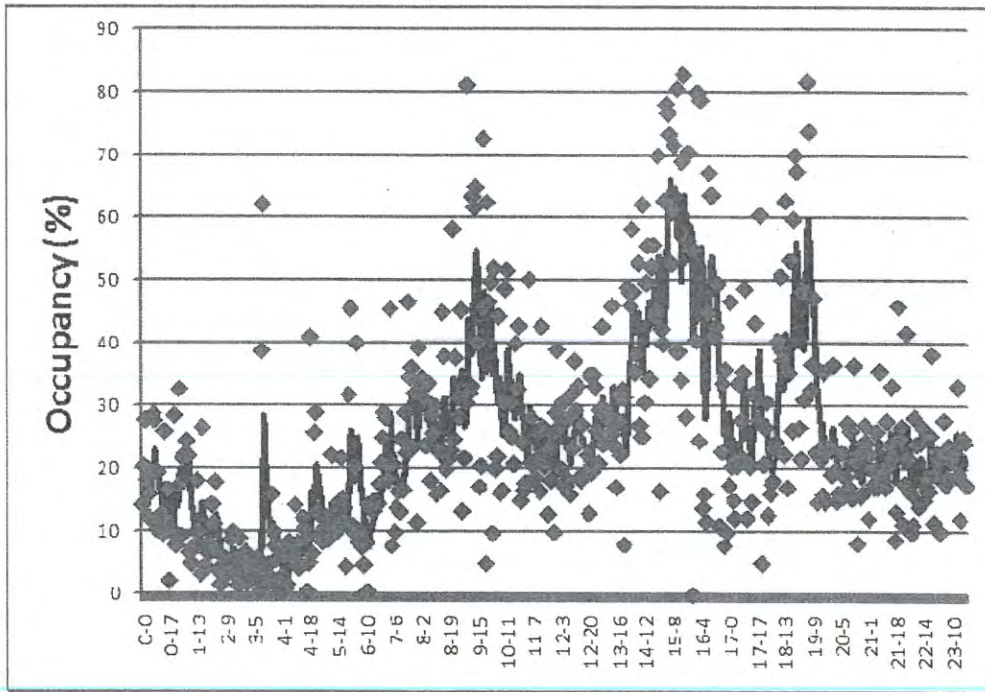
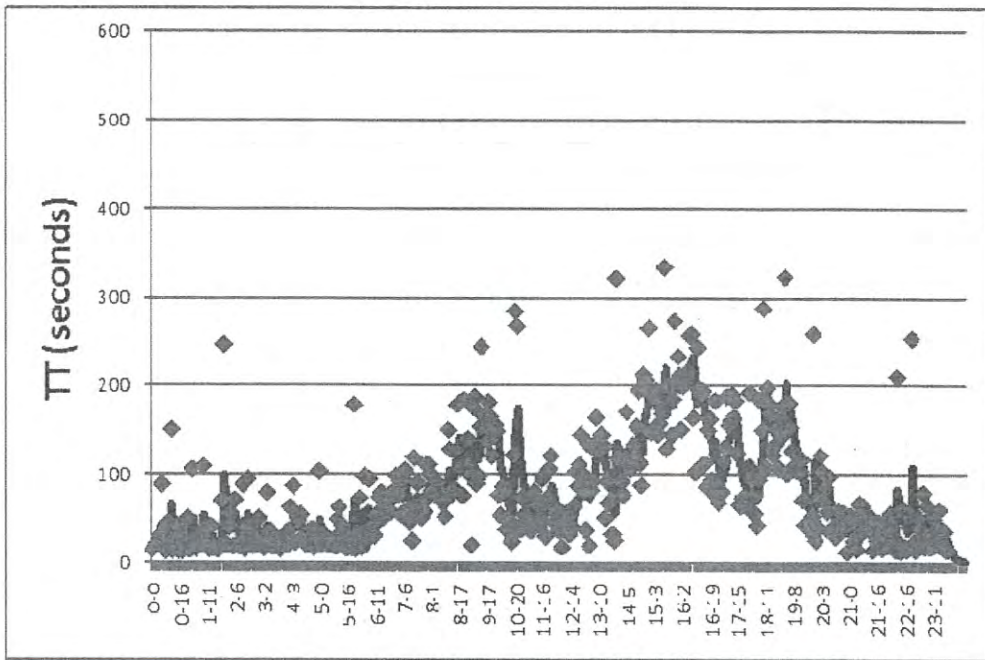
Figure 10 also shows the smoothed data in red, in each case. The purpose of the smoothing is to highlight the underlying trends and to investigate whether the patterns are logical, as well as whether the metrics are appropriate for their intended purposes, namely (a) provide a logical basis for effective control, and (b) provide an insight that can be readily understood.

Figure 11 shows the data in another format, a display of travel times and occupancies. Given the randomness inherent in traffic, some of the scatter is expected. In this case, the data is aggregated in 3-minute, 9-minute, and 15-minute periods. The scatter decreases and the correlation increases as the aggregation period increases, but the underlying relation persists.

Figure 11 also highlights the reality that some decisions are best made by aggregated data --- for instance, in the control concept, while 3-minute data is useful for some decisions (split allocation, in LEVEL 2), it is the more aggregated data or the smoothed data that is needed for LEVEL 1 decisions. Figure 10 reinforces this.

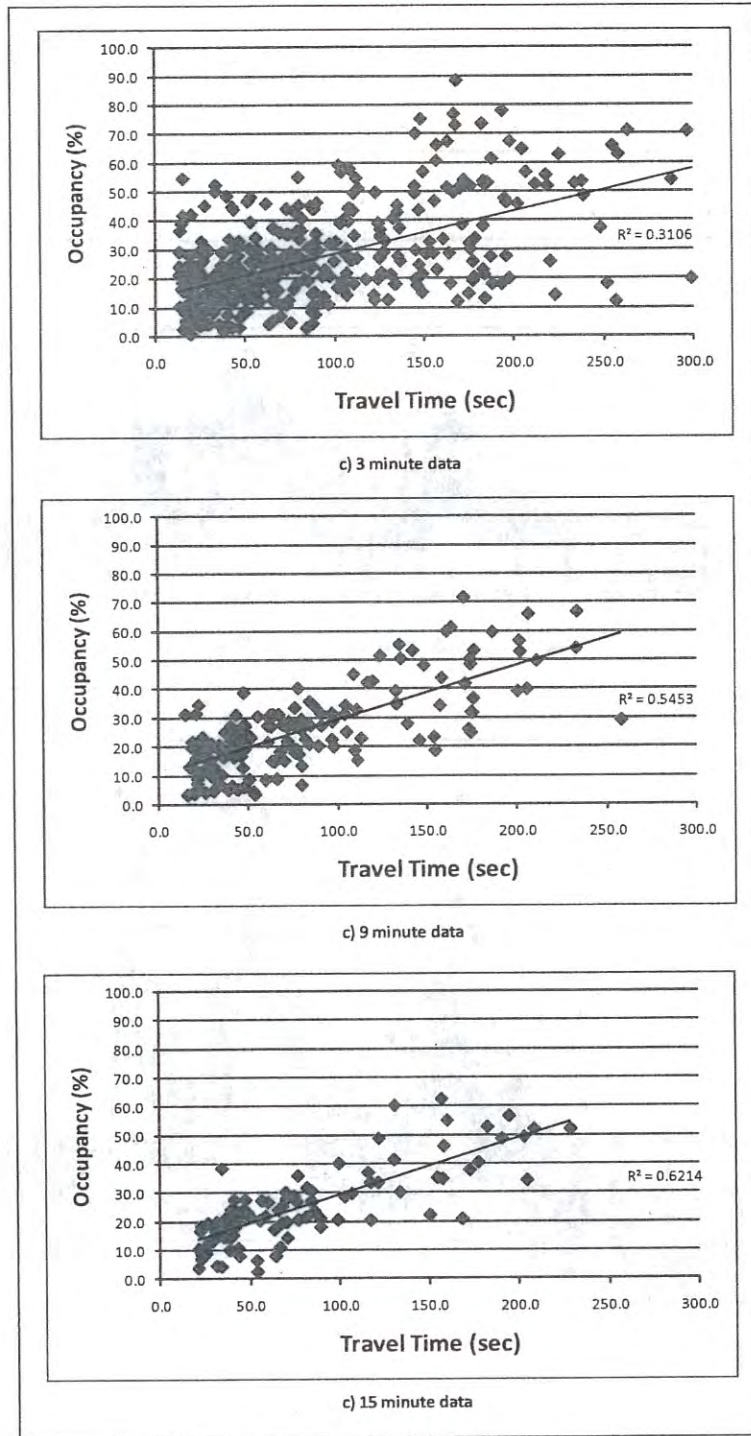
Figure 12 repeats Figure 11, but with the added emphasis that the data clusters, and that each cluster can have distinct meaning in exercising control.

³ It is now standard in some computer tools, reverses the “time” and “space” axes from earlier times, in order to accommodate printing.



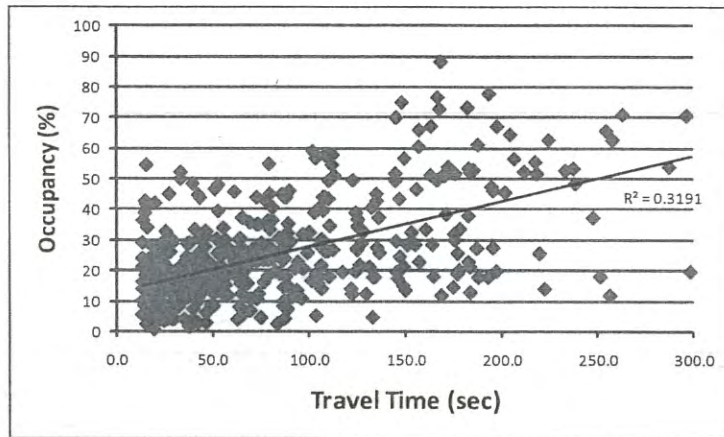
Note: 3-minute data shown in blue, smoothed data shown in red.

Figure 10: Travel Time and Occupancy Data, at One Test Location

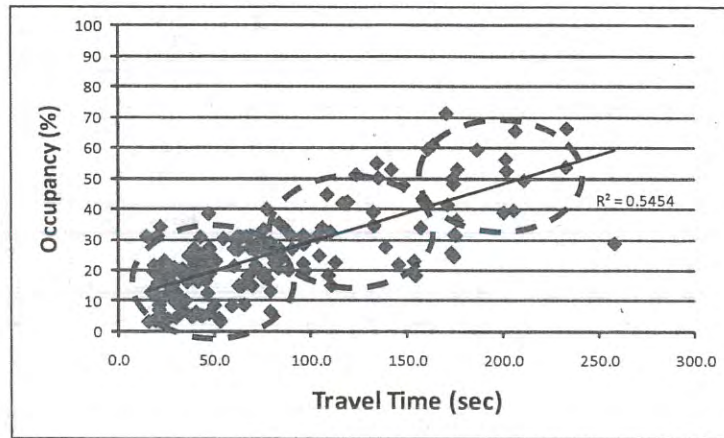


Note: no travel times more than 400 seconds included in the data.

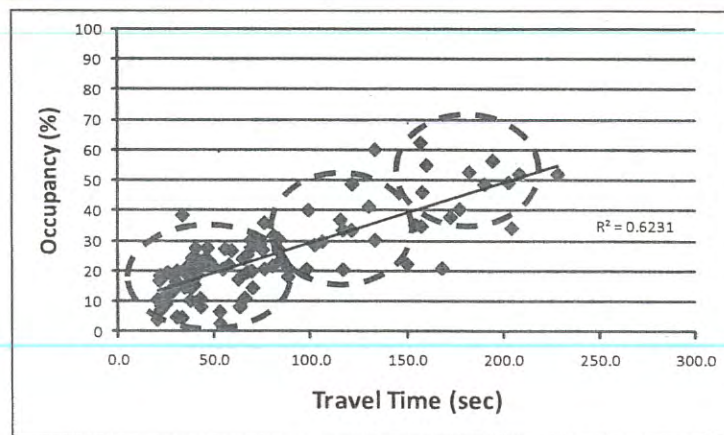
Figure 11: Correlation of Travel Time in One Segment (57th Street, EB, Lex to 3rd) with Observed Occupancy in the Upstream Feeder Block (57th Street, EB, Park to Lex)



c) 3 minute data



c) 9 minute data



c) 15 minute data

Note: no travel times more than 400 seconds included in the data.

Figure 12: Potential Clusters on Figure 11 Data

7. Data at the Time of the Jan 31, 2011 Field Visit

There was a Jan 31, 2011 field visit by NYCDOT to one of the RTMS locations in the zone, namely on 3rd Avenue between 44th and 45th Streets. This section makes a record of the traffic conditions at the time of the visit, from 1pm to 3pm. The flows, occupancies, and travel times seen in the field can then be comported to these numbers.

Figure 13 shows the location, albeit at a time absent of traffic due to the happenstance of the Google Street View recording and absent of winter conditions.

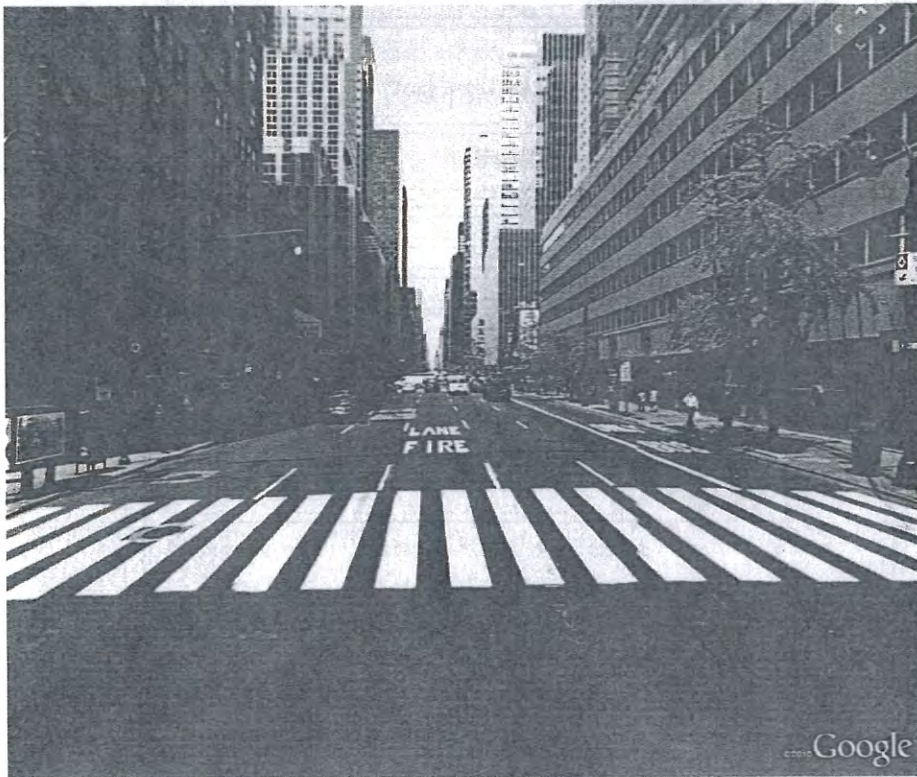


Figure 9: 3rd Avenue, Looking North from 44th to 45th Streets, Manhattan

Figure 14 shows the observed individual travel times from the ETC readers, from the NYCDOT data available for use on the project. The time segment from 1pm to 3pm is extracted, for emphasis. The segment is from 42nd to 49th Streets, due to the location of the readers.

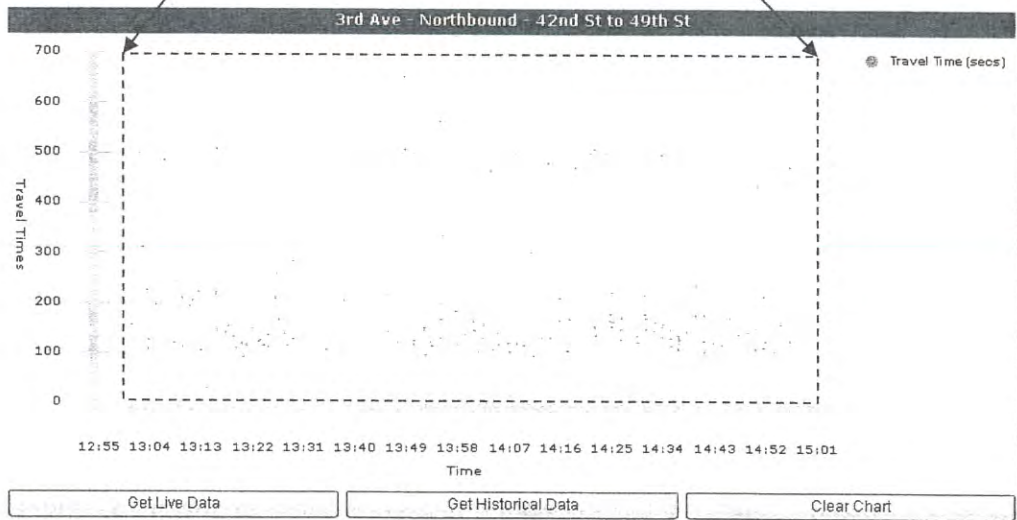
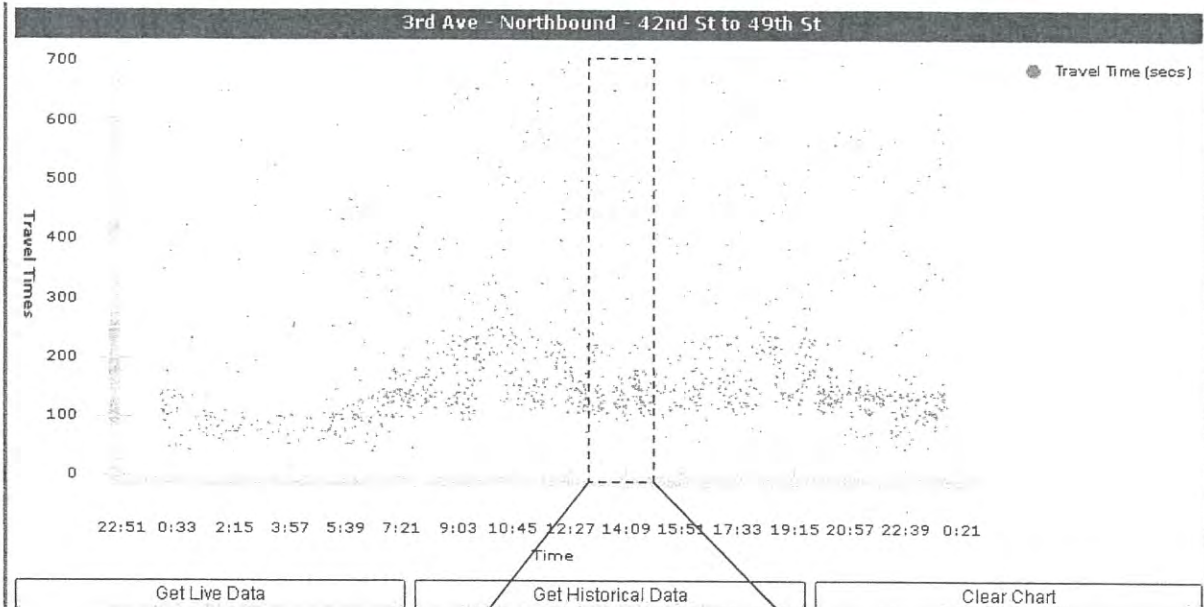


Figure 14: Travel Time Record for Jan 31 2011, 3rd Avenue from 42nd to 49th Streets

Figure 15 shows the key data results from the RTMS and the ETC detectors, namely:

- Point occupancy at the RTMS site in Lanes 2-4, on a 3-minute basis;
- Observed flow rate (vphpl) at the RTMS site in Lanes 2-4, on a 3-minute basis;
- Travel time from 42nd to 49th Streets, from the ETC readers, averaged over 3-minutes.

Each of the quantities is also shown in terms of smoothed data, with exponential smoothing and a 0.70 weight given to history from the prior 3-minute observations.

Figure 16 displays the observed occupancy versus observed flow, also on a 3-minute basis, during the 1pm to 3pm period. The significance of the Figure 16 data is its potential for use in control decisions. (The period happened to be relatively uneventful, as shown in the Figure 15 data; the Figure 16 shows no acute occupancy readings, although there was some variation and some related queueing).

8. Glossary

ETC – refers to the Electronic Toll Collection transponders, which are EZPass devices in the vehicles. Specifically, in the present context, refers to the ETC readers used to obtain travel time samples on segments of certain arterials and cross streets in Manhattan, by NYCDOT.

RTMS – the side-fire microwave detector used in NYC to obtain occupancy and flow observations by lane. The same devices can be mounted for longitudinal observations.

LEVEL 1 – refers to the first of two levels of active traffic management being designed for use in Manhattan. LEVEL 1 makes decisions on which traffic signal plans are to be used for a given period, with the period generally measured in hours. LEVEL 1 decisions in effect modify the schedule of when specific plans are used.

LEVEL 2 -- – refers to the second of two levels of active traffic management being designed for use in Manhattan. LEVEL 2 makes decisions on the allocation of green time amongst phases, generally at key critical intersections within the zone or approaching it.

GPS – generally, global positioning system. In the present context, the use of a GPS reader to record a sequence of location observations, and keep a record of times and positions, by means of a commercially available device that allows the information to be downloaded and use to construct travel time histories, time-space diagrams, and other displays and statistics.

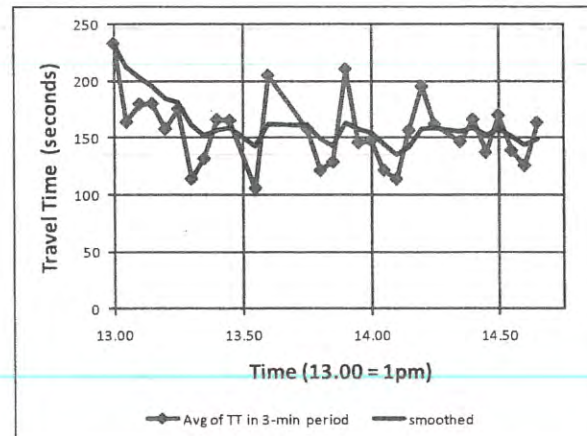
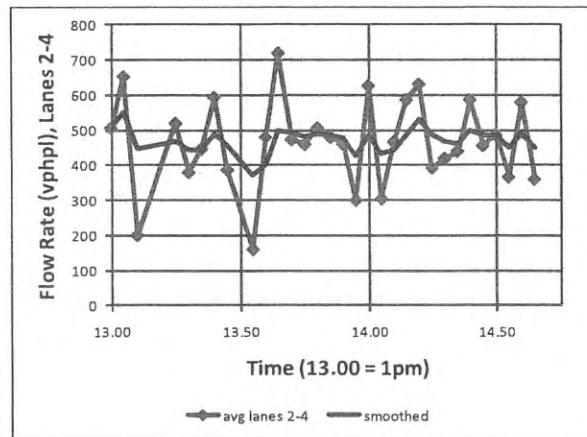
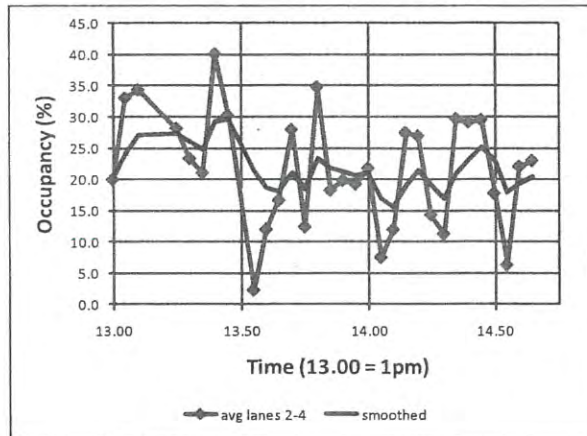


Figure 15: Observations during the Field Visit of Jan 31, 2011 (3rd Avenue, between 44th and 45th Streets), 1pm to 3pm

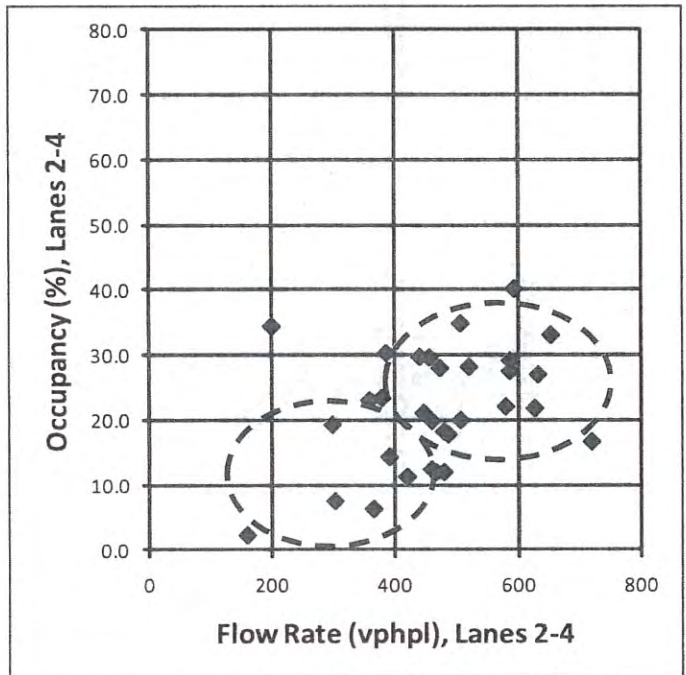
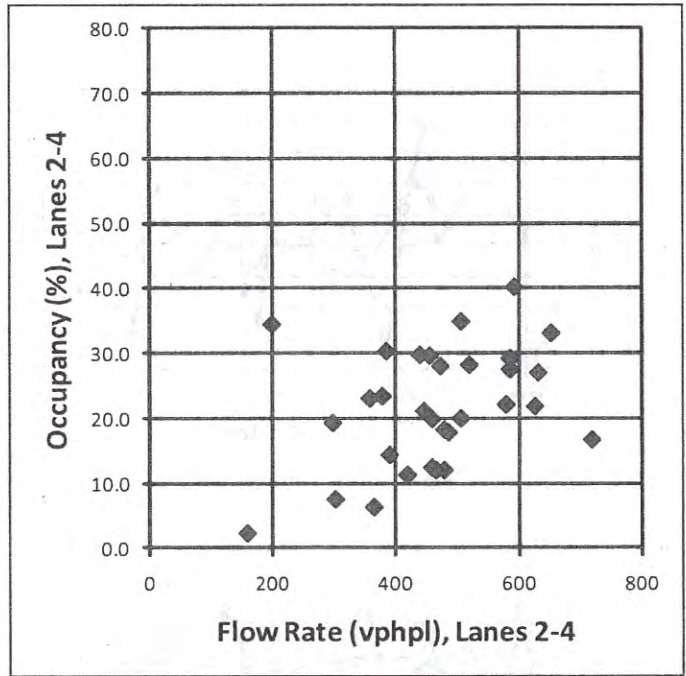


Figure 16: Relation of the Occupancy and Flow Data, at the Field Visit Site, 1pm to 3pm

Appendix A

E-ZPass Tag Reader – Travel Time Data

Appendix A – E-ZPass Tag Reader – Travel Time Data

This Appendix presents the travel time data sets for the segments shown in Figure A1 for the dates shown in Table A1. This data was made available by NYCDOT.

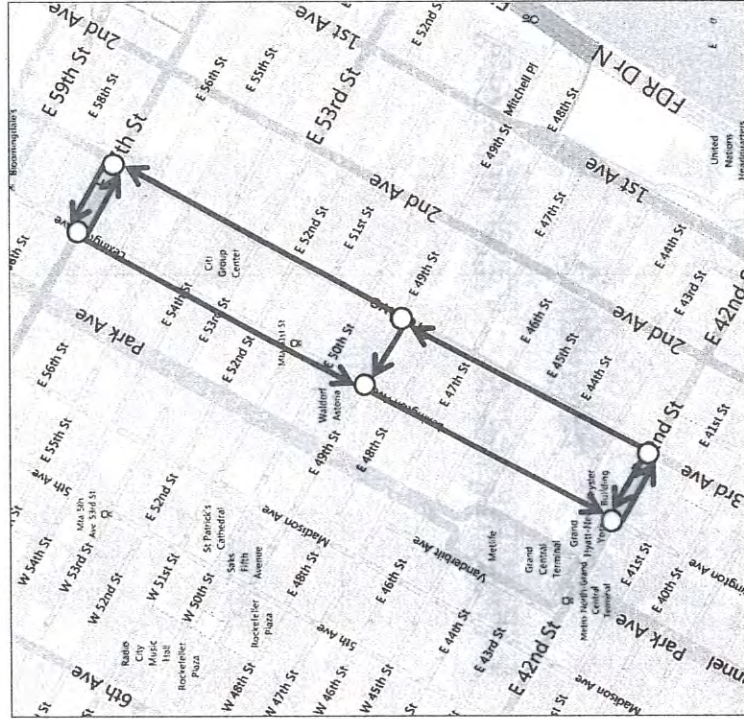


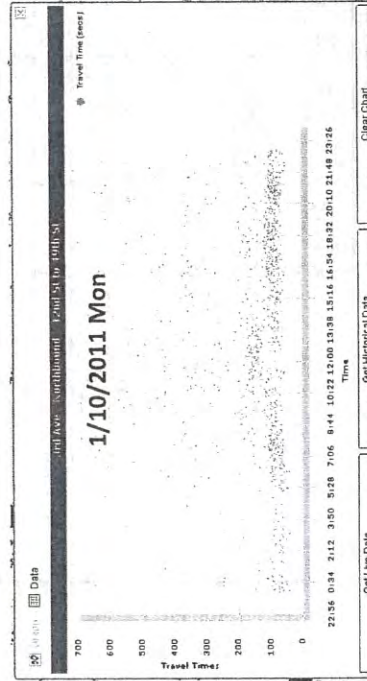
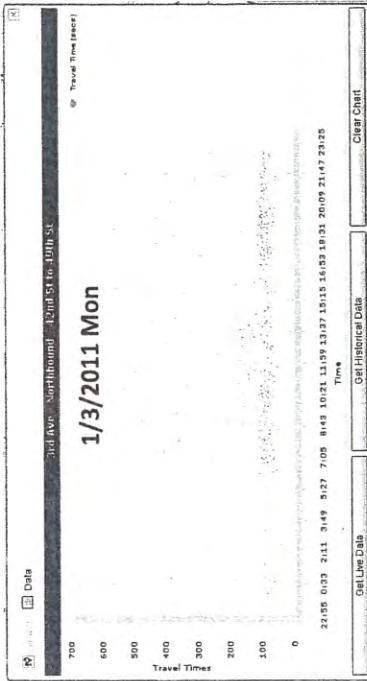
Figure A-1: Travel Time Data Segments

This data is organized by segment, by day of week. The data is presented in a series of panel displays comparing the “Pre-Existing” to the “Base as Implemented” in Figures A2 through A51.

Table A1: Available Travel Time Data

Travel Time Inventory Data for January 2011																	
Link	Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
3rd between 42nd and 49th		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
3rd between 49th and 57th			✓					✓	✓	✓	✓	✓	✓	✓	✓		
Lex between 49th and 42nd						✓		✓	✓	✓	✓	✓	✓	✓	✓		
Lex between 57th and 49th		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
49th between 3rd and Lex		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
42nd between 3rd and Lex										✓							
42nd between Lex and 3rd										✓							
57th between Lex and 3rd										✓							
	Day	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Link																	
3rd between 42nd and 49th		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3rd between 49th and 57th		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lex between 49th and 42nd		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lex between 57th and 49th		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
49th between 3rd and Lex		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
42nd between 3rd and Lex										✓							
42nd between Lex and 3rd										✓							
57th between Lex and 3rd		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Pre-Existing



Base as Implemented

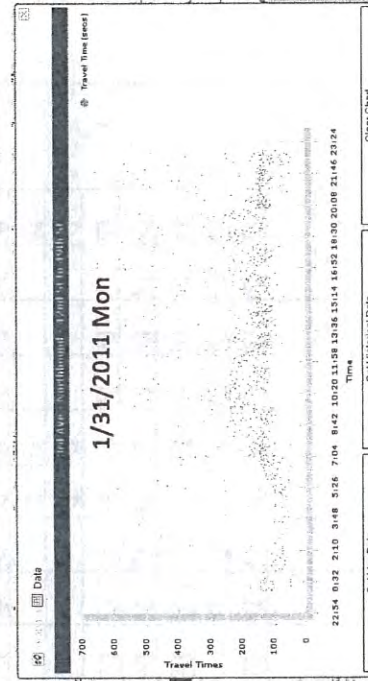
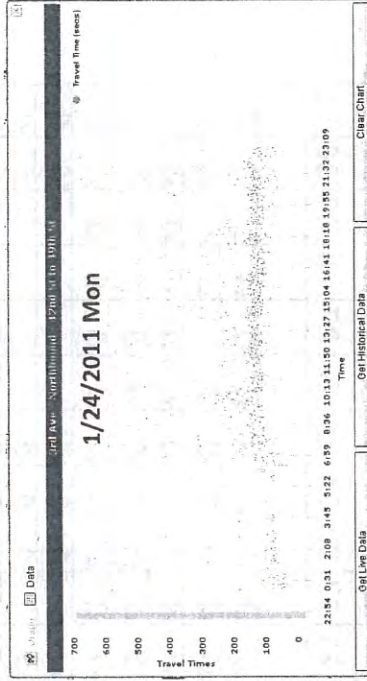
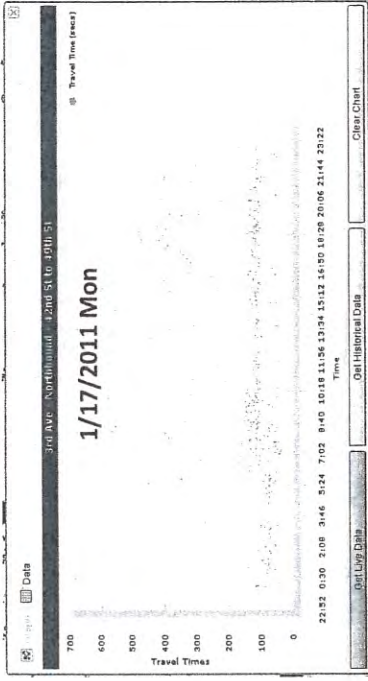
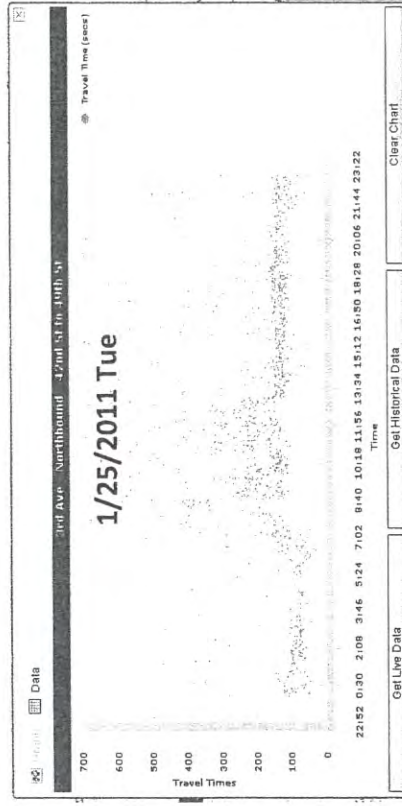
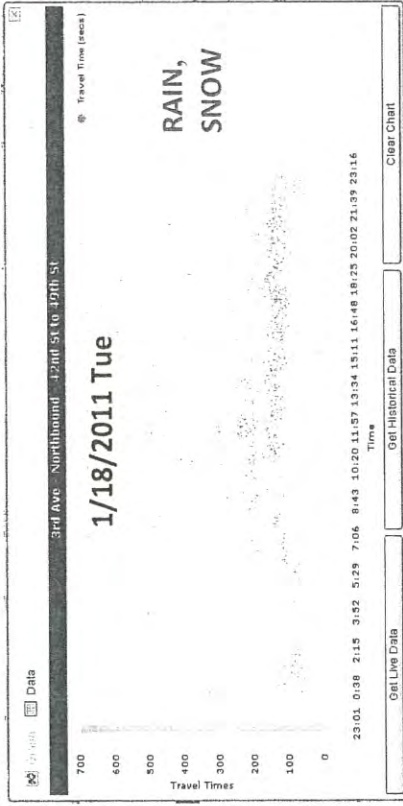


Figure A - 2: Travel Time (sec) Monday 3rd Ave. between 42nd St. and 49th St.

Base as Implemented



Pre-Existing

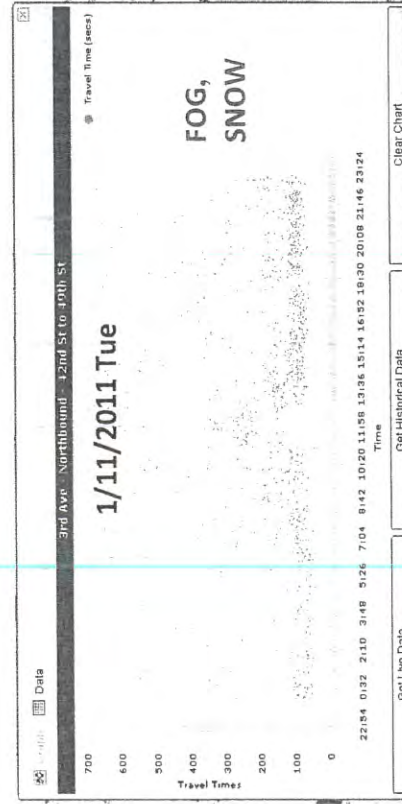
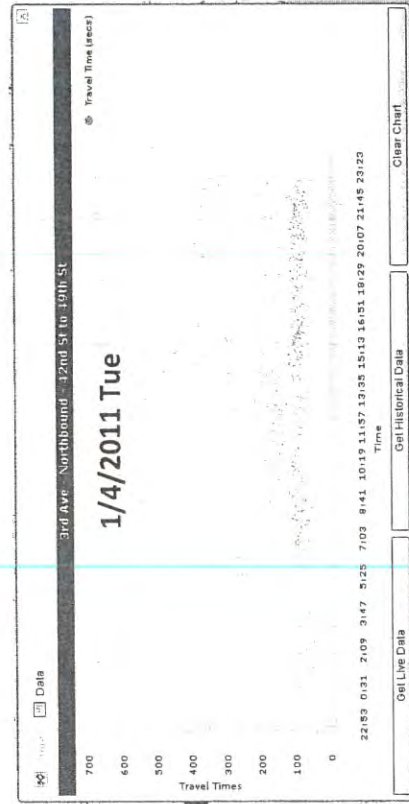
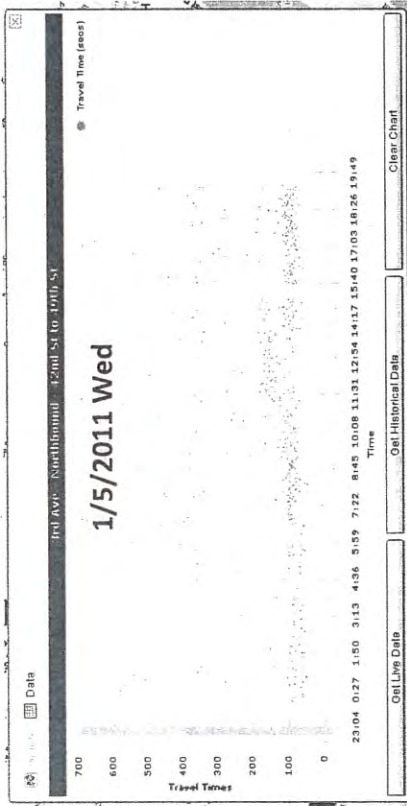


Figure A - 3: Travel Time (sec) Monday 3rd Ave. between 42nd St. and 49th St.

Pre-Existing



Base as Implemented

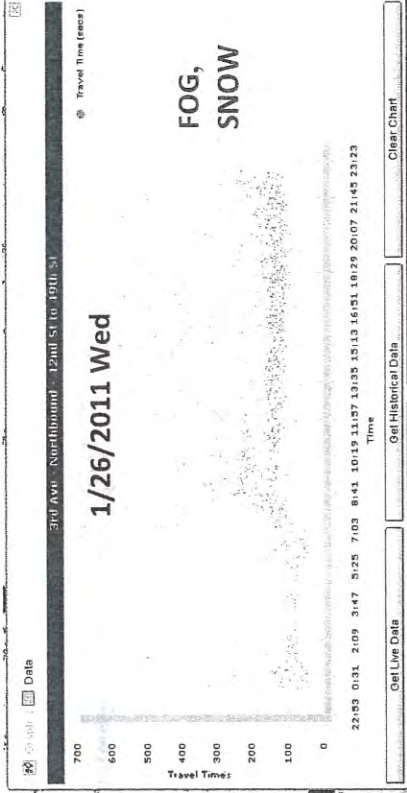
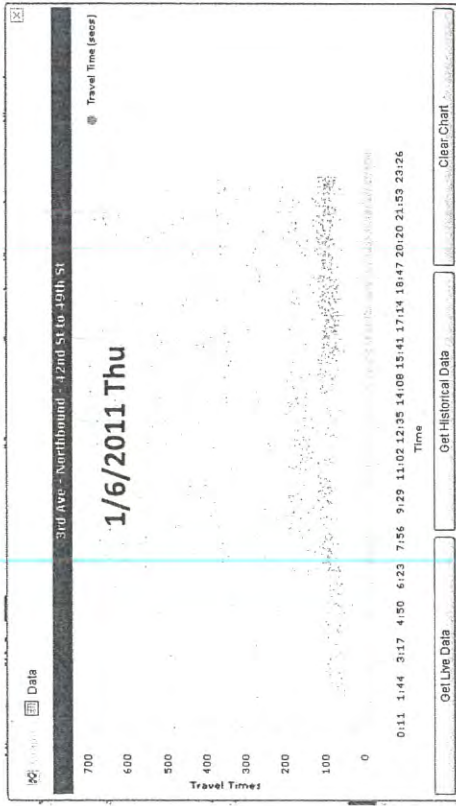


Figure A - 4: Travel Time (sec) Wednesday 3rd Ave. between 42nd St. and 49th St.

Pre-Existing



Base as Implemented

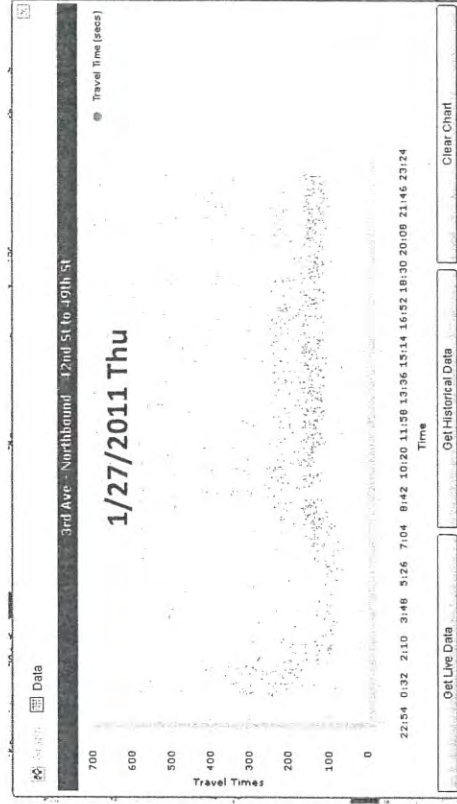
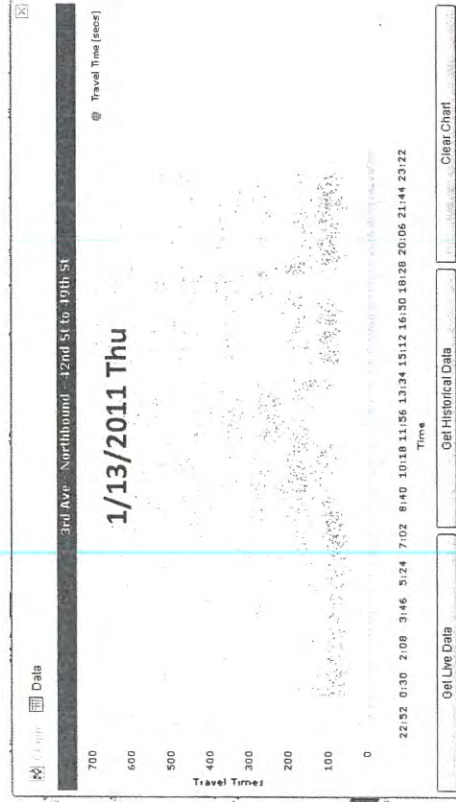
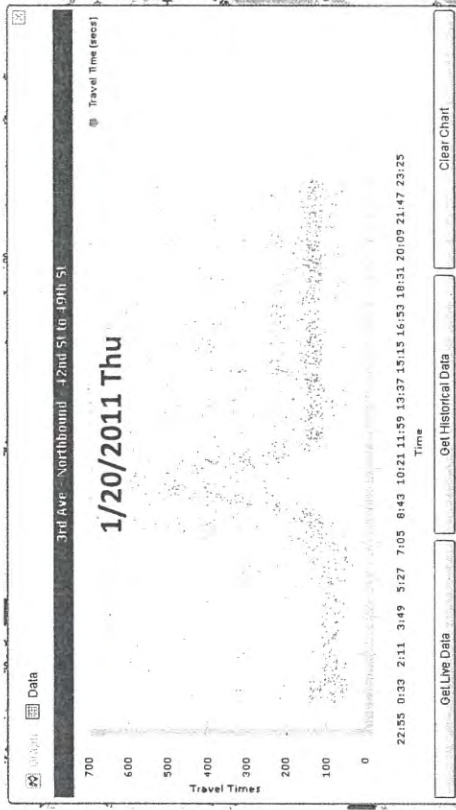


Figure A - 5: Travel Time (sec) Thursday 3rd Ave. between 42nd St. and 49th St.

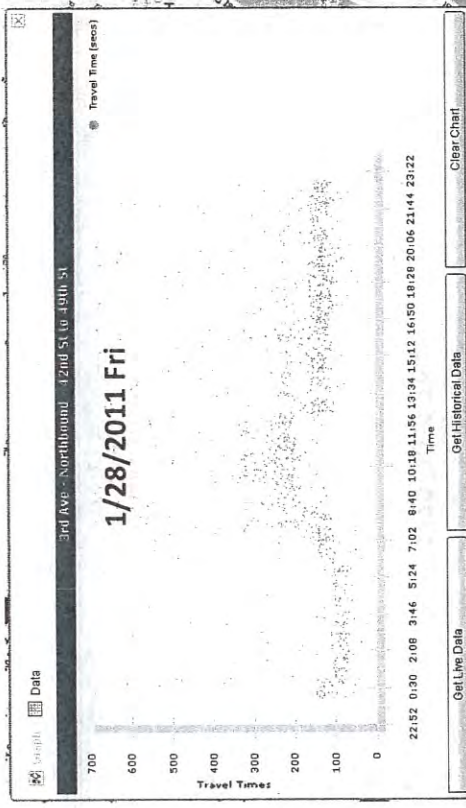
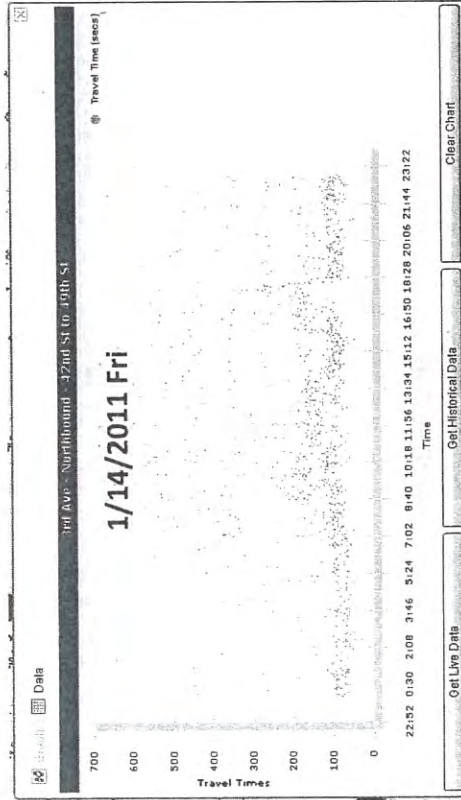
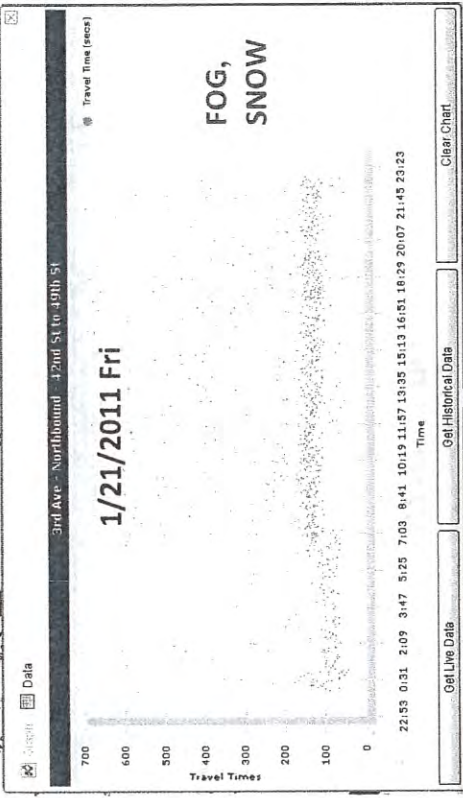
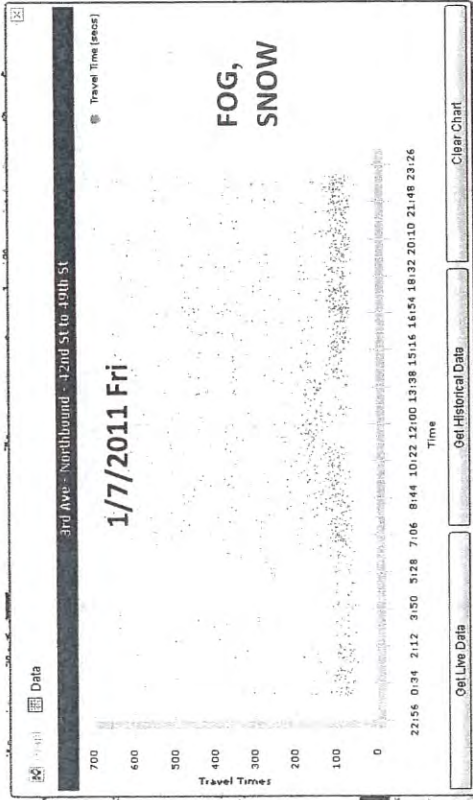
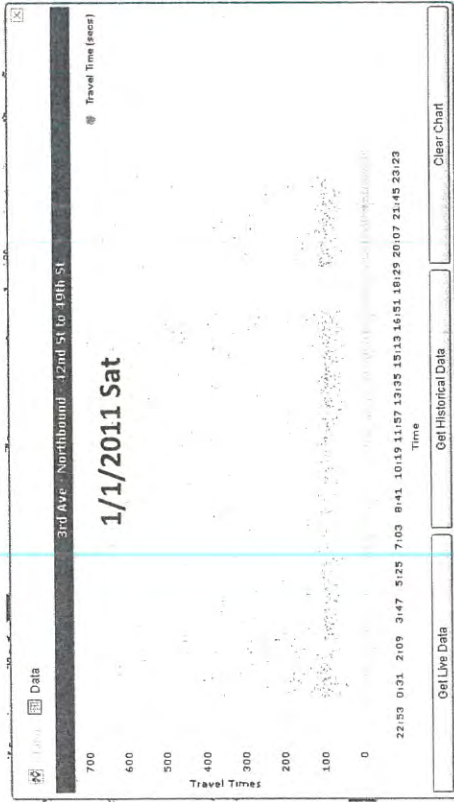


Figure A - 6: Travel Time (sec) Friday 3rd Ave. between 42nd St. and 49th St.

Pre-Existing



Base as Implemented

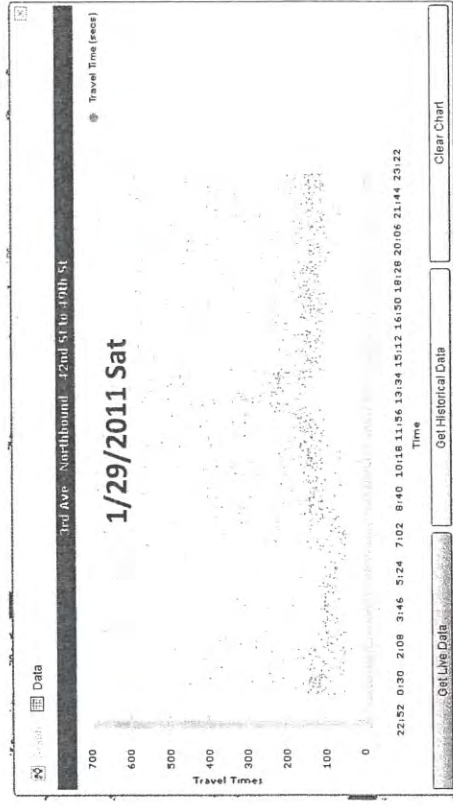
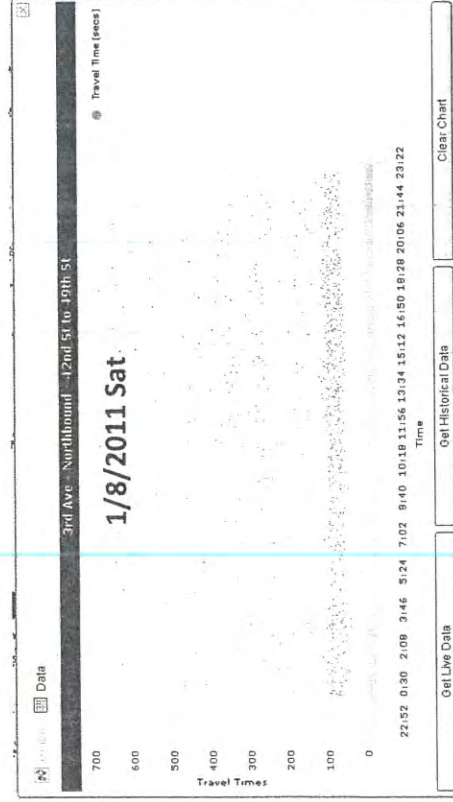
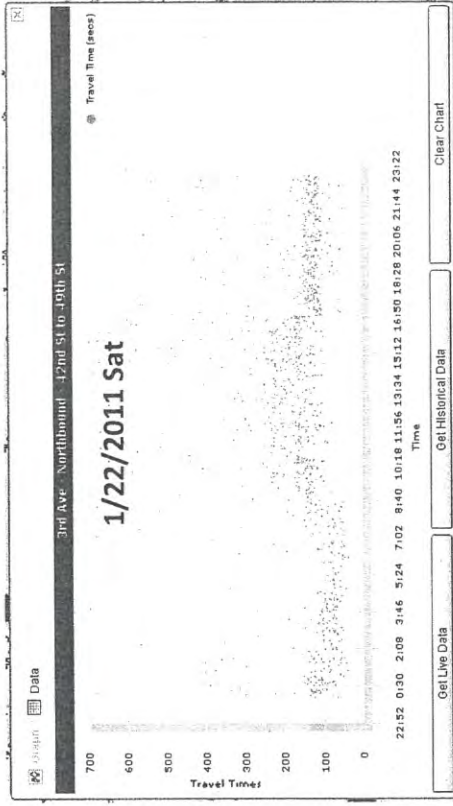
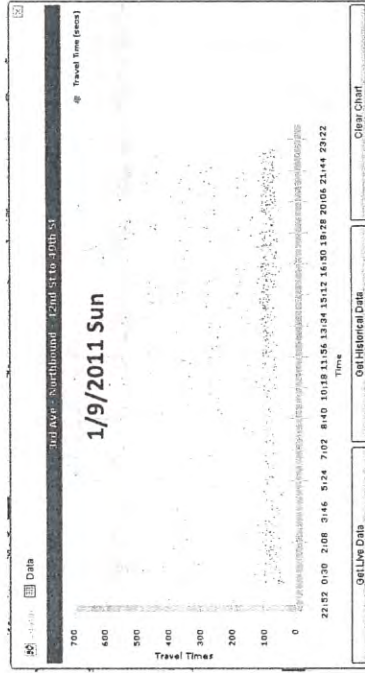
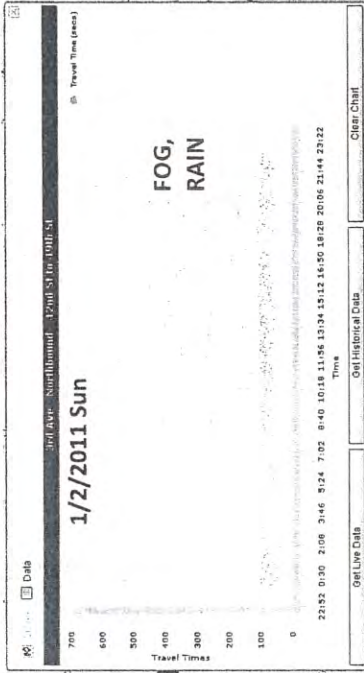


Figure A - 7: Travel Time (sec) Saturday 3rd Ave. between 42nd St. and 49th St.

Pre-Existing



Base as Implemented

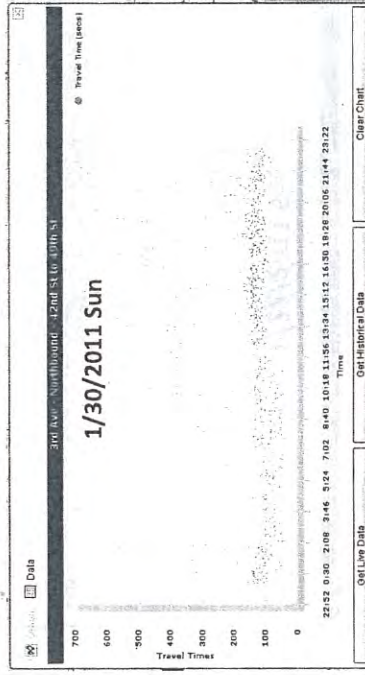
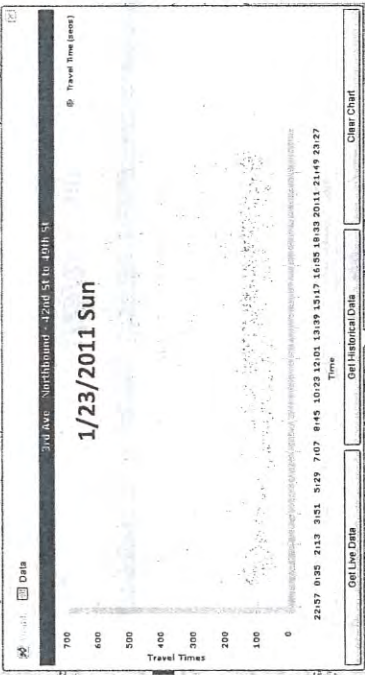
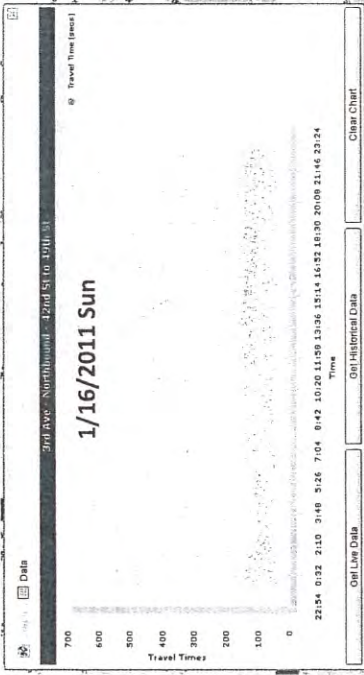
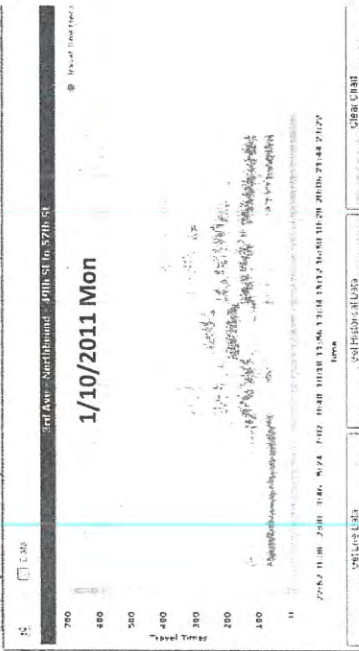
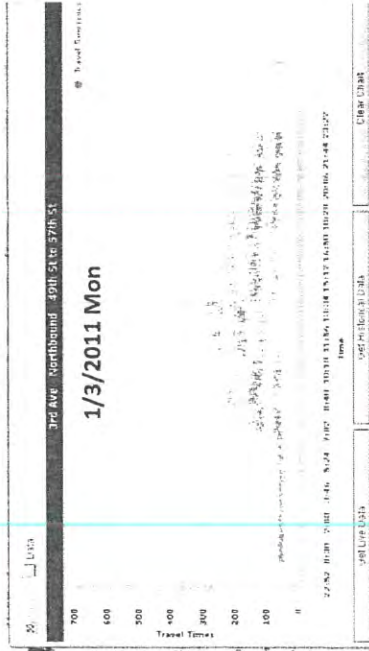


Figure A - 8: Travel Time (sec) Sunday 3rd Ave. between 42nd St. and 49th St.

Pre-Existing



Base as Implemented

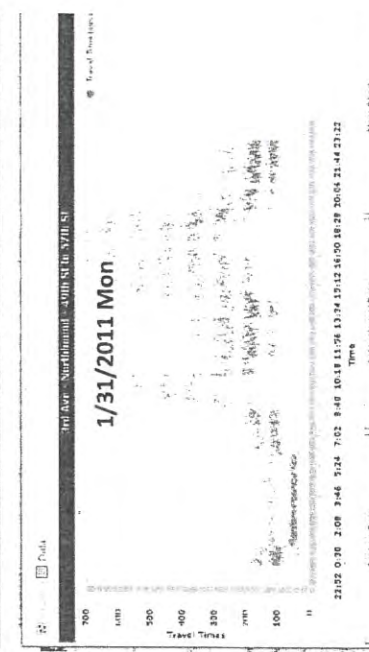
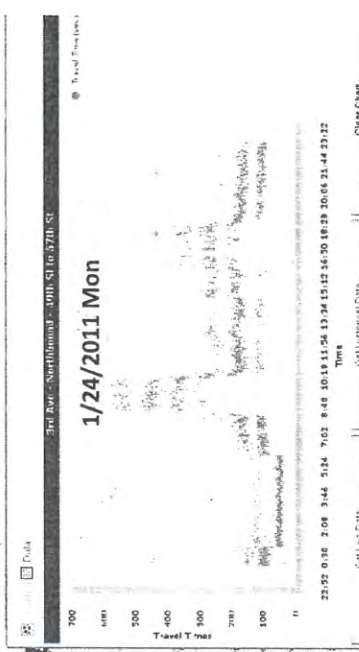
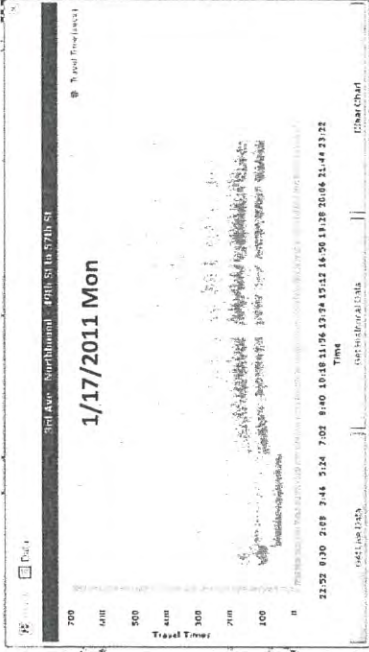
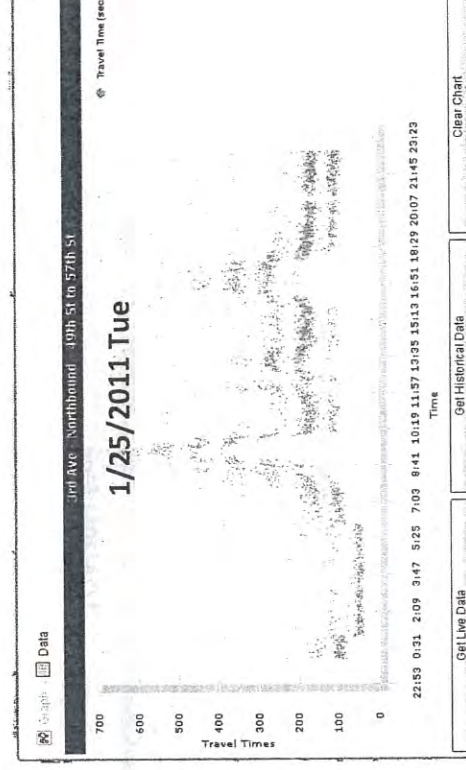
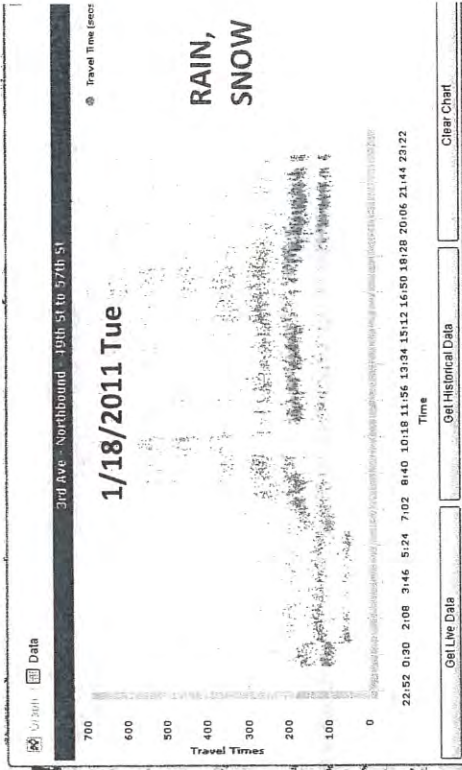


Figure A - 9: Travel Time (sec) Monday 3rd Ave. between 49th St. and 57th St.

Base as Implemented



Pre-Existing

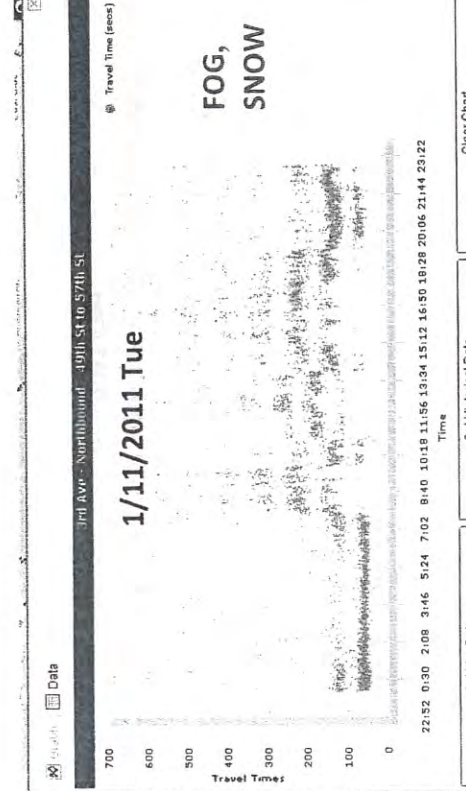
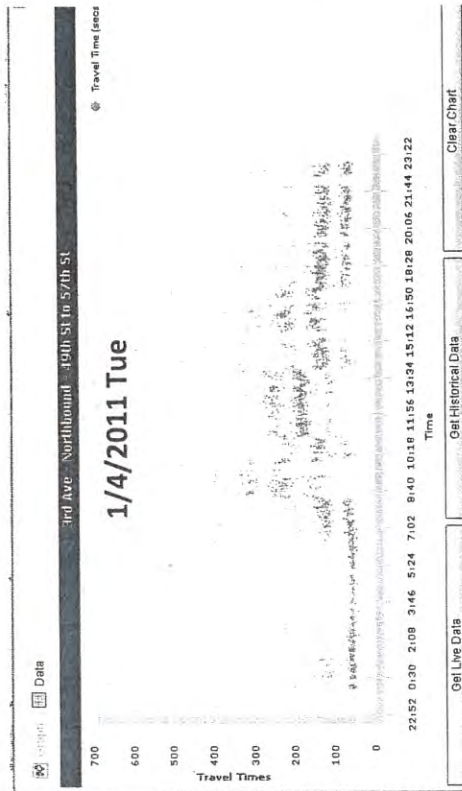
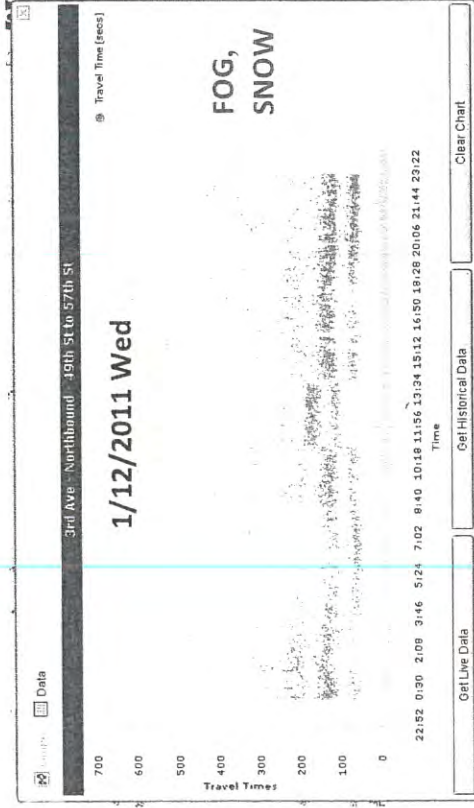


Figure A - 10: Travel Time (sec) Tuesday 3rd Ave. between 49th St. and 57th St.

Pre-Existing



Base as Implemented

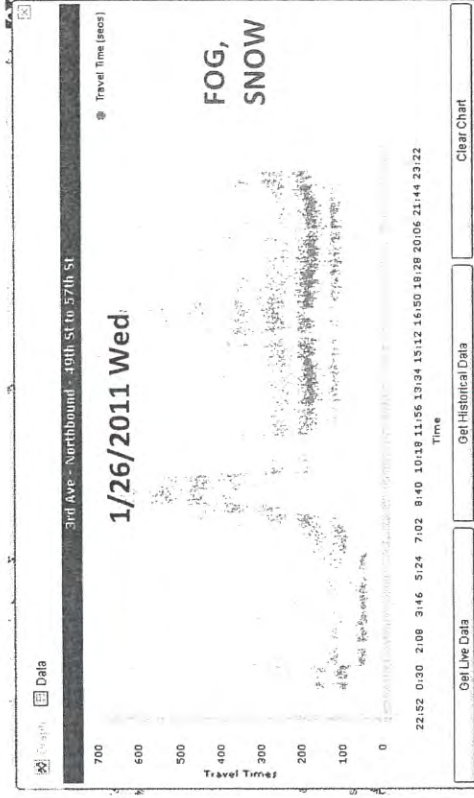
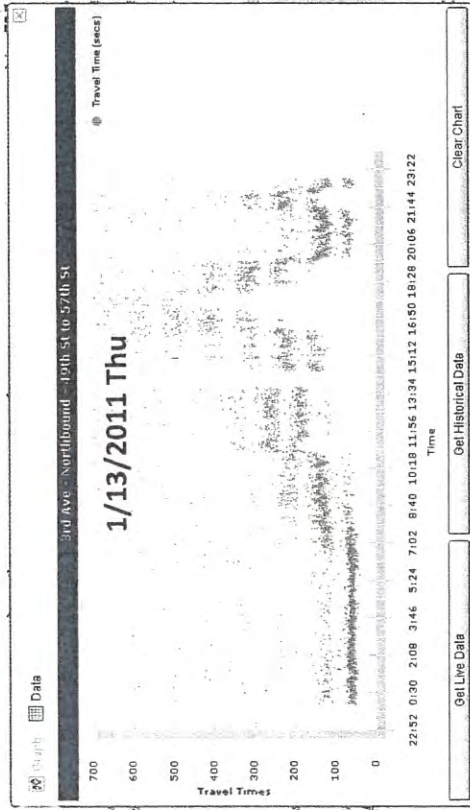


Figure A - 11: Travel Time (sec) Wednesday 3rd Ave. between 49th St. and 57th St.

Pre-Existing



Base as Implemented

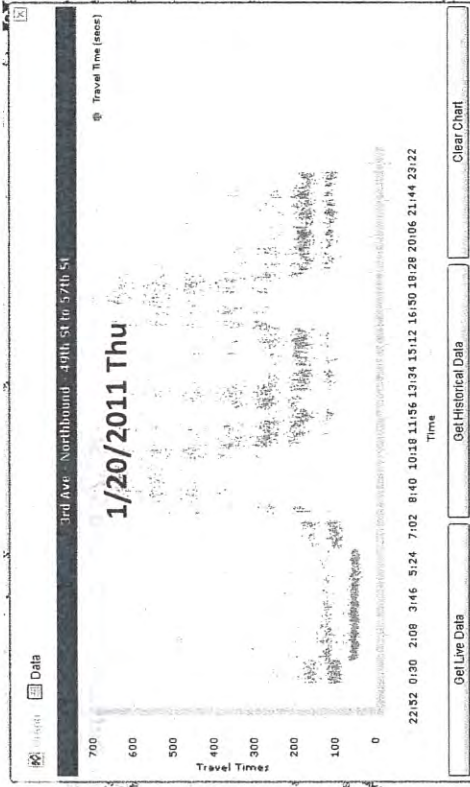
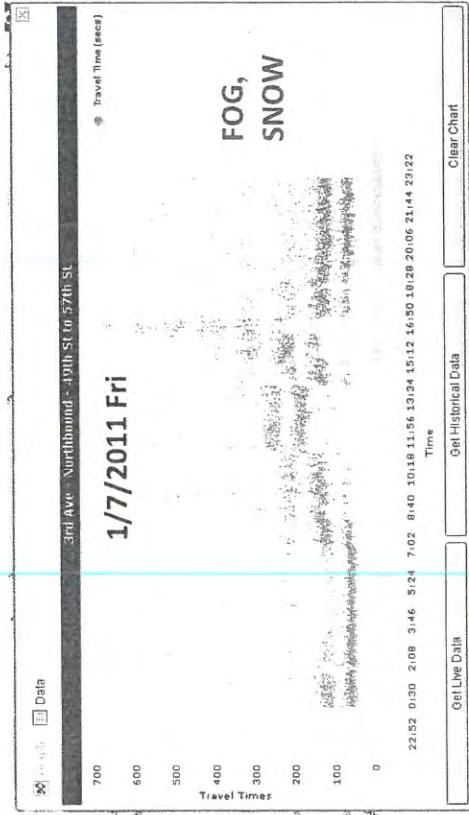


Figure A - 12: Travel Time (sec) Thursday 3rd Ave. between 49th St. and 57th St.

Pre-Existing



Base as Implemented

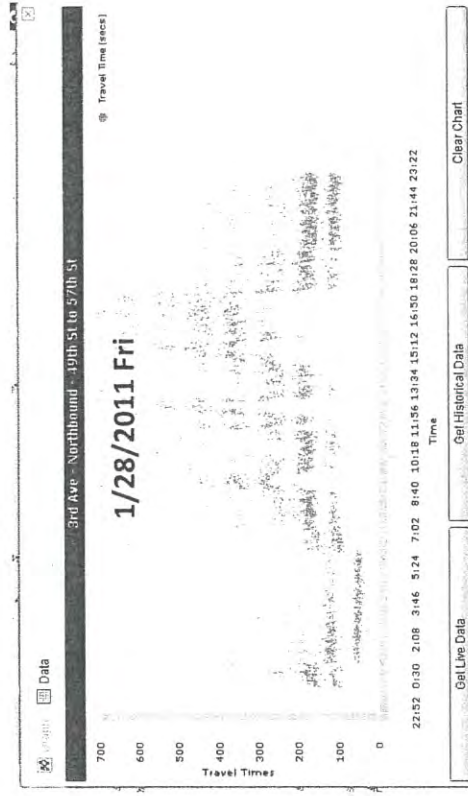
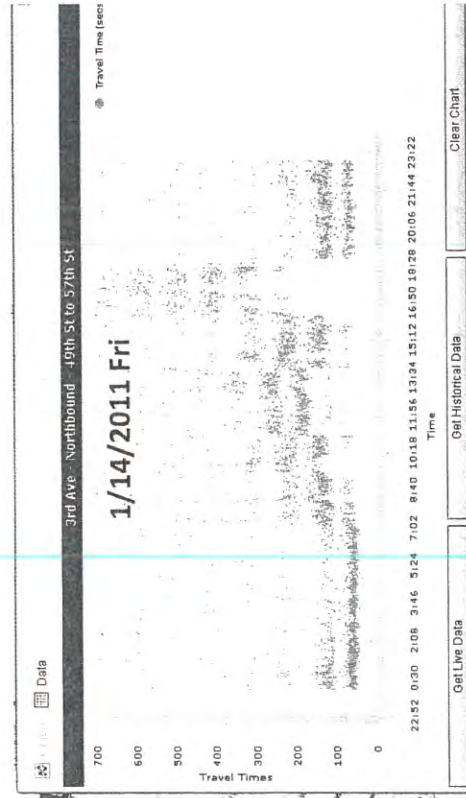
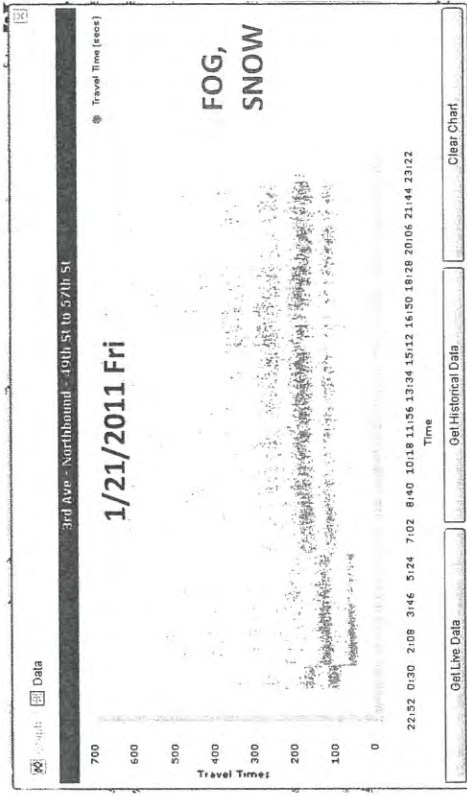
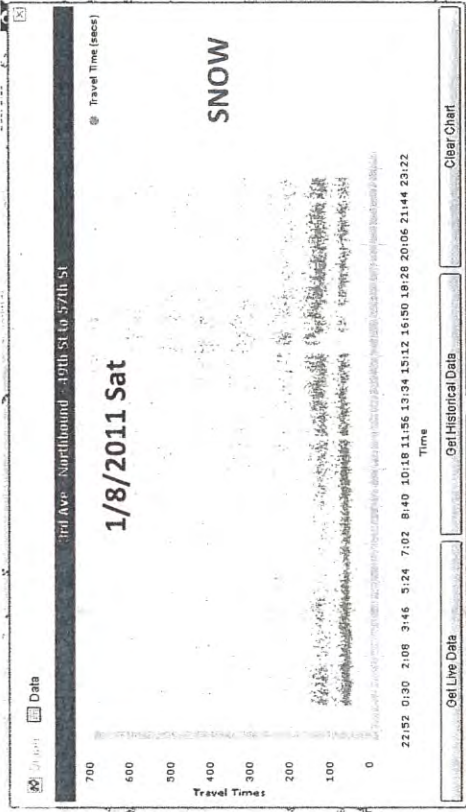


Figure A - 13: Travel Time (sec) Friday 3rd Ave. between 49th St. and 57th St.

Pre-Existing



Base as Implemented

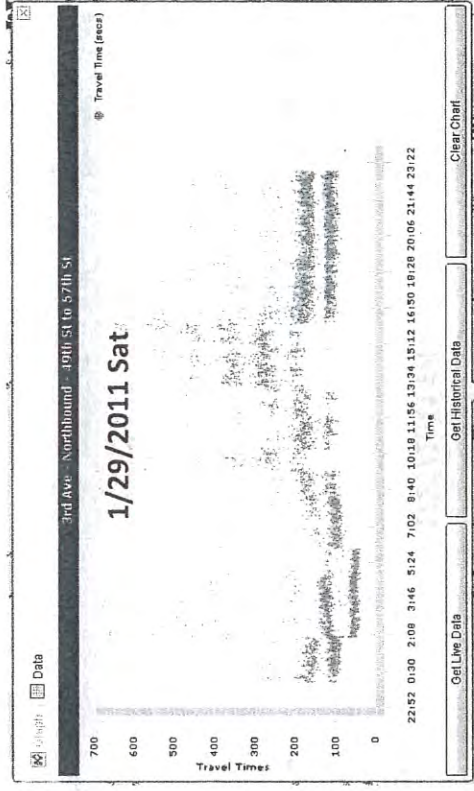
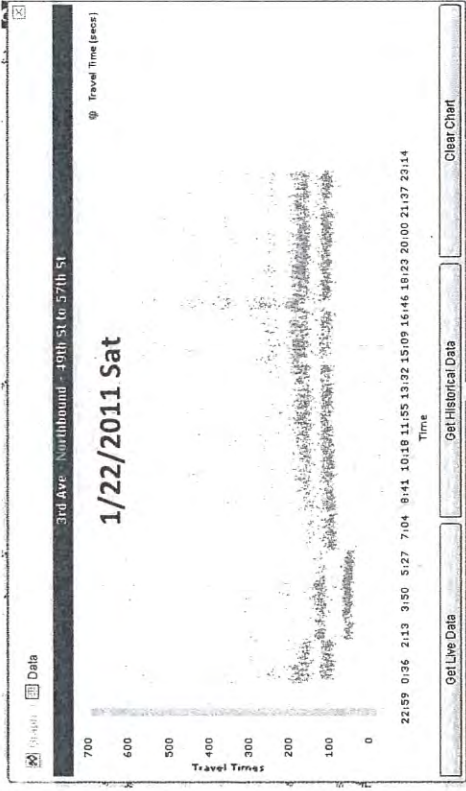
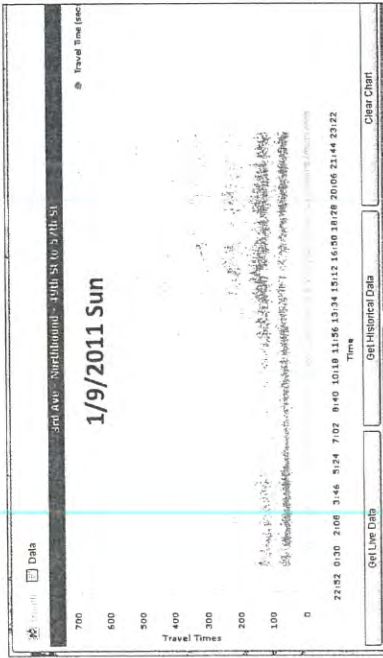


Figure A - 14: Travel Time (sec) Saturday 3rd Ave. between 49th St. and 57th St.

Pre-Existing



Base as Implemented

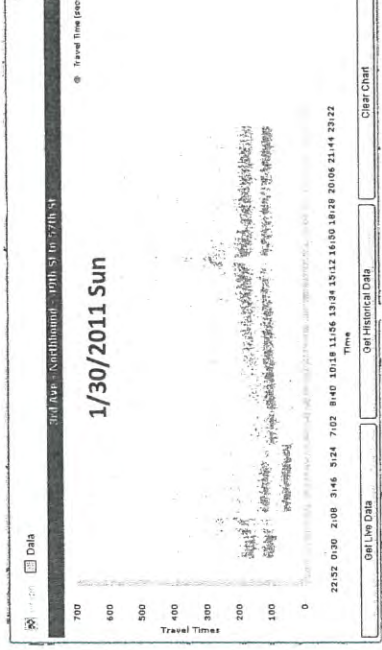
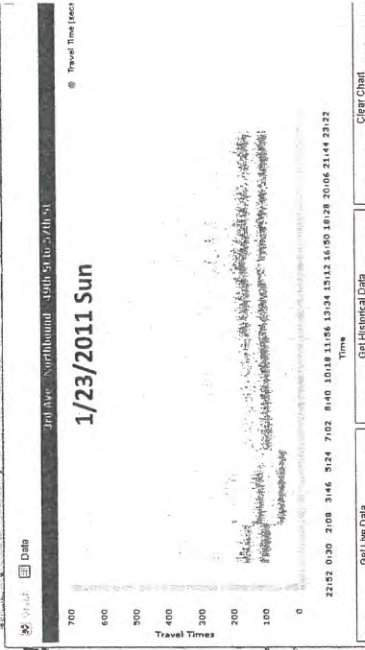
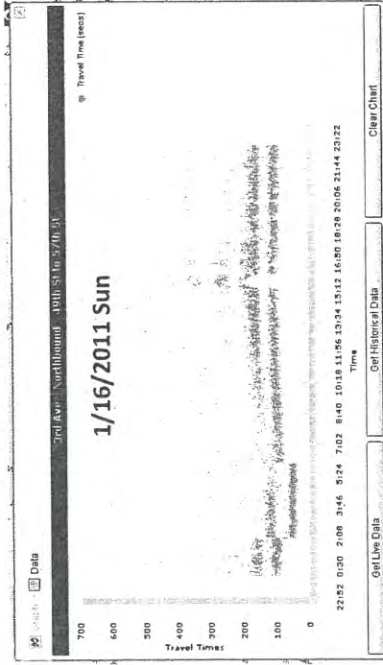
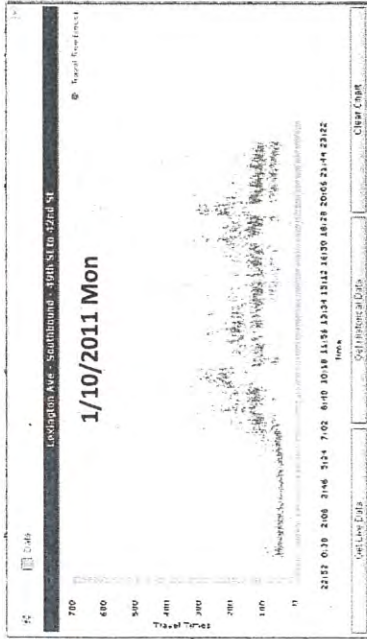


Figure A - 15: Travel Time (sec) Sunday 3rd Ave. between 49th St. and 57th St.

Pre-Existing



Base as Implemented

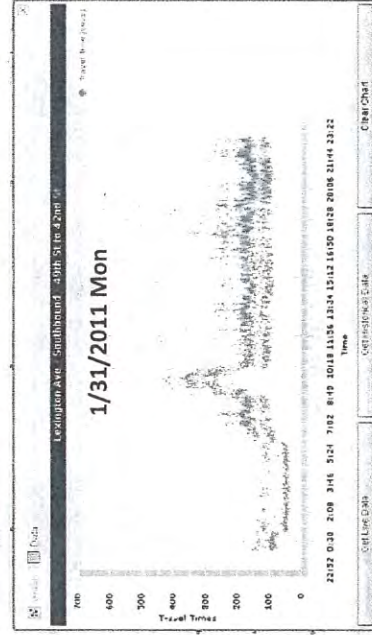
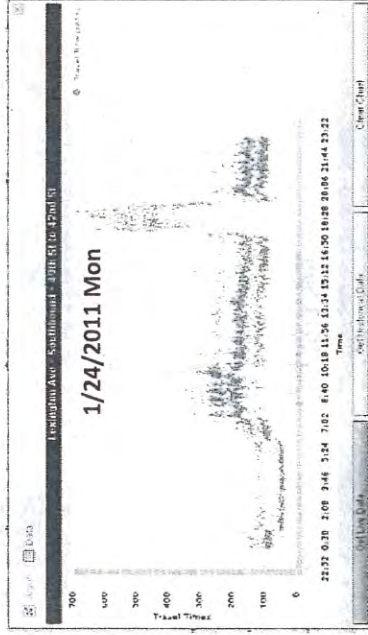
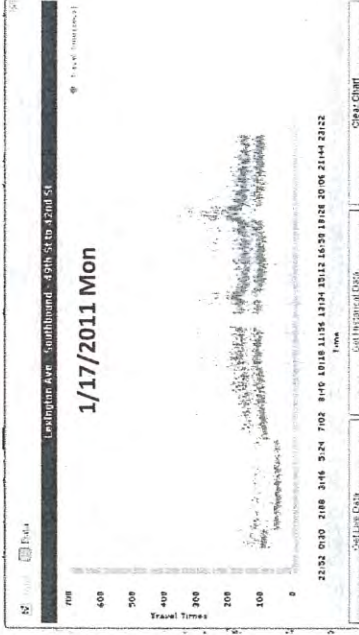


Figure A - 16: Travel Time (sec) Monday Lexington Ave. between 49th St. and 42nd St.

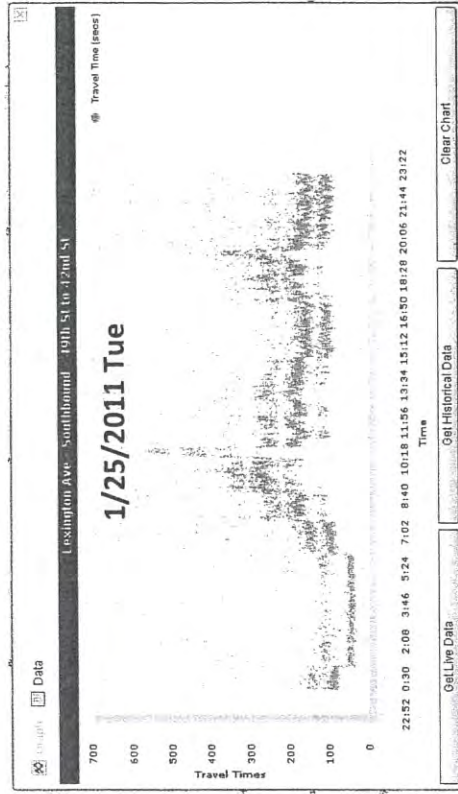
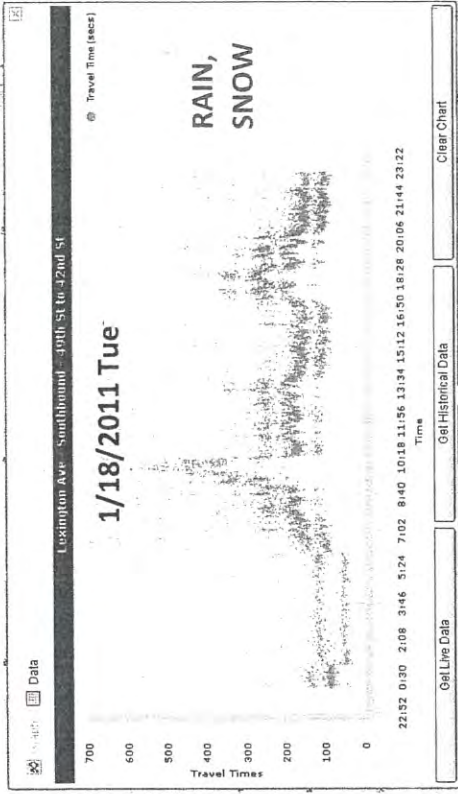
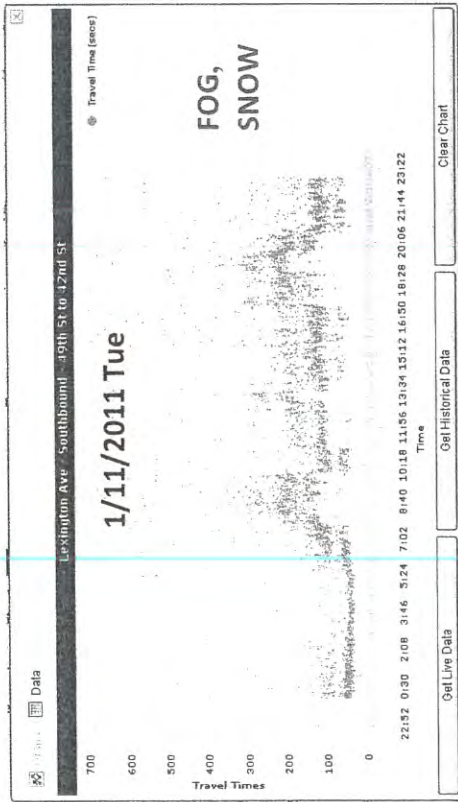
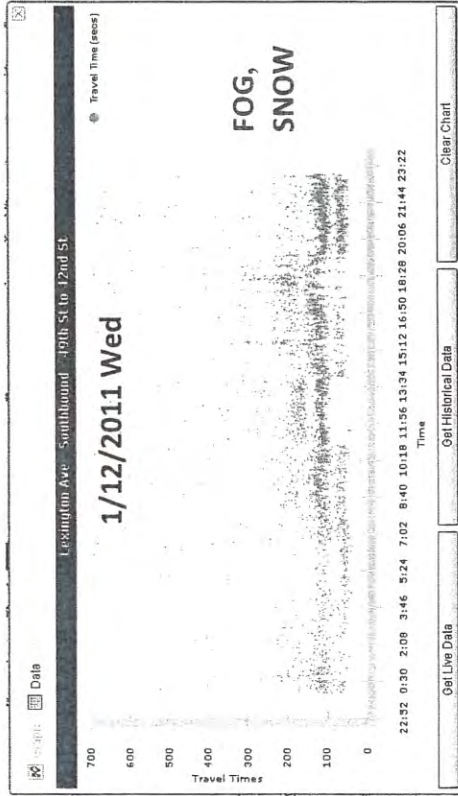


Figure A - 17: Travel Time (sec) Tuesday Lexington Ave. between 49th St. and 42nd St.

Pre-Existing



Base as Implemented

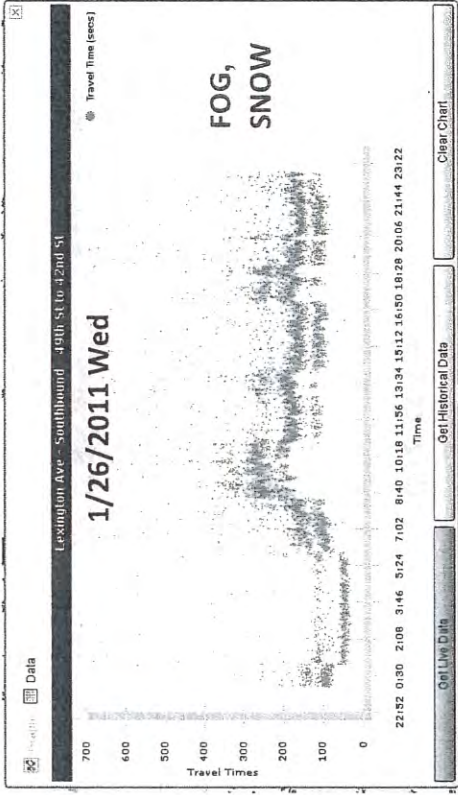
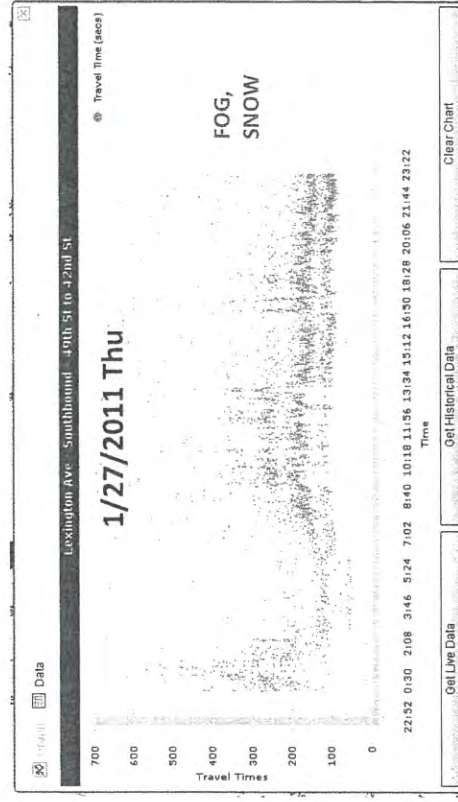
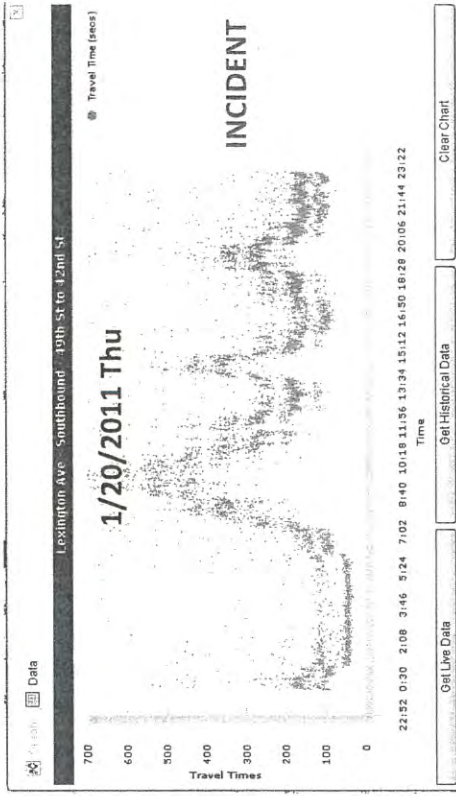


Figure A - 18: Travel Time (sec) Wednesday Lexington Ave. between 49th St. and 42nd St.

Base as Implemented



Pre-Existing

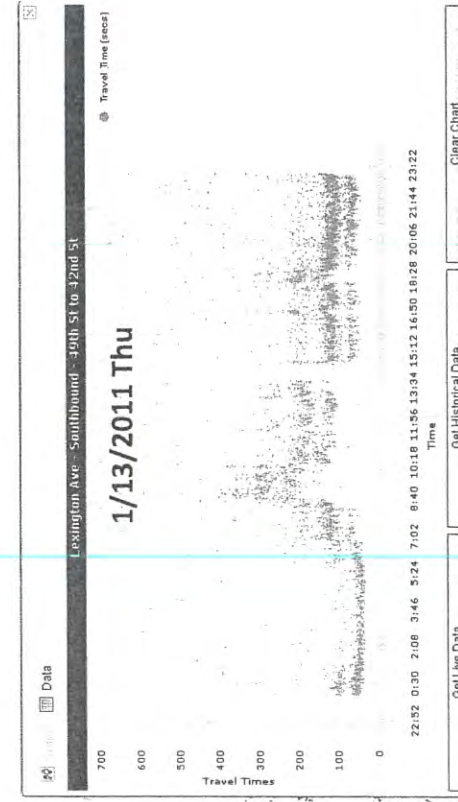
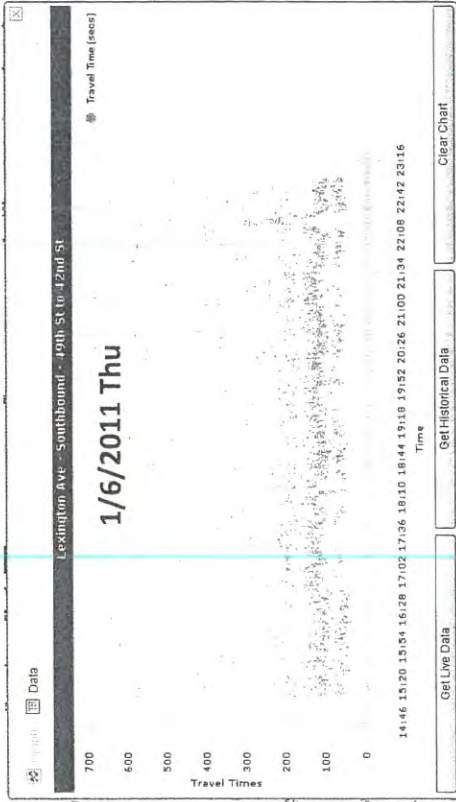
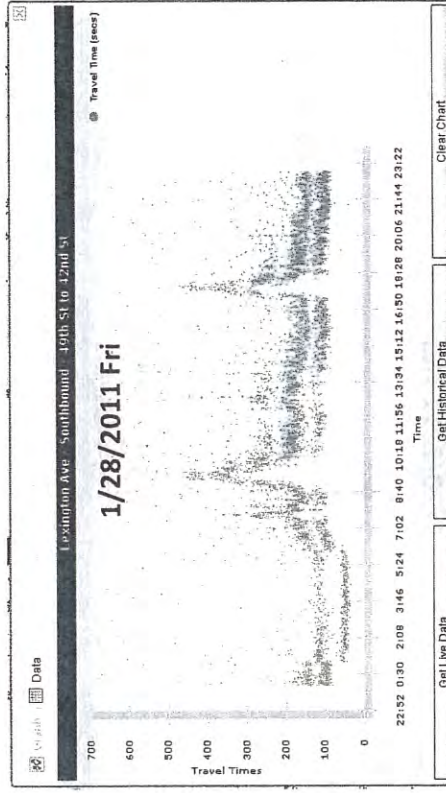
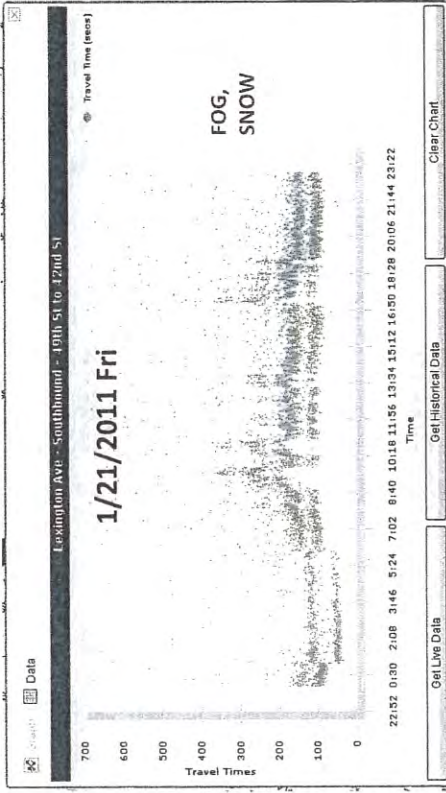


Figure A - 19: Travel Time (sec) Thursday Lexington Ave. between 49th St. and 42nd St.

Base as Implemented



Pre-Existing

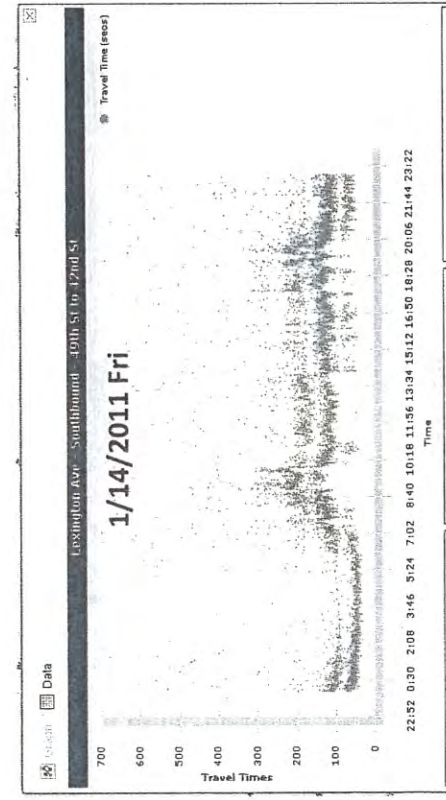
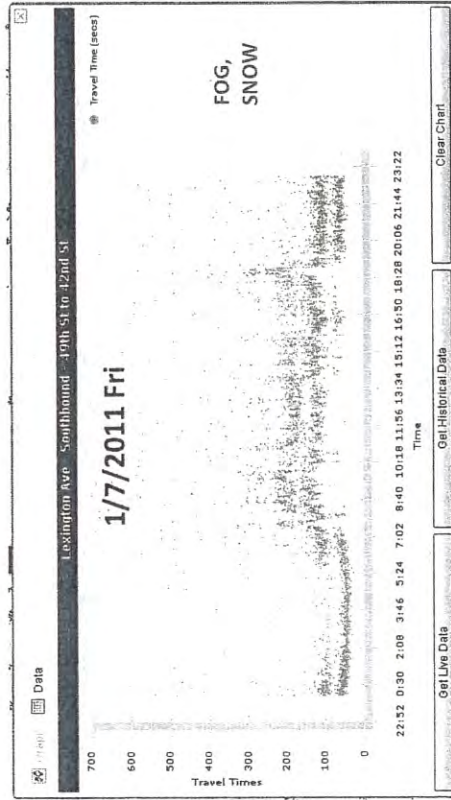
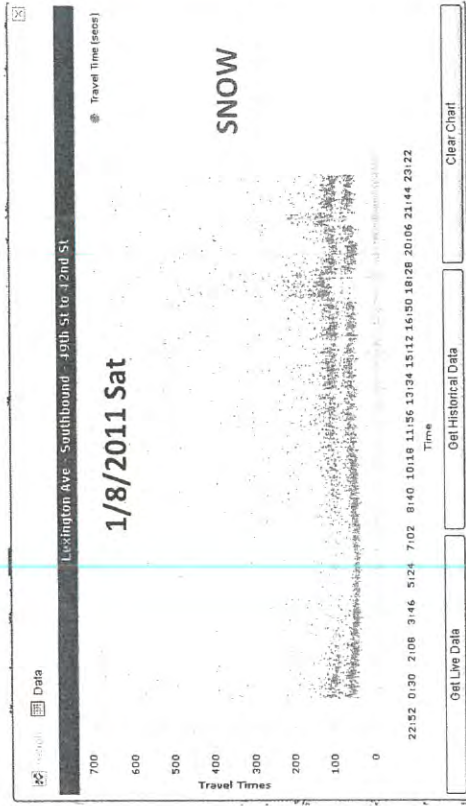


Figure A - 20: Travel Time (sec) Friday Lexington Ave. between 49th St. and 42nd St.

Pre-Existing



Base as Implemented

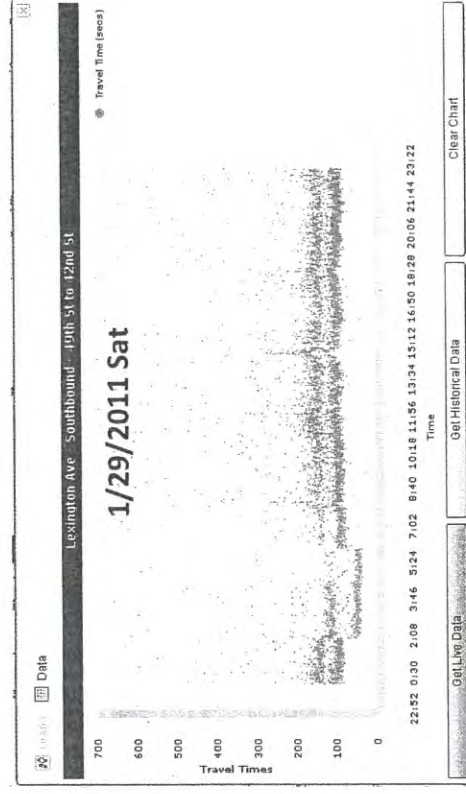
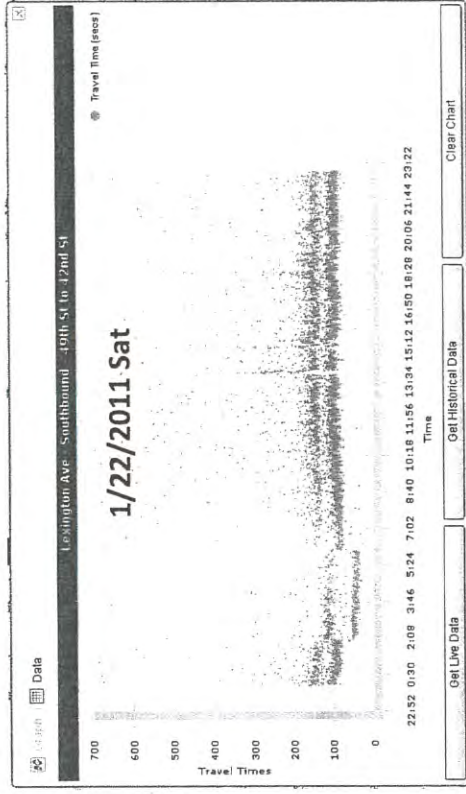
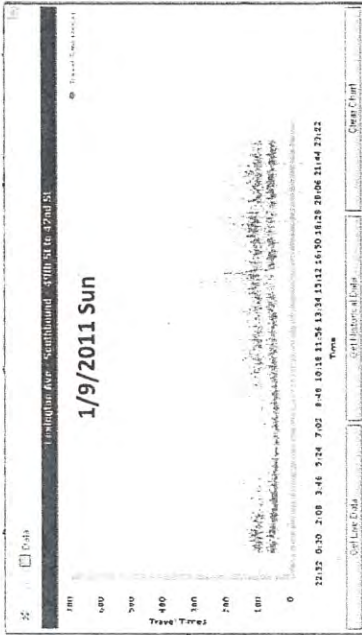


Figure A - 21: Travel Time (sec) Saturday Lexington Ave. between 49th St. and 42nd St.

Pre-Existing



Base as Implemented

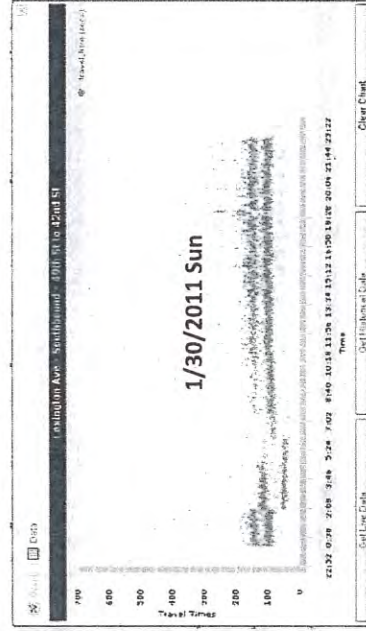
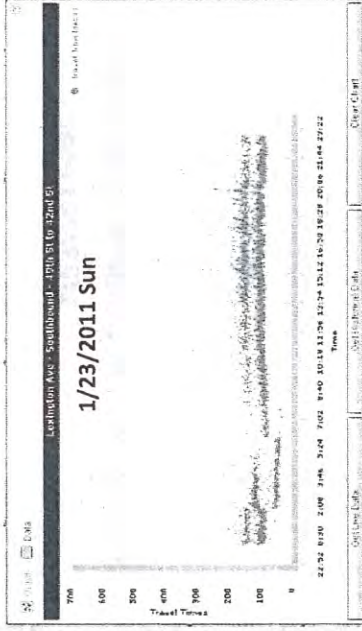
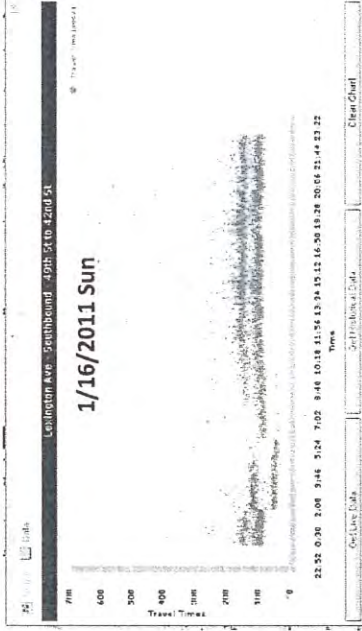
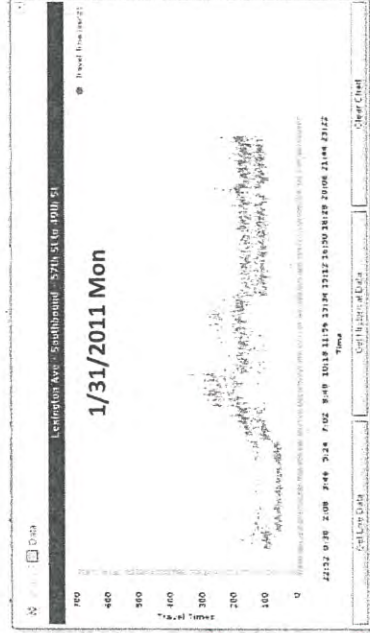
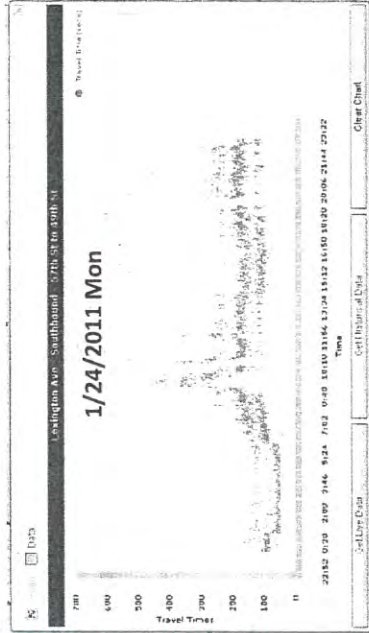
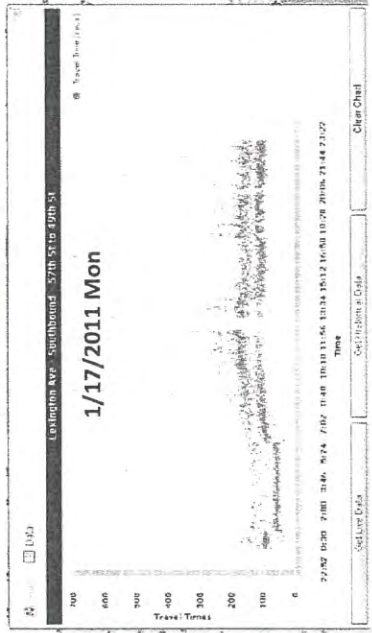


Figure A - 22: Travel Time (sec) Sunday Lexington Ave. between 49th St. and 42nd St.

Base as Implemented



Pre-Existing

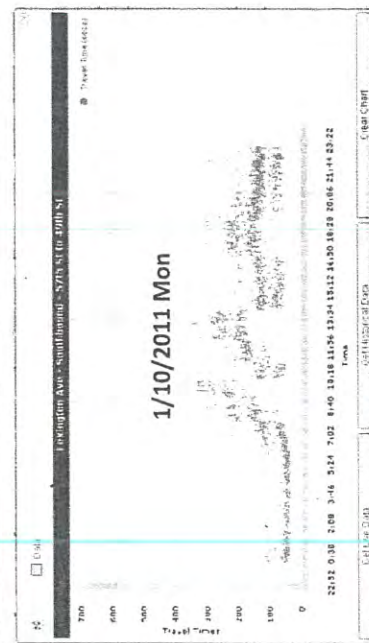
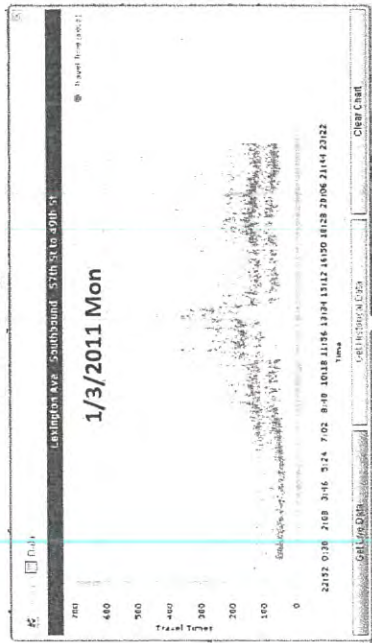
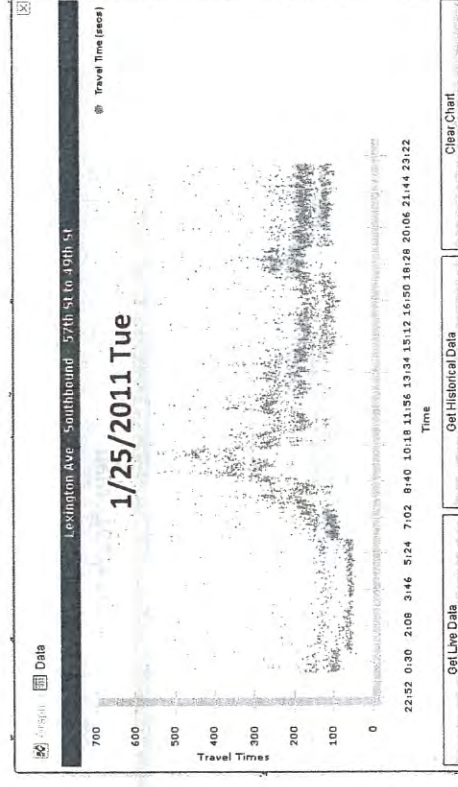
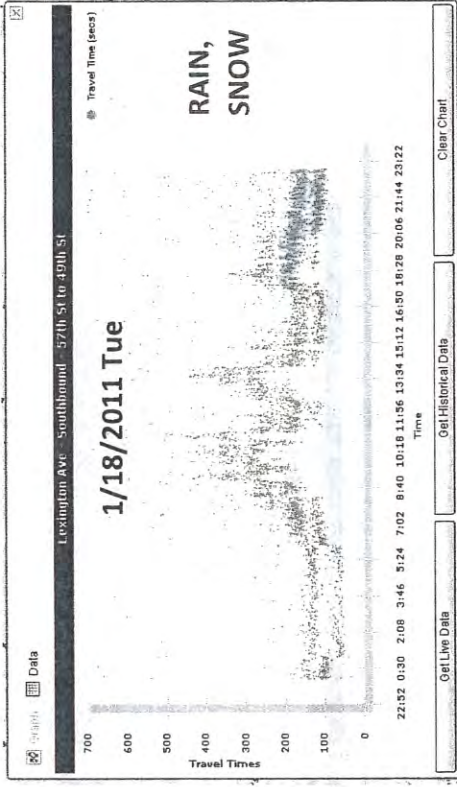


Figure A - 23: Travel Time (sec) Monday Lexington Ave. between 57th and 49th St.

Base as Implemented



Pre-Existing

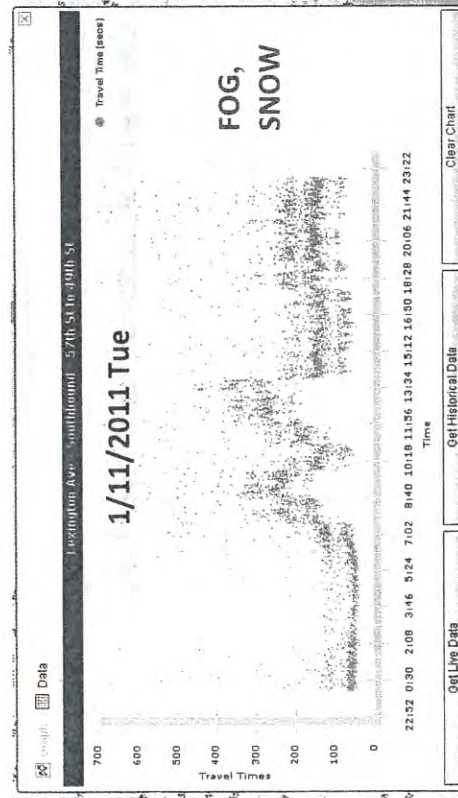
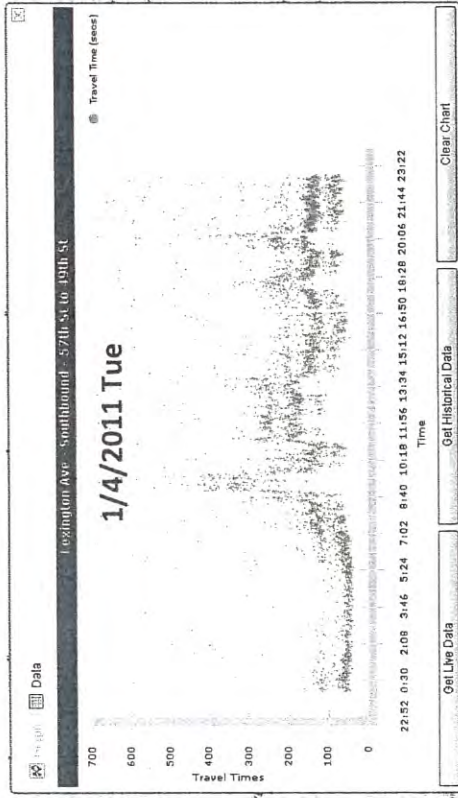
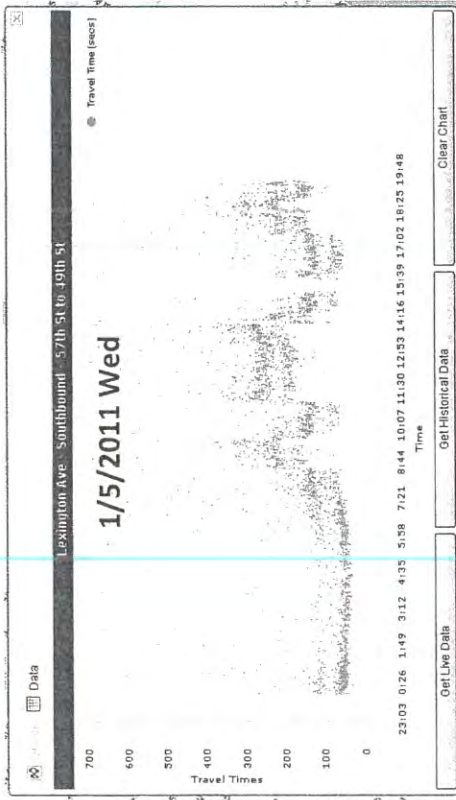


Figure A - 24: Travel Time (sec) Tuesday Lexington Ave. between 57th and 49th St.

Pre-Existing



Base as Implemented

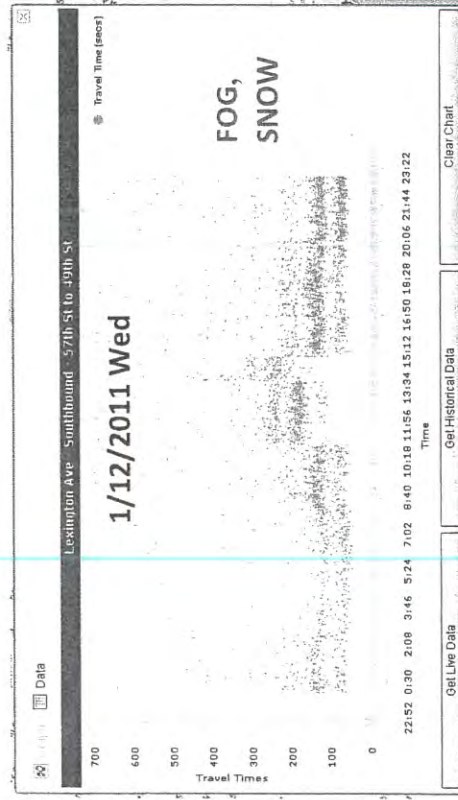
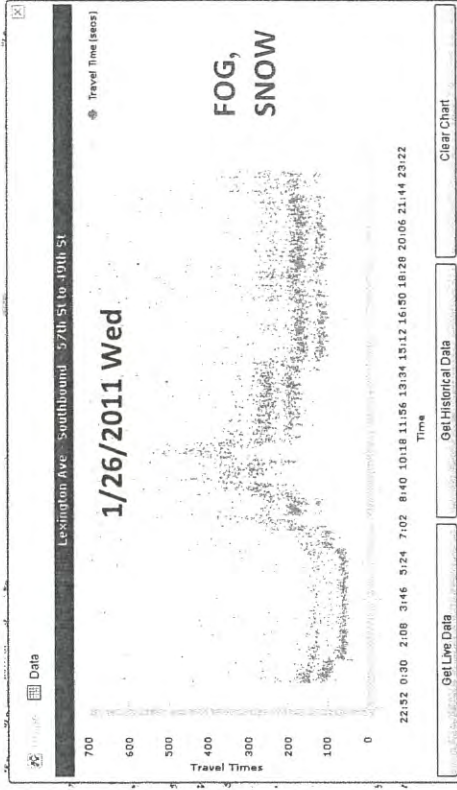
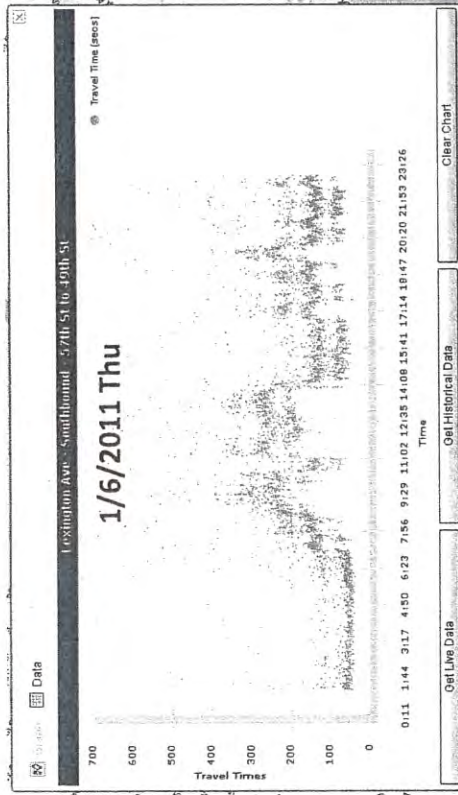


Figure A - 25: Travel Time (sec) Wednesday Lexington Ave. between 57th and 49th St.

Pre-Existing



Base as Implemented

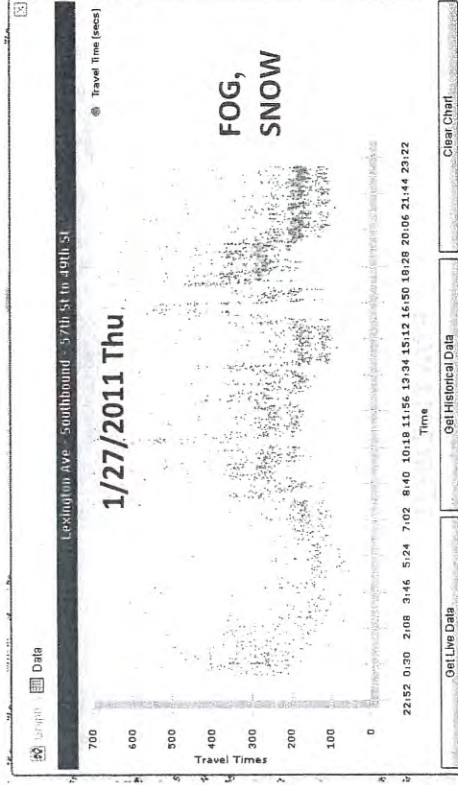
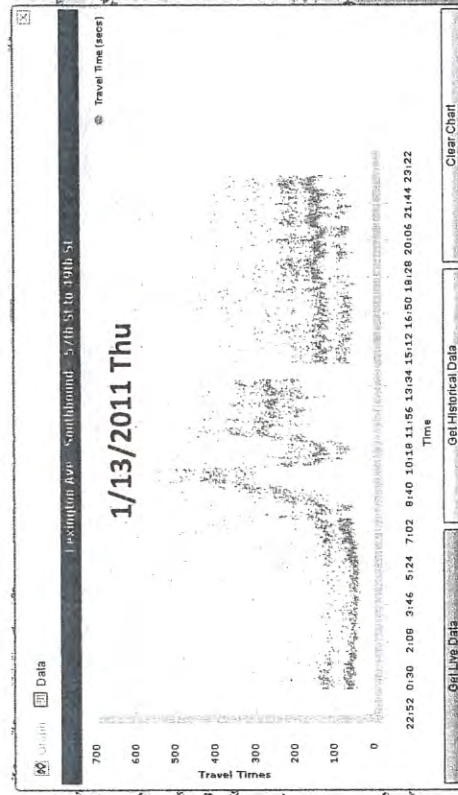
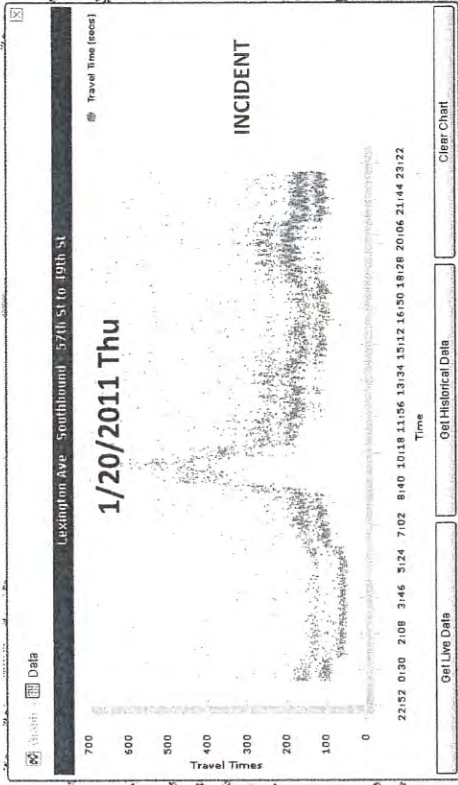
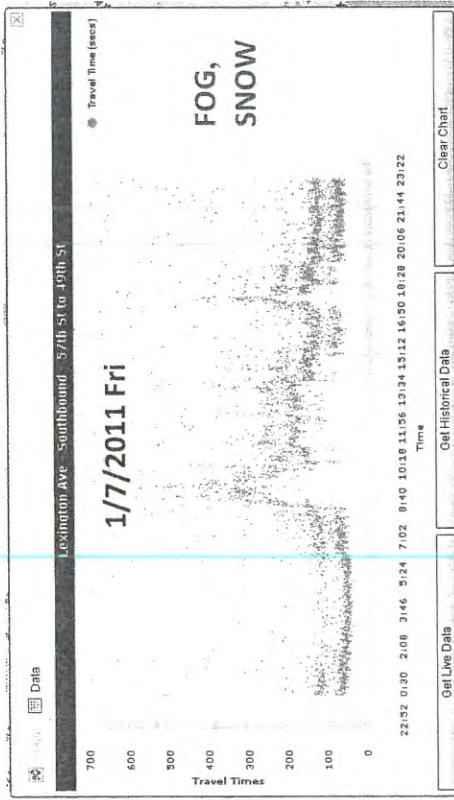


Figure A - 26: Travel Time (sec) Thursday Lexington Ave. between 57th and 49th St.

Pre-Existing



Base as Implemented

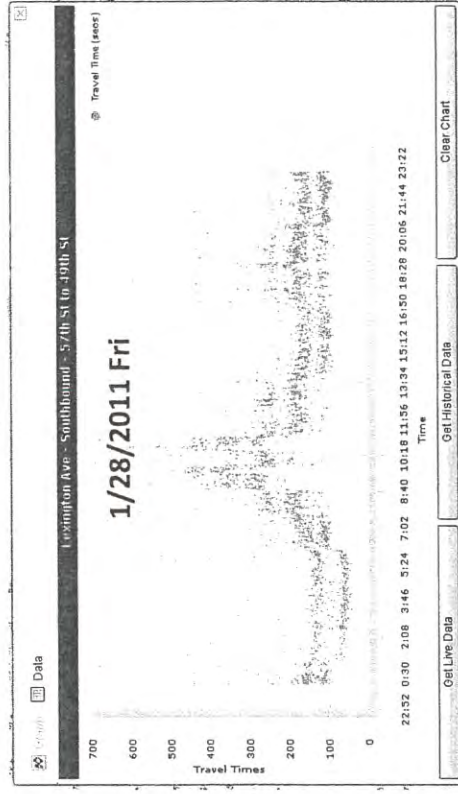
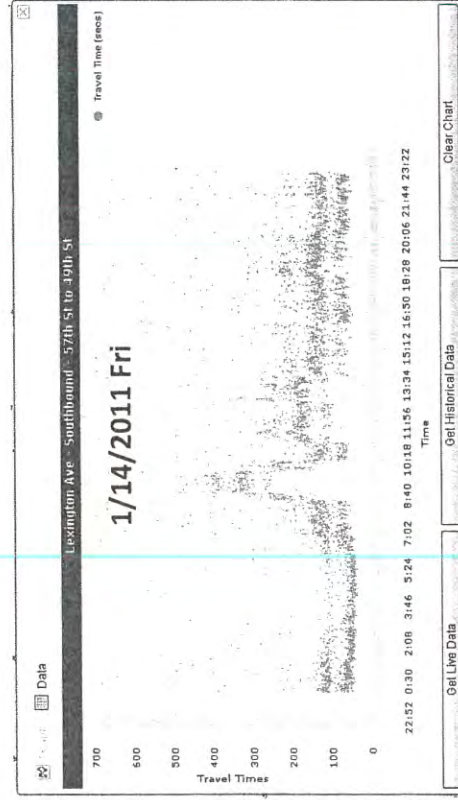
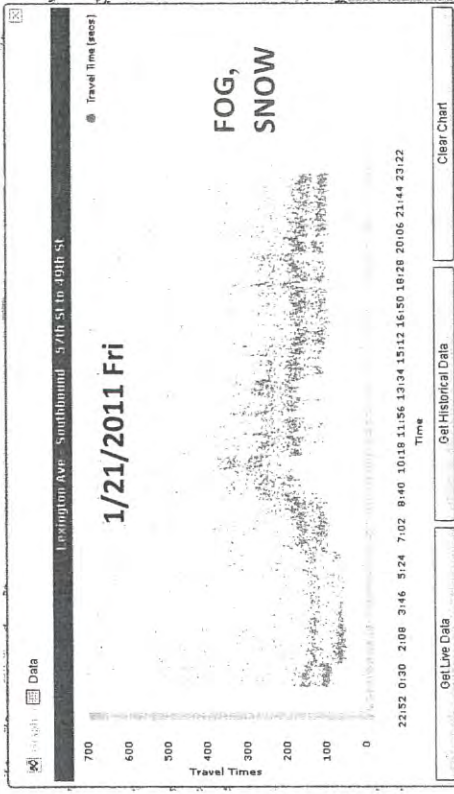
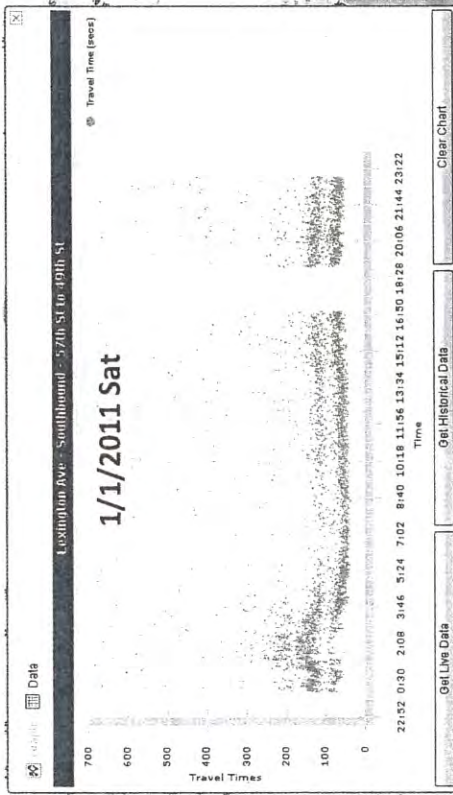


Figure A - 27: Travel Time (sec) Friday Lexington Ave. between 57th and 49th St.

Pre-Existing



Base as Implemented

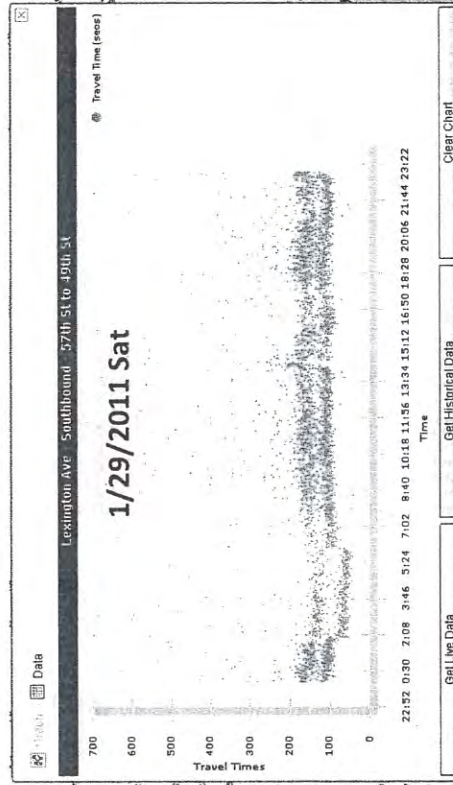
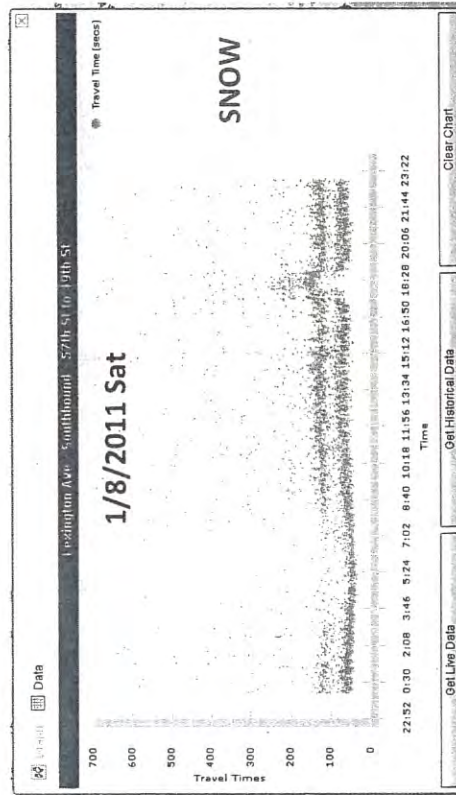
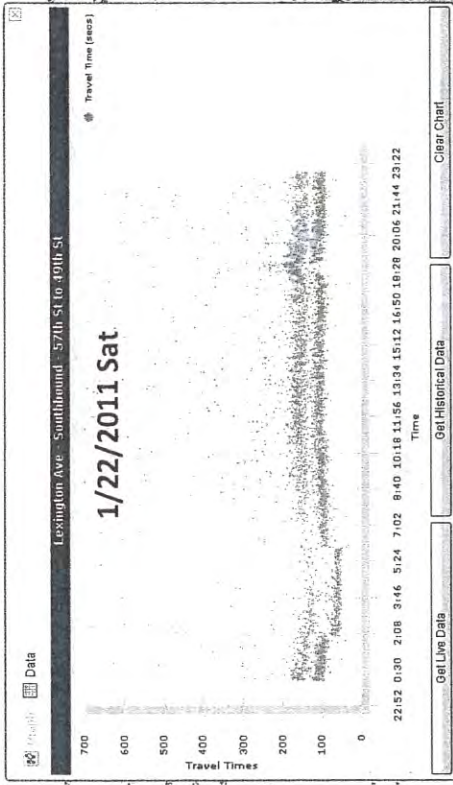
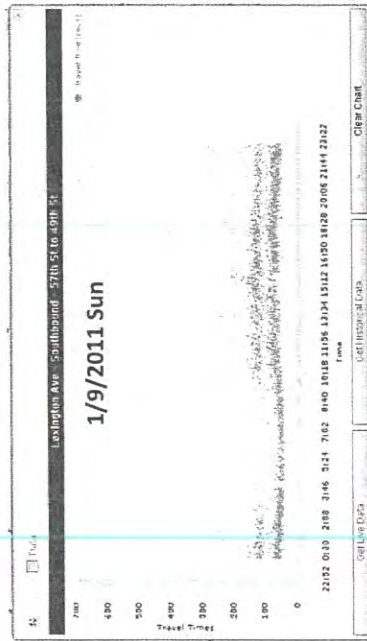
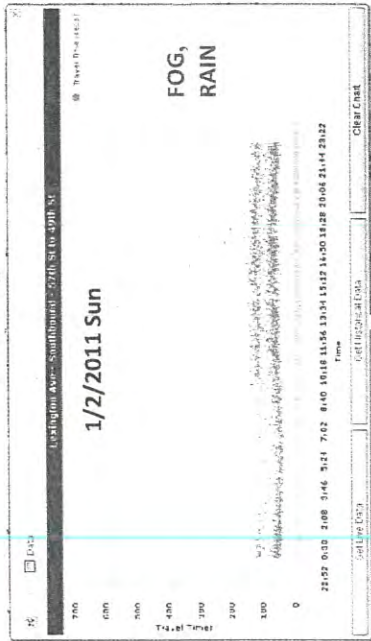


Figure A - 28: Travel Time (sec) Saturday Lexington Ave. between 57th and 49th St.

Pre-Existing



Base as Implemented

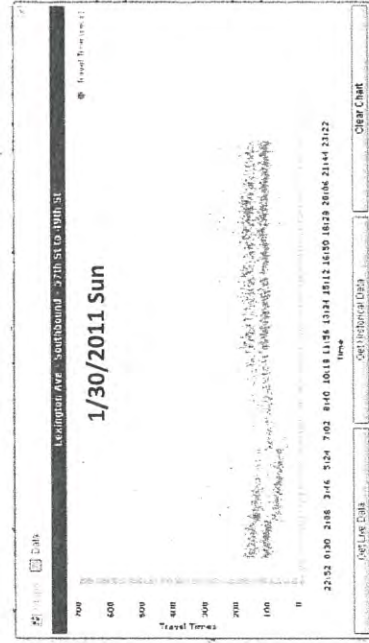
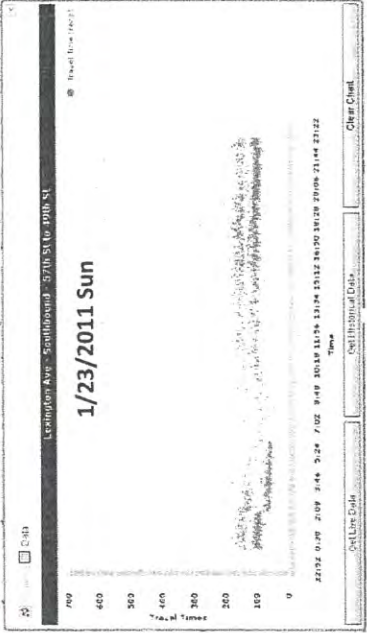
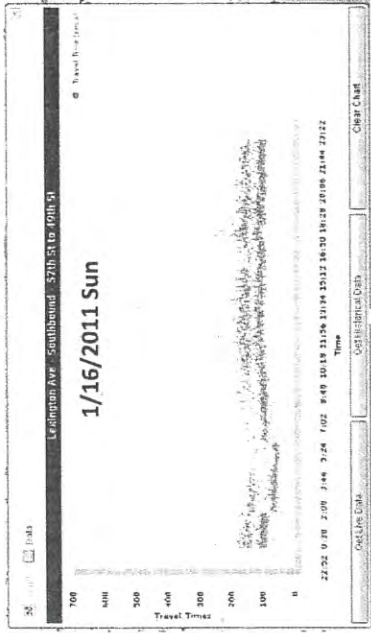
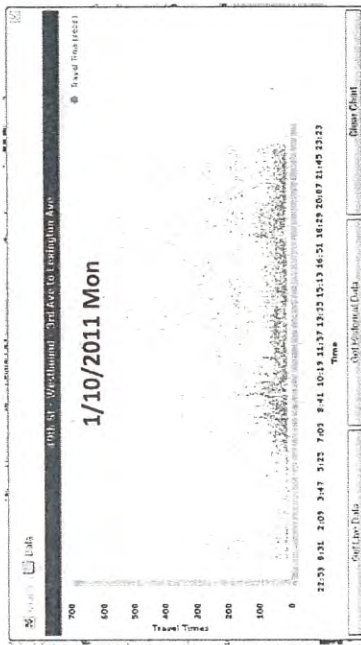
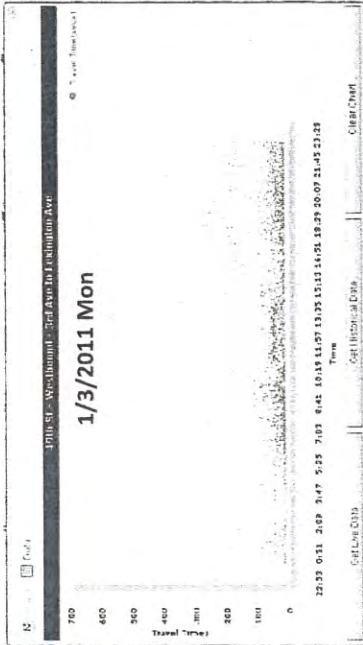


Figure A - 29: Travel Time (sec) Sunday Lexington Ave. between 57th and 49th St.

Pre-Existing



Base as Implemented

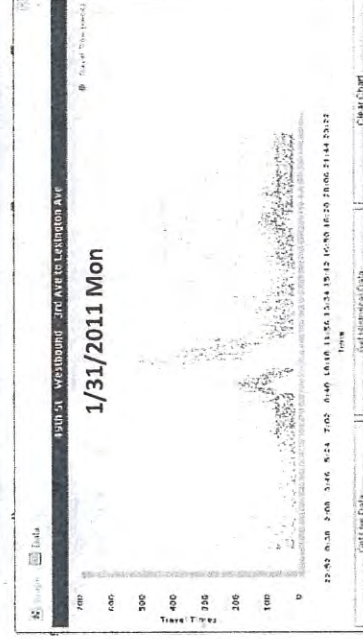
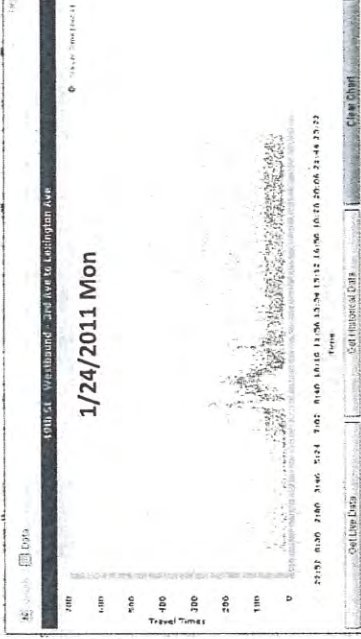
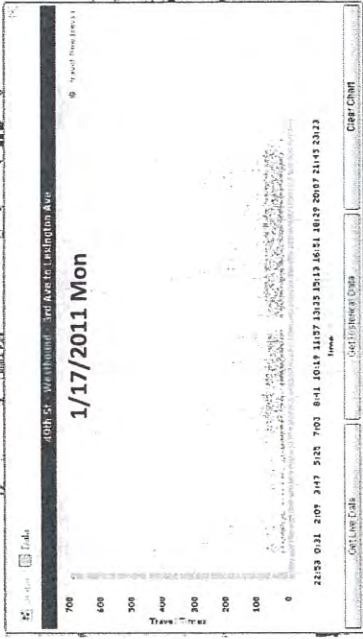
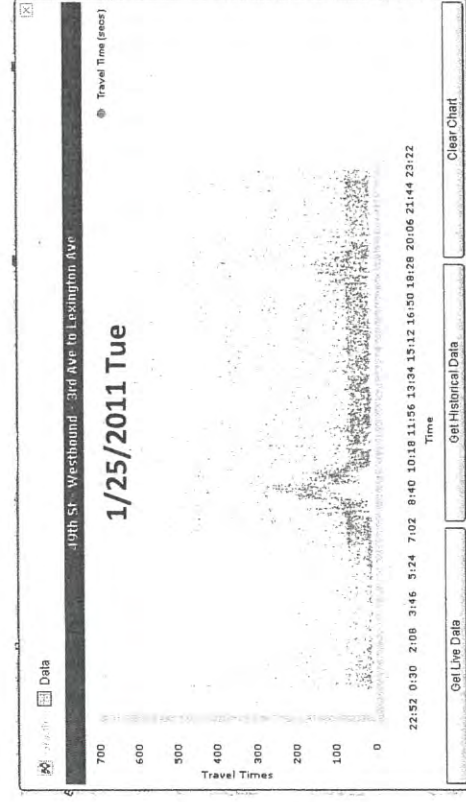
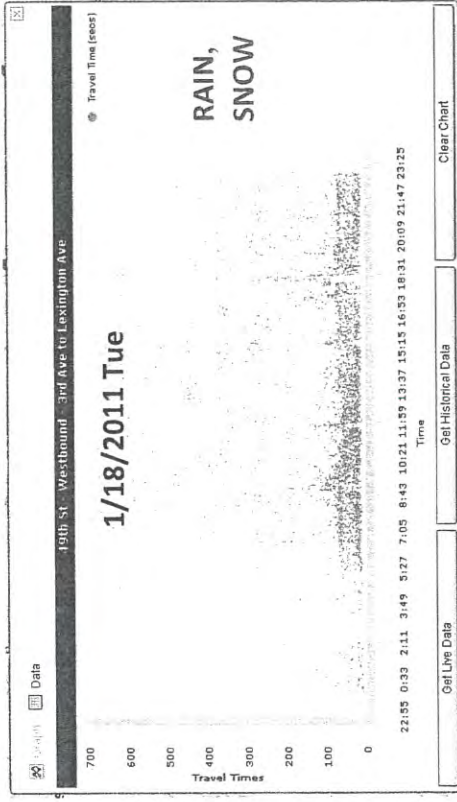


Figure A - 30: Travel Time (sec) Monday 49th St. between 3rd Ave. and Lexington Ave.

Base as Implemented



Pre-Existing

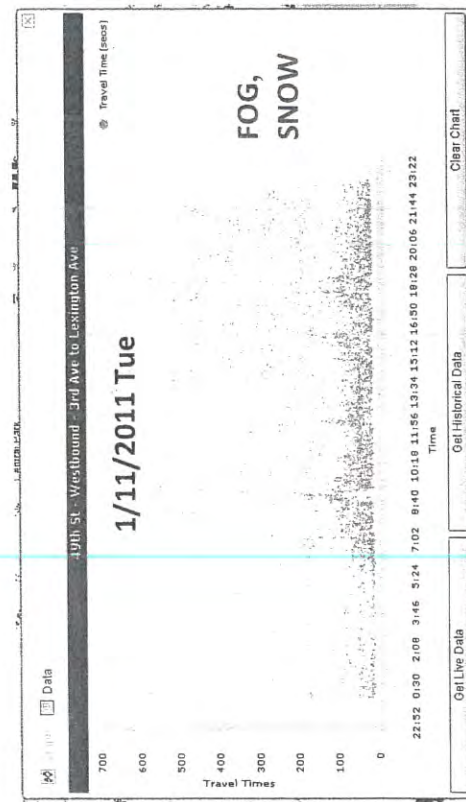
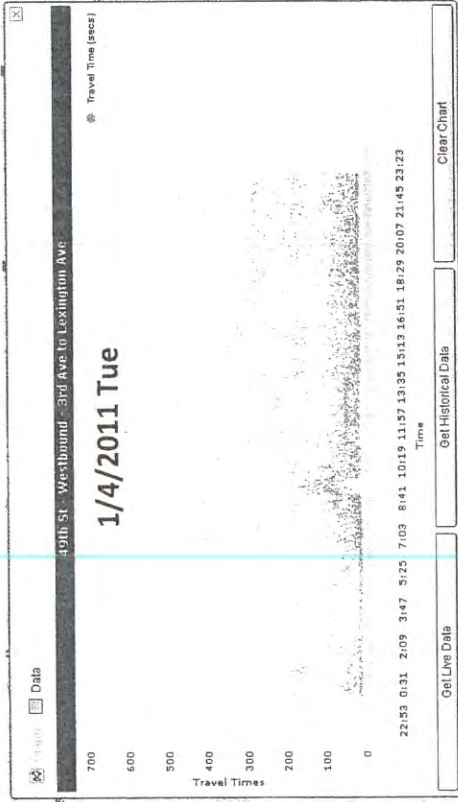
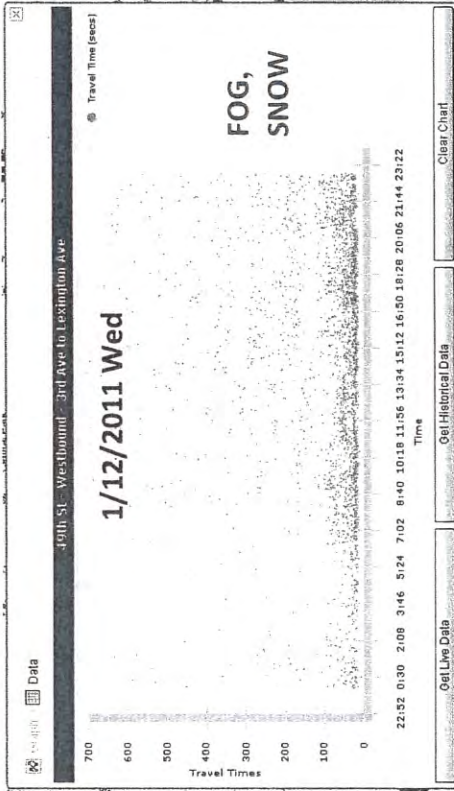


Figure A - 31: Travel Time (sec) Tuesday 49th St. between 3rd Ave. and Lexington Ave.

Pre-Existing



Base as Implemented

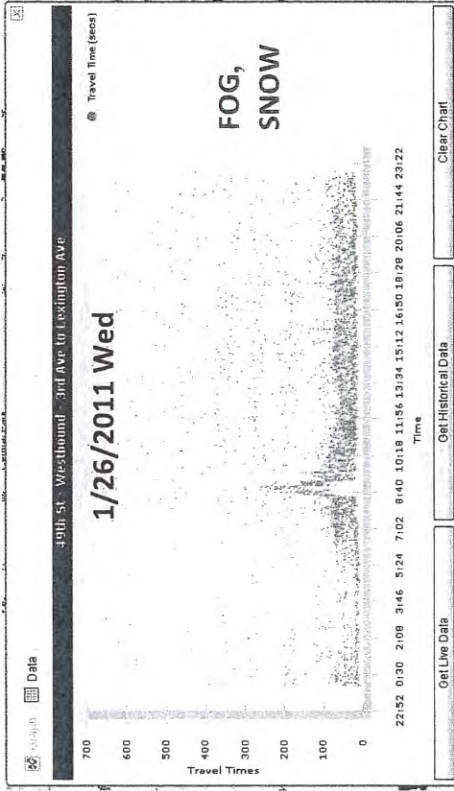
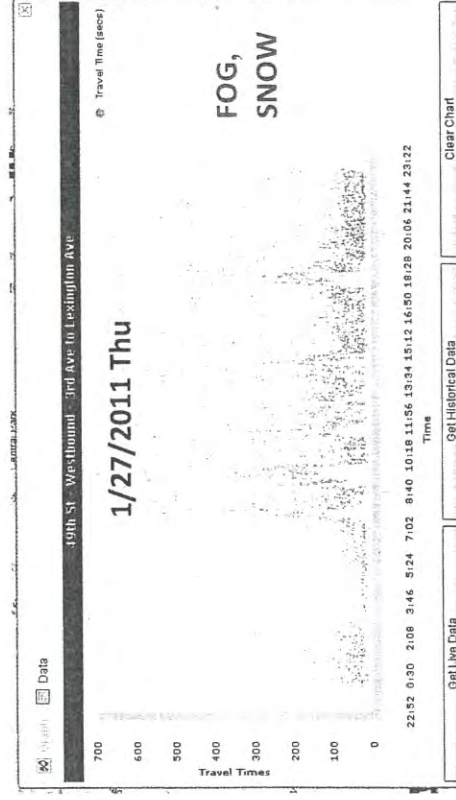
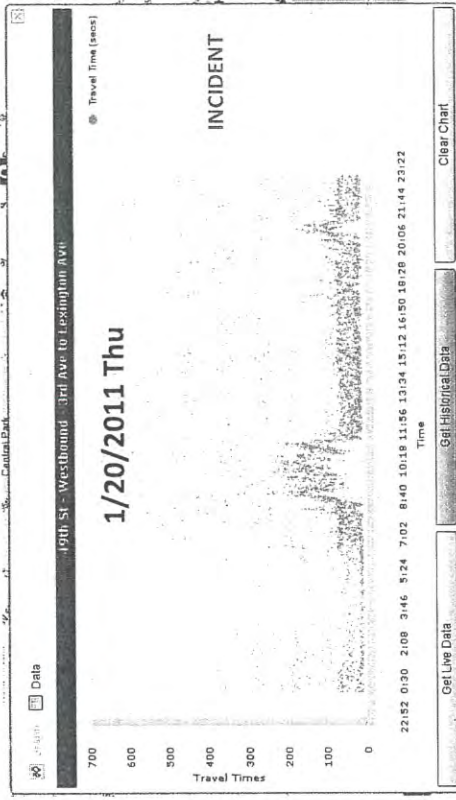


Figure A - 32: Travel Time (sec) Wednesday 49th St. between 3rd Ave. and Lexington Ave.

Base as Implemented



Pre-Existing

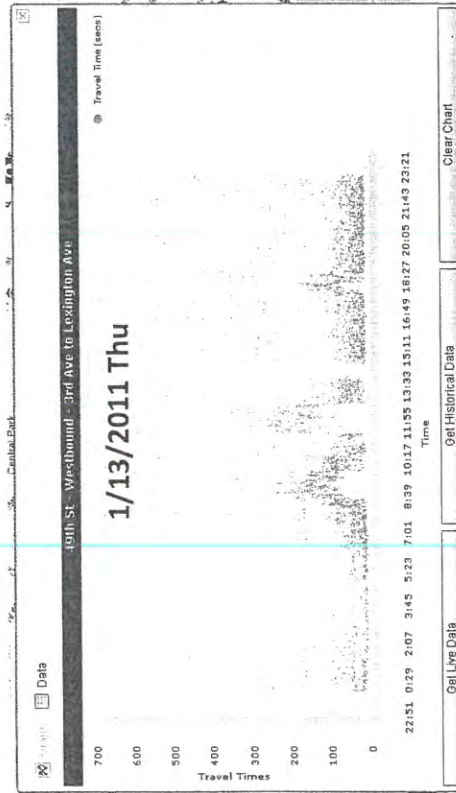
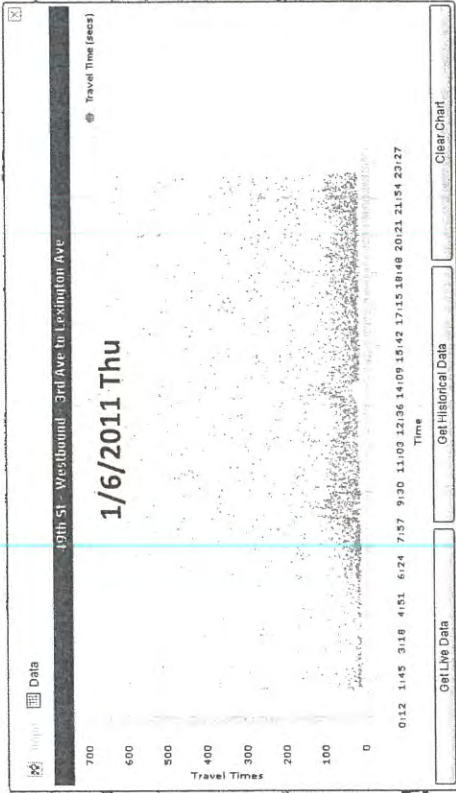
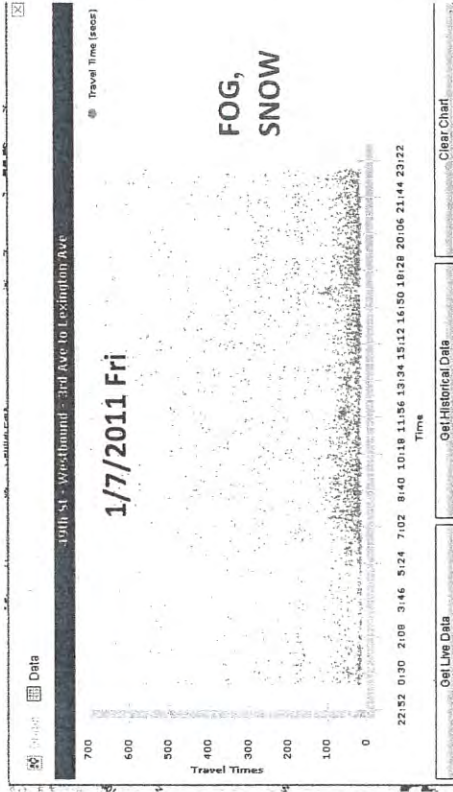


Figure A - 33: Travel Time (sec) Thursday 49th St. between 3rd Ave. and Lexington Ave.

Pre-Existing



Base as Implemented

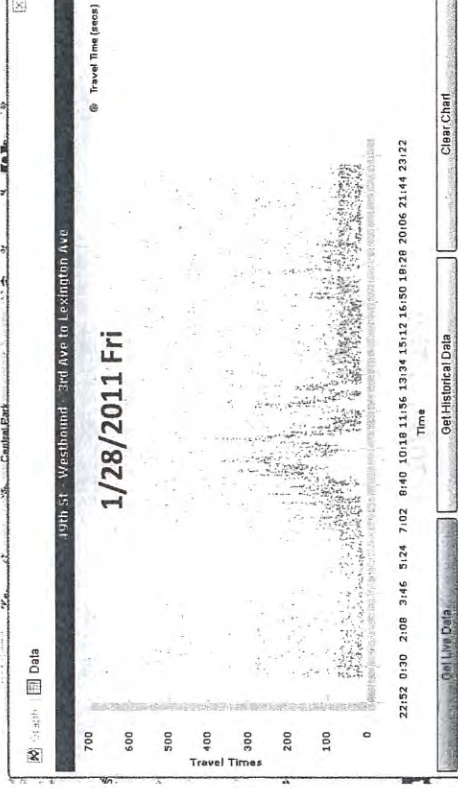
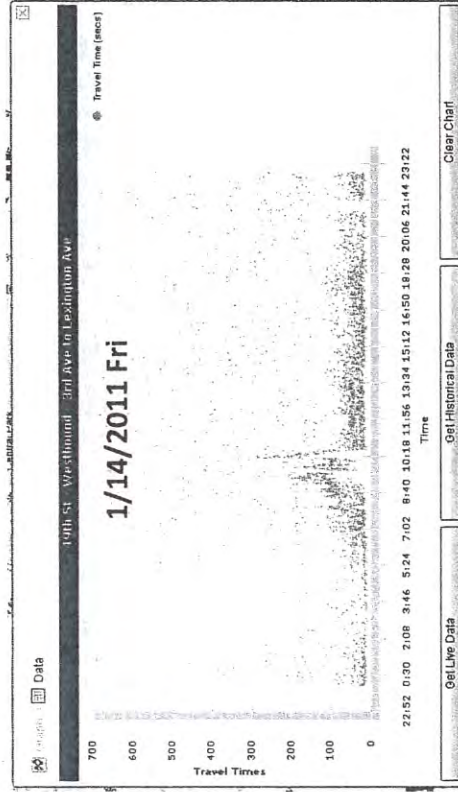
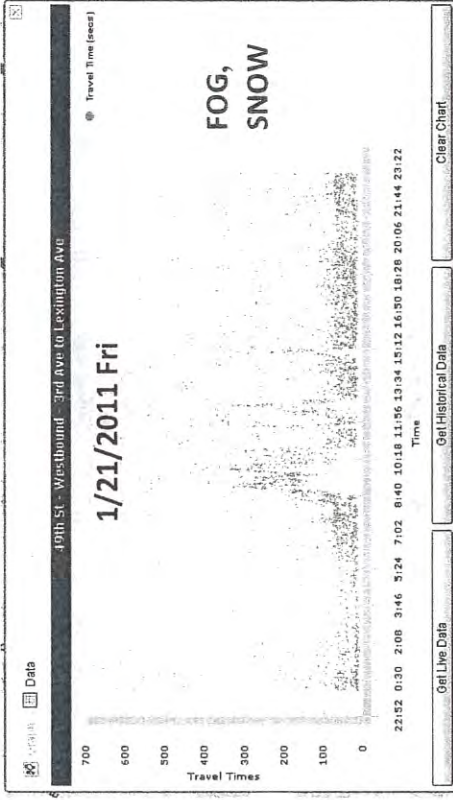
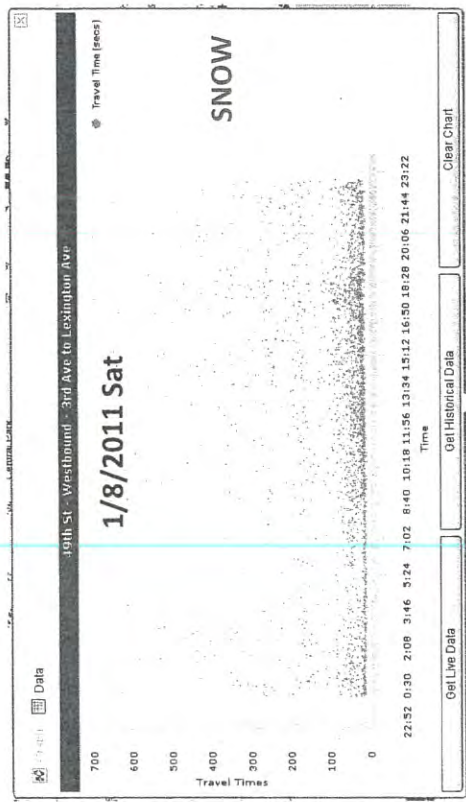


Figure A - 34: Travel Time (sec) Friday 49th St. between 3rd Ave. and Lexington Ave.

Pre-Existing



Base as Implemented

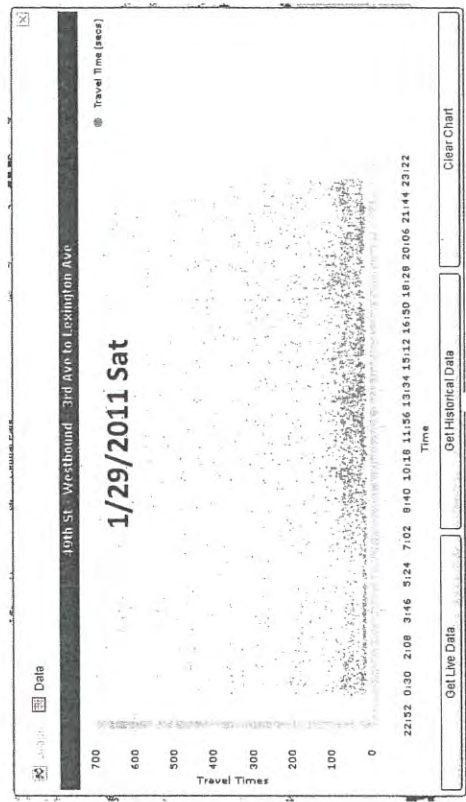
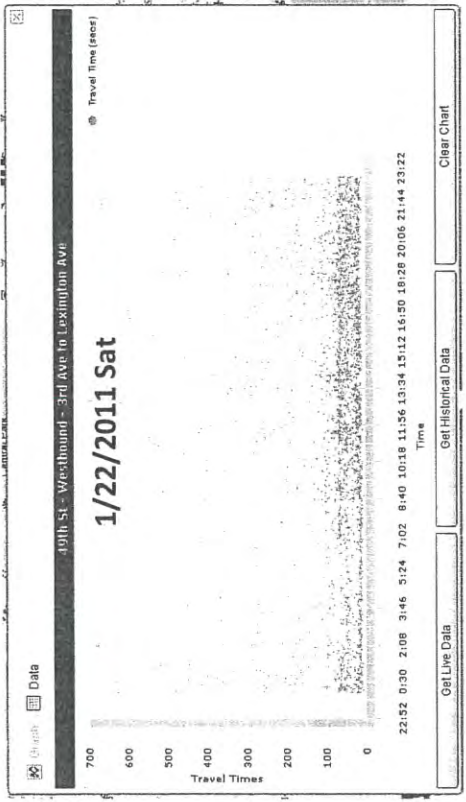
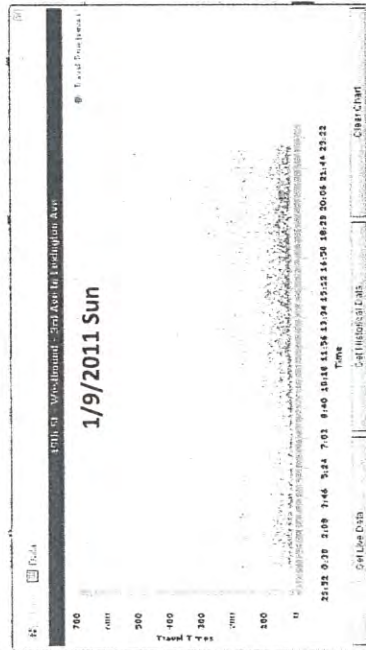
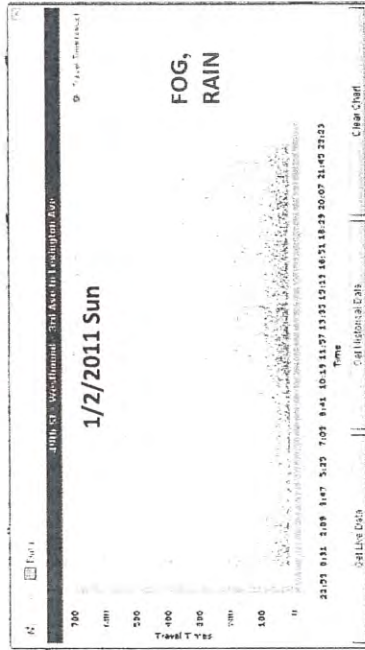


Figure A - 35: Travel Time (sec) Saturday 49th St. between 3rd Ave. and Lexington Ave.

Pre-Existing



Base as Implemented

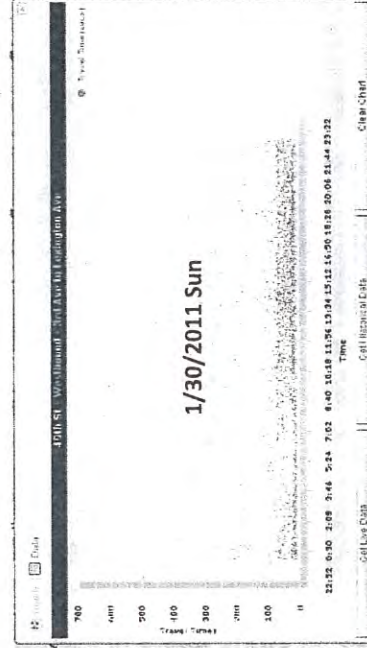
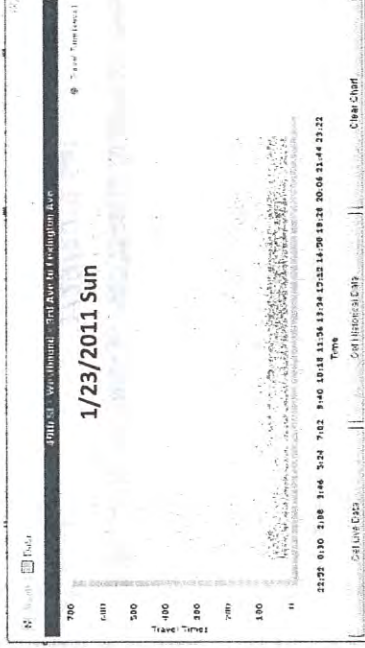
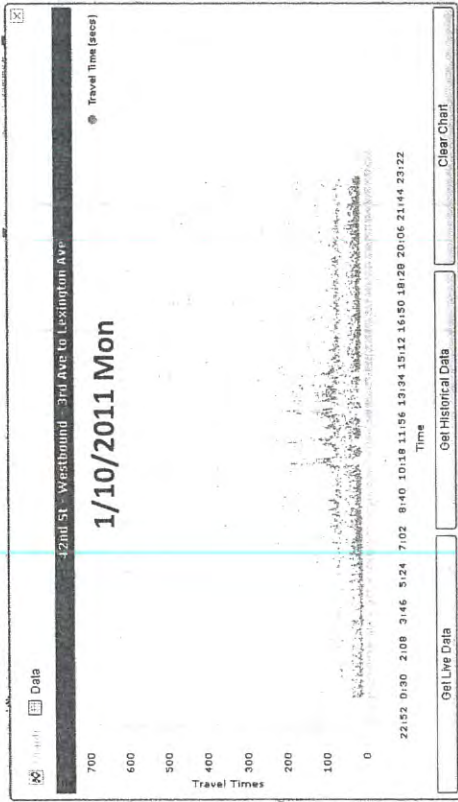


Figure A - 36: Travel Time (sec) Sunday 49th St. between 3rd Ave. and Lexington Ave.

Pre-Existing



Base as Implemented

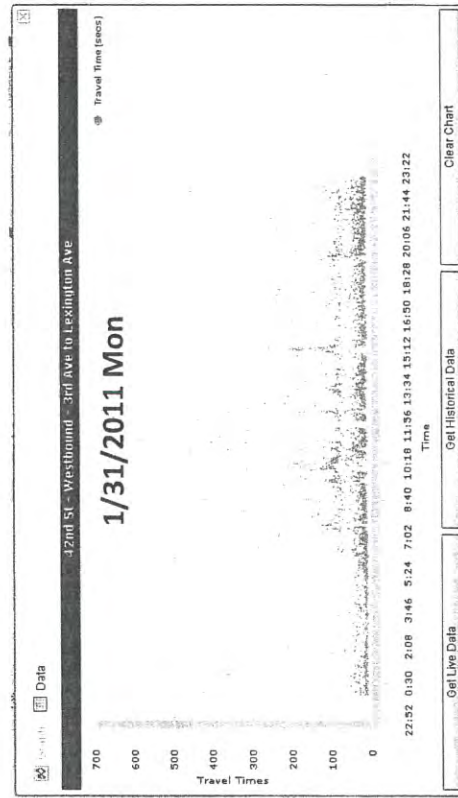
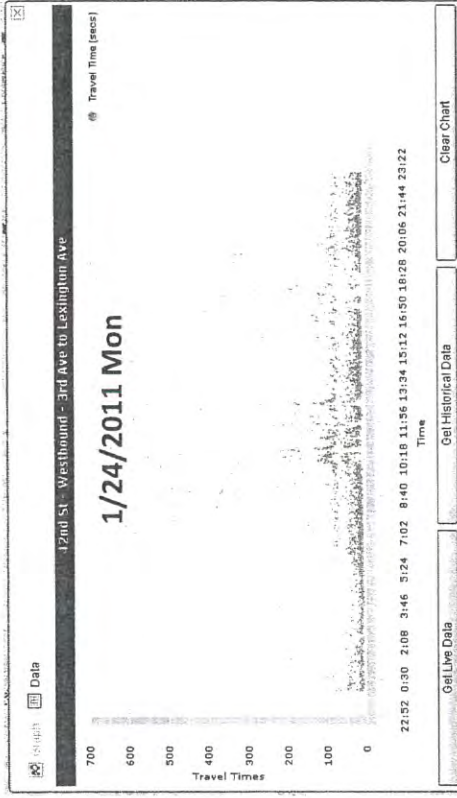


Figure A - 37: Travel Time (sec) Monday 42nd St. between 3rd Ave. and Lexington Ave.

Base as Implemented

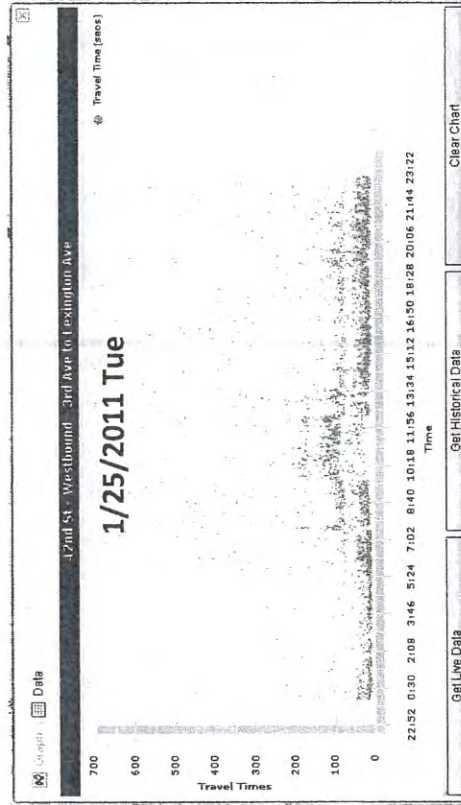
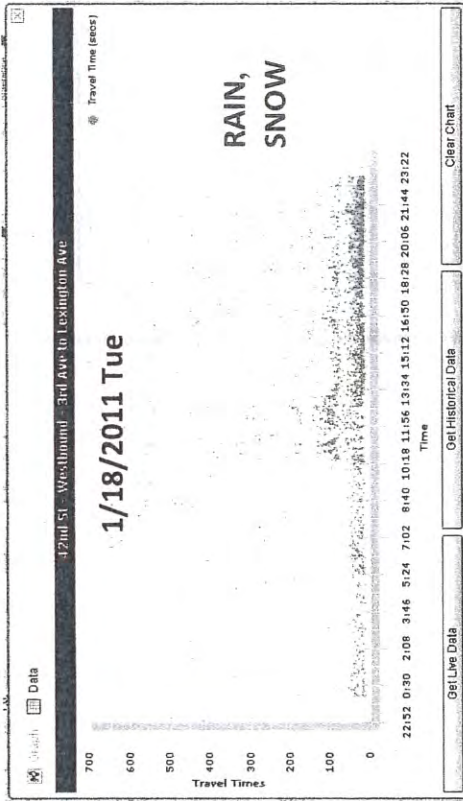
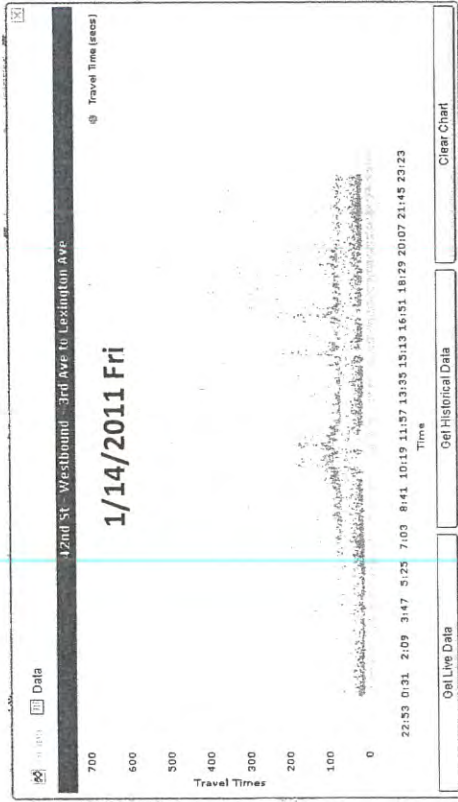


Figure A - 38: Travel Time (sec) Tuesday 42nd St. between 3rd Ave. and Lexington Ave.

Pre-Existing



Base as Implemented

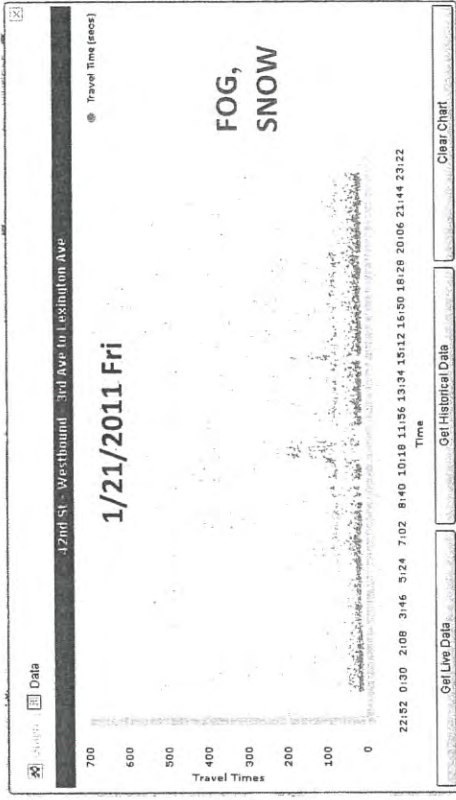
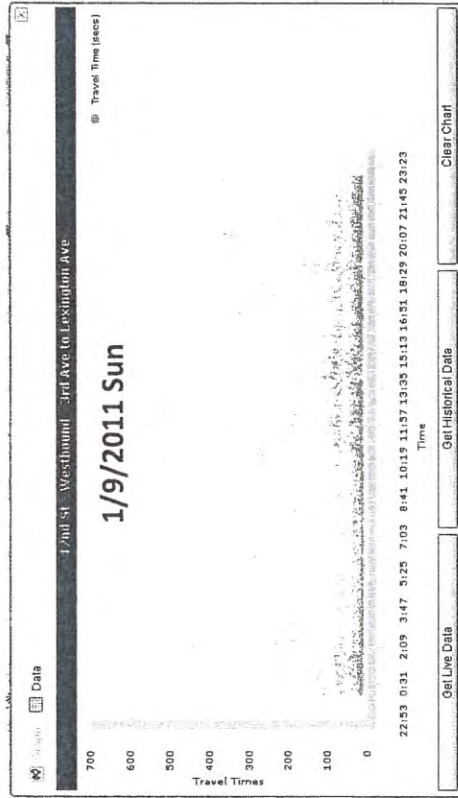


Figure A - 39: Travel Time (sec) Friday 42nd St. between 3rd Ave. and Lexington Ave.

Pre-Existing



Base as Implemented

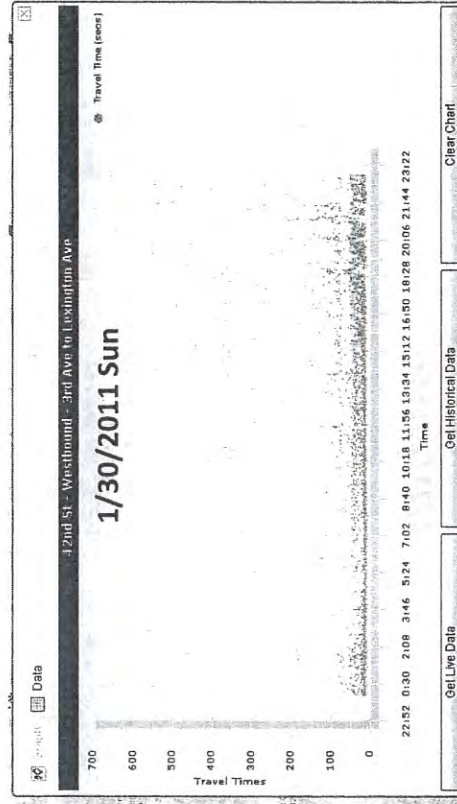
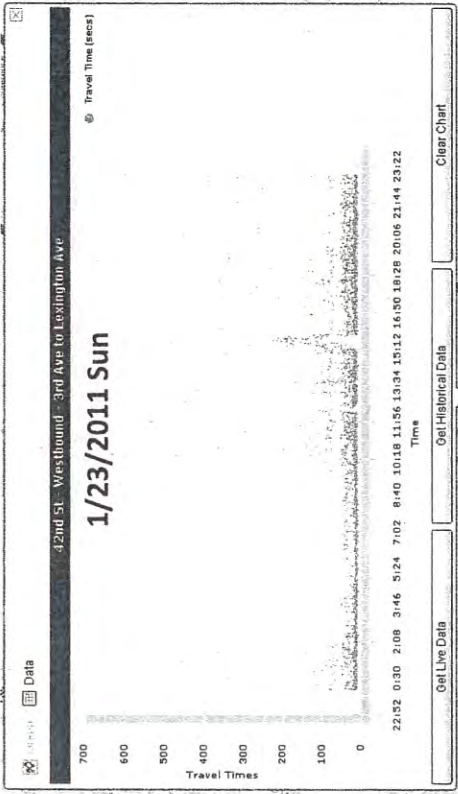
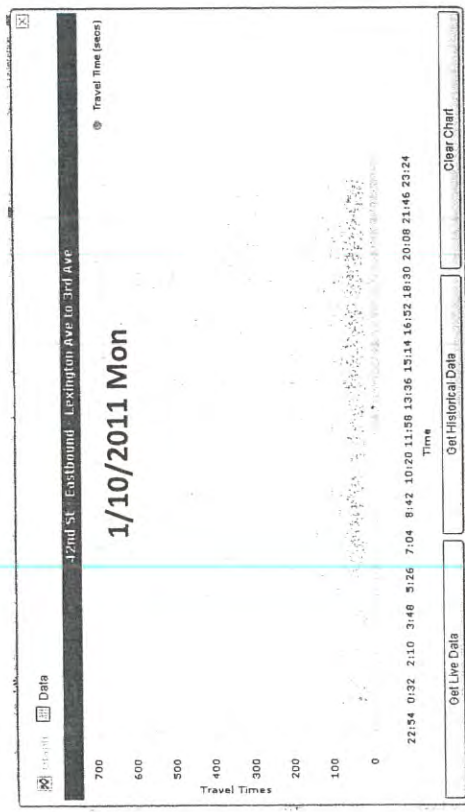


Figure A - 40: Travel Time (sec) Sunday 42nd St. between 3rd Ave. and Lexington Ave.

Pre-Existing



Base as Implemented

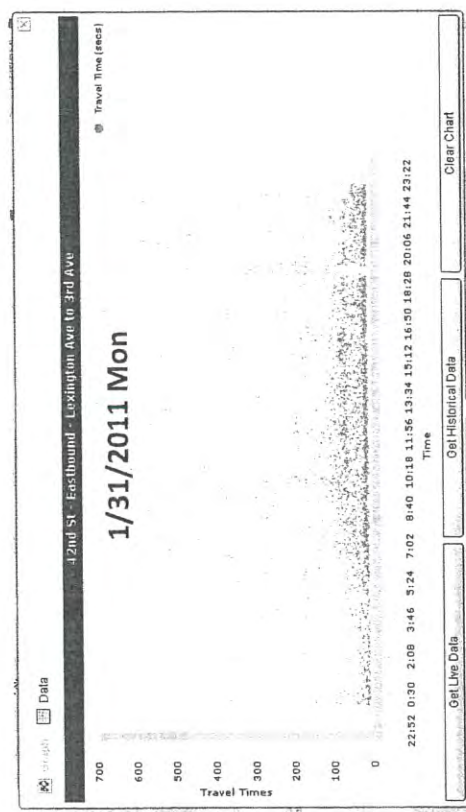
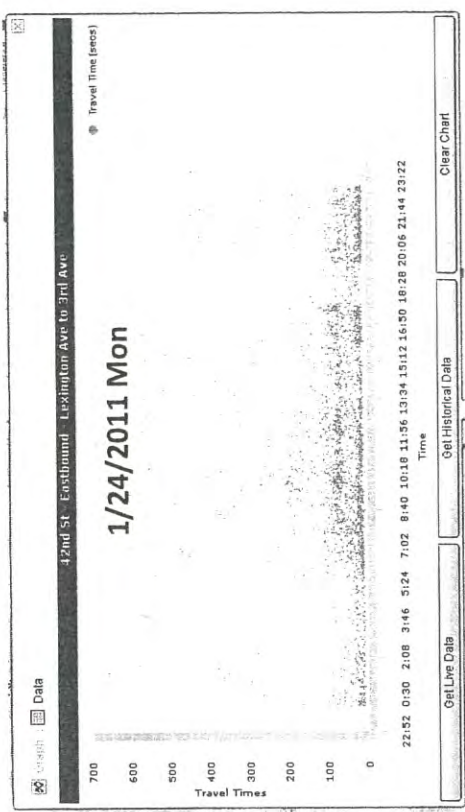


Figure A - 41: Travel Time (sec) Monday 42nd St. between Lexington Ave. and 3rd Ave.

Base as Implemented

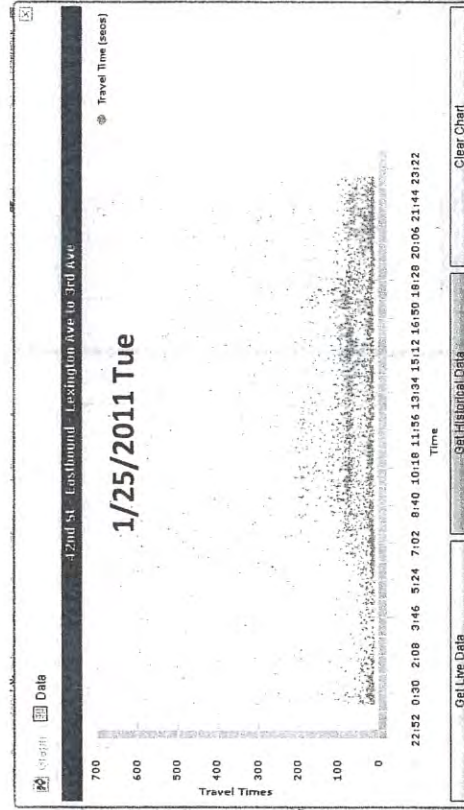
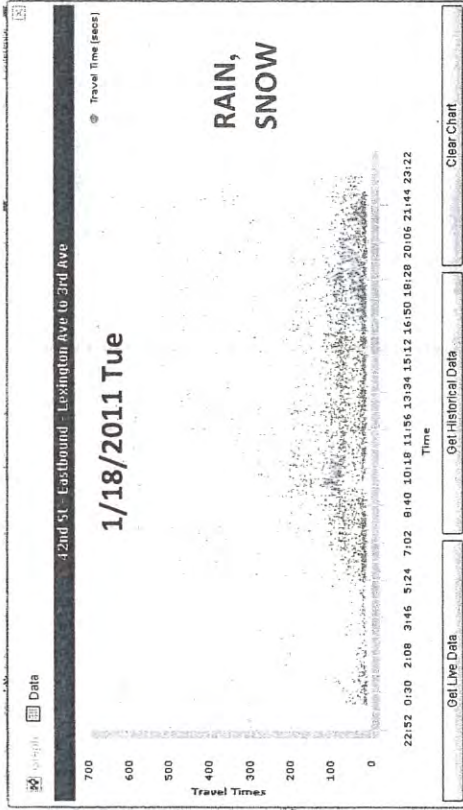
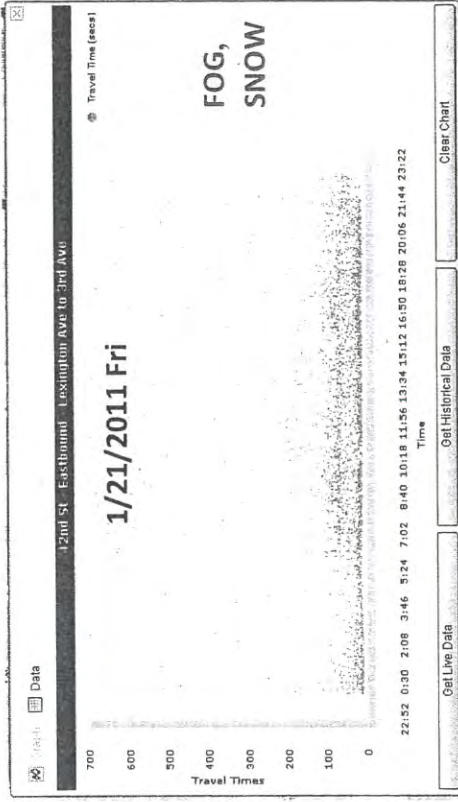


Figure A - 42: Travel Time (sec) Tuesday 42nd St. between Lexington Ave. and 3rd Ave.

Base as Implemented



Pre-Existing

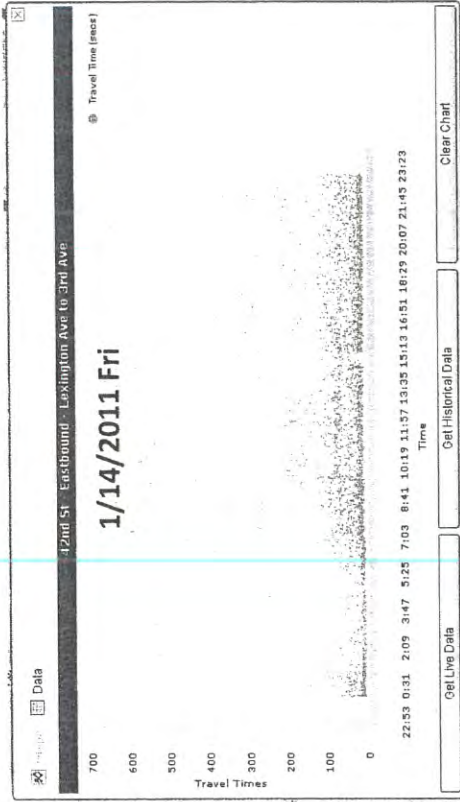
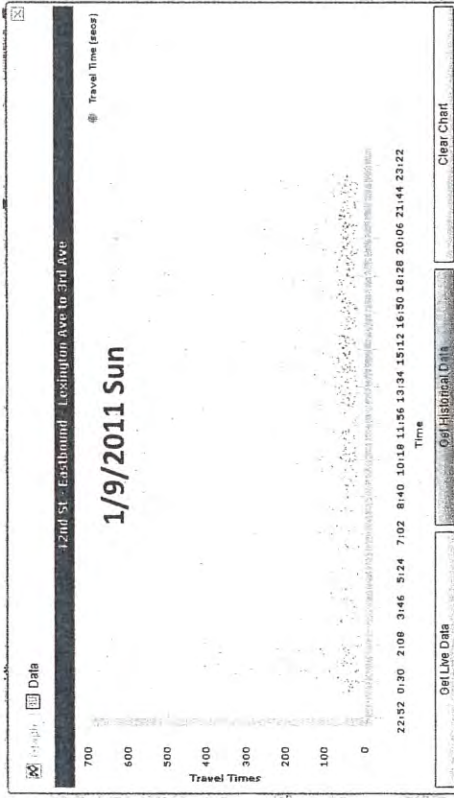


Figure A - 43: Travel Time (sec) Friday 42nd St. between Lexington Ave. and 3rd Ave.

Pre-Existing



Base as Implemented

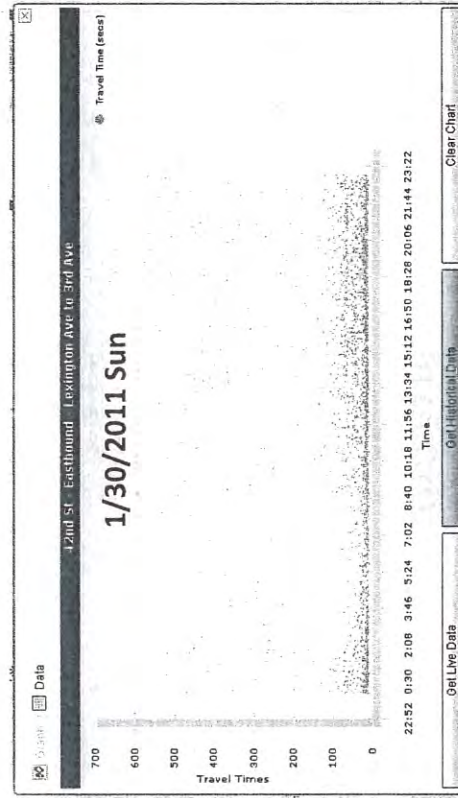
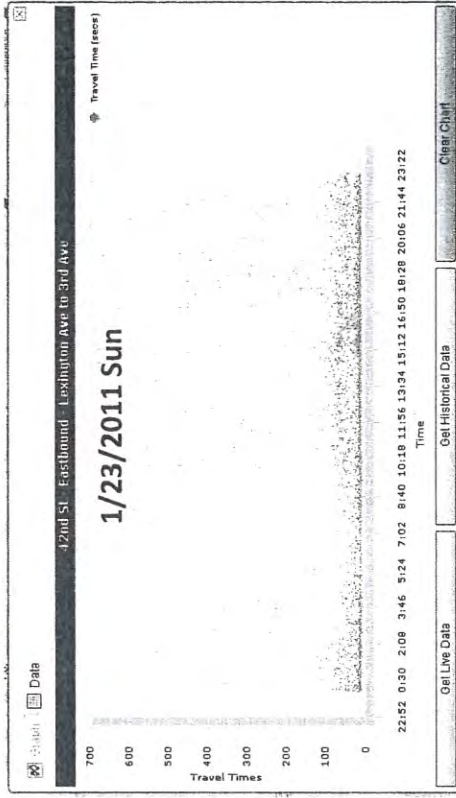
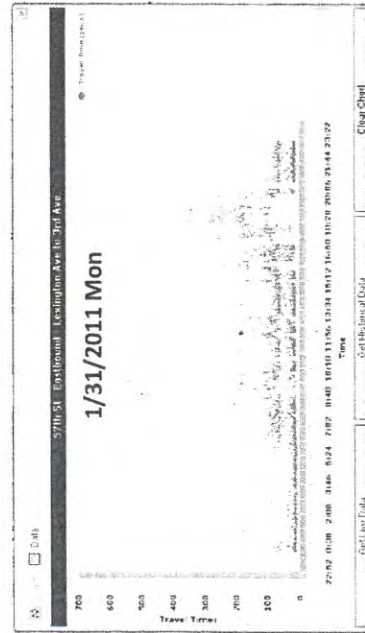
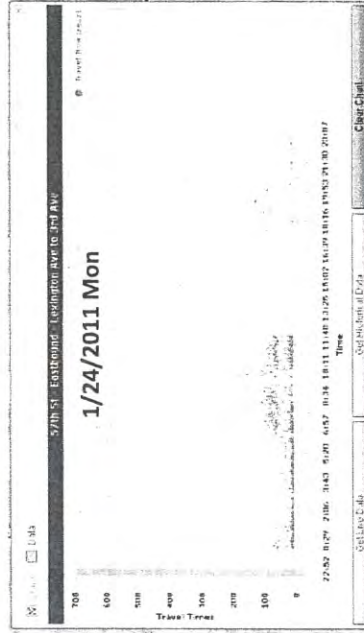
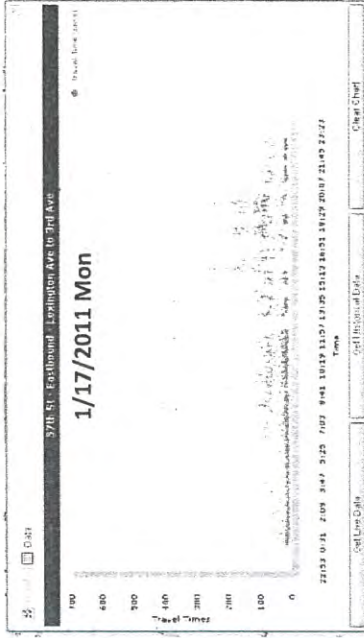


Figure A - 44: Travel Time (sec) Sunday 42nd St. between Lexington Ave. and 3rd Ave.

Base as Implemented



Pre-Existing

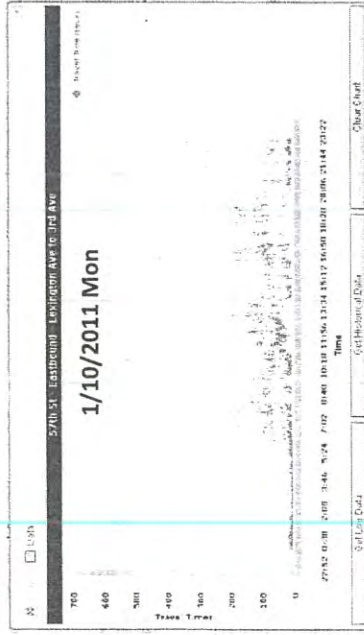
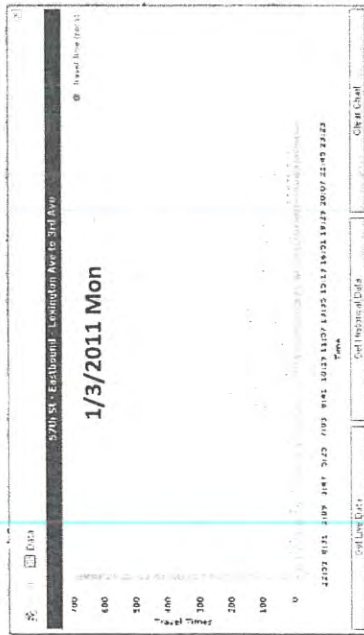
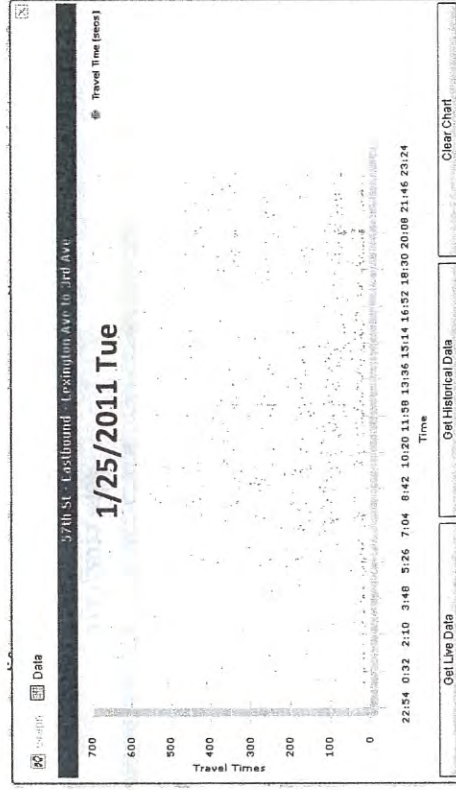
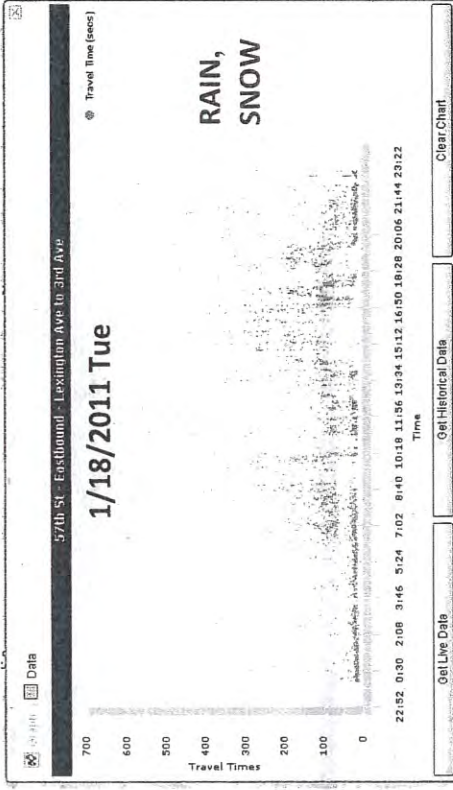


Figure A - 45: Travel Time (sec) Monday 57th St. between Lexington Ave. and 3rd Ave.

Base as Implemented



Pre-Existing

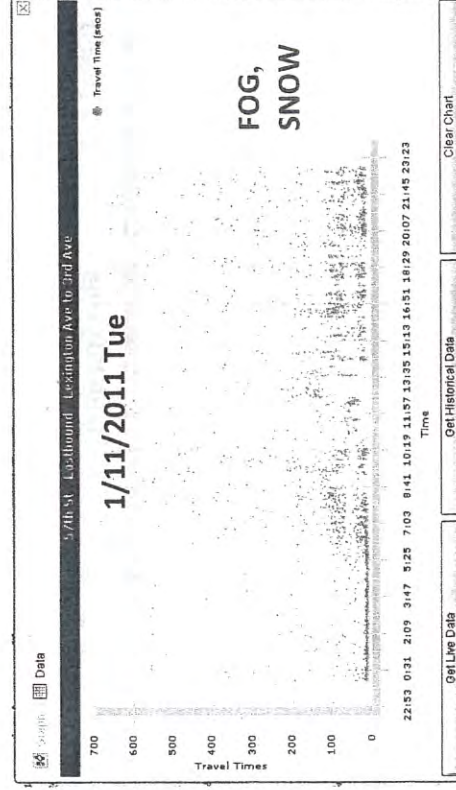
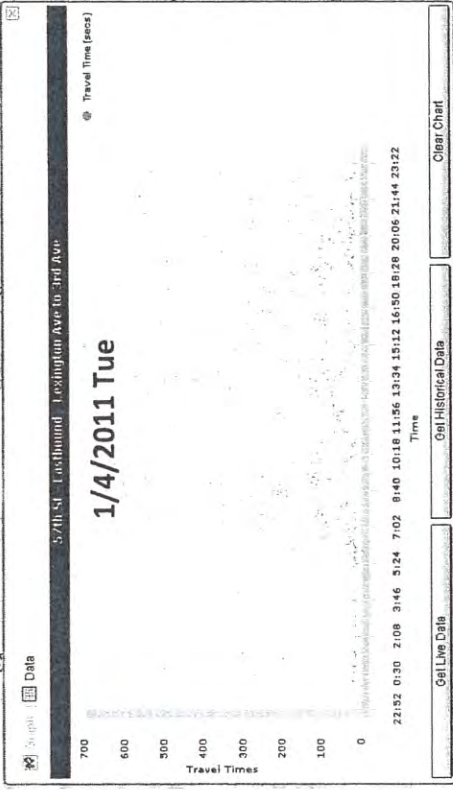
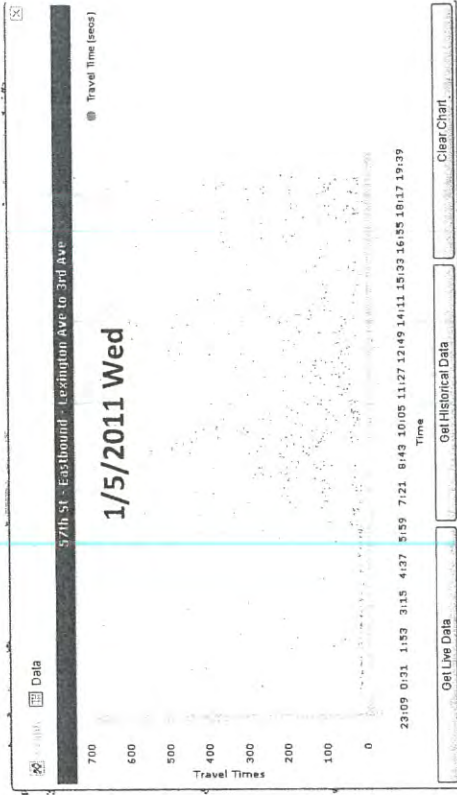


Figure A - 46: Travel Time (sec) Tuesday 57th St. between Lexington Ave. and 3rd Ave.

Pre-Existing



Base as Implemented

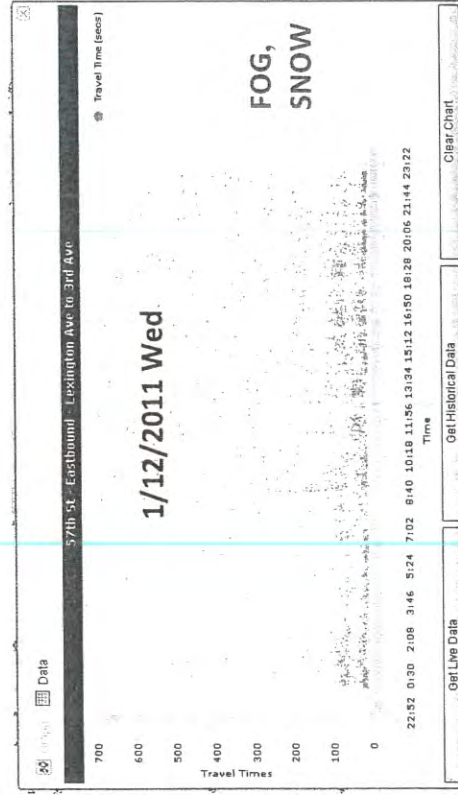
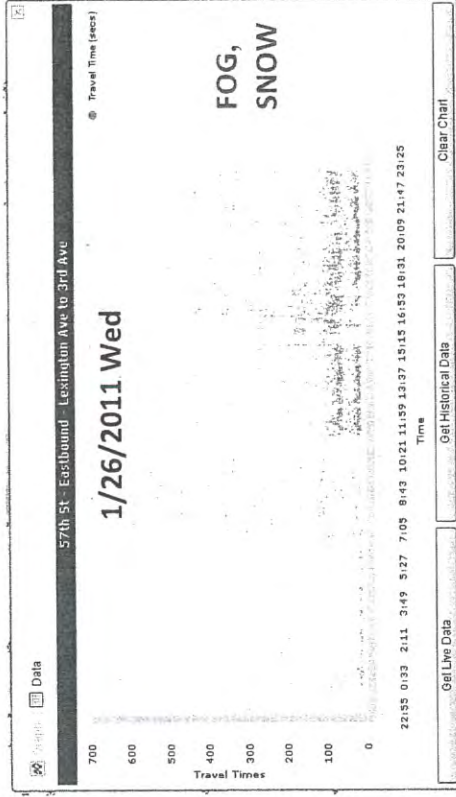
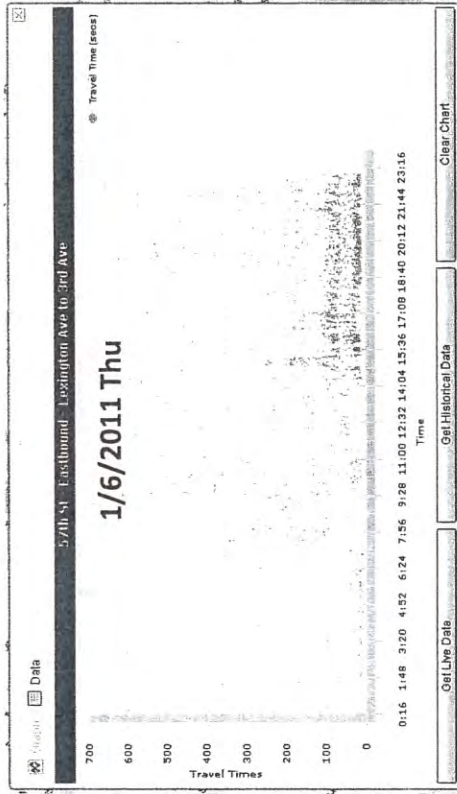


Figure A - 47: Travel Time (sec) Wednesday 57th St. between Lexington Ave. and 3rd Ave.

Pre-Existing



Base as Implemented

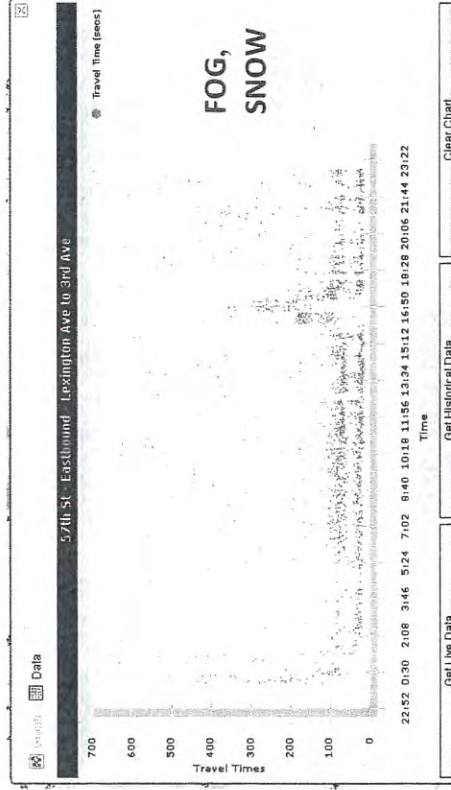
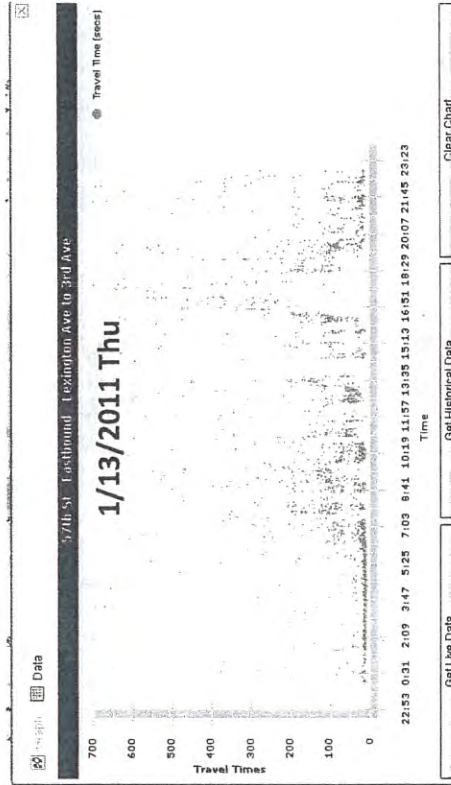
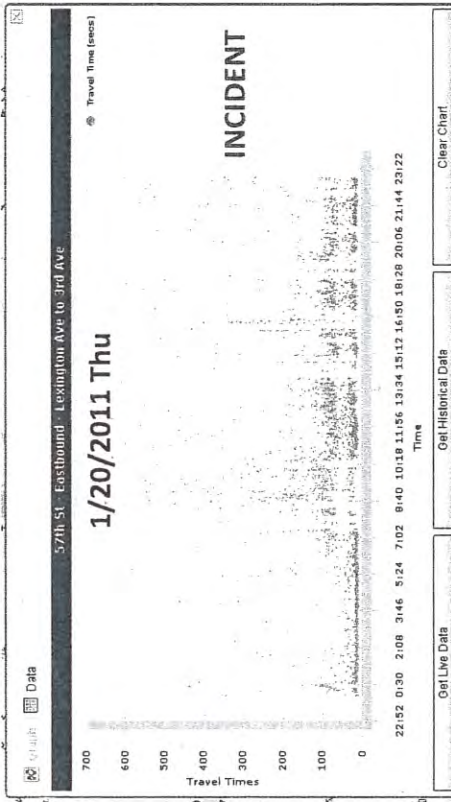
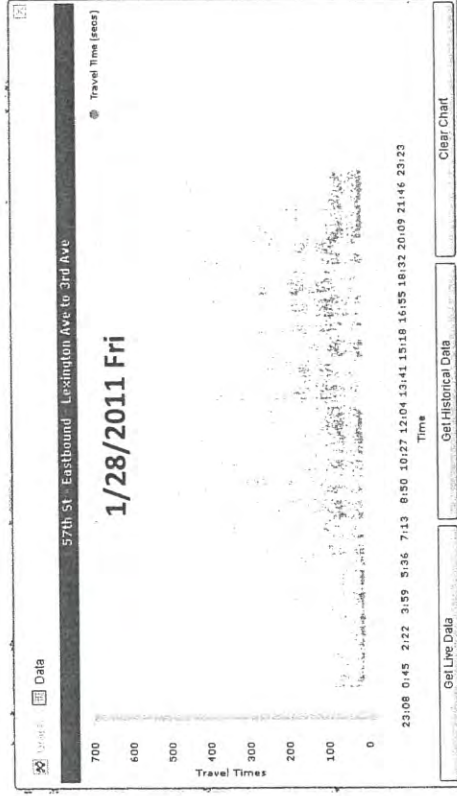
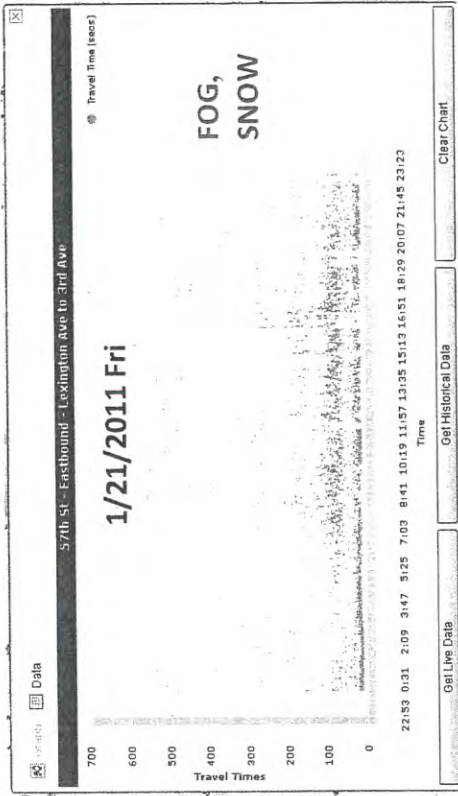


Figure A - 48: Travel Time (sec) Thursday 57th St. between Lexington Ave. and 3rd Ave.

Base as Implemented



Pre-Existing

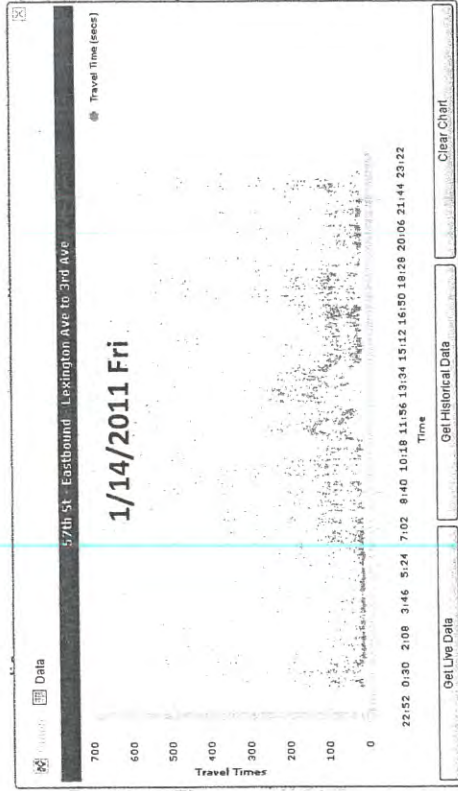
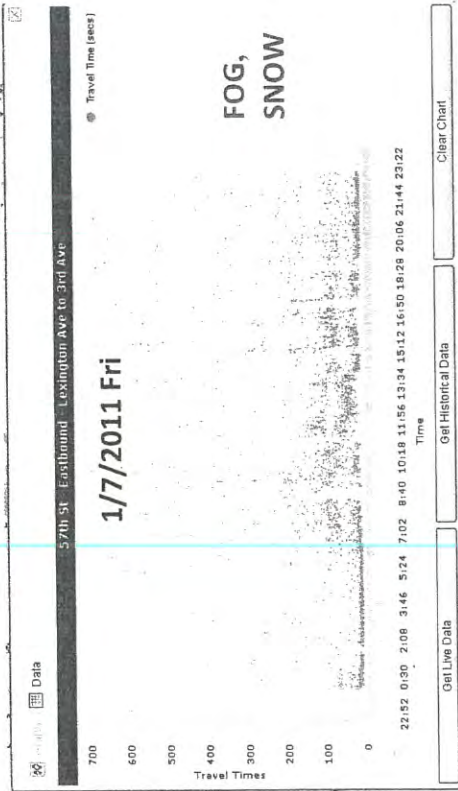
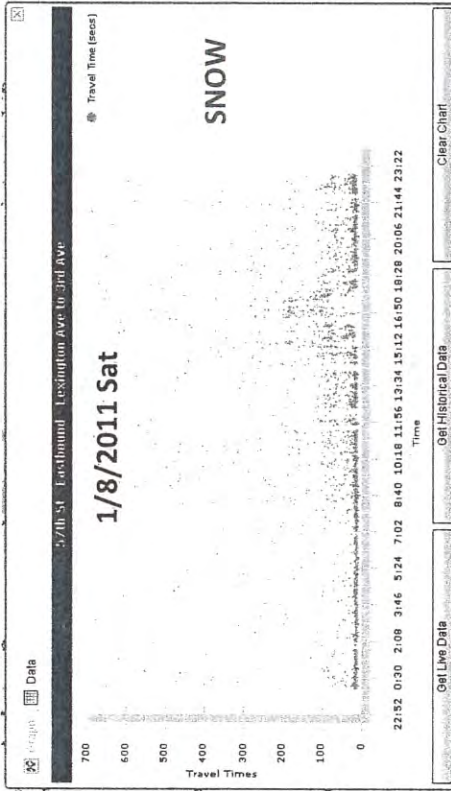


Figure A - 49: Travel Time (sec) Friday 57th St. between Lexington Ave. and 3rd Ave.

Pre-Existing



Base as Implemented

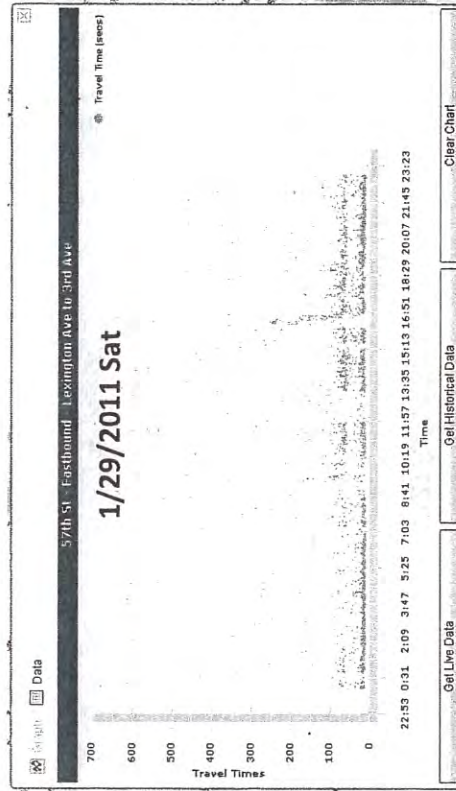
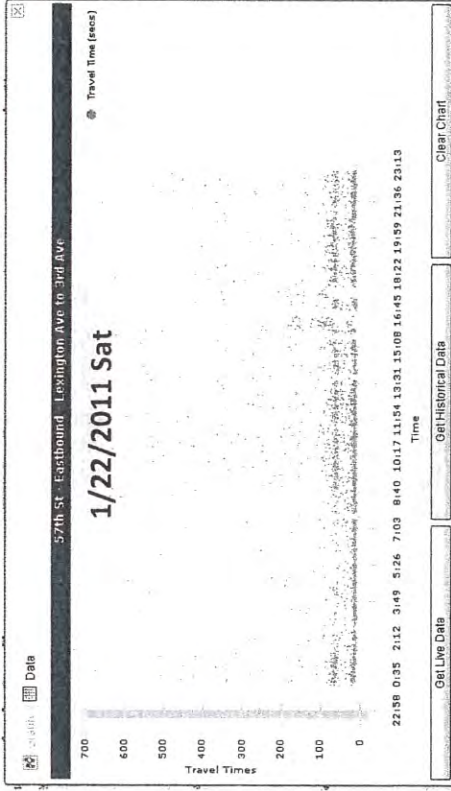
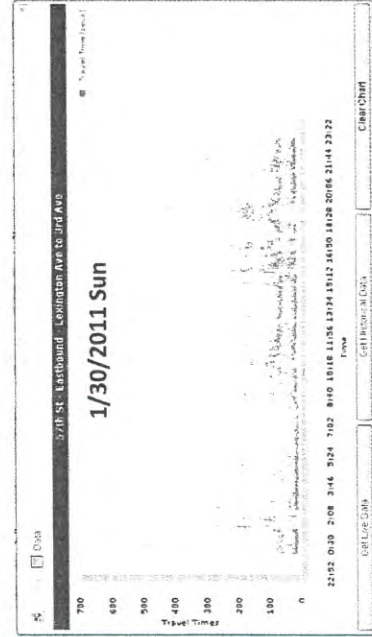
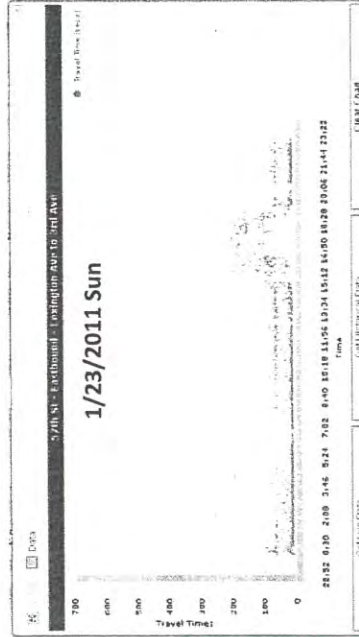
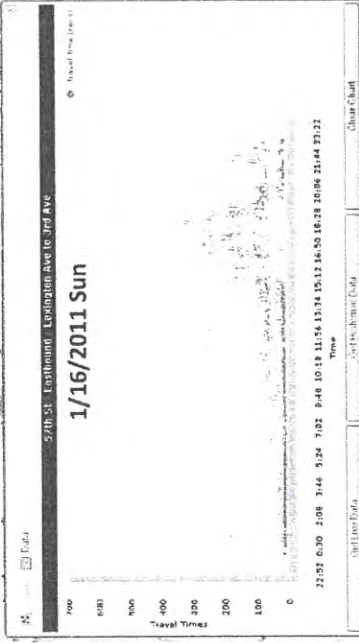


Figure A - 50: Travel Time (sec) Saturday 57th St. between Lexington Ave. and 3rd Ave.

Base as Implemented



Pre-Existing

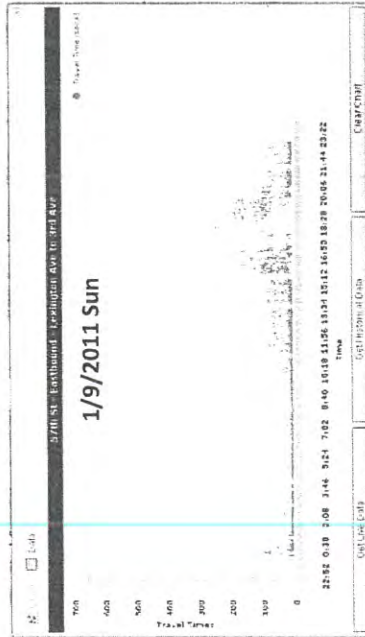
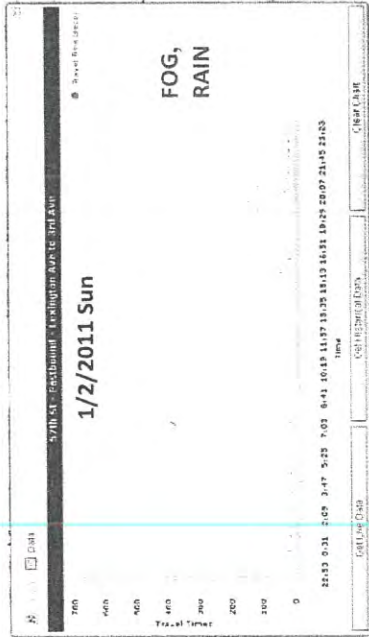


Figure A - 51: Travel Time (sec) Sunday 57th St. between Lexington Ave. and 3rd Ave.

Appendix B

RTMS Data

Appendix B – RTMS Data

This Appendix presents a subset of the RTMS data at the following eight locations for four dates (1/10, 1/14, 1/21, and 1/31):

- 1) 3rd Avenue between 44th Street and 45th Street
- 2) 3rd Avenue between 47th Street and 48th Street
- 3) Lexington Avenue between 63rd and 62nd Street
- 4) Lexington Avenue between 59st and 58th Street
- 5) Lexington Avenue between 51st and 50th Street
- 6) 57th Street between 2nd Avenue and 3rd Avenue
- 7) 57th Street between 3rd Avenue and Lexington Avenue
- 8) 58th Street between 2nd Avenue and 3rd Avenue
- 9) 58th Street between 3rd Avenue and Lexington Avenue

The data is provided in 30 second intervals by NYCDOT via the ACDSS interface at the TMC. Figures C1 through C9 present the average flow per hour by lane for each location, and Figures C10 through C18 present the average occupancy per hour by lane for each location.

The figures suggest that the average flow and occupancy observed at these locations exhibit variability across the days, and in the before and after conditions.

3rd Ave Between 44th and 45th - RTMS Data

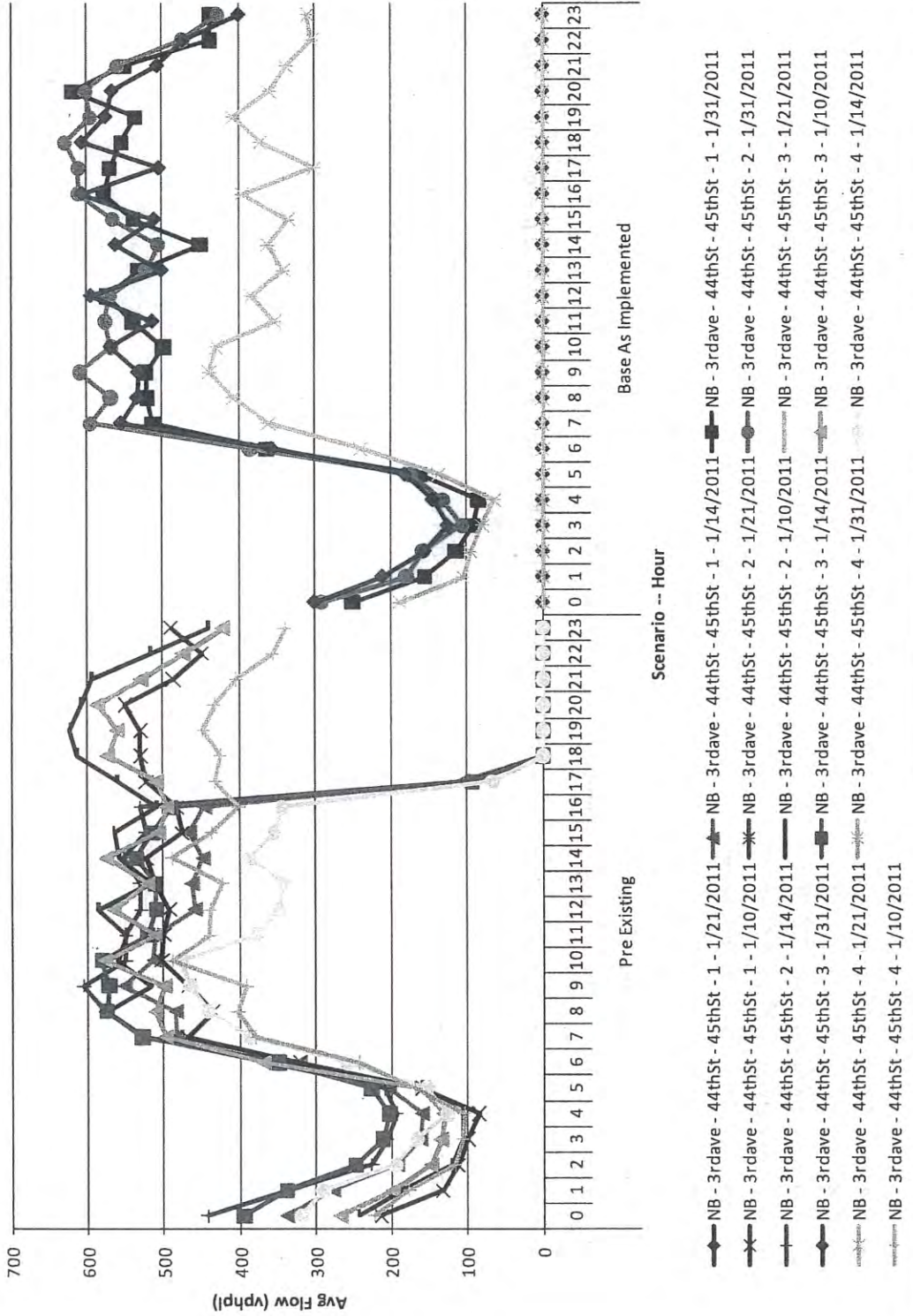


Figure B-1: 3rd Avenue RTMS Location: 44th and 45th St - Average Flow Per Lane

3rd Ave Between 47th and 48th - RTMS Data

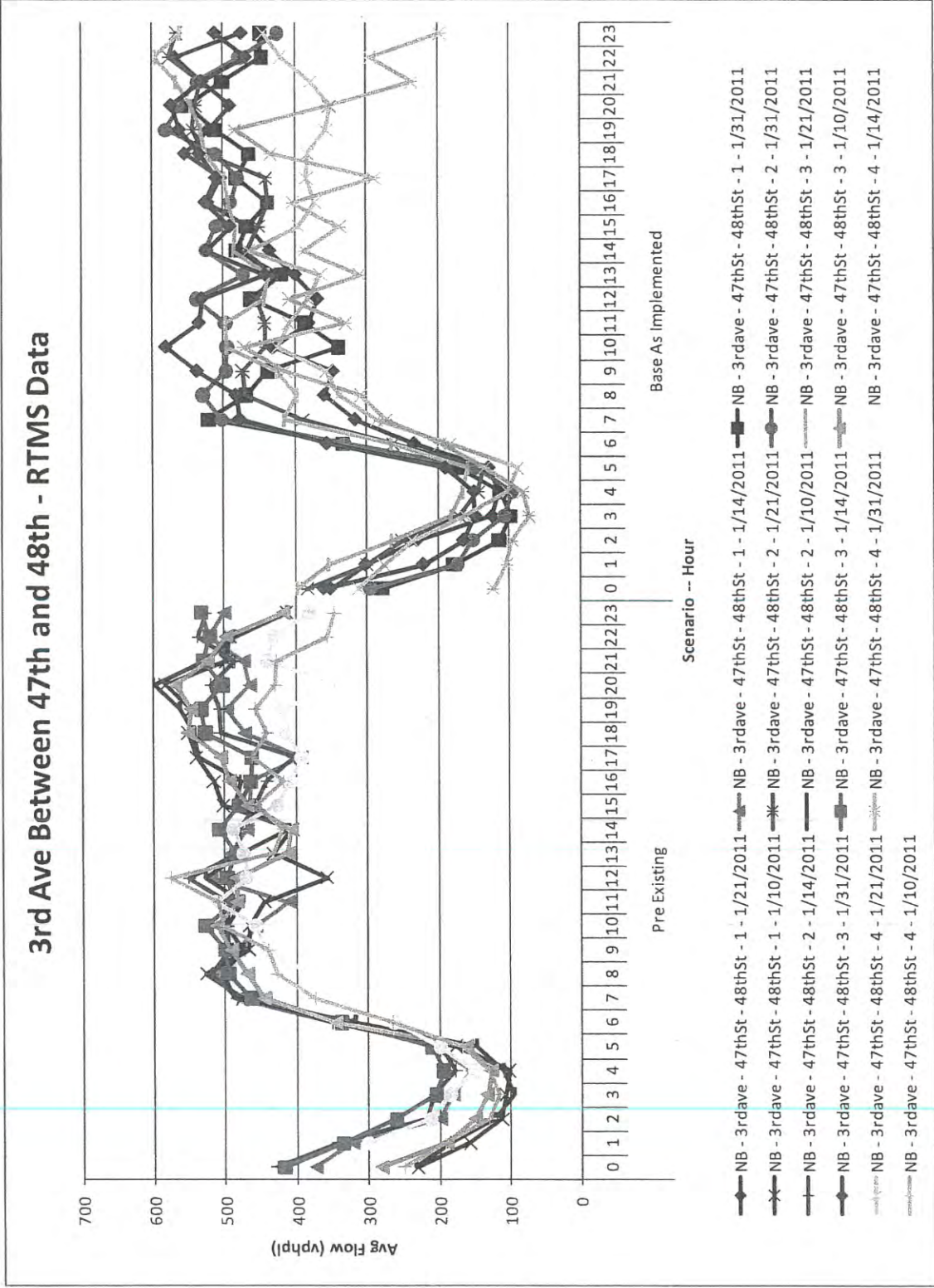


Figure B-2: 3rd Avenue RTMS Location: 47th and 48th St – Average Flow Per Lane

Lex Ave Between 51st and 50th - RTMS Data

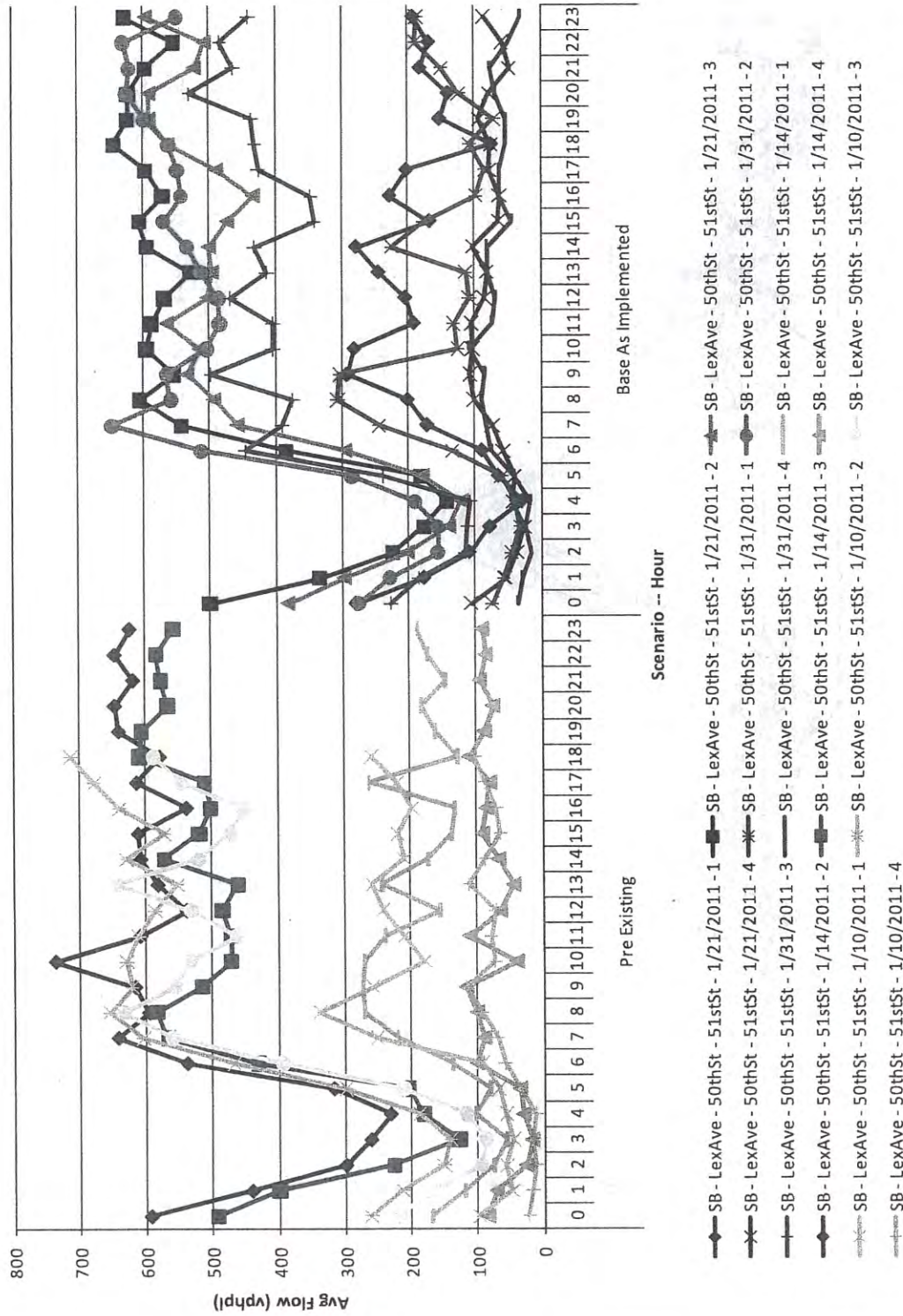


Figure B-3: Lexington Avenue RTMS Location: 51 and 50 St – Average Flow Per Lane

Lex Ave Between 58th and 59th - RTMS Data

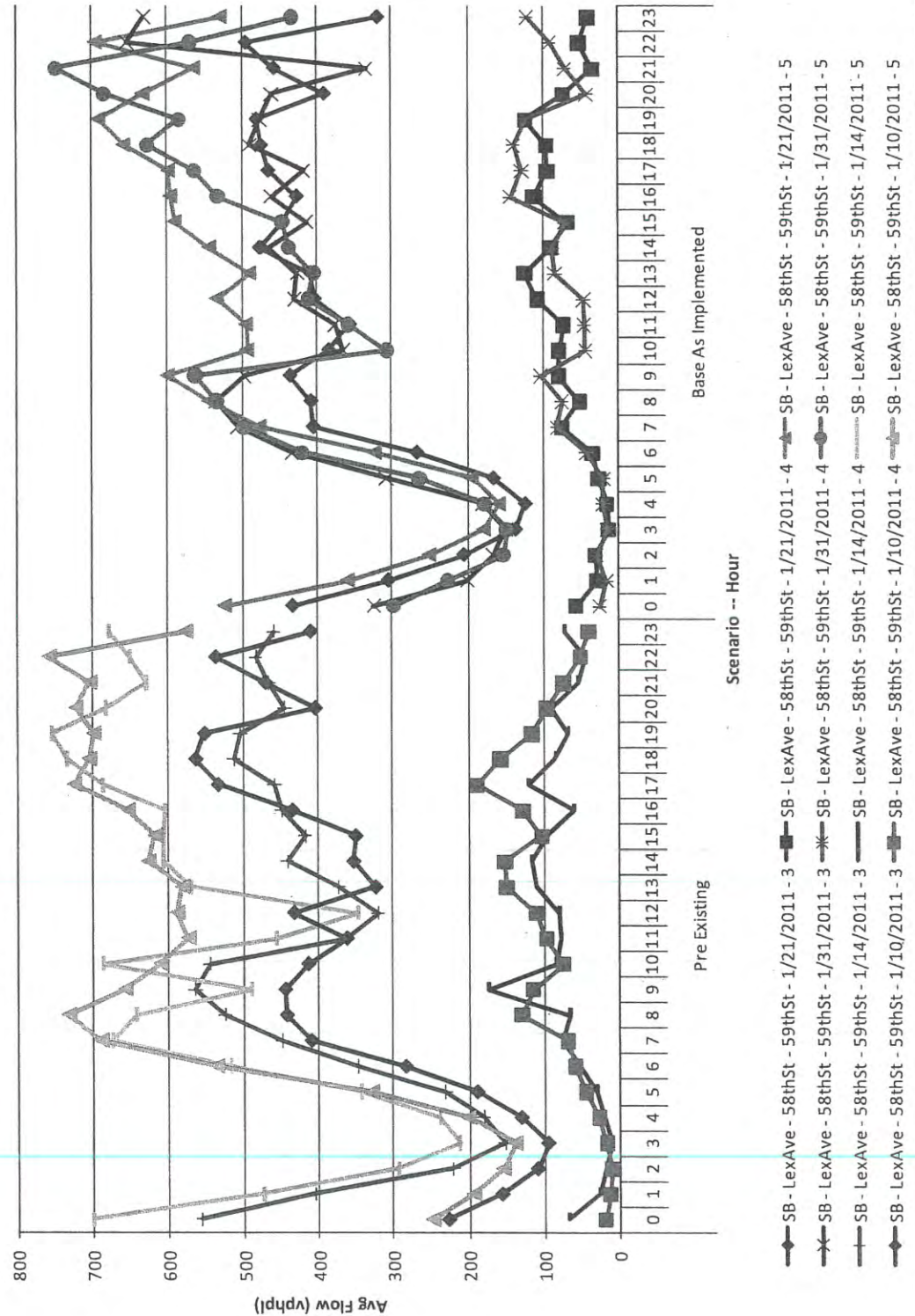


Figure B-4: Lexington Avenue RTMS Location: 58 and 59 St – Average Flow Per Lane

Lex Ave Between 62nd and 63rd - RTMS Data

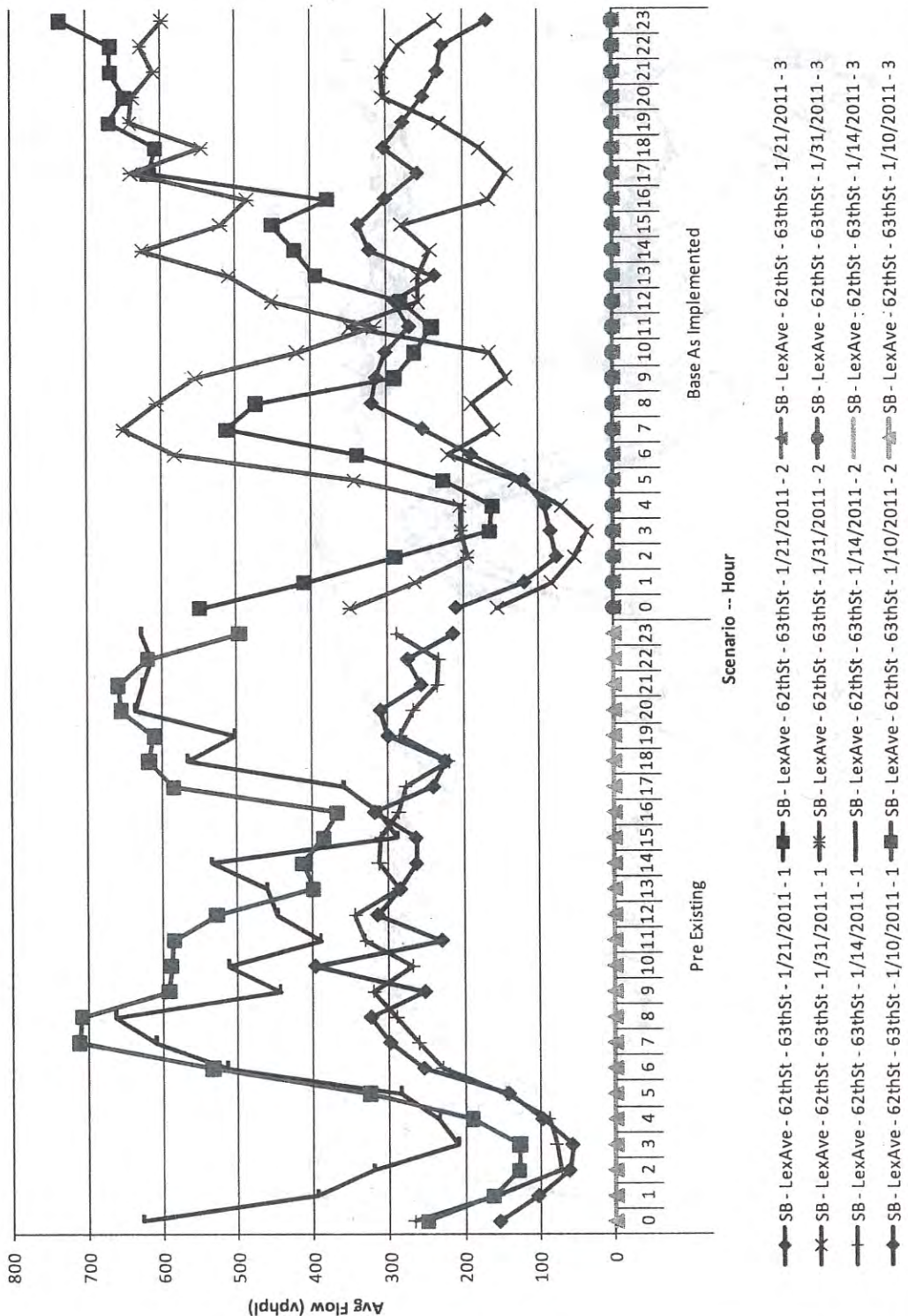


Figure B-5: Lexington Avenue RTMS Location: 62 and 63 St -- Average Flow Per Lane

57th St Between 2nd and 3rd - RTMS Data

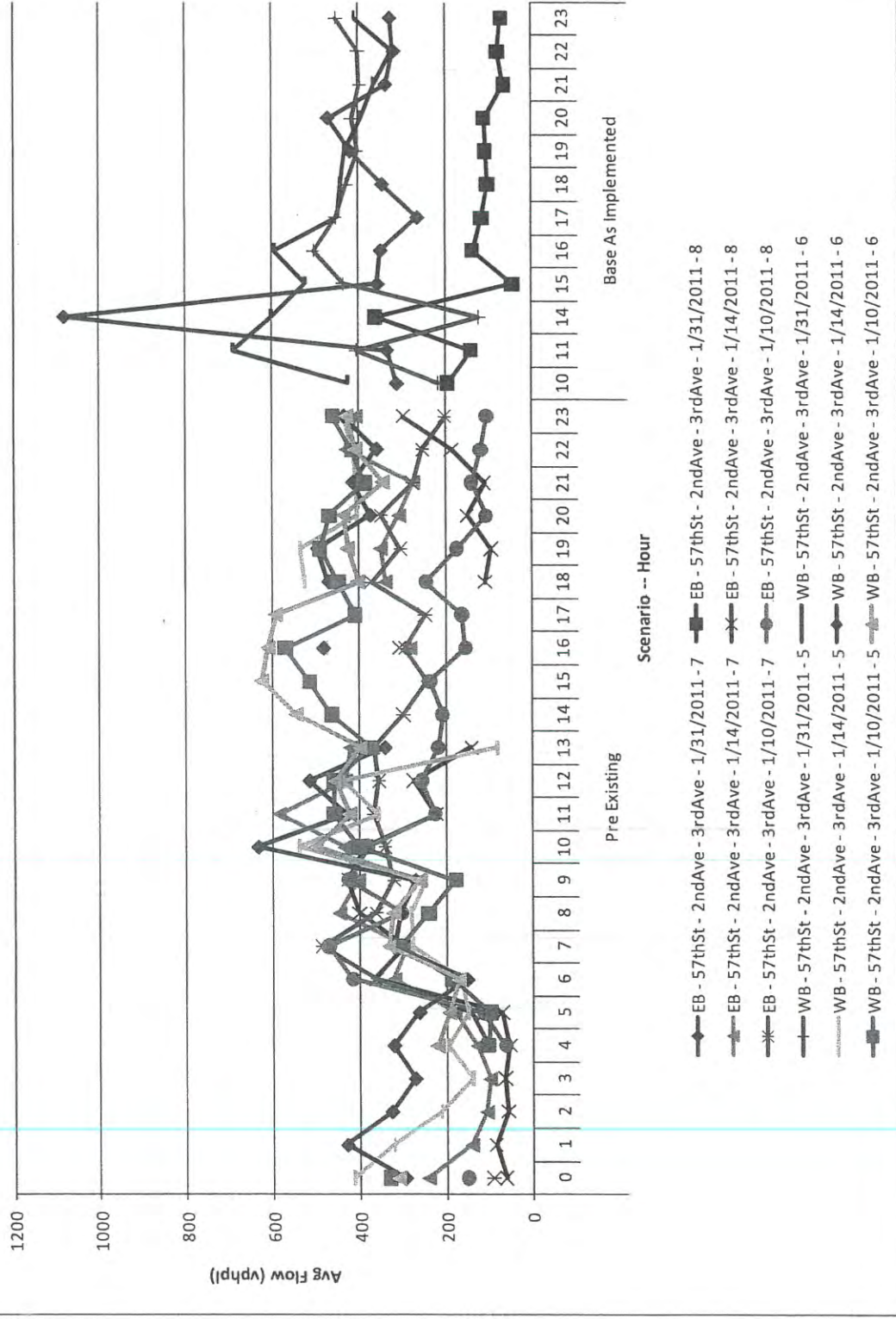


Figure B-6: 57th St RTMS Location: 2nd and 3rd Avenue – Average Flow Per Lane

57th St Between 3rd and Lex - RTMS Data

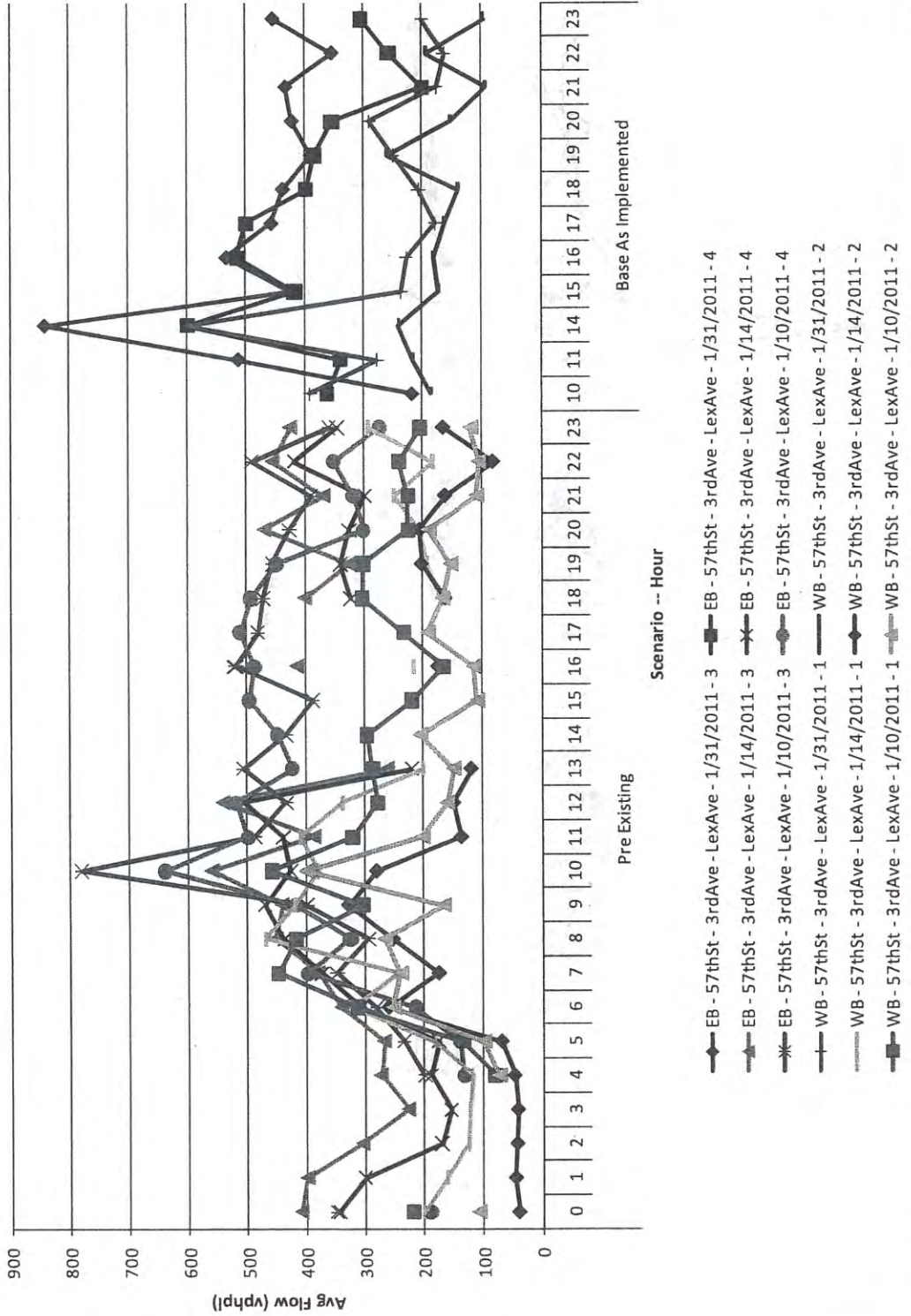


Figure B-7: 57th St RTMS Location: 3rd and Lex Avenue – Average Flow Per Lane

58th St Between 3rd and Lex - RTMS Data

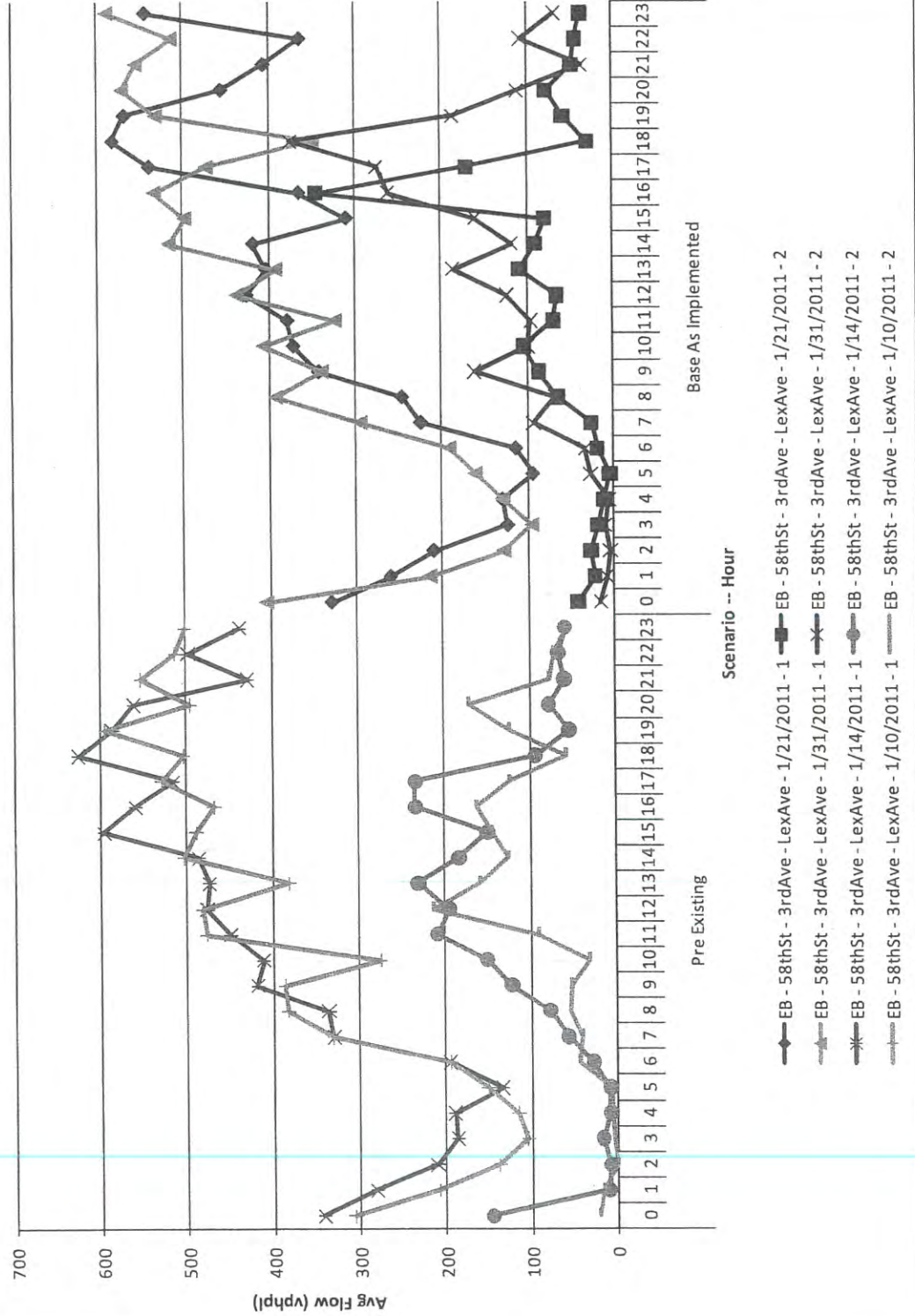
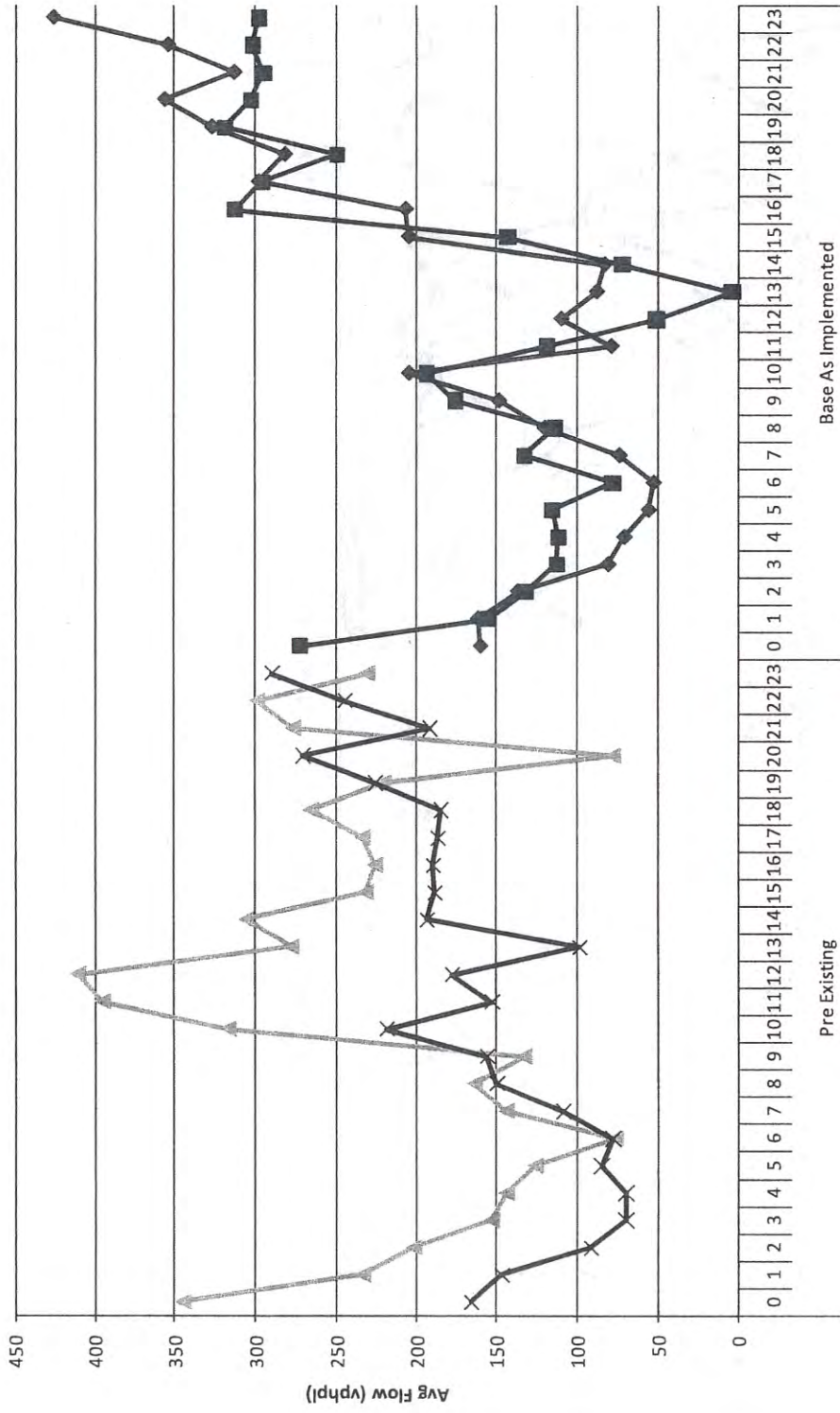


Figure B-8: 58th St RTMS Location: 3rd and Lex Avenue – Average Flow Per Lane

58th St Between 2nd and 3rd - RTMS Data



- EB - 58thSt - 2ndAve - 3rdAve - 1/21/2011 - 3
- EB - 58thSt - 2ndAve - 3rdAve - 1/31/2011 - 3
- EB - 58thSt - 2ndAve - 3rdAve - 1/14/2011 - 3
- EB - 58thSt - 2ndAve - 3rdAve - 1/10/2011 - 3

Figure B-9: 58th St RTMS Location: 2nd and 3rd Avenue – Average Flow Per Lane

3rd Between 44 and 45 St - RTMS Data

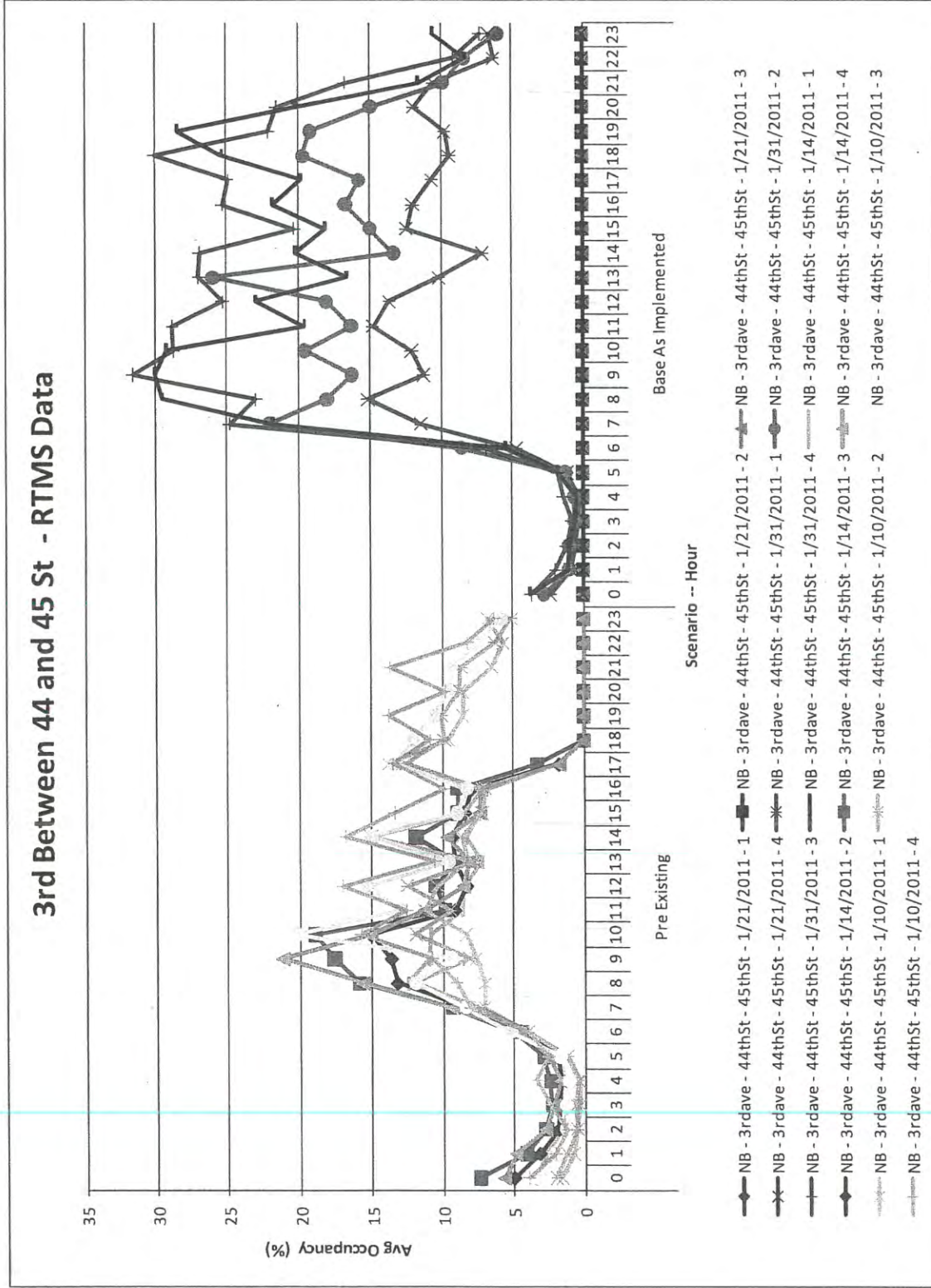


Figure B-10: 3rd Avenue RTMS Location: 44th and 45th St – Average Occupancy Per Lane

3rd Between 47 and 48 St - RTMS Data

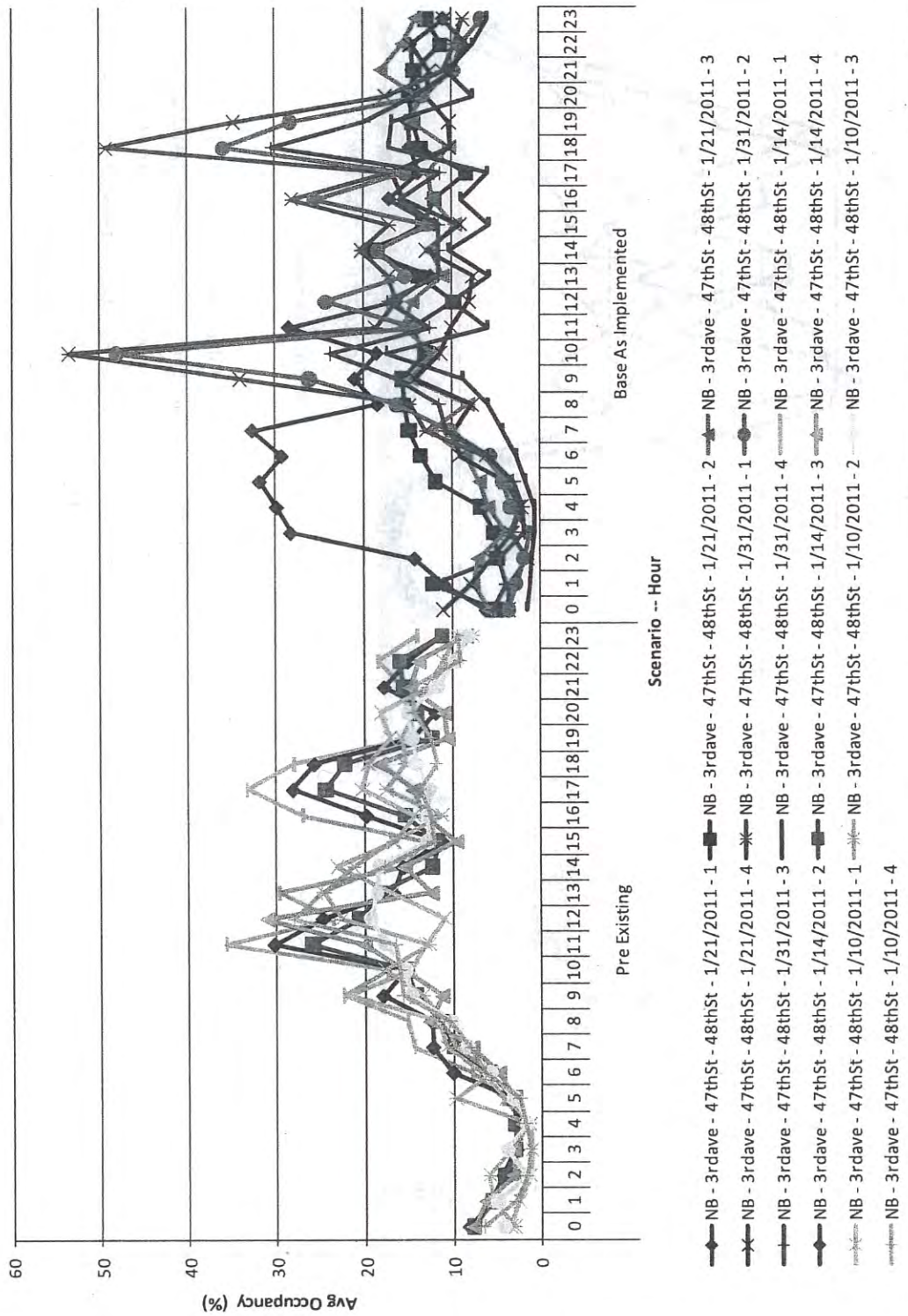


Figure B-11: 3rd Avenue RTMS Location: 47th and 48th St -- Average Occupancy Per Lane

Lex Between 51 and 50 St - RTMS Data

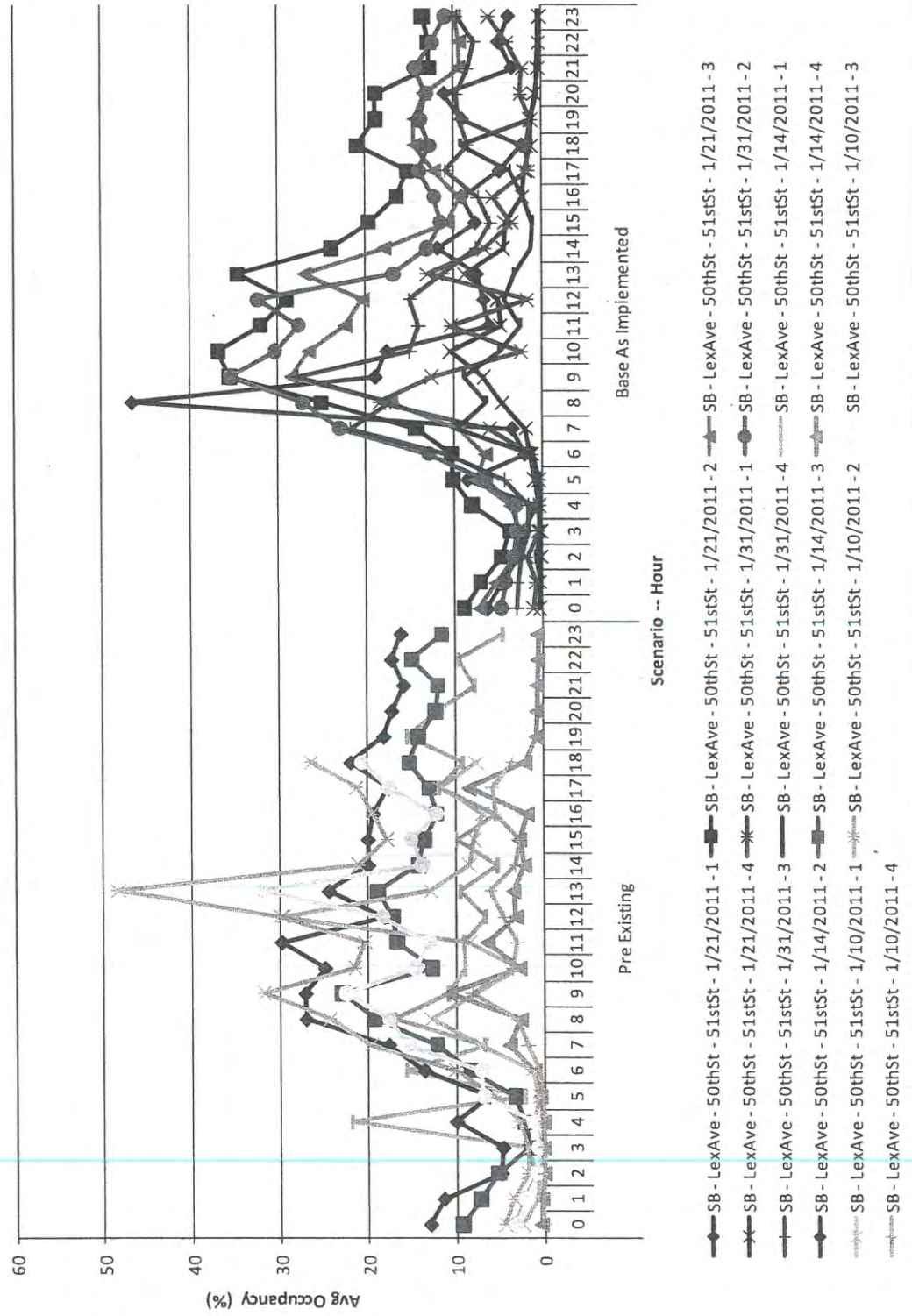


Figure B-12: Lexington Avenue RTMS Location: 51 and 50 St – Average Occupancy Per Lane

Lex Between 58 and 59 St - RTMS Data

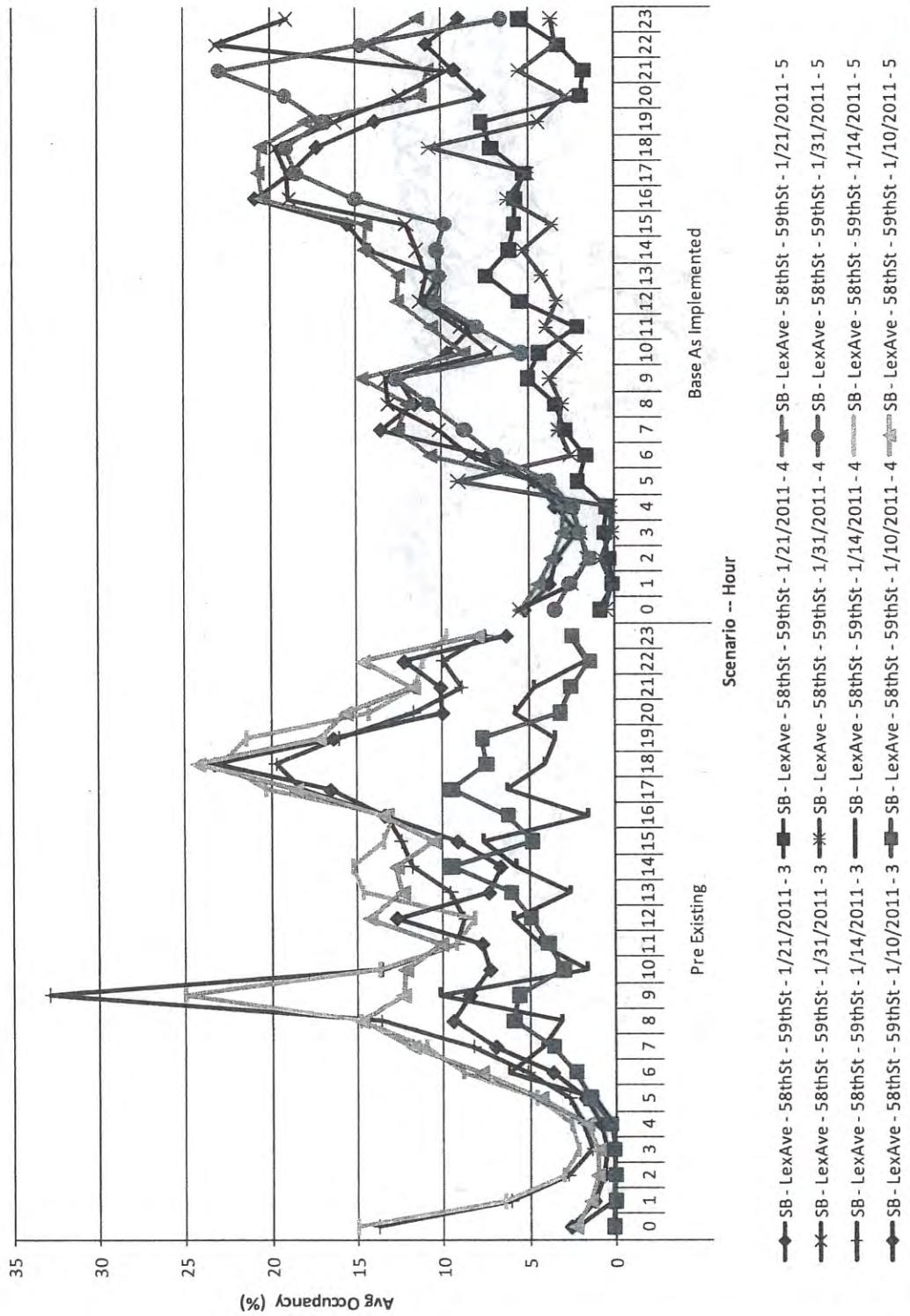


Figure B-13: Lexington Avenue RTMS Location: 58 and 59 St -- Average Occupancy Per Lane

Lex Between 63rd and 62nd St - RTMS Data

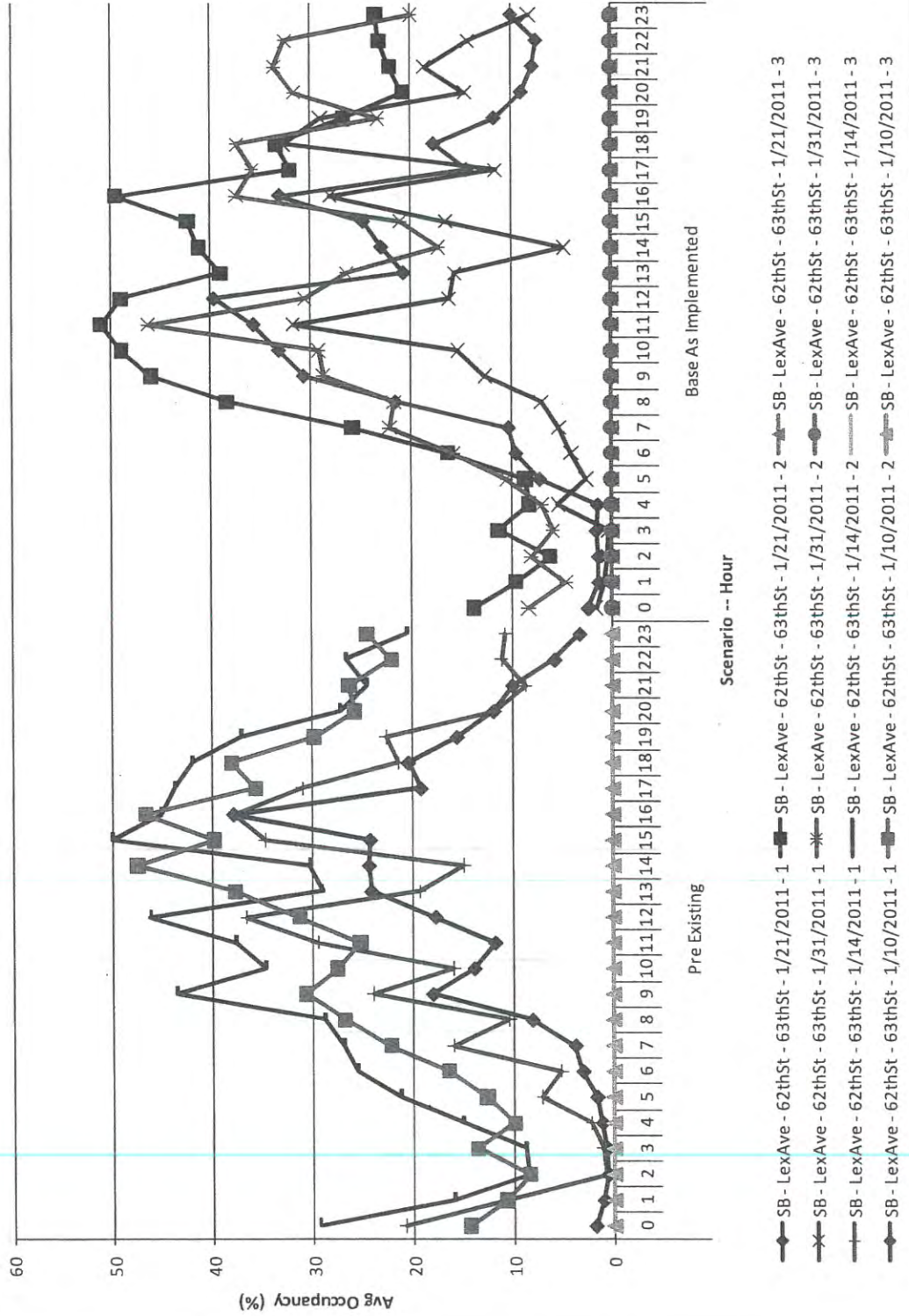


Figure B-14: Lexington Avenue RTMS Location: 62 and 63 St – Average Occupancy Per Lane

57th St Between 2nd and 3rd - RTMS Data

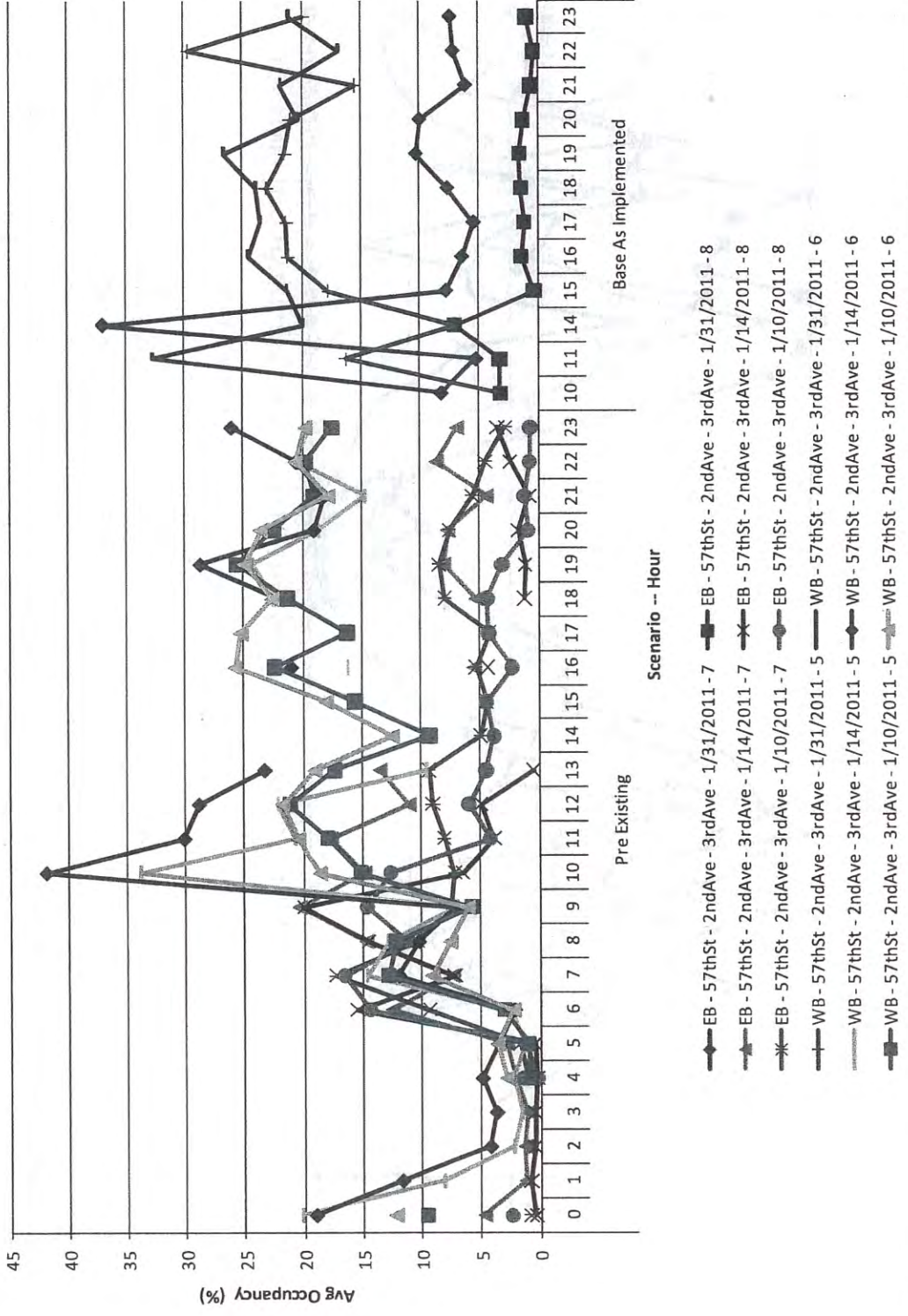


Figure B-15: 57th St RTMS Location: 2nd and 3rd Avenue – Average Occupancy Per Lane

57th St Between 3rd and Lex - RTMS Data

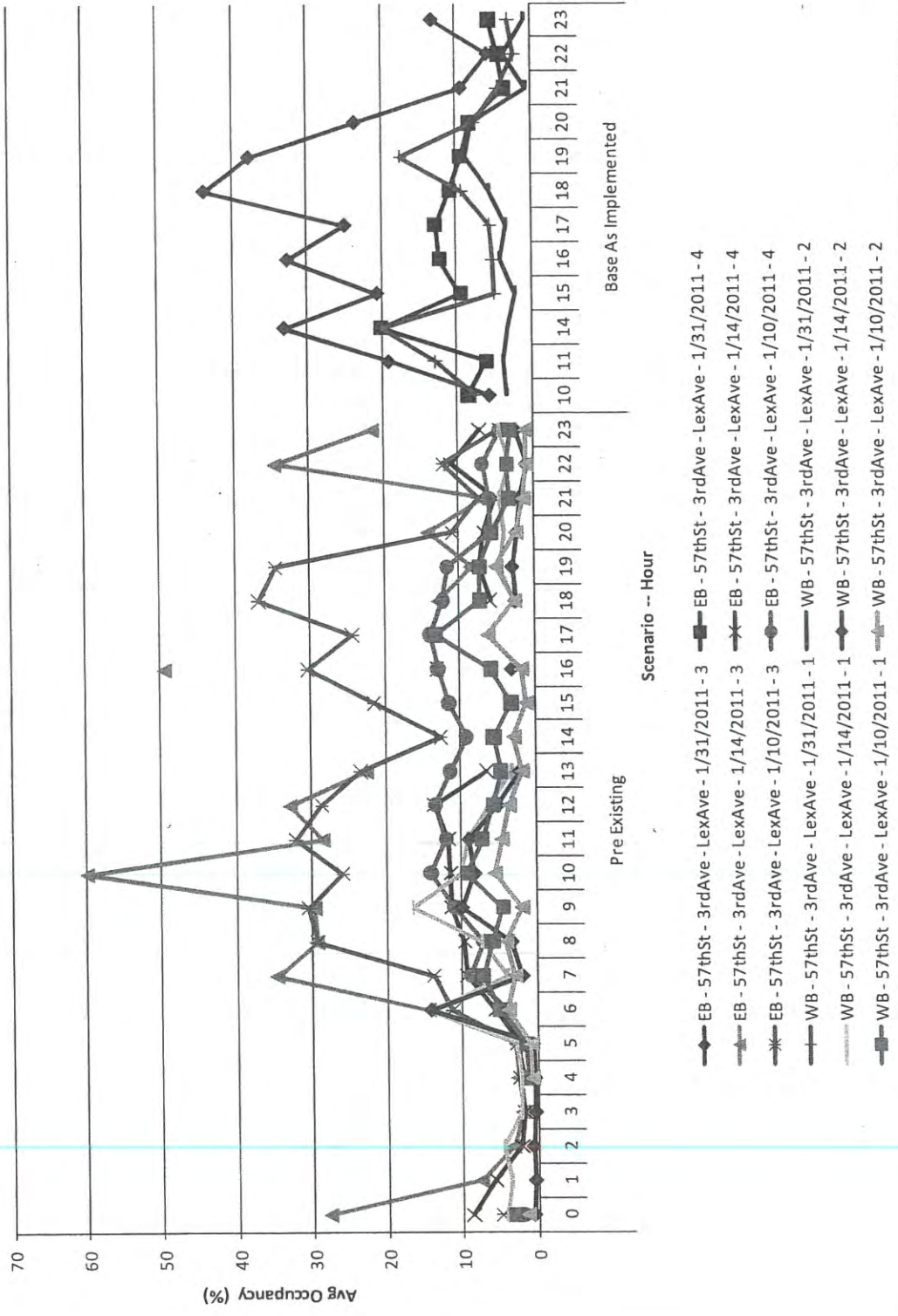


Figure B-16: 57th St RTMS Location: 3rd and Lex Avenue – Average Occupancy Per Lane

58th St Between 2nd and 3rd - RTMS Data

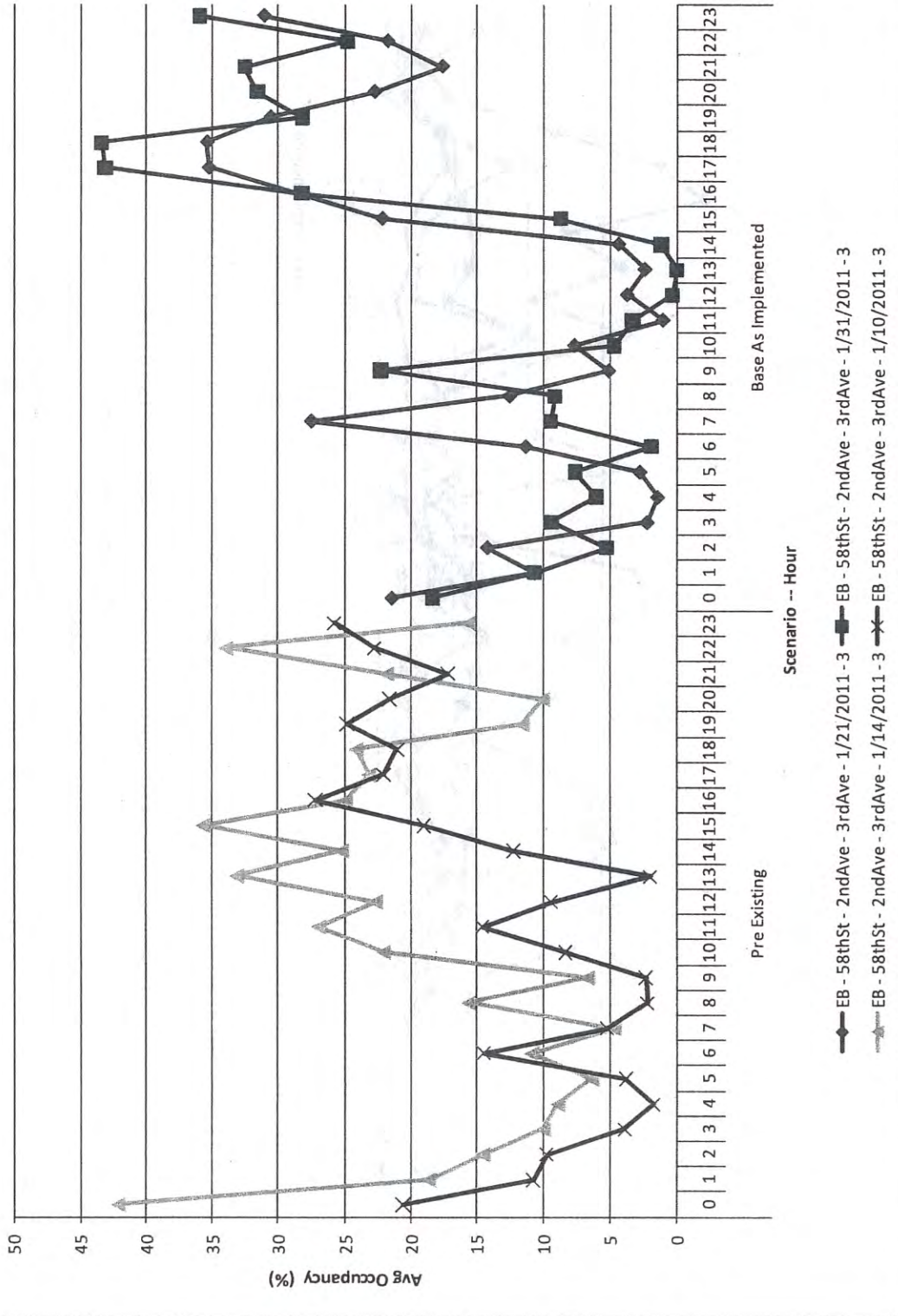


Figure B-17: 58th St RTMS Location: 2nd and 3rd Avenue -- Average Occupancy Per Lane

58th St Between 3rd and Lex - RTMS Data

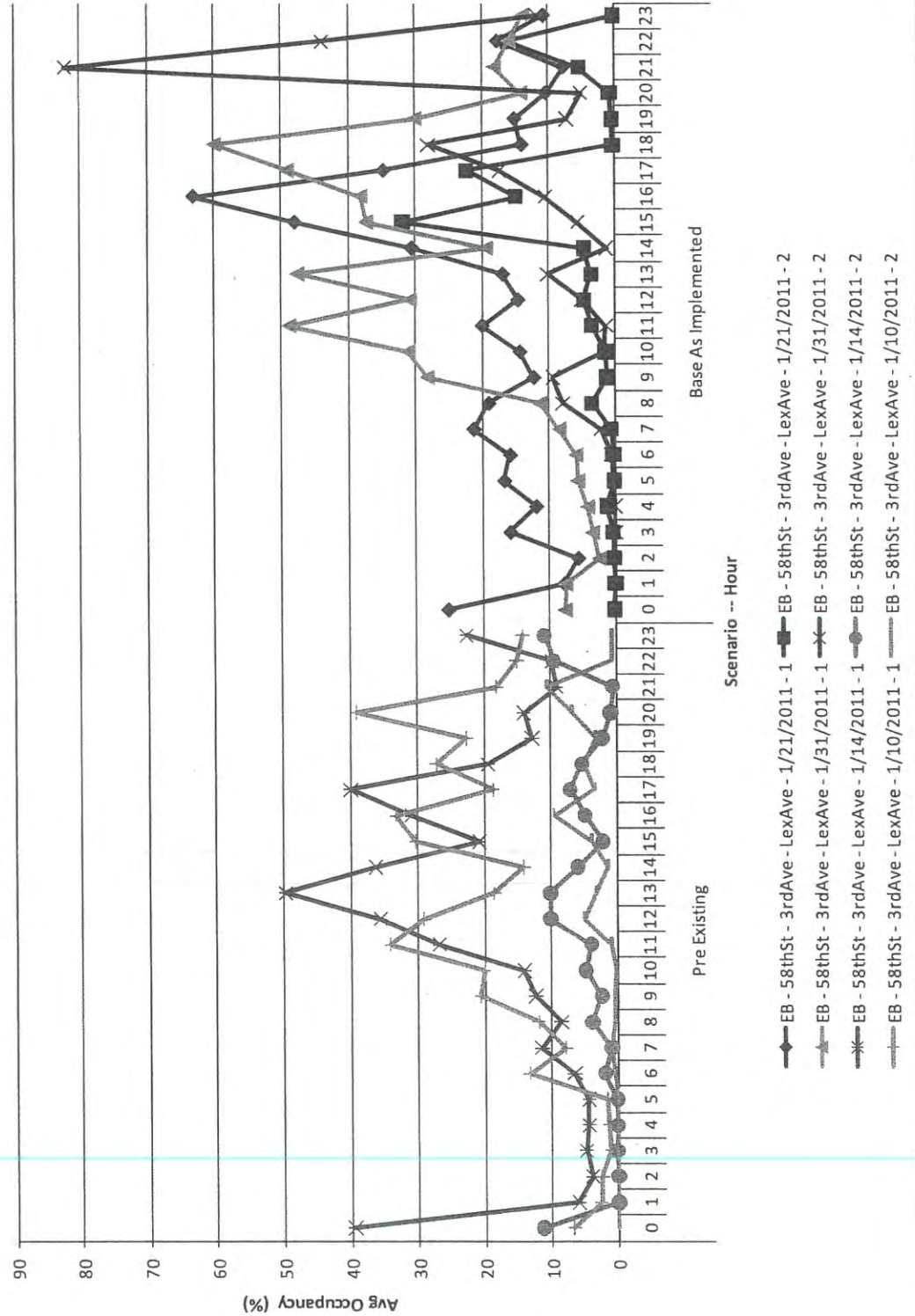


Figure B-18: 58th St RTMS Location: 3rd and Lex Avenue – Average Occupancy Per Lane

Appendix C

GPS-based Travel Time Data

Notes	
1	All pre-existing travel time runs are shown in shades of <i>red</i> .
2	All candidate baseline travel time runs are shown in shades of <i>blue</i> .
3	Considerable variation exists, in areas unaffected by signal plan changes <i>and</i> within changed areas

Appendix C – GPS Travel Time Data

This Appendix presents the GPS based travel time runs collected in the field. Table C-1 provides a summary of the travel times within the zone and Figures C-1 through C-9 present these trips in the form of time-space diagrams. The figures are grouped by Avenues (2nd, 3rd, and Lex) and by peak period (AM, Midday, and PM).

These travel time samples were collected by NYCDOT staff and KLD staff during the December 2010 and January 2011.

The data was processed using Mapitude (GIS analysis tool developed by Caliper Corporation) and presented in charts using Excel.

The GPS logging units were standard vehicle navigation units – Garmin nuvi 255.

Field observations related to incidents and weather were also collected.

Table C-1: Summary of Travel Times Observed within the Zone (59th Street to 42nd Street)

	AM		MID-DAY		PM	
	Pre-Existing	Baseline	Pre-Existing	Baseline	Pre-Existing	Baseline
2nd Avenue	268	347		444	372	249
		362		290		
		439		406		
Lexington Ave	434	607	389	996	398	524
	710	736	529	472		
		613	448	773		
		719				
3rd Avenue	380	279	565	279	415	565
	272	1097	442	535	219	896
	264	371	760	374		745
		343		448		993
		1096				

	FROM	TO
AM	6AM	10AM
MID-DAY	10AM	2PM
PM	2PM	7PM

All table entries in seconds.

Note: The observations crossed out were collected on days that had incidents reported on the QBB

2nd Ave - Time Space Diagram - Weekday (6:00AM-10:00AM)

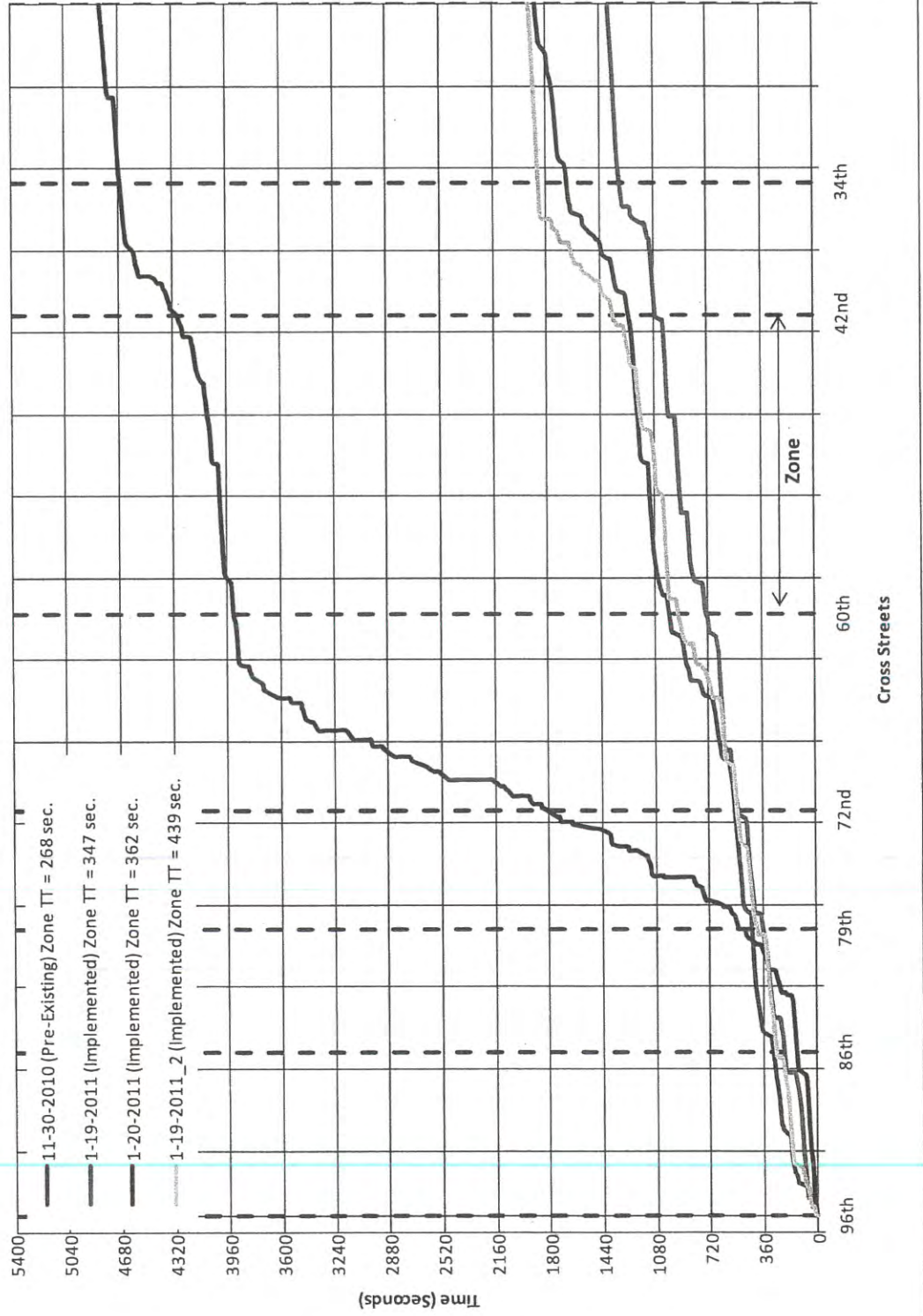


Figure C-1 – GPS Based Travel Time Data – 2nd Avenue – AM Peak Period

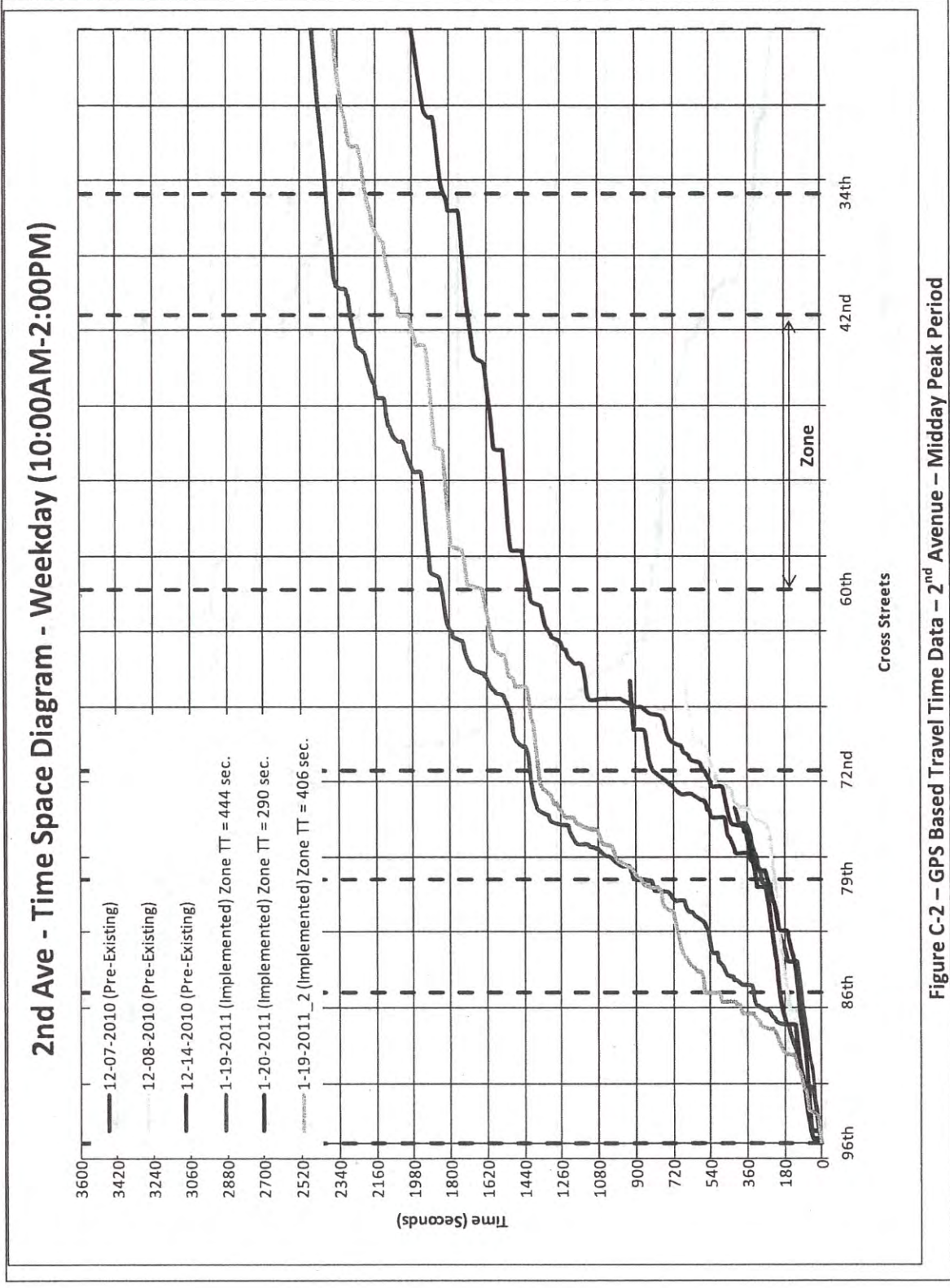


Figure C-2 – GPS Based Travel Time Data – 2nd Avenue – Midday Peak Period

2nd Ave - Time Space Diagram - Weekday (2:00PM-7:00PM)

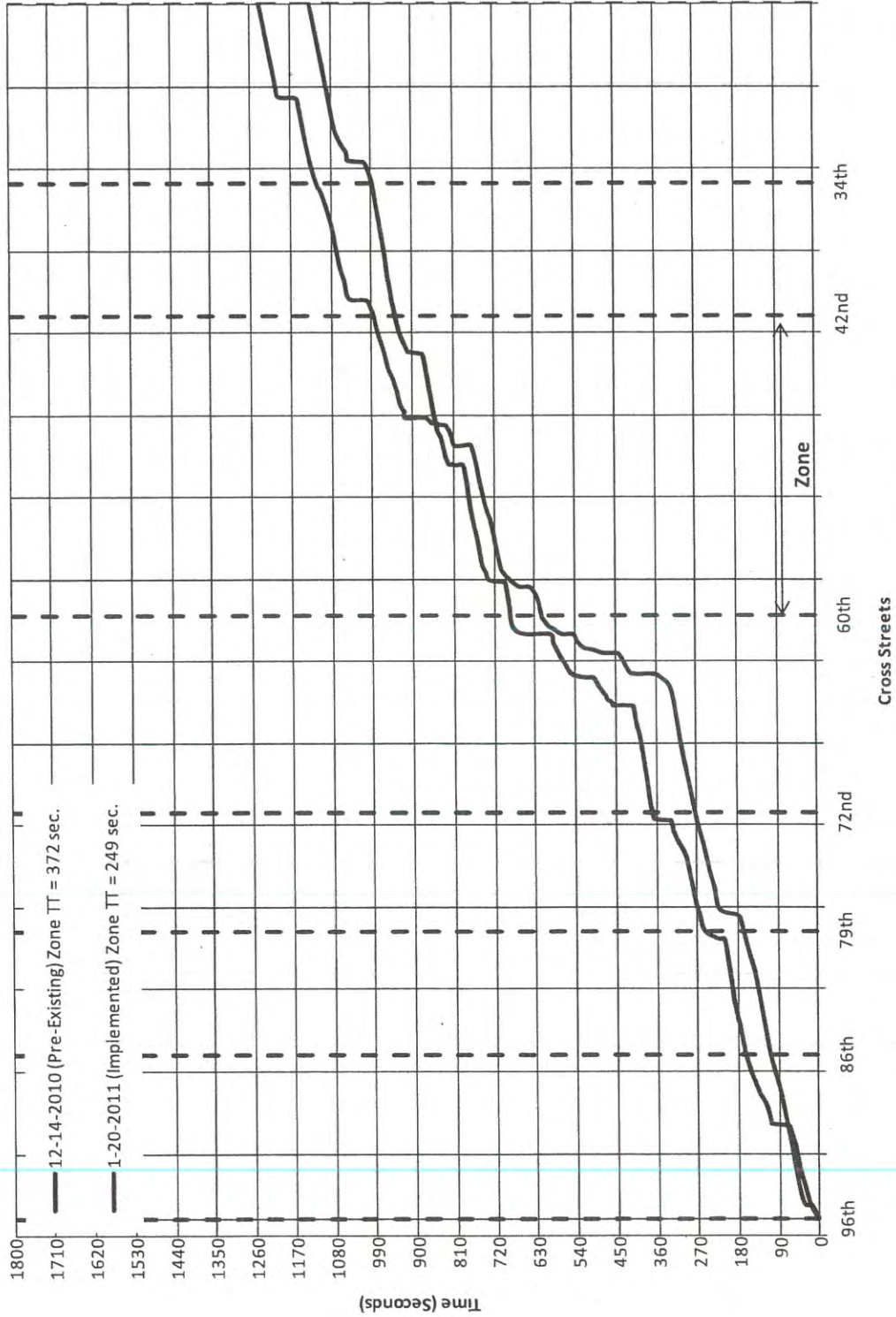


Figure C-3 – GPS Based Travel Time Data – 2nd Avenue – PM Peak Period

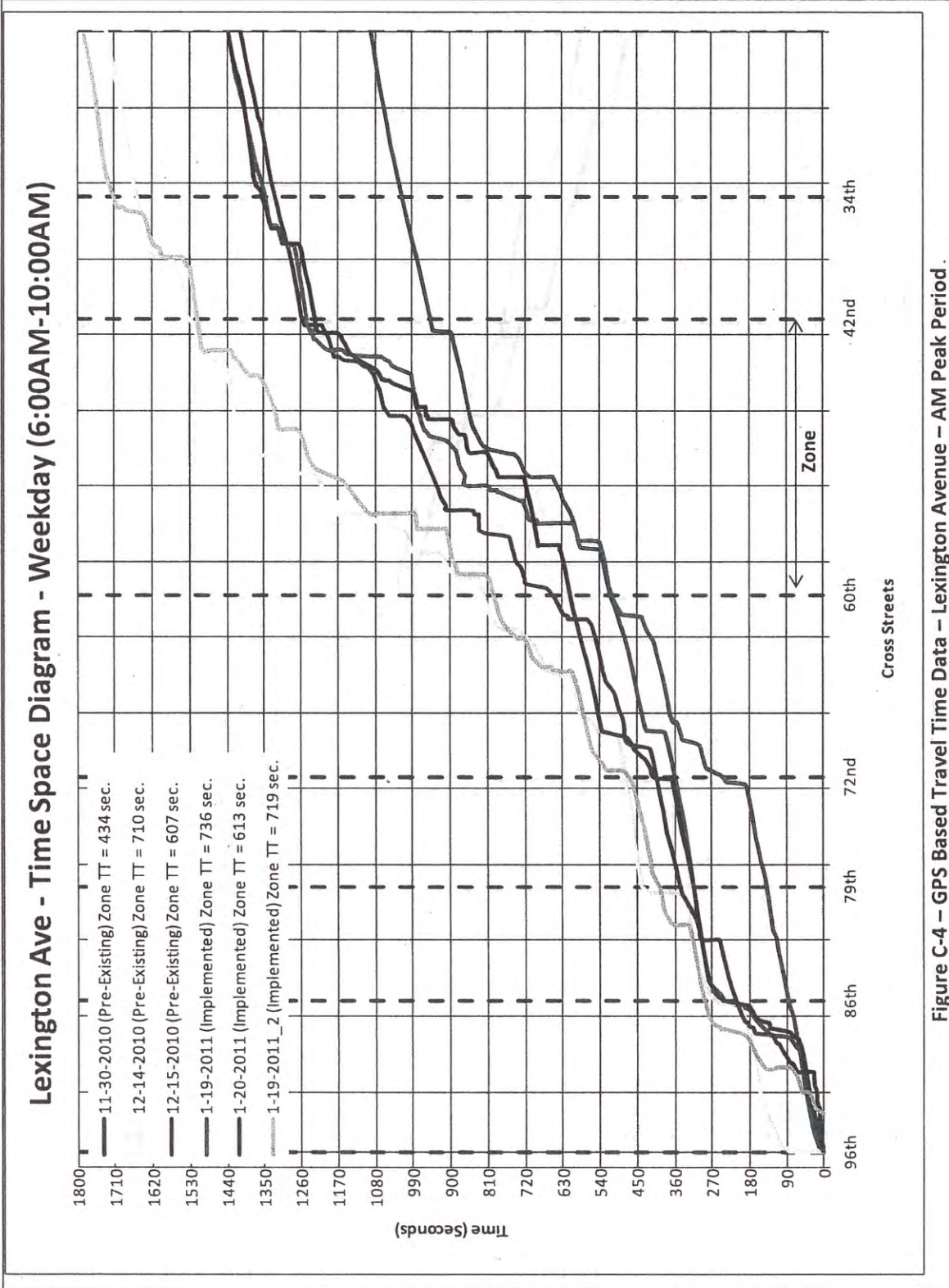


Figure C-4 – GPS Based Travel Time Data – Lexington Avenue – AM Peak Period

Lexington Ave - Time Space Diagram - Weekday (10:00AM-2:00PM)

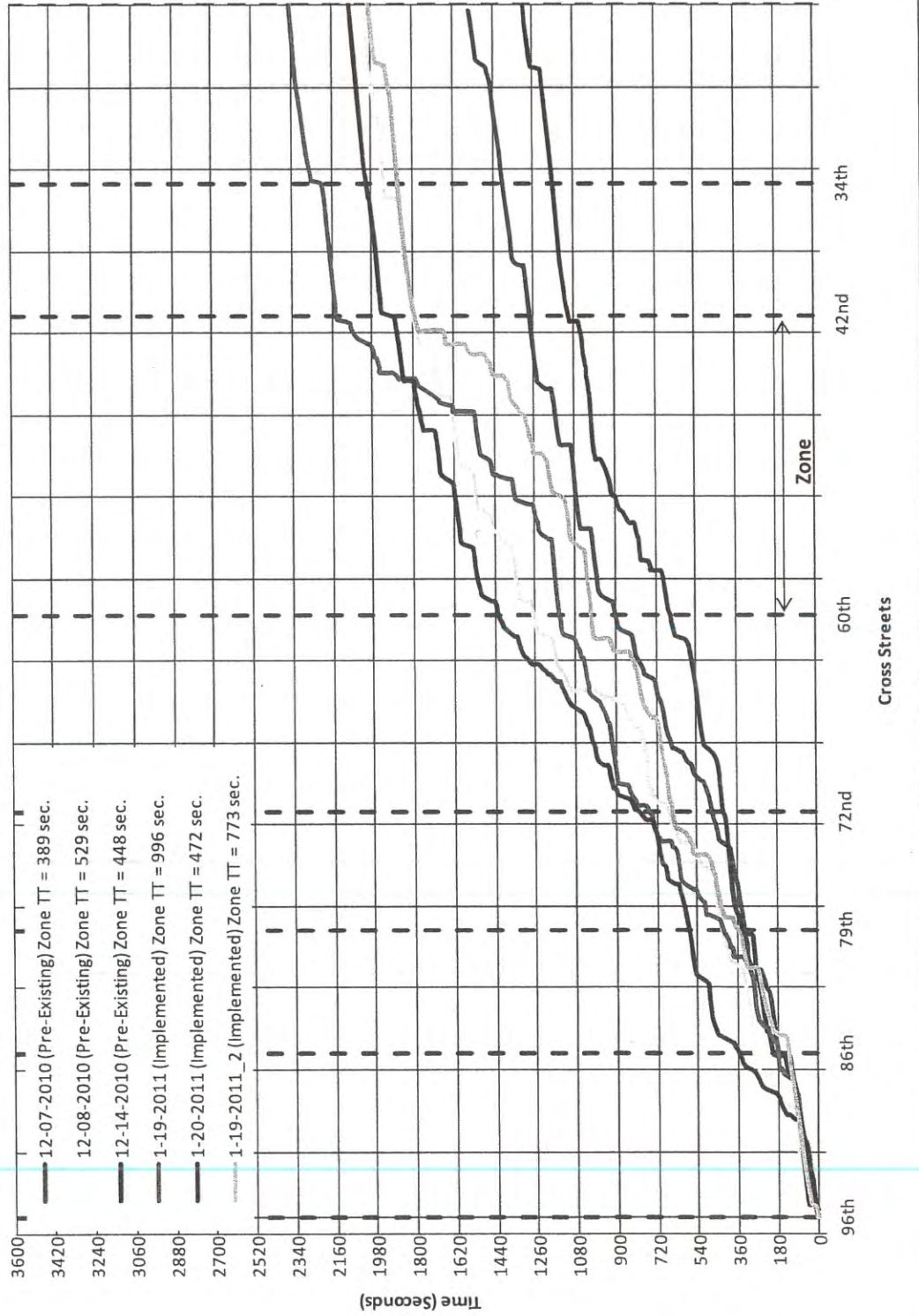


Figure C-5 – GPS Based Travel Time Data – Lexington Avenue – Midday Peak Period

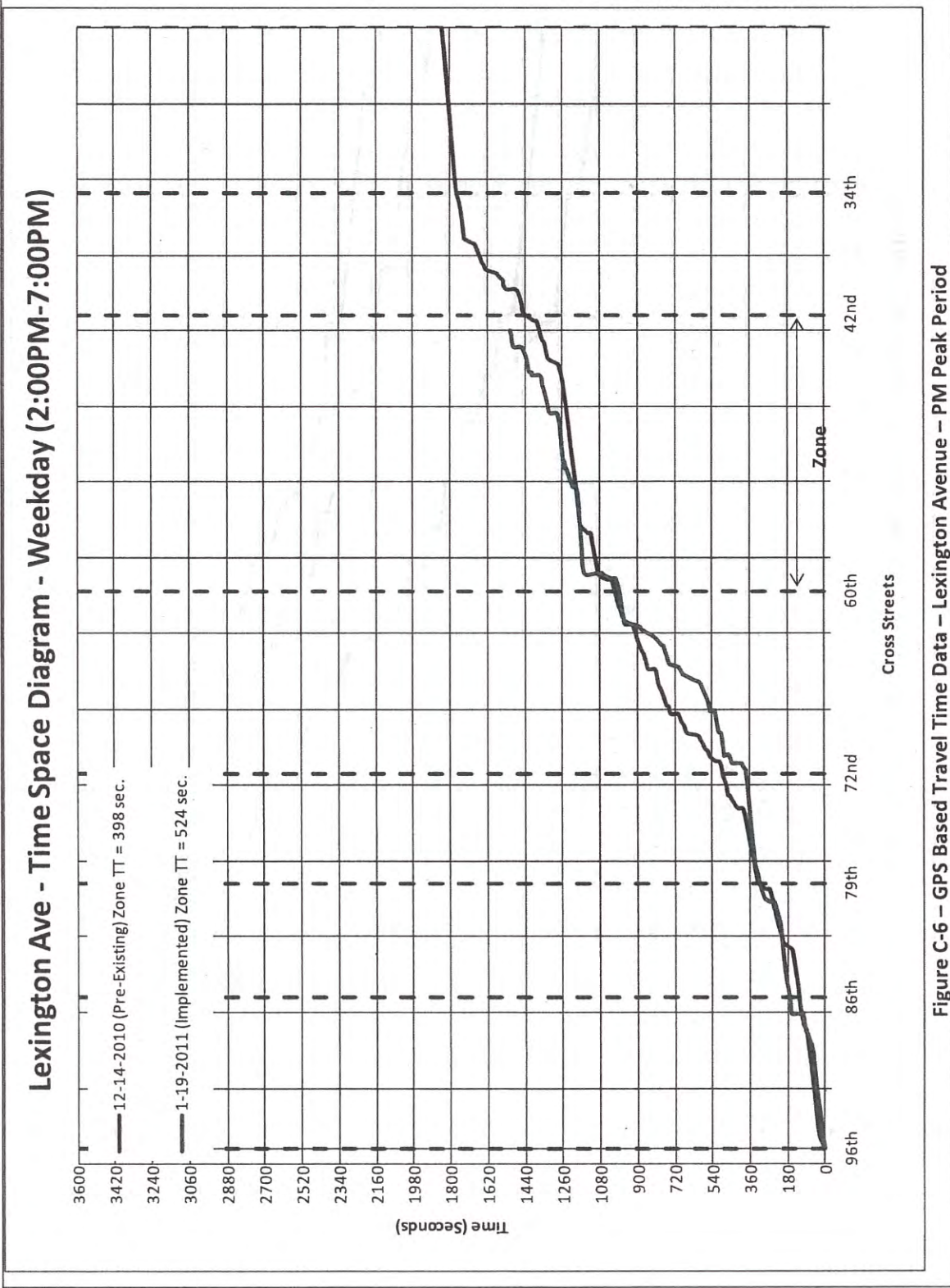


Figure C-6 – GPS Based Travel Time Data – Lexington Avenue – PM Peak Period

3rd Ave - Time Space Diagram - Weekday (6:00AM-10:00AM)

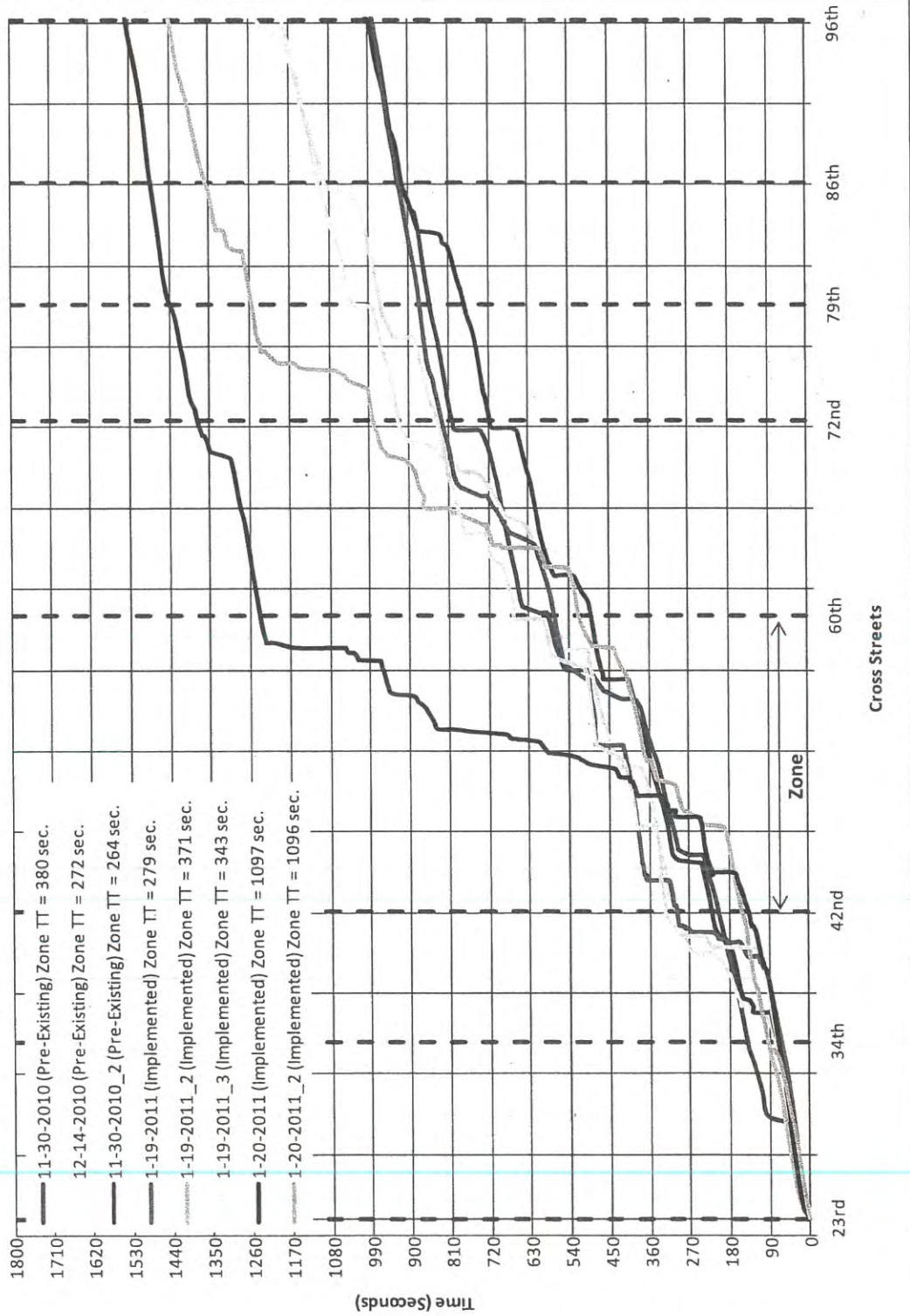


Figure C-7 – GPS Based Travel Time Data – 3rd Avenue – AM Peak Period

3rd Ave - Time Space Diagram - Weekday (10:00AM-2:00PM)

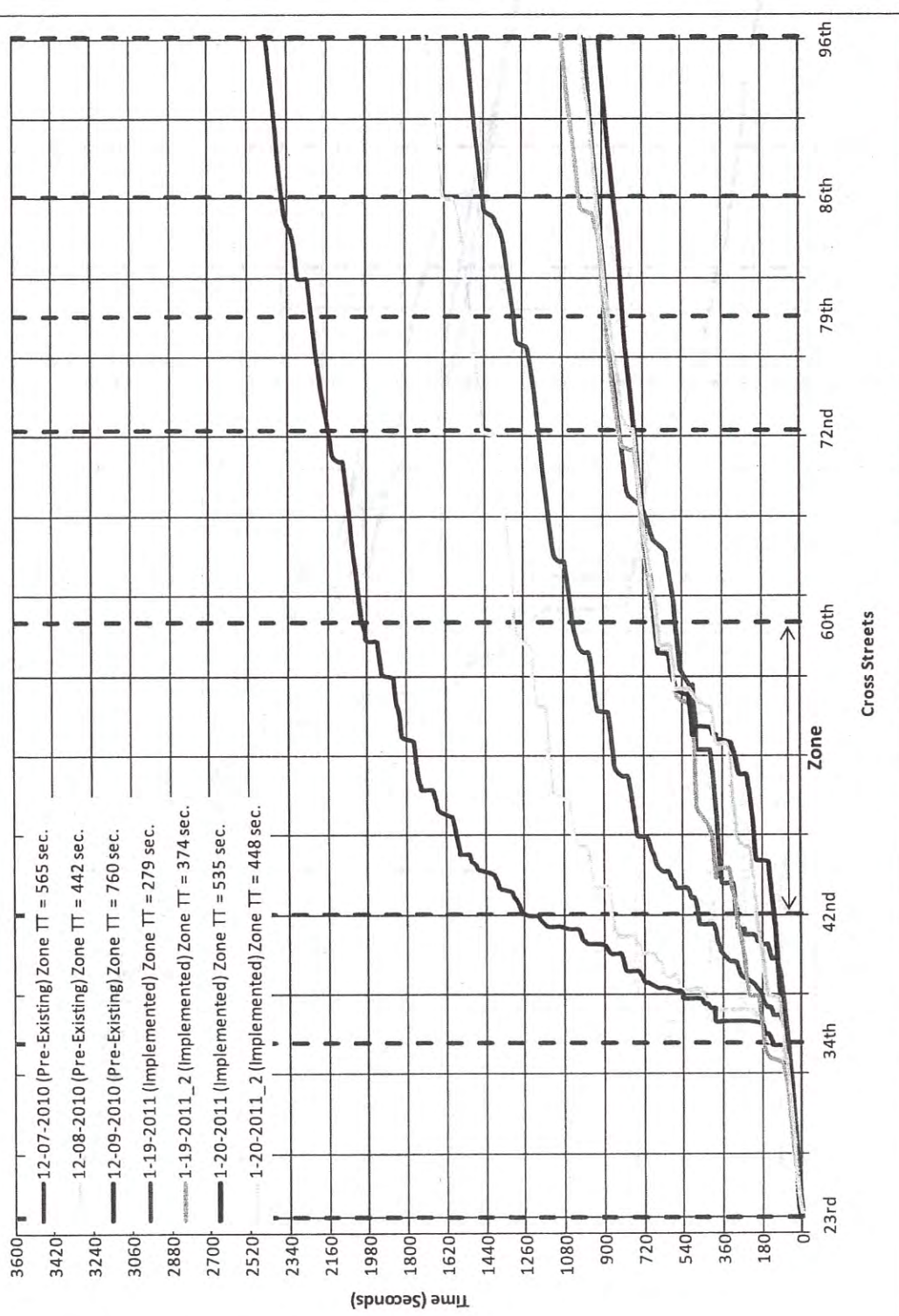


Figure C-8 – GPS Based Travel Time Data – 3rd Avenue – Midday Peak Period

3rd Ave - Time Space Diagram - Weekday (2:00PM-7:00PM)

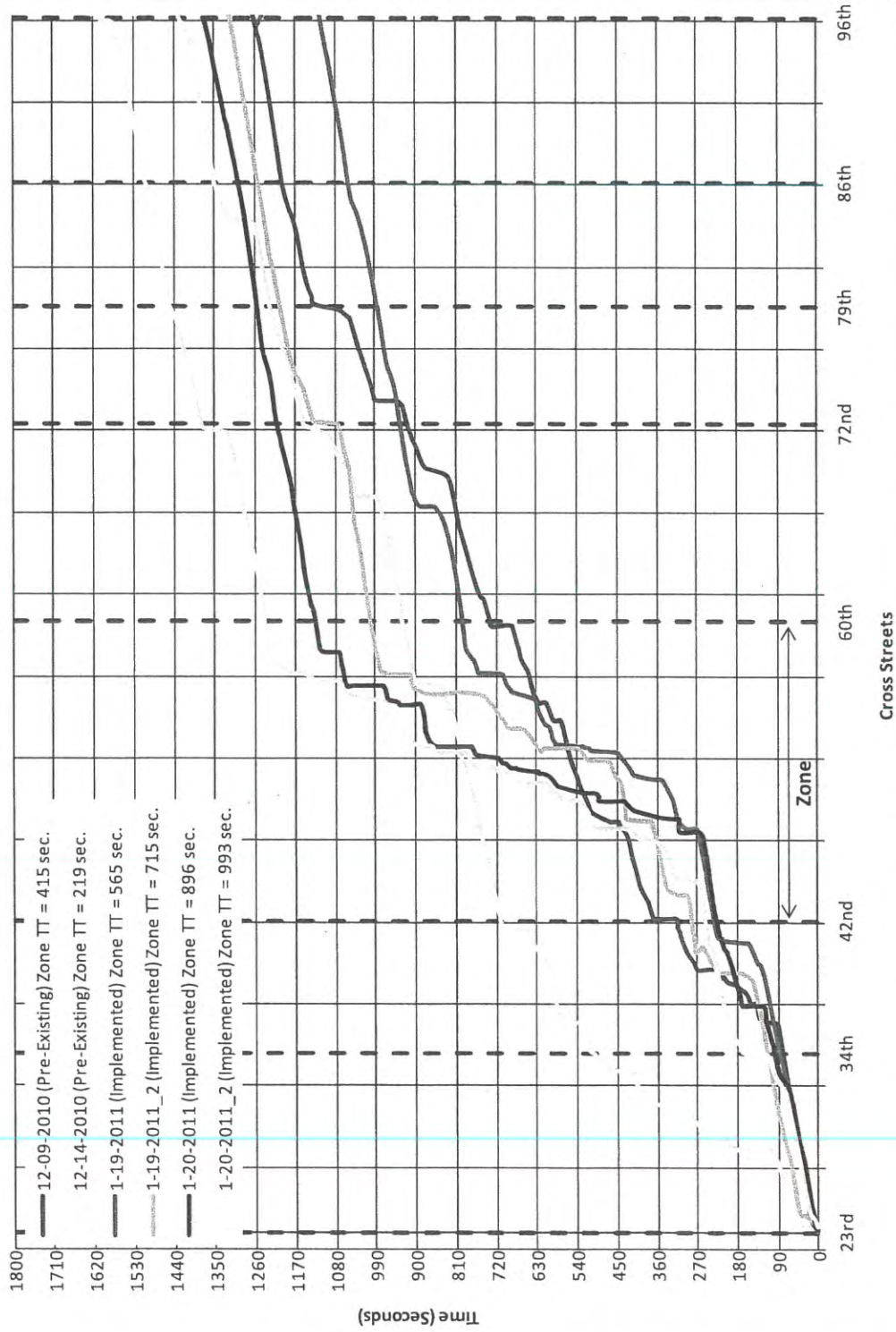


Figure C-9 – GPS Based Travel Time Data – 3rd Avenue – PM Peak Period