TECHNICAL MEMORANDUM #3

Midtown in Motion

Active Traffic Management Through Adaptive Signal Control in Midtown Manhattan – Preliminary Assessment of Traffic Impacts

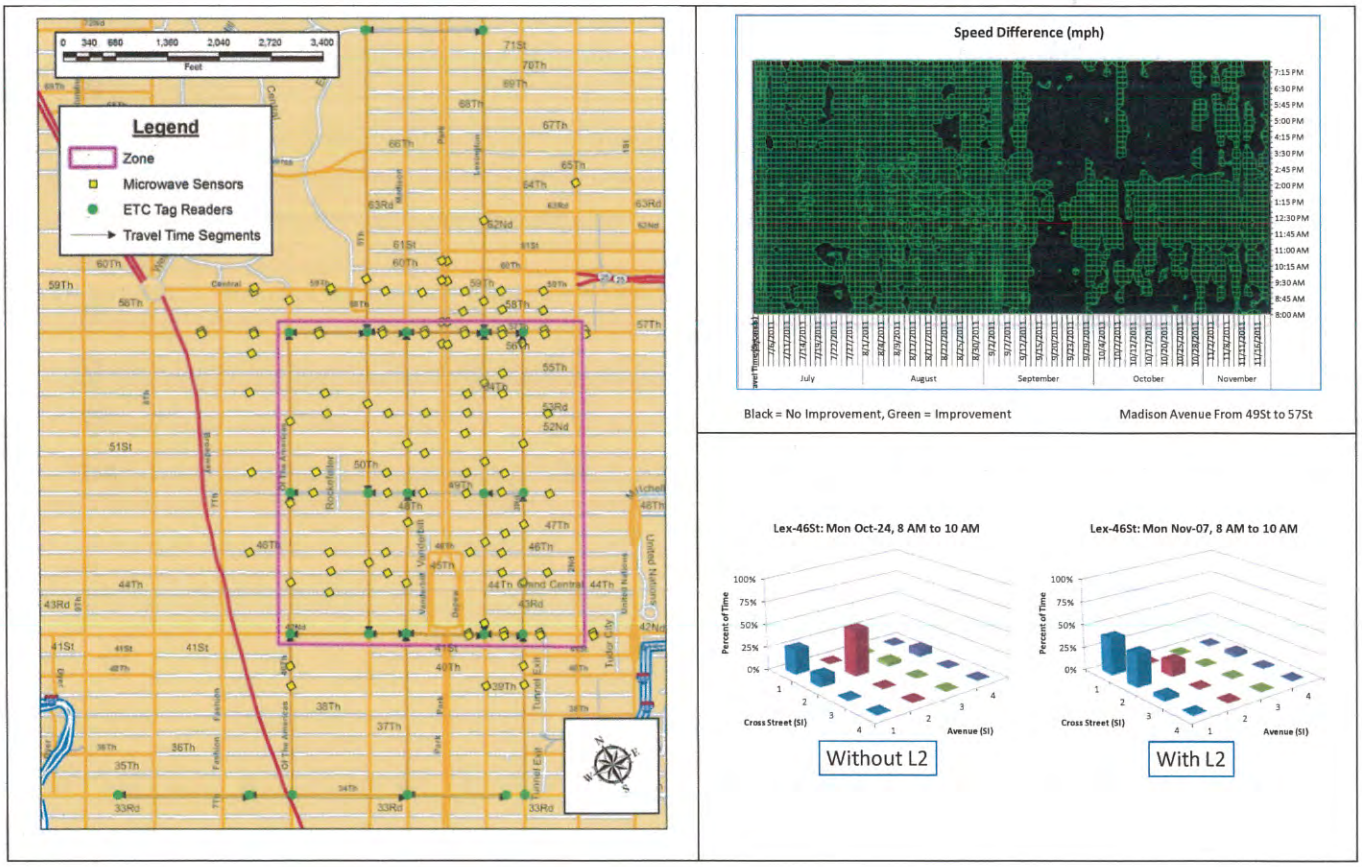

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TABLE OF CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

On July 18, 2011 Mayor Michael Bloomberg announced the start of Midtown in Motion (MIM). The Mayor was joined by the New York City Department of Transportation's (NYCDOT) Commissioner Janette Sadik-Khan and the Administrator of Federal Highway Administration (FHWA) Victor Mendez in this inaugural event. Since the announcement MIM has been operational with critical enhancements being introduced from July through November 2011. This technical memorandum describes data collected during operation of MIM, analysis and development of metrics to evaluate system performance, the results of the evaluation and plans for future enhancements and expansion.

The NYCDOT has Instituted the MIM project to promote multimodal mobility in the Midtown Core of Manhattan, a 110 square block area or "zone" from 2nd to 6th Avenues, 42nd to 57th Streets. Midtown Manhattan is the powerhouse of the City's economy and an unreliable traffic network would undermine Midtown's sustainability and vitality. Continued economic growth in this area is essential in order for the City to compete successfully with other world-class cities. The MIM Project utilizes "active traffic management (ATM)" and the full capabilities of the NYCDOT Intelligent Transportation System (ITS) infrastructure -- advanced solid-state traffic controllers, network of sensors (video, microwave, electronic toll collection readers), wireless communication system, and the New York City Traffic Control System software system that manages the project. This realizes the long standing interest in managing entries into the Midtown core. The signal-timing measures applied by MIM complement other efforts by the City to improve traffic operations and safety. These efforts include turn bays and split phase signals.

MIM provides for signal timing changes on two levels: Level 1 is strategic and implemented by avenue, to rebalance the traffic entering the zone by changing the signal plan on the avenue approach to the zone. Level 2 is more tactical, in that it is designed to address shorter–term fluctuations of "severity" of congestion on competing approaches (avenues and crosstown streets) at certain key intersections, and adjust the allocation of green time to alleviate a localized congestion problem that is developing.

Level 1 control has been operational since July 2011 with testing having begun in December 2010. The system runs between 8AM to 8PM Monday through Friday and based on the real time traffic conditions alerts the operators in the NYCDOT Traffic Management Center (TMC) to changes in the travel time and vehicle speed and recommends signal timing adjustments. The operator then reviews video cameras and other sources of information in the vicinity of the flagged avenue to identify the cause for the change in travel time. The TMC supervisor then decides the appropriate course of action to handle the event, which could be signal timing adjustments or requesting that NYPD address the situation (e.g., disabled vehicle, illegally parked vehicles). Level 1 controls consist of four recommended signal timing plans that are based on the number of times vehicles must stop for a given roadway segment.

To evaluate the system performance a comparison of travel time by roadway segments was performed. Given the inherent variability in the data resulting from the continual changes in traffic operations, a screening process was developed to exclude data from the evaluation that represents special events

(e.g., UN Week, Holidays) or trip patterns that include individual vehicle trips with stops (e.g., deliveries, curb side activities, taxi pick ups, drop offs). The screened data was compared to the average travel time from a week in June (when the signal system was operating in the pre-existing condition).

Table ES-1 presents a comparison of the average travel speeds within the zone and approaching the zone before and after MIM was implemented. This table suggests that average speed within the zone is better when compared to the "Before" condition. The median improvement in average speed was 10% inside the zone. Outside the zone average speeds generally decreased. However, the slower speeds were comparable to the improved speeds within the zone. We can anticipate the restoration of speeds on the avenues approaching the zone through future expansion of MIM when they are included in the zone. Furthermore, changes to the Level 1 baseline will be considered as a tool to address congestion problems within the zone more precisely. This may result in less restrictive signal plans outside the expanded zone.

Table ES -1 – Level 1 Speed Comparison Before and After MIM (mph)

		6th Avenue		5th Avenue		Madison Avenue		Lexington Avenue		3rd Avenue	
		Before	After	Before	After	Before	After	Before	After	Before	After
AM	Zone	7.4	8.5	6.9	7.1	6.9	7.8	5.3	5.3	5.6	6.5
	Outside	7.7	7.2	8.1	7.9	5.8	5.3	7.9	7.7	5.3	5.9
	Overall	7.5	8.0	7.5	7.5	6.5	6.7	6.3	6.2	5.5	6.3
MD	Zone	7.3	8.0	7.6	7.8	6.3	10.6	6.7	9.2	5.7	7.9
	Outside	9.2	7.7	5.3	5.6	5.6	7.7	6.7	6.1	5.7	6.3
	Overall	7.9	7.9	6.3	6.6	6.0	9.4	6.7	7.3	5.7	7.3
PM	Zone	6.6	7.0	5.2	6.0	7.6	8.2	8.6	8.8	5.1	5.3
	Outside	8.8	7.4	7.0	6.3	8.6	7.3	5.9	5.6	7.7	7.0
	Overall	7.2	7.1	5.9	6.1	7.9	7.8	7.0	6.8	5.8	5.8

Note: Roadway segments with improved speed are highlighted; Before – Pre-existing covers the period June 2 to June 8, 2011; After covers the period June 20 to Nov 4, 2011.

Level 2 control has been under testing from September through November 2011. Level 2 control is based on Severity Index (SI) which is related to an estimate of queue length (traffic congestion) by approach. Three separate metrics were developed to evaluate performance using SI: Relative distribution of SI, Average SI by approach, and Equity ratio. The relative distribution of SI is a representation of the congestion levels measured through travel time between approaches for a specific time period, the average SI and "equity ratios" are metrics that help quantify traffic conditions at the intersection for a specific time period.

Based on data available to date, it appears that Level 2 is helping to reduce queuing while achieving equity during the period, where feasible. The results are not uniform at all intersections. Level 2 implementation suggests that there are intervals wherein the "splits" (time allocated for the green

signal) can be adjusted to better service needs to either the avenue or crosstown street, which is part of the objectives of MIM.

As part of the efforts in the coming months, additional constraints such as considering SI from adjacent intersections will be incorporated into Level 2 Control. Adjustments to Level 1 control parameters (thresholds) for initiating signal timing adjustments need to be investigated to make the system more responsive to changing traffic conditions.

In addition to system refinements listed above, an analysis of the recommendations and actions taken by the TMC will be performed to look for patterns in actions by time of day. If such patterns exist, they can be incorporated into the standard time of day signal plans. This will be a continual process and will meet the overall objective of being responsive under the MIM project.

1 OVERVIEW

1.1 Introduction

On July 18, 2011 Mayor Michael Bloomberg announced the start of the Midtown in Motion (MIM). The Mayor was joined by New York City Department of Transportation's (NYCDOT) Commissioner Janette Sadik-Khan and the Administrator of Federal Highway Administration (FHWA) Victor Mendez in this inaugural event. Since the announcement, MIM has been operational with critical enhancements being introduced from July through November 2011. This technical memorandum describes the initial four months of MIM operation, analysis and development of metrics to evaluate system performance, the results of the evaluation and plans for future enhancements and expansion.

The memorandum is organized as follows: The following section is an overview of the system. Sections 2 and 3 discuss the data, metrics and results of the evaluation of Level 1 and Level 2 Control, respectively.

1.2 Level One and Level Two Control

The NYCDOT has Instituted the MIM project to enhance multimodal mobility in the Midtown Core of Manhattan, a 110 square block area or "zone" from 2nd to 6th Avenues, 42nd to 57th Streets. The MIM Project utilizes "active traffic management (ATM)" and the full capabilities of the NYCDOT Intelligent Transportation System (ITS) infrastructure -- advanced solid-state traffic controllers (103), video cameras (32), microwave sensors (100), electronic toll collection readers (23 intersections)), a wireless communication system (NYCWin) and the New York City Traffic Control System software system that manages the project. Figure 1-1 and Figure 1-2 present the zone and the ITS technologies deployed. The signal-timing measures applied by MIM complement other efforts by the City to improve traffic operations and safety. These efforts include turn bays and split phase signals.

Control Philosophy

MIM provides for signal timing plan changes on two levels: Level 1 is strategic and implemented by avenue, to rebalance the traffic being delivered to the zone by changing the signal plan on the avenue approach to the zone. Level 2 is more tactical, in that it is designed to address shorter–term fluctuations of "severity" of congestion on competing approaches (avenues and crosstown streets) at certain key intersections, and adjust the allocation of green time to alleviate a localized congestion problem that is developing. Figure 1-3 presents the system overview.

Midtown in Motion
The Zone, Travel Time Segments, & Level 2 Intersections

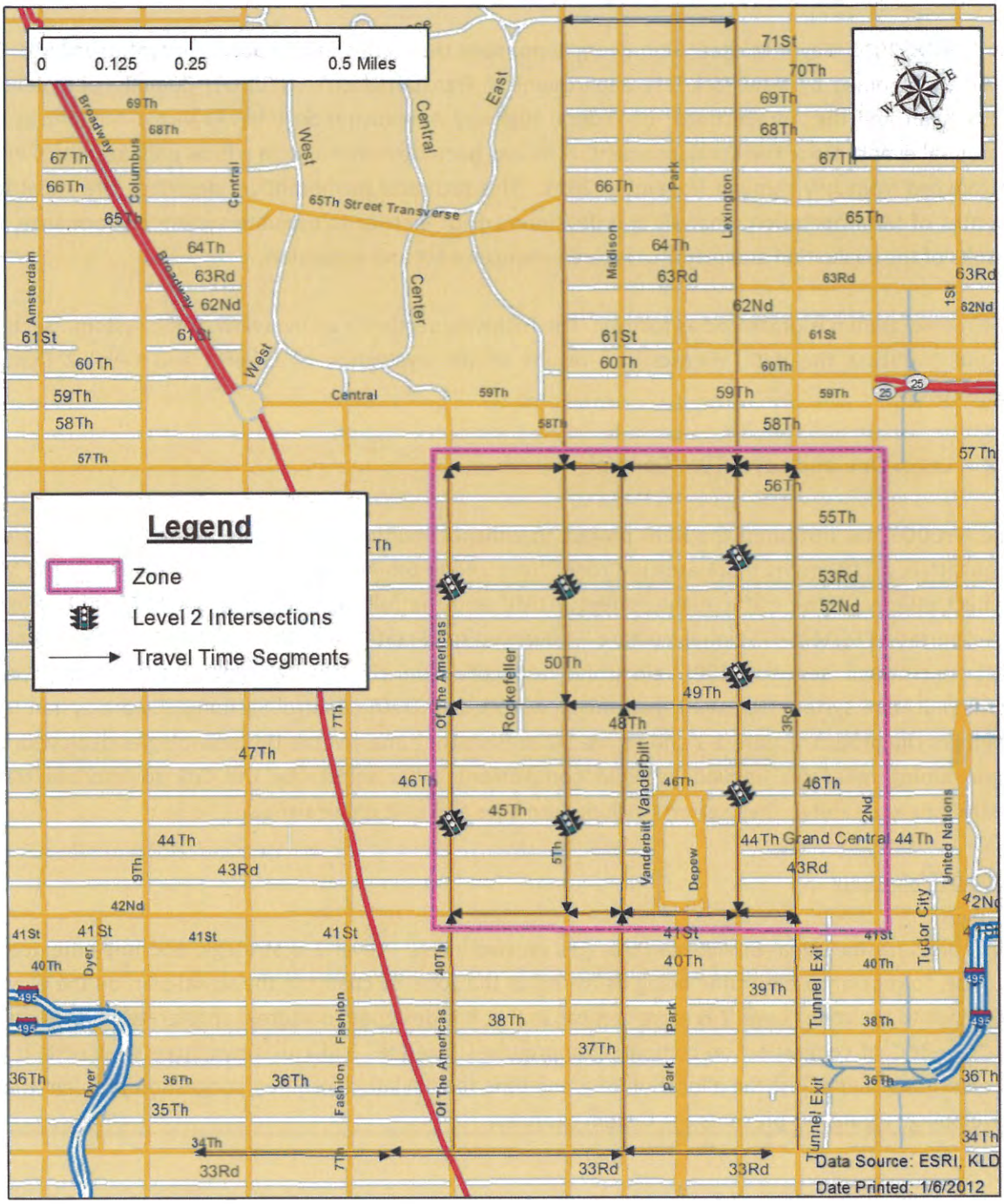


Figure 1-1 – Midtown in Motion Study Area, Level 2 Intersections, and Travel Time Segments

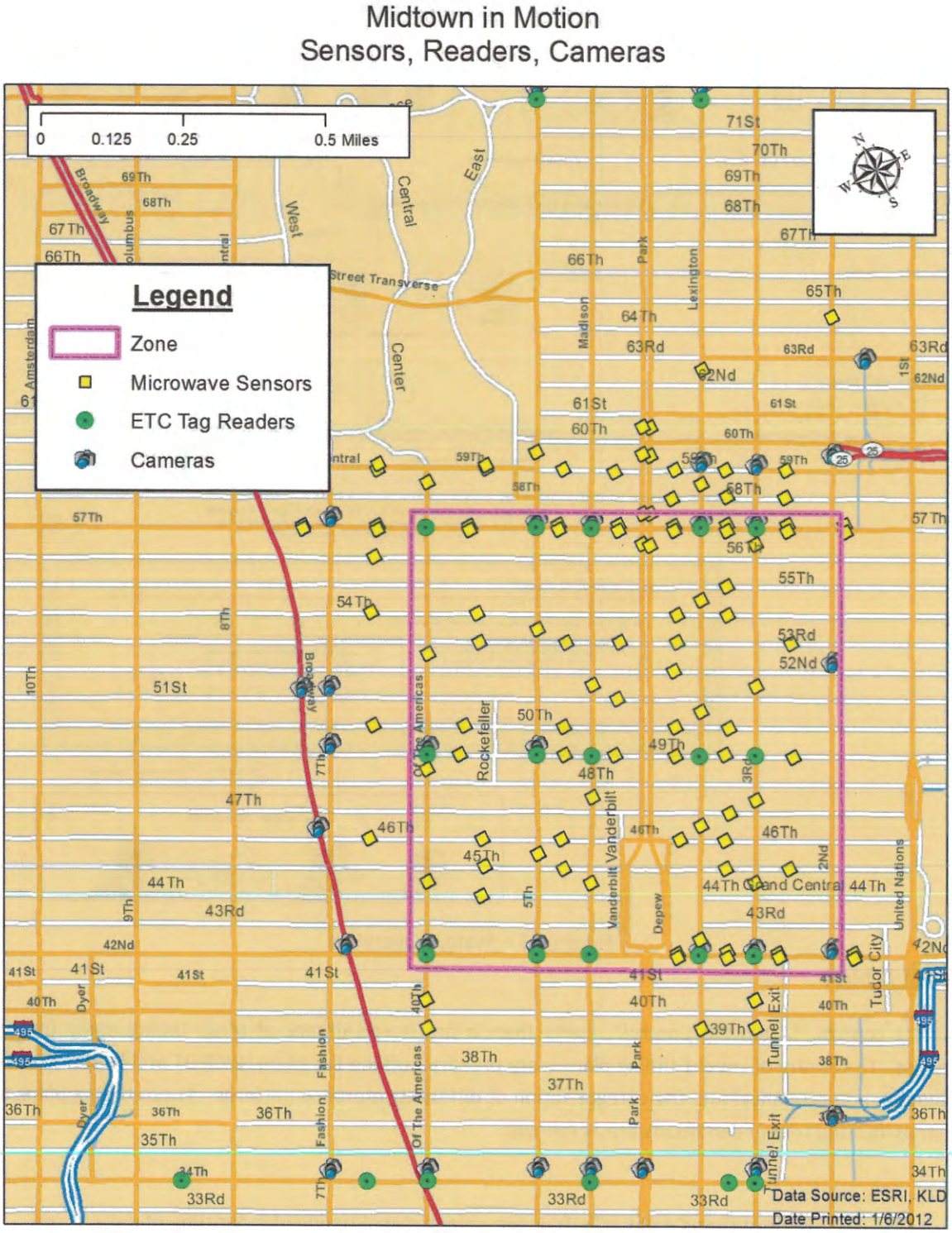


Figure 1-2 – Midtown in Motion Study Area, Microwave Sensors, Tag Readers, and Cameras

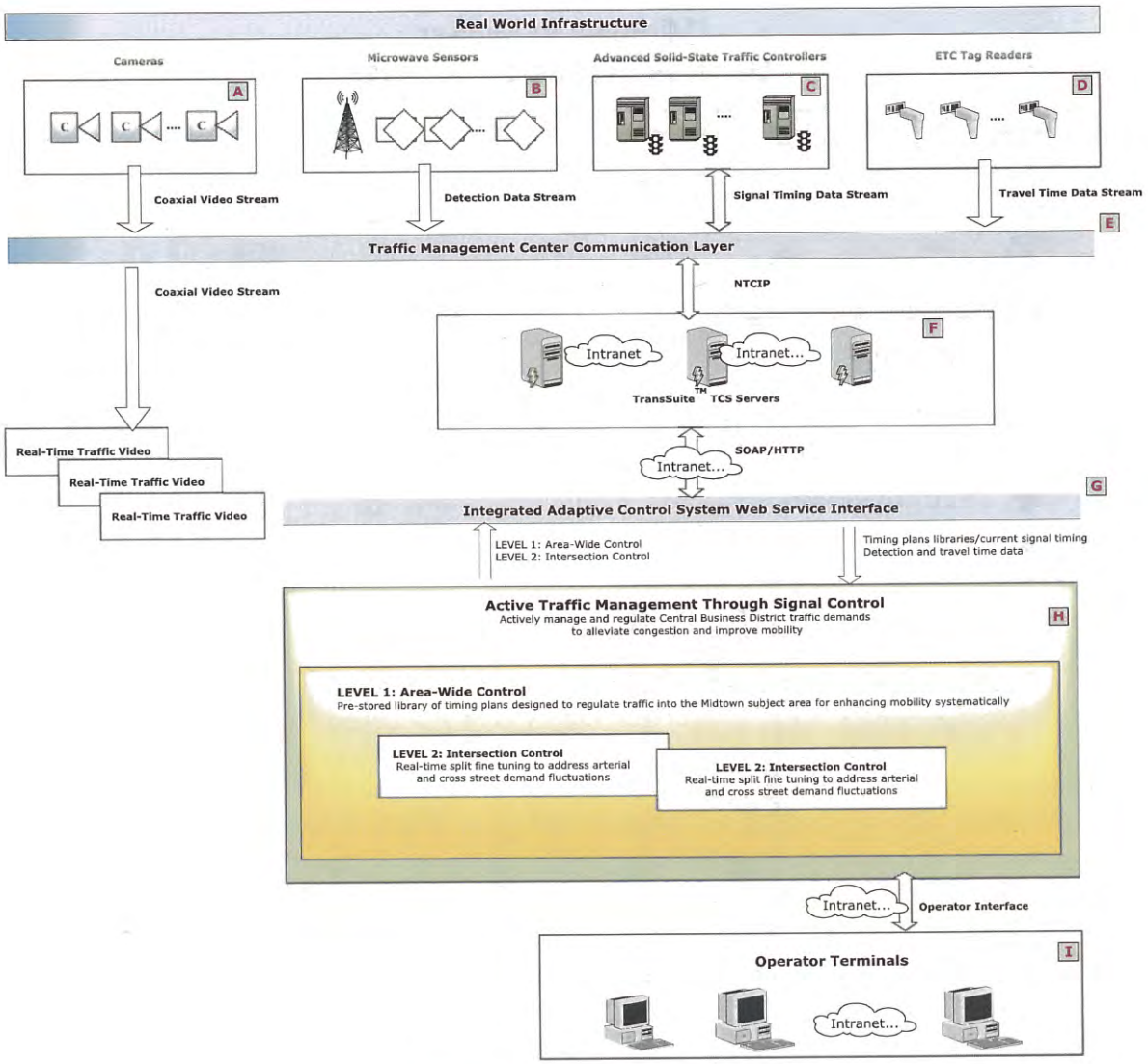


Figure 1-3 – System Overview

Level 1 Control

Level 1 control, "Areawide Control", starts from a pre-stored library of *three* timing plans for each avenue. The library of Level 1 timing plans were prepared offline based on NYCDOT archived traffic data (volume and occupancy) and the categorization of different reference patterns. These timing plans and their associated trigger conditions are as follows:

- Timing Plans
  - Central Time Of Day (CTOD) is the default signal timing plan for time of day control.
  - Network Balancing Plan (NBP) includes simultaneous offset on approaches to the zone with minimal green window tapering.
  - Advanced Control Plan 1 (AC1) includes simultaneous offset on approaches to the zone with increased green window tapering

- Advanced Control Plan 2 (AC2) includes simultaneous offset on approaches to the zone with higher green window tapering compared to AC1

➢ Trigger Condition
  - CTOD – one or no stops (travel time < 180 seconds) for both segments inside the box along the avenue.
  - NBP -- if two stop condition on any segment inside the box along the avenue (180 seconds < travel time < 270 seconds).
  - AC1 – if 3 stop condition on any segment inside the box along the avenue (270 seconds < travel time < 360 seconds)
  - AC2 – if 3+ stop condition on any segment inside the box along the avenue (travel time > 360 seconds)

Activation of a certain combination of timing plans (i.e., "strategy") is triggered by real-time travel time data; in this implementation, ETC transponder readers are employed to provide detailed individual-vehicle-trip based travel time data.

When in real-time operation, individual-vehicle-trip based travel time data are aggregated into a vector of indexes. Level 1 control uses these indexes to determine the best strategy (i.e., combination of timing plans). Relevant sequence of timing plans are extracted from the library and implemented in the field so that the target reference pattern can be established.

In order to build responsive traffic control, the decision-making interval of 6 minutes was selected, with the 50th percentile of the last 15-minute data as the key indicator. Using this approach, the control can avoid short term fluctuations/variations on traffic demand and be quick enough to respond to varying traffic conditions.

Level 2 Control

Complementing Level 1 control is Level 2 control. Level 2 control, "Intersection Control", is a granular level fine tuning tested initially at thirteen critical intersections (7 are currently in the field testing and 6 under testing using dummy controllers). Under Level 2, *only intersection splits* are adjusted in real-time. The control objective of Level 2 is to balance traffic congestion severity between competing approaches. A Severity Index (SI) is the derived Measure of Effectiveness (MOE) which is based on queue length thresholds expressed as a 1: Not significant, 2: Warning, 3: Significant, and 4: Very Significant.

As long as both competing approaches experience the same level of severity, there will be no adjustment in the "split" of signal green time between the crosstown streets and avenues. However, if there is any difference, a modest split adjustment of the traffic signals will be recommended. The amount of split adjustment will range from 2 to 3 seconds on each step, subject to overall limits. This control will be implemented with a three-cycle-interval. Because this level is more about queue/space control, three signal cycles are expected to be effective.

1.3 Operating Protocol

The system is currently installed in the TMC. Figure 1-4 shows a screen shot of the system in operation from the TMC. The system runs between 8AM to 8PM Monday through Friday and based on the real time traffic conditions alerts the operators in the NYCDOT Traffic Management Center (TMC) to changes in the travel time. The operator then reviews video cameras and other sources of information in the vicinity of the flagged avenue to identify the cause for the change in the travel time. The TMC supervisor then decides the course of action to handle the event, which could be signal timing adjustments or requesting that NYPD address the situation (e.g., disabled vehicle, double parked vehicles). There is a continuous log of these events, decisions in the TMC with the log in the system regarding the recommendations made over time.

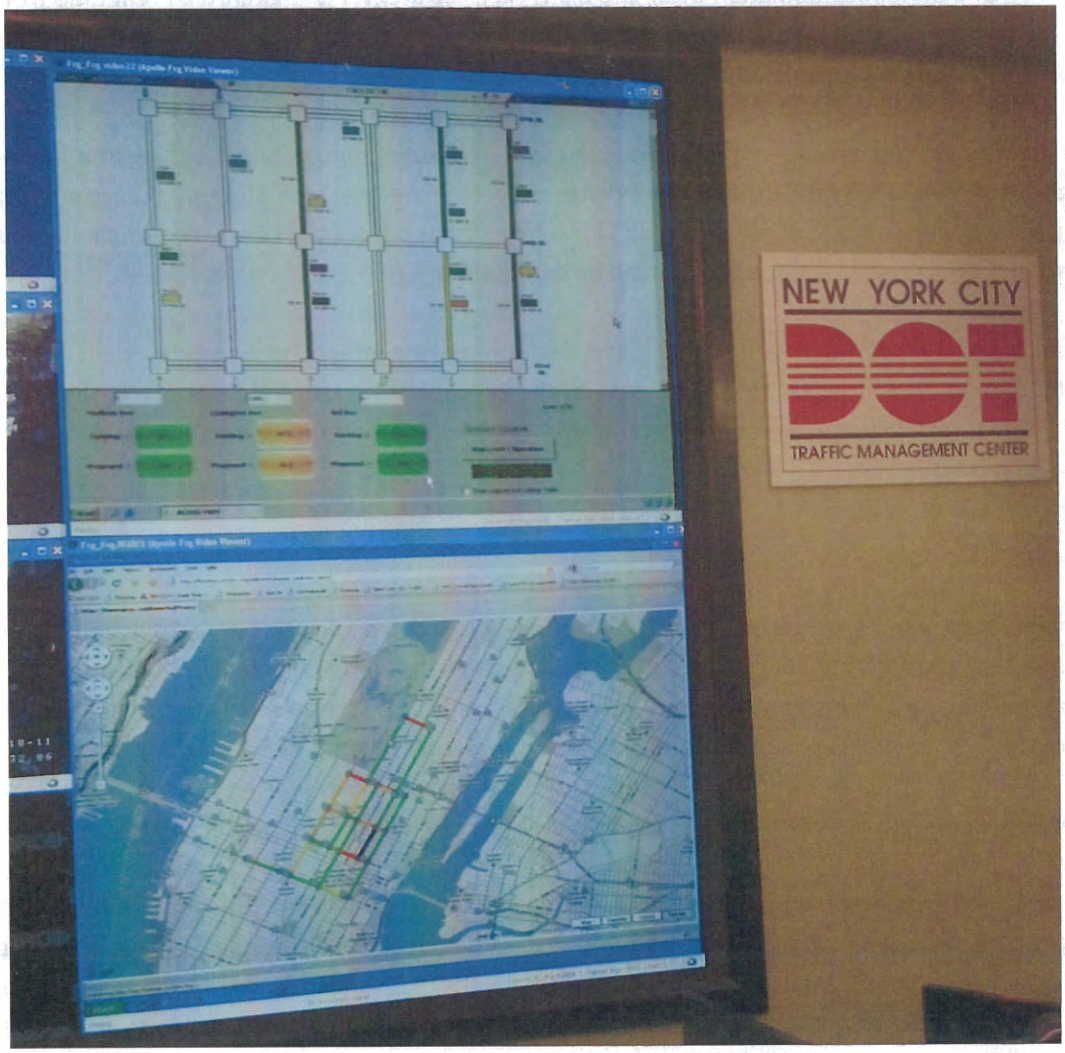


Figure 1-4 – Decision Support System in the TMC

2 LEVEL 1 CONTROL ANALYSIS

Level 1 control has been in effect since July 2011. The evaluation is being completed by comparing the travel time for the segments collected by the ETC tag readers for two different traffic control conditions, pre-existing vs. real time control. The former corresponds to the signal settings in the field before MIM, and the latter is the signal settings under real time control.

Between July and November of 2011, interim results have been presented and discussed with NYCDOT. This section summarizes the results of the comparison of data from July to November (Real Time) to the Pre-Existing conditions.

The analysis of the data has been focused on three peak periods for each weekday (Mon-Fri). They are defined as AM (8AM to 10AM), MD (11AM to 1PM), and PM (4PM to 6PM).

2.1 Data Sampling

The most important thing in data sampling for the comparison of different traffic control policies is to select data which are affected primarily by traffic control policies. The external factors that influence travel time can be categorized into two parts. The first part is data affected by holidays, special events and incidents. The second part is a function of trip type. For example, trips on a particular segment that have to stop for activities (e.g., taxi drop offs, pick ups, deliveries and curb side activities) have longer travel times compared to the those that have no activity related stops, and hence need to be considered as outliers. The following section discusses these two categories of outliers.

Outliers based on holidays, special events and incidents

Based on analysis of the data collected to date in 2011, one observation stands out – there is noticeable variability in the data. For example, Figure 2-1 shows a plot of 5 days of data from one travel time segment to illustrate the general day-to-day variability. Hence the median has been used a metric for representative values. Looking at the variations in the median travel time across months as shown in Figure 2-2, it becomes clear that certain days are abnormal in patterns.

When the underlying traffic pattern changes radically due to large systemic re-routings (as distinct from one or more incidents, the MIM response has to include comparable control pattern changes. The most recent UN General Assembly event is such an example. But it occurred during the test of the initial features of the system, and it was decided by NYCDOT to not implement MIM in that period. This is logical, given that special signalization inside the zone is needed for the changed flow patterns, and it was too early in the test cycle to do this also. Hence the UN week was not included in the before/after analysis.

Given that we are looking to compare the performance of different traffic control policies, we need to carefully exclude days that appear to be impacted by external factors such as holidays and days with major incidents. Hence a generic sampling methodology was developed and applied for the analysis.

The following is the step-by-step procedure to sample the data:

1. Exclude days such as holidays, UN convention days, or other prescheduled event days.

   Those are the days to be excluded: July 4 – Independence Day, September 5 – Labor Day, October 10 – Columbus Day, November 11–Veterans Day and UN Week – 9/19/2011 to 9/23/2011.

   TCS Server Updates and Expansion of Wireless Control System – During this event, the real time control was not fully implemented due to the loss of communication. Since November 4, 2011, all days were excluded.
2. Remove incomplete data due to communication failures.

   If the data for a given peak period is either partially or fully missing due to communication failures, the data will be removed.
3. Remove outliers for each peak period, for a given day, and for a given section. Outliers are identified by the following steps :
   a. Calculate the median travel time for each segment in 15 minute intervals from 8AM to 8PM (a total of Forty-Eight 15-min intervals) for all days.
   b. Calculate the average of all these medians for each and every 15 minute interval, by segment
   c. Calculate the standard deviation of the medians using the average value calculated in (b).
   d. Flag each interval if the median is more than one standard deviation away from the average.
   e. If more than 50 percent of intervals are flagged for a given peak period (AM, MD, or PM) of a given day for a given segment, the dataset (all 8 intervals) for during this peak period is flagged.
   f. Any 15-min interval or peak period (AM, MD, PM) flagged as an outlier is excluded from the analysis.

Table 2-1 presents an illustration of the steps outline above

Table 2-1 – Outlier Identification Sample (6 Ave – W 49 St to W 57 St)

Time	Observed	Mean	Stdev	Outlier
4:00 PM	207	208	82	
4:15 PM	208	217	85	
4:30 PM	323	239	98	
4:45 PM	395	250	115	Yes
5:00 PM	394	244	113	Yes
5:15 PM	309	228	116	
5:30 PM	311	234	115	
5:45 PM	308	240	121	

Note: Observed – This is the median value in the 15-min interval on 9/14/11. Mean, Standard Deviation – These are the interval specific values based on median travel times in July through November

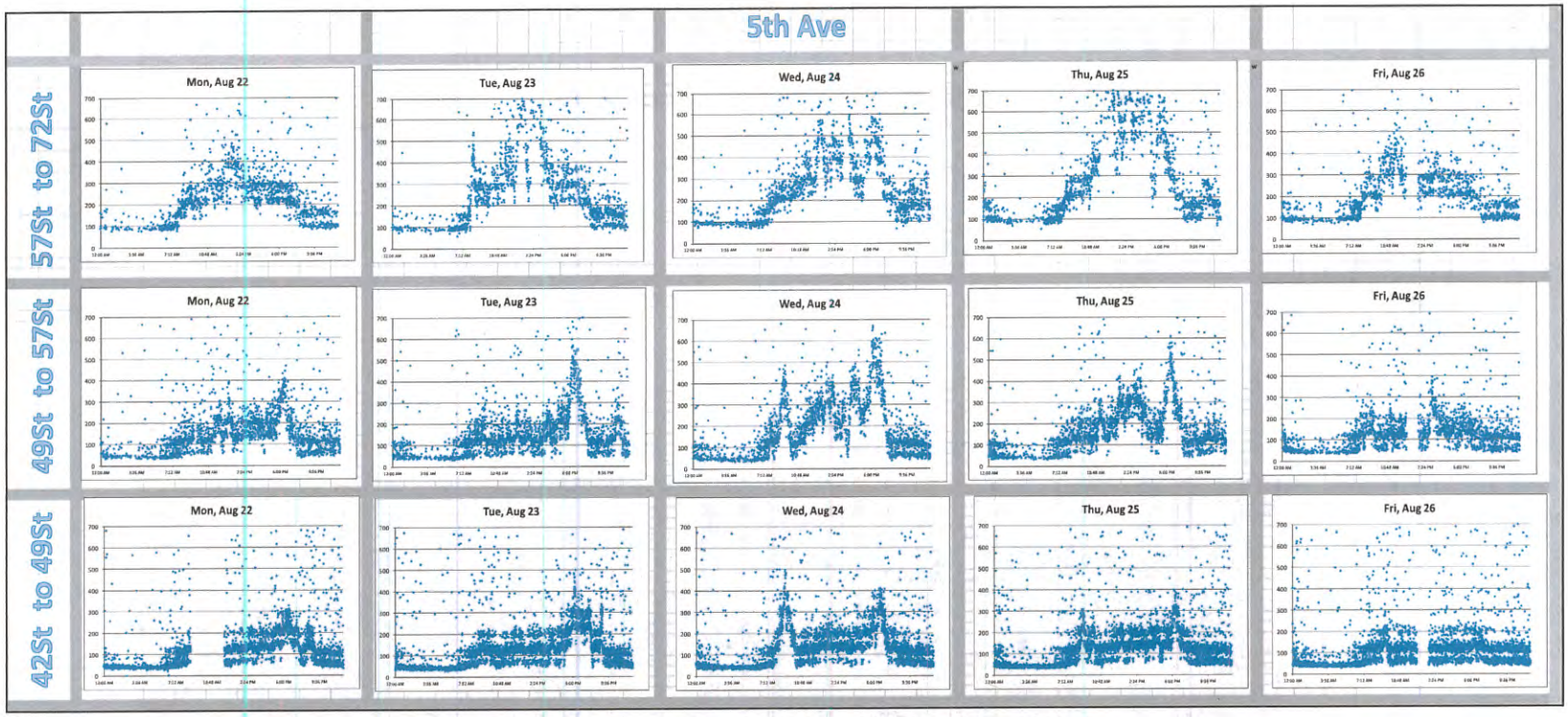


Figure 2-1 – Travel Time (Individual Vehicles) for 1 Week

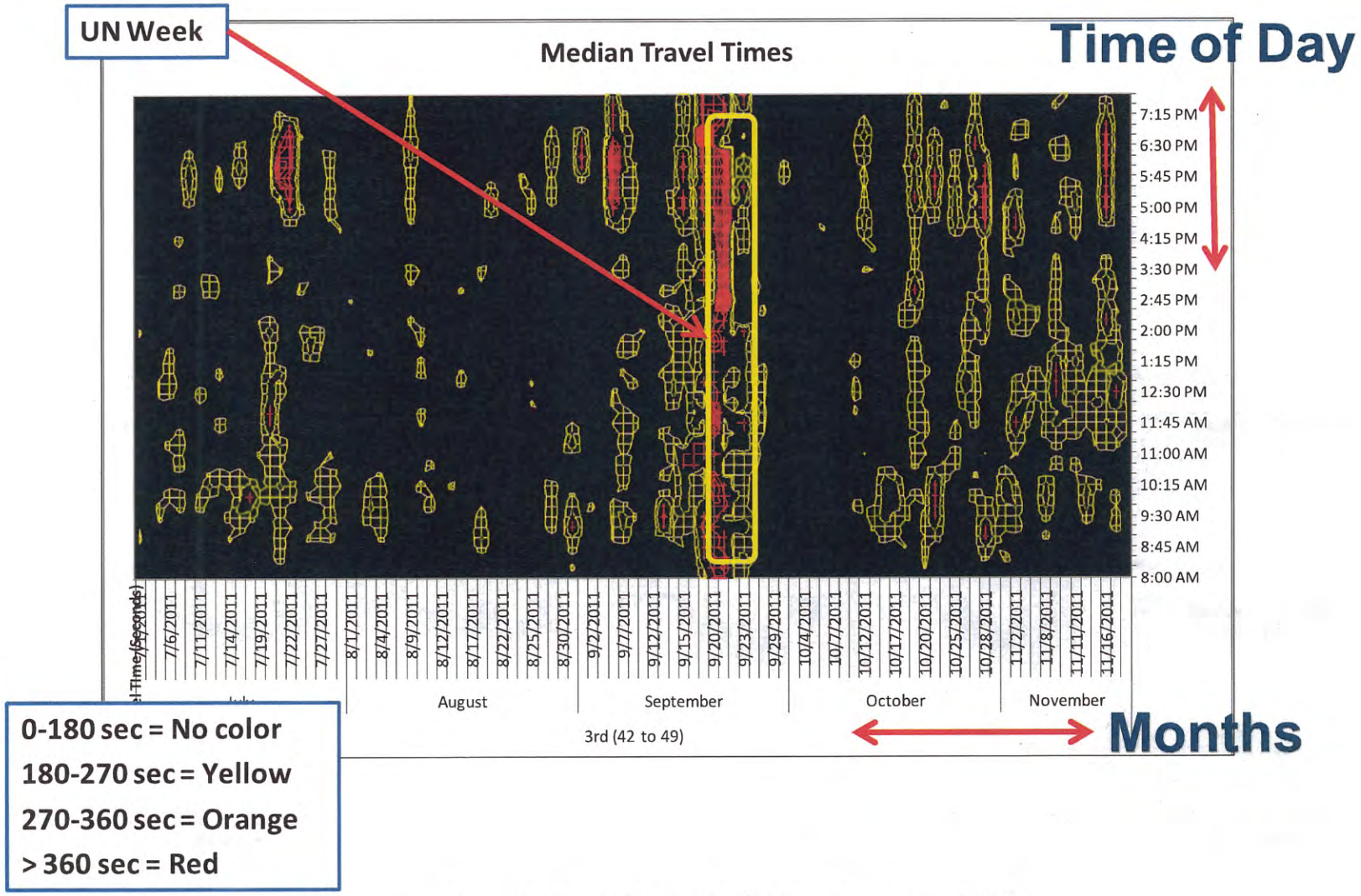


Figure 2-2 – Median Travel Time for 3rd Avenue (E 42 St to E 49 St)

Using the process outlined above, Table 2-2 shows the sampling rate – a measure of the number of observations that were not excluded as outliers – for each segment on the avenues. It is interesting to note that, on average, 15% of the data has been flagged as outliers for the July to November 2011 data. This screening method is designed to identify the central tendency/underlying pattern of the travel time data. The smaller sample size in the before period (June 2011) limits the effectiveness of the screening technique. So the data for all days in June 2011 was reviewed using the scatter plot matrix to ensure that abnormal patterns were not included. But as a second check, the screening method was applied despite the sample size; comparable but milder improvements were observed.

Table 2-2 – Sampling Rates by Avenues

		6Ave		5Ave		Madison		Lexington		3Ave	
		Before	After	Before	After	Before	After	Before	After	Before	After
AM	72St to 57St			80%	86%			100%	89%		
	57St to 49St	100%	90%	100%	80%	100%	82%	100%	84%	100%	84%
	49St to 42St	80%	81%	100%	83%	100%	89%	100%	91%	100%	93%
	42St to 34St	80%	66%			100%	92%			100%	81%
MD	72St to 57St			100%	81%			80%	81%		
	57St to 49St	100%	88%	100%	81%	100%	87%	100%	90%	100%	85%
	49St to 42St	80%	78%	100%	88%	100%	82%	100%	92%	100%	91%
	42St to 34St	80%	74%			100%	92%			80%	83%
PM	72St to 57St			100%	84%			100%	77%		
	57St to 49St	100%	80%	100%	82%	100%	78%	100%	94%	100%	80%
	49St to 42St	80%	83%	100%	86%	100%	92%	100%	94%	100%	90%
	42St to 34St	80%	80%			100%	93%			80%	78%

Note: The data for the Before period is between 6/2 and 6/8 and for the After period is between 6/20 and 11/4.

Outliers based on trip type (with and without activity related stops)

With the final list of selected days, the raw data, i.e. individual travel time measurements, were retrieved. For the comparative analysis, observations greater than 720 seconds for 7 or 8 block segments, and observations greater than 900 seconds for the 15 block segments were excluded. These thresholds are set by carefully examining multiple days of the raw data. Appendix A presents the dates and times used in the analysis, by segment. Table 2-3 and 2-4 show the results of the comparative analysis.

Table 2-3 – Comparison of Average Travel Time (seconds/vehicle)

AM Peak Period (8:00AM-10:00AM)

	6th Ave		5th Ave		Madison Ave		Lexington Ave		3rd Ave	
	Before	After	Before	After	Before	After	Before	After	Before	After
Zone	358	314	385	375	385	339	505	506	476	405
Outside	184	198	328	336	244	270	337	346	267	239

MD Peak Period (11:00AM-1:00PM)

	6th Ave		5th Ave		Madison Ave		Lexington Ave		3rd Ave	
	Before	After	Before	After	Before	After	Before	After	Before	After
Zone	362	332	350	339	423	250	398	288	465	336
Outside	154	185	498	473	253	183	394	437	249	224

PM Peak Period (4:00PM-6:00PM)

	6th Ave		5th Ave		Madison Ave		Lexington Ave		3rd Ave	
	Before	After	Before	After	Before	After	Before	After	Before	After
Zone	404	381	516	444	350	326	311	303	519	499
Outside	161	191	379	424	165	194	451	473	185	204

Note: Roadway segments with improvement are highlighted in green

Table 2-4 – Comparison of Average Speed (mph)

AM Peak Period (8:00AM-10:00AM)

	6th Ave		5th Ave		Madison Ave		Lexington Ave		3rd Ave	
	Before	After	Before	After	Before	After	Before	After	Before	After
Zone	7.4	8.5	6.9	7.1	6.9	7.8	5.3	5.3	5.6	6.6
Outside	7.7	7.2	8.1	7.9	5.8	5.3	7.9	7.7	5.3	5.9

MD Peak Period (11:00AM-1:00PM)

	6th Ave		5th Ave		Madison Ave		Lexington Ave		3rd Ave	
	Before	After	Before	After	Before	After	Before	After	Before	After
Zone	7.3	8.0	7.6	7.8	6.3	10.6	6.7	9.2	5.7	7.9
Outside	9.2	7.7	5.3	5.6	5.6	7.7	6.8	6.1	5.7	6.3

PM Peak Period (4:00PM-6:00PM)

	6th Ave		5th Ave		Madison Ave		Lexington Ave		3rd Ave	
	Before	After	Before	After	Before	After	Before	After	Before	After
Zone	6.6	7.0	5.2	6.0	7.6	8.2	8.6	8.8	5.1	5.3
Outside	8.8	7.4	7.0	6.3	8.6	7.3	5.9	5.6	7.7	7.0

Note: Roadway segments with improvement are highlighted in green

As seen in both tables the average speed/travel time within the zone is better compared to the "Before" condition. The median improvement in average speed was 10% inside the zone. Outside the zone average speeds generally decreased. However, the slower speeds were comparable to the improved speeds within the zone. We can anticipate the restoration of speeds on the avenues approaching the zone through future expansion of MIM when they are included in the zone. Furthermore, changes to the Level 1 baseline will be considered as a tool to address congestion problems within the zone more precisely. This may result in less restrictive signal plans outside the expanded zone.

Travel time reliability was analyzed using the standard deviation of the travel time and the comparison is shown in Table 2-5. Given the differences in the sample sizes (Before: June 2-8, After: June 20-Nov 3) any travel time reliability improvements could not be detected, if they existed (the before data set dominates in the combined standard deviation used in t-tests, for instance). As the MIM expansion goes forward, early placement of the ETC readers will allow better "before" sampling and also allow travel time reliability changes to be identified.

Table 2-5 – Comparison of Travel Time Reliability Using Standard Deviation of Travel Time

		6th Avenue		5th Avenue		Madison Avenue		Lexington Avenue		3rd Avenue	
		Before	After	Before	After	Before	After	Before	After	Before	After
AM	72St to 57St			166	149			149	132		
	57St to 49St	104	109	86	101	104	92	117	115	162	139
	49St to 42St	88	79	84	85	114	92	85	90	124	106
	42St to 34St	84	88			105	114			157	104
MD	72St to 57St			203	164			108	126		
	57St to 49St	104	104	112	104	81	78	72	83	88	89
	49St to 42St	81	80	91	77	80	79	92	77	138	95
	42St to 34St	79	92			98	80			138	99
PM	72St to 57St			133	142			162	153		
	57St to 49St	122	119	102	116	107	112	97	85	148	139
	49St to 42St	75	87	110	85	72	83	82	85	126	106
	42St to 34St	82	91			81	81			108	93

2.2 System Responsiveness

The system has been in operation since July 2011. Approximately, there are 4 signal plan changes under MIM per day on each Avenue. See Table 2-6 and Table 2-7 for detail. These changes were done manually because VTCS was still in place. As the migration from VTCS to NYC_TCS with the ASTC controllers outside the zone takes place, we expect easier and probably even more use of the recommendations.

Table 2-6 – Average Percent of Time for Implementation of Signal Timing Plans

Plan	6th Avenue	5th Avenue	Madison Avenue	Lexington Avenue	3rd Avenue
NBP	79%	68%	72%	78%	63%
AC1	15%	21%	14%	13%	22%
AC2	6%	11%	14%	9%	15%
Note: Based on TMC operator log files from 8/5/2011 through 11/3/2011, 8AM to 8PM					

Table 2-7 – Average Signal Timing Plan Changes per Day by Avenue

	6th Avenue	5th Avenue	Madison Avenue	Lexington Avenue	3rd Avenue
No. of Plan Changes per day	2	4	4	4	5
Note: Based on TMC operator log files from 8/5/2011 through 11/3/2011, 8AM to 8PM					

The system has shown improvements in travel time (Table 2-4) and the responsiveness has been quantified in Tables 2-6 and 2-7. These actions suggest a responsive system that resulted in improved mobility. One of the challenges that has to be addressed, probably by simulation, is the "what if" condition of what would have happened (quantitatively assessed) if the recommended control were not exercised.

3 LEVEL 2 CONTROL

3.1 Control Algorithm

The Level 2 control algorithm has been developed and refined during the evaluation period from July to November 2011. The algorithm was initially focused to reduce unbalanced demand between the avenue and the crosstown street caused by a short term allocation of green time (split) at an individual intersection. However, the split adjustment at a local level can bring a systemic impact to neighboring intersections. Considering this effect, the algorithm has been refined to use the travel time measure as an additional constraint to determine a split. As a result, systemic impacts were not noticeable along the Avenues. The travel time data did not show a change based on level 2 operations. The revised Level 2 control algorithm is presented in Table 3-1.

Table 3-1 – Level 2 Control Algorithm

Travel Time <= 1 stop*		Crosstown Street Severity Index			
		1	2	3	4
Avenue Severity Index	1	Do Nothing	Add 2 secs to Cross St	Add 3 secs to Crosstown Street	Add 3 secs to Crosstown Street
	2	Add 2 secs to Avenue	Do Nothing	Add 2 secs to Crosstown Street	Add 2 secs to Crosstown Street
	3	Add 3 secs to Avenue	Add 2 secs to Avenue	Reset to NBP	Reset to NBP
	4	Add 3 secs to Avenue	Add 2 secs to Avenue	Reset to NBP	Reset to NBP

Travel Time > 1 stop		Cross Street Severity Index			
		1	2	3	4
Avenue Severity Index	1	Reset to NBP	Reset to NBP	Reset to NBP	Reset to NBP
	2	Add 2 secs to Avenue	Reset to NBP	Reset to NBP	Reset to NBP
	3	Add 3 secs to Avenue	Add 2 secs to Avenue	Reset to NBP	Reset to NBP
	4	Add 3 secs to Avenue	Add 2 secs to Avenue	Reset to NBP	Reset to NBP

* If median travel time of the given segment over the last 15 min is less than 180 seconds

3.2 Implementation

The Level 2 implementation schedule is shown in Table 3-2. Table 3-3 shows the list of intersections with their control constraints such as minimum phase durations. "Dummy" controllers located in the TMC were used for testing purposes before implementation. Theses controllers have mirror images of the control plan database from the field controllers and can simulate responses to the real time algorithm without actually changing the traffic lights in the field.

Table 3-2 –Level 2 Implementation Schedule

Intersection	With Dummy Controllers	Real Controllers
Lexington @ E 54 St	8/2/2011 – 8/16/2011	8/17/2011 to Present
Lexington @ E 50 St	9/15/2011 – 11/3/2011	11/4/2011 to Present
Lexington @ E 46 St	9/15/2011 – 11/3/2011	11/4/2011 to Present
5Ave @ 53St	9/15/2011 – 11/3/2011	11/4/2011 to Present
5Ave @ 45St	9/15/2011 – 11/3/2011	11/4/2011 to Present
6Ave @ 53St	9/15/2011 – 11/3/2011	11/4/2011 to Present
6Ave @ 45St	9/15/2011 – 11/3/2011	11/4/2011 to Present

Table 3-3 – Minimum Phase Durations for the Intersection under Level 2

Intersection	Minimum Split for Phase 1	Minimum Split for Phase 2
Lexington Ave @ E 54 St	42	34
Lexington Ave @ E 50 St	41	33
Lexington Ave @ E 46 St	43	29
5 Ave @ 53St	41	33
5 Ave @ 45St	41	33
6 Ave @ W 53St	41	33
6 Ave @ W 45St	41	33

Note: Minimum Spilt is defined as "minimum duration of a particular phase to meet pedestrian crossing requirements." Phase 1 corresponds to the Avenue, Phase 2 corresponds to the cross streets.

The changes to the split under Level 2 are performed automatically without operator intervention. The system calculates the new split every 3 cycles (270 seconds).

3.3 Measure of Effectiveness

The **Severity Index** (SI) is an index that ranges from 1 to 4 representing the extent of congestion. A higher index corresponds to longer queues and relates to a more severe congestion level. This index is calculated for each approach and is used to recommend the split change. Since the control interval is every 3 cycles which is 270 seconds, there can be up to 13 estimates per hour.

To evaluate the performance at an intersection level, the SI for both competing approaches should be looked at together. Three ways are presented herein to build up some insights.

1. SI distribution table
2. Average SI
3. Equity ratio

SI distribution table

This table is a representation of the relative distribution of the SI values for a given time period. See Figure 3-1. The 16 cells in the table are the combination of the arterial approach SI and its corresponding crosstown street approach SI. For a given period (AM, MD or PM), the number of occurrences of each pair is calculated and converted into percentages to represent the relative distribution.

Each cell in percentage is the percent of the number of occurrence of that pair over the number of occurrence of all pairs.

$$\%\ \text{Occurrence of } SI_{IJ}\ (SI_{\text{avenue}} = I, SI_{\text{crosstown street}} = J) = \frac{\text{Number of Occurrence of } SI_{IJ}}{\text{Number of Occurrence of all pairs}} * 100$$

This table shows how the competing approaches on an intersection perform over time. The higher percentages heading toward the upper left hand corner which is SI = 1 for both approaches will imply the better performance. This table can be presented with either frequency or percent frequency. Figure 3-2 is an illustrative chart using field data.

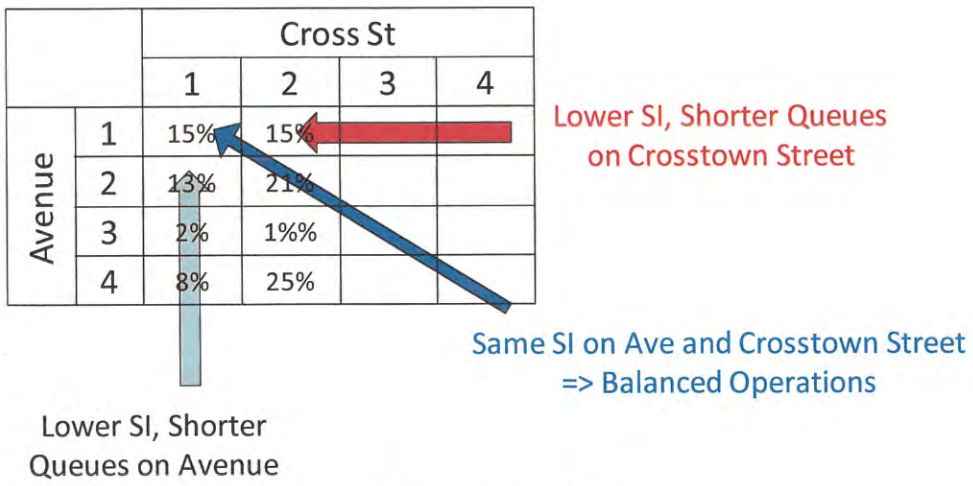


Figure 3-1 – SI Distribution

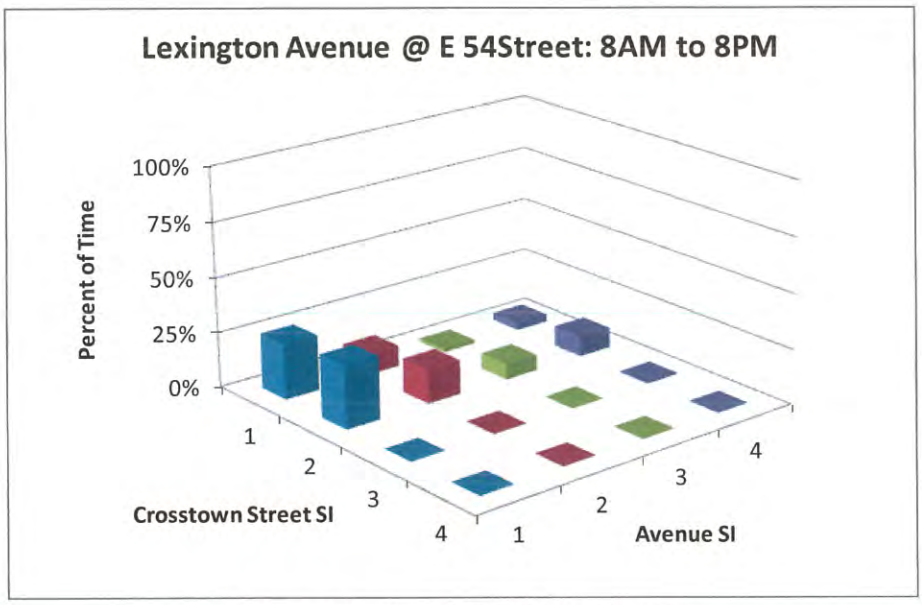


Figure 3-2 – Illustrative SI Distribution

Average SI

The average SI is a good indicator to tell how the approach performs over the given period. The average SI for an approach for a given period is calculated as follows.

$$SI_{avg} = \sum_{i=1}^{4} i \times \%SI_i$$

Where SI_{avg} = average SI for a given period

i = Index 1 through 4

$\%SI_i$ = Percent Occurrence of SI with i

For example, if percent occurrence of SI over time is 40%, 30%, 20%, 10% for SI = 1, 2, 3, and 4 respectively, the average SI is...

SI_{avg} = 1 * 40% + 2 * 30% + 3 * 20% + 4 * 10% = 2.

This implies the approach experienced the congestion with SI = 2 on an average for a given period. A lower average SI is preferred.

Equity Ratio

"Equity Ratio" is defined as

$$\text{Equity Ratio} = \frac{\text{Average SI for Crosstown Street Appraoch}}{\text{Average SI for Avenue Street Appraoch}}$$

This ratio is based on the average SI calculated for the competing approaches. This will imply how equally the congestion is managed for the competing approach in a given intersection for a given period of time. The value closer to 1 implies balanced control in terms of extent of congestion. A value greater than 1 implies the avenue approach is favored over the crosstown street. A value lesser than 1 implies the crosstown street is favored over the avenue. The equity ratio is a useful metric to quantify the intersection performance.

3.4 Level 2 Results

Using the three metrics presented in the Section 3.3 a comparative analysis was completed. Improvements were observed at four out of five intersections with sufficient data. Table 3-4 shows the dates selected used for the analysis and Tables 3-5 through 3-9 present the SI distribution results. Figures 3-3 to 3-7 present the SI distribution in Tables 3-5 to 3-9.

Table 3-4 – Selected Periods for Level 2 Analysis

Intersection	Without L2	With L2
Others	10/21/2011 – 11/2/2011	11/4/2011 – 11/28/2011
Lexington Ave & 54 St	8/2/11 – 8/16/11	

There were periods with communication issues (TMC upgrades) or intermittent field detector issues (blockages) that resulted in "invalid" data. These were dropped as part of the analysis and the effective sampling rate is shown in Table 3-10 along with the Average SI and Equity Ratios.

Note: Results for five out of the seven intersections are presented here, because the system upgrades, communication failures and blockages resulted in loss of data.

Table 3-5 – SI Distribution Table for Lexington Ave @ E 54 St

Without L2

Avenue SI	Crosstown Street SI 1	2	3	4
1	582	541	0	0
2	109	116	0	0
3	31	30	0	0
4	53	61	1	1

Avenue SI	Crosstown Street SI 1	2	3	4
1	38%	35%	0%	0%
2	7%	8%	0%	0%
3	2%	2%	0%	0%
4	3%	4%	0%	0%

Average SI – Avenue	1.38
Average SI – Crosstown Street	1.49
Equity Ratio	1.09

With L2

Avenue SI	Crosstown Street SI 1	2	3	4
1	104	118	0	0
2	39	64	1	0
3	6	29	0	0
4	14	38	2	0

Avenue SI	Crosstown Street SI 1	2	3	4
1	25%	28%	0%	0%
2	9%	15%	0%	0%
3	1%	7%	0%	0%
4	3%	9%	0%	0%

Average SI – Avenue	1.64
Average SI – Crosstown Street	1.61
Equity Ratio	0.98

Table 3-6 – SI Distribution Table for Lexington Ave @ E 50 St

Without L2

Avenue SI	Crosstown Street SI 1	2	3	4
1	230	429	130	5
2	43	108	38	1
3	4	7	6	0
4	3	3	4	0

Avenue SI	Crosstown Street SI 1	2	3	4
1	23%	42%	13%	0%
2	4%	11%	4%	0%
3	0%	1%	1%	0%
4	0%	0%	0%	0%

Average SI – Avenue	1.22
Average SI – Crosstown Street	1.91
Equity Ratio	1.57

With L2

Avenue SI	Crosstown Street SI 1	2	3	4
1	385	339	148	18
2	68	81	28	6
3	11	16	1	0
4	14	8	6	1

Avenue SI	Crosstown Street SI 1	2	3	4
1	34%	30%	13%	2%
2	6%	7%	2%	1%
3	1%	1%	0%	0%
4	1%	1%	1%	0%

Average SI – Avenue	1.24
Average SI – Crosstown Street	1.78
Equity Ratio	1.44

Table 3-7 – SI Distribution Table for Lexington Ave @ E 46 St

Without L2

Avenue SI	Crosstown Street SI 1	2	3	4
1	274	236	15	1
2	40	127	17	0
3	9	12	3	0
4	7	7	3	3

Avenue SI	Crosstown Street SI 1	2	3	4
1	36%	31%	2%	0%
2	5%	17%	2%	0%
3	1%	2%	0%	0%
4	1%	1%	0%	0%

Average SI – Avenue	1.32
Average SI – Crosstown Street	1.62
Equity Ratio	1.23

With L2

Avenue SI	Crosstown Street SI 1	2	3	4
1	576	328	19	8
2	113	160	12	5
3	17	30	4	2
4	19	43	5	2

Avenue SI	Crosstown Street SI 1	2	3	4
1	43%	24%	1%	1%
2	8%	12%	1%	0%
3	1%	2%	0%	0%
4	1%	3%	0%	0%

Average SI – Avenue	1.37
Average SI – Crosstown Street	1.52
Equity Ratio	1.11

Table 3-8 – SI Distribution Table for 6 Ave @ W 53 St

Without L2

Avenue SI	Crosstown Street SI 1	2	3	4
1	158	16	0	0
2	144	51	0	0
3	33	12	0	0
4	241	276	0	0

Avenue SI	Crosstown Street SI 1	2	3	4
1	17%	2%	0%	0%
2	15%	5%	0%	0%
3	4%	1%	0%	0%
4	26%	30%	0%	0%

Average SI – Avenue	2.88
Average SI – Crosstown Street	1.38
Equity Ratio	0.48

With L2

Avenue SI	Crosstown Street SI 1	2	3	4
1	76	21	0	0
2	26	46	0	0
3	1	22	0	0
4	27	174	0	0

Avenue SI	Crosstown Street SI 1	2	3	4
1	19%	5%	0%	0%
2	7%	12%	0%	0%
3	0%	6%	0%	0%
4	7%	44%	0%	0%

Average SI – Avenue	2.71
Average SI – Crosstown Street	1.67
Equity Ratio	0.61

Table 3-9 – SI Distribution Table for 6 Ave @ W 45 St

Without L2

Avenue SI	Crosstown Street SI 1	2	3	4
1	121	508	14	0
2	20	132	6	0
3	15	35	1	0
4	22	168	10	0

Avenue SI	Crosstown Street SI 1	2	3	4
1	12%	48%	1%	0%
2	2%	13%	1%	0%
3	1%	3%	0%	0%
4	2%	16%	1%	0%

Average SI – Avenue	1.72
Average SI – Crosstown Street	1.86
Equity Ratio	1.08

With L2

Avenue SI	Crosstown Street SI 1	2	3	4
1	176	331	18	0
2	35	139	12	0
3	7	38	4	0
4	74	292	24	0

Avenue SI	Crosstown Street SI 1	2	3	4
1	15%	29%	2%	0%
2	3%	12%	1%	0%
3	1%	3%	0%	0%
4	6%	25%	2%	0%

Average SI – Avenue	2.18
Average SI – Crosstown Street	1.80
Equity Ratio	0.82

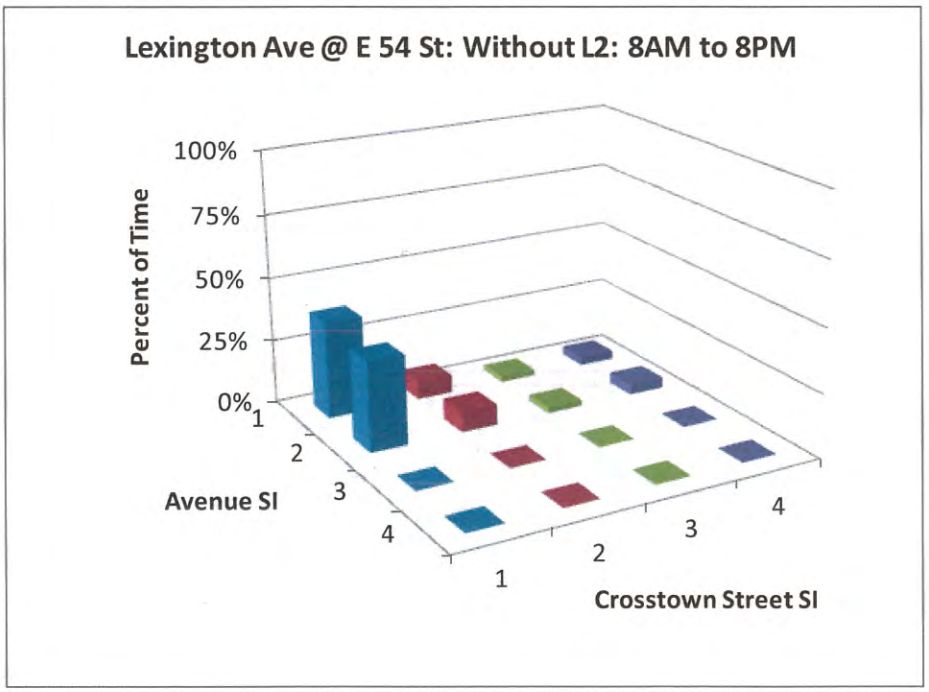
Table 3-10 – Average SI and Equity Ratio Comparison

		Without Level 2					With Level 2					
		Average SI		Equity Ratio	Sample Size	Sampling Rate	Average SI		Equity Ratio	Sample Size	Sampling Rate	% Active[2]
		Avenue	Crosstown Street				Avenue[1]	Crosstown Street[1]				
Lex Ave @ E 54 St	8AM-8PM	1.38	1.49	1.09	1,525	64%	1.64	1.61	*0.98*	415	10%	67%
	AM	2.05	1.53	0.75	230	58%	**1.95**	**1.52**	*0.78*	65	10%	59%
	MD	1.13	1.41	1.25	213	53%	1.34	1.53	*1.14*	74	11%	69%
	PM	1.28	1.49	1.16	282	71%	1.49	1.62	*1.08*	65	10%	79%
Lex Ave @ E 50 St	8AM-8PM	1.22	1.91	1.57	1,011	49%	1.24	**1.78**	*1.44*	1,130	28%	57%
	AM	1.16	1.67	1.45	165	48%	1.23	1.68	*1.36*	180	27%	37%
	MD	1.29	1.83	1.42	167	48%	**1.20**	**1.67**	*1.39*	211	32%	64%
	PM	1.25	2.01	1.61	170	49%	1.26	**1.86**	*1.47*	179	27%	77%
Lex Ave @ E 46 St	8AM-8PM	1.32	1.62	1.23	754	36%	1.37	**1.52**	*1.11*	1,343	34%	73%
	AM	1.55	1.52	0.98	143	41%	**1.53**	**1.46**	0.96	226	34%	58%
	MD	1.22	1.70	1.39	135	39%	1.29	**1.55**	*1.20*	224	34%	80%
	PM	1.26	1.61	1.28	97	28%	1.33	**1.47**	*1.10*	233	35%	78%
6 Ave @ W 53 St	8AM-8PM	2.88	1.38	0.48	931	45%	**2.72**	1.67	*0.61*	393	10%	93%
	AM	2.55	1.21	0.48	174	50%	2.67	1.73	*0.65*	48	7%	95%
	MD	2.76	1.34	0.49	154	44%	**2.32**	1.62	*0.70*	71	11%	90%
	PM	2.95	1.42	0.48	144	42%	**2.91**	1.73	*0.59*	70	11%	94%
6 Ave @ W 45 St	8AM-8PM	1.72	1.86	1.08	1,052	51%	2.18	**1.80**	0.82	1,150	29%	83%
	AM	1.88	1.76	0.94	190	55%	2.10	**1.72**	0.82	178	27%	92%
	MD	1.90	1.94	1.02	180	52%	2.12	**1.77**	0.84	196	29%	79%
	PM	1.66	1.92	1.16	181	52%	2.29	**1.80**	0.79	189	28%	85%

Note: 1. Improvements in SI and Equity Ratio are highlighted

2. % Active – Is the percentage of time the signal settings are different from the existing

3. AM = 8AM to 10AM, MD = 11AM to 1PM, PM = 4PM to 6PM



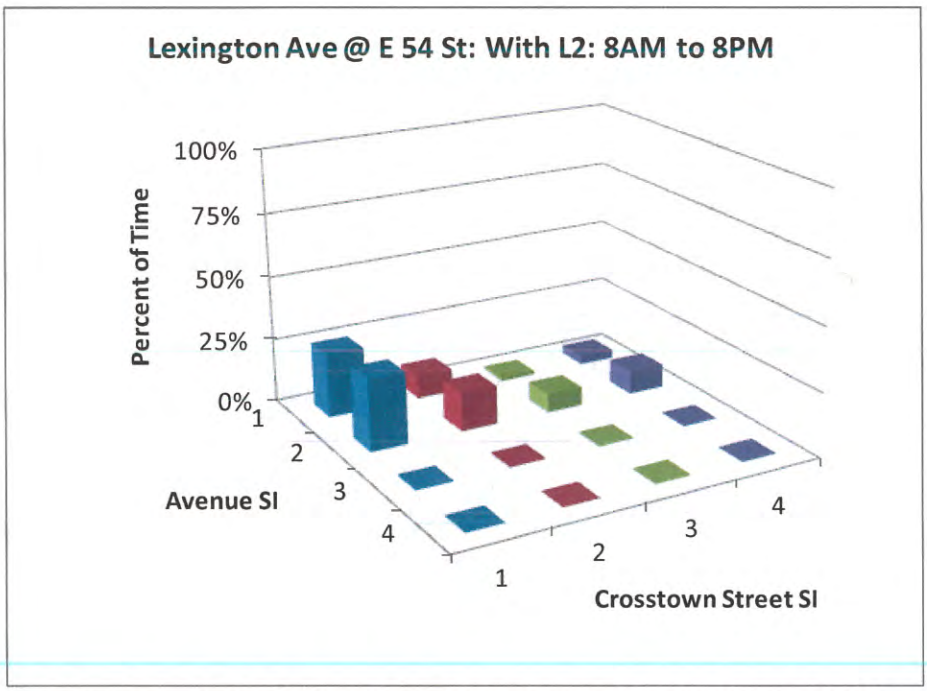
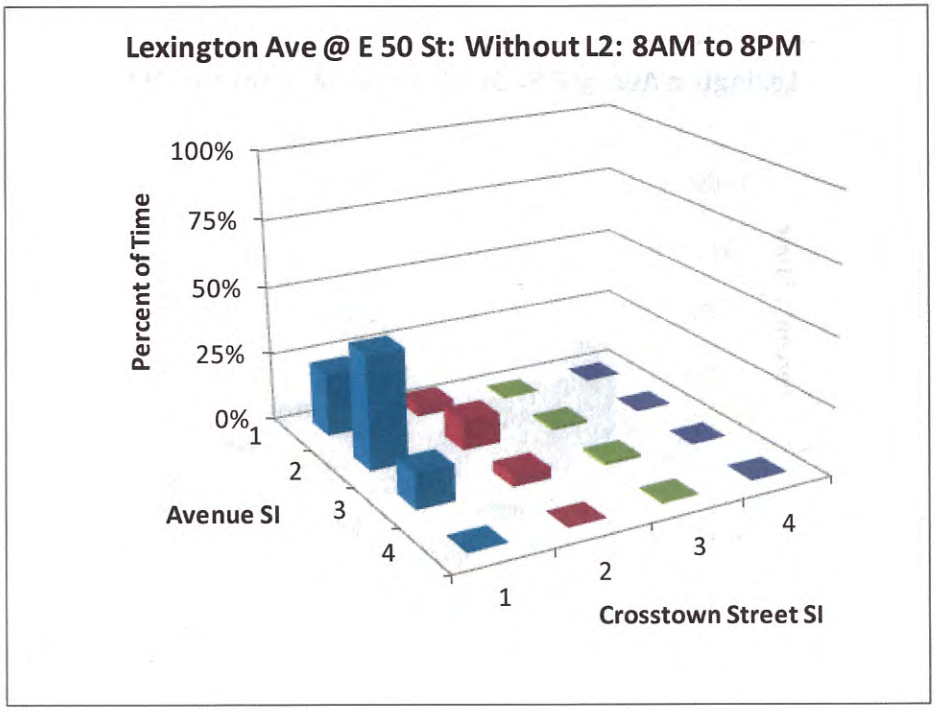


Figure 3-3 – SI Distribution Charts for Lexington @ E 54St (8AM to 8PM)



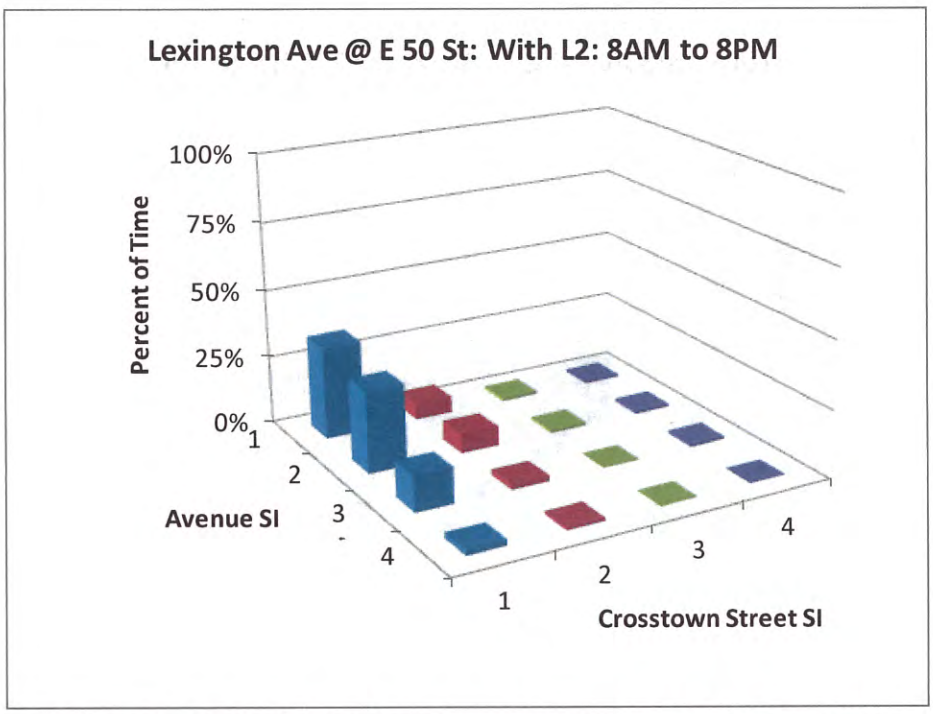
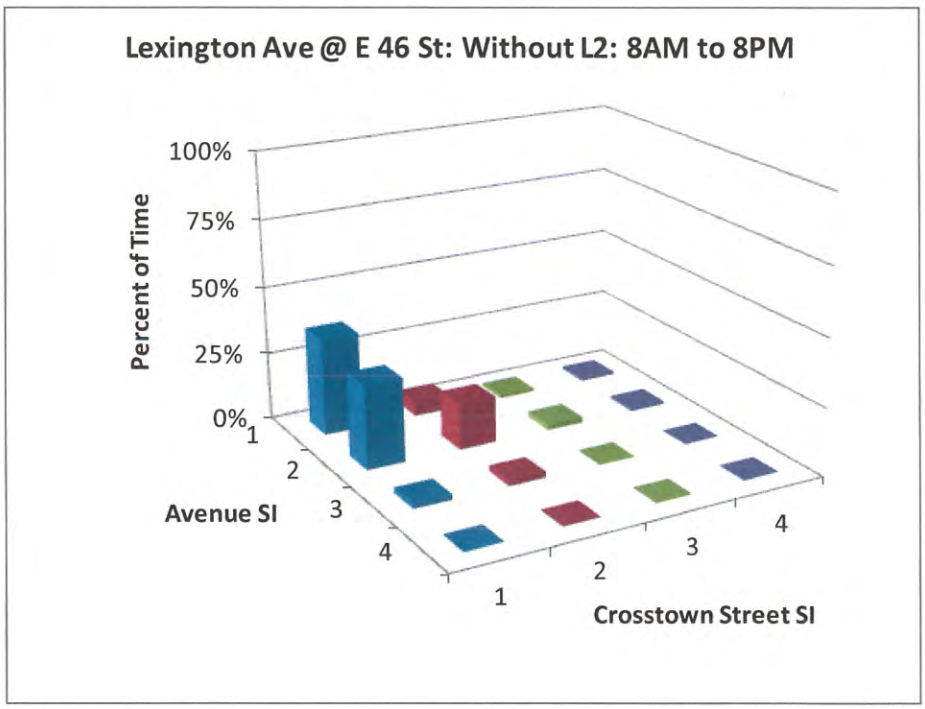


Figure 3-4 – SI Distribution Charts for Lexington @ E 50St (8AM to 8PM)



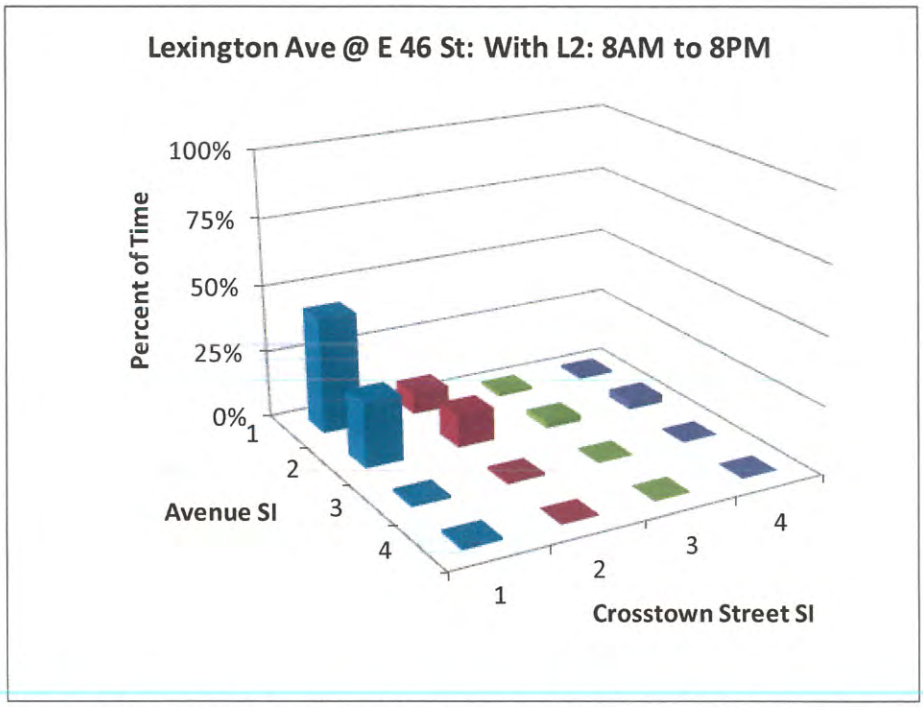
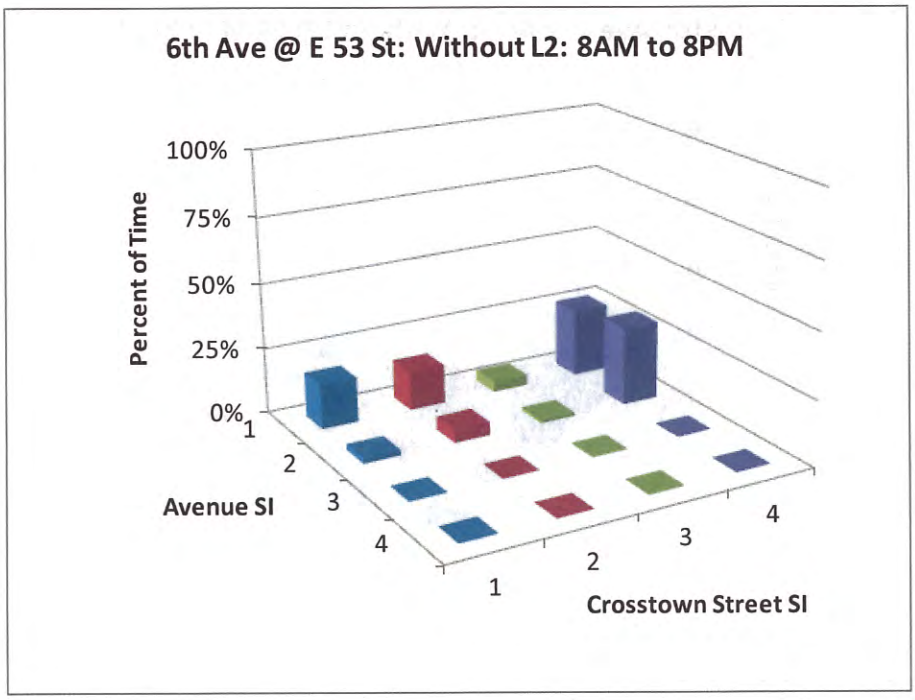


Figure 3-5 – SI Distribution Charts for Lexington @ E 46St (8AM to 8PM)



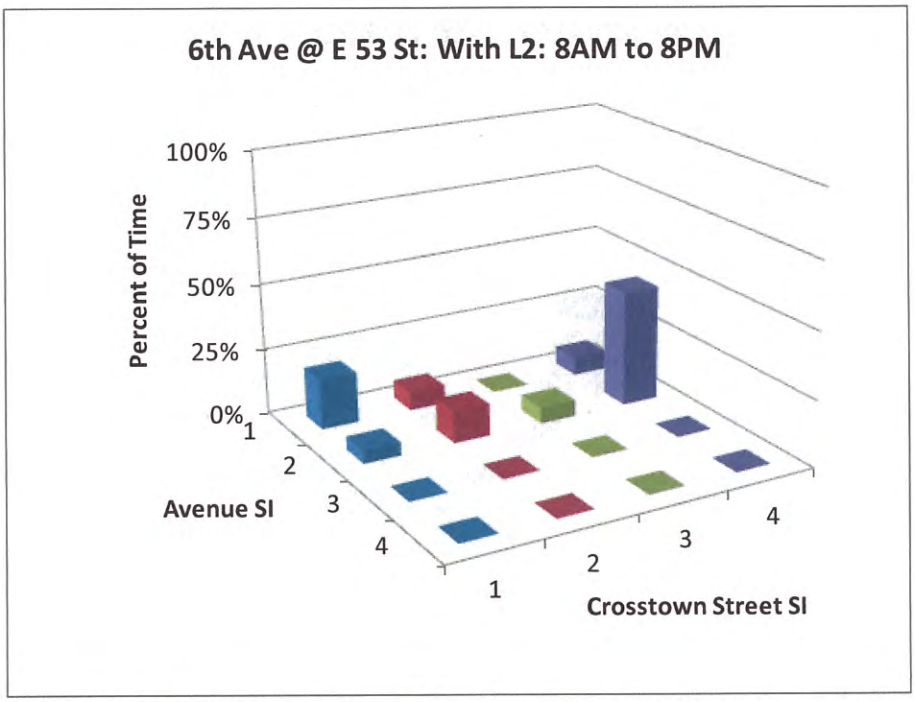
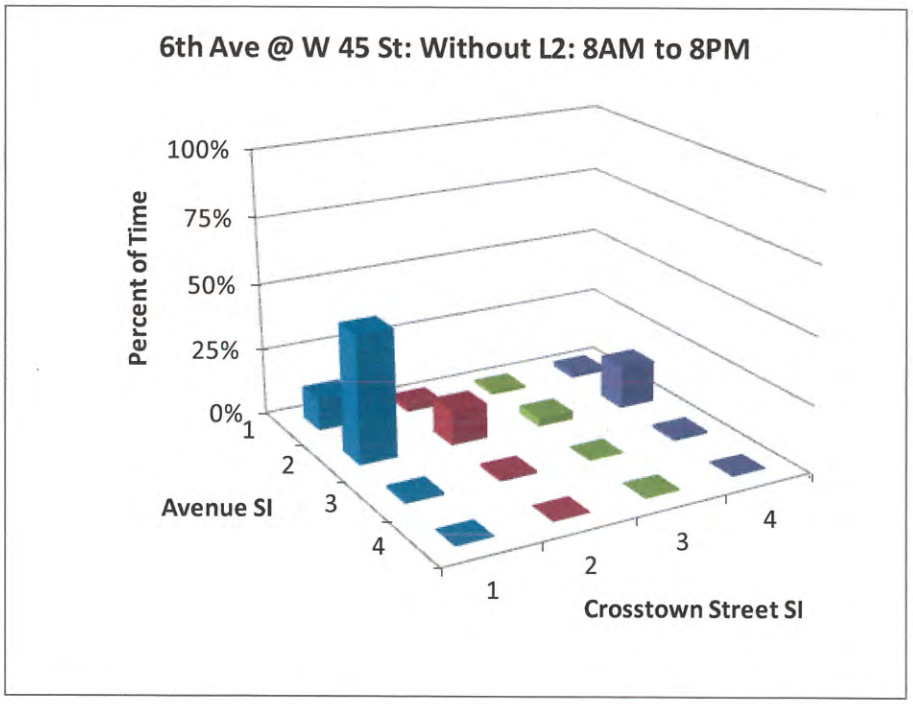


Figure 3-6 – SI Distribution Charts for 6th Avenue @ W 53St (8AM to 8PM)



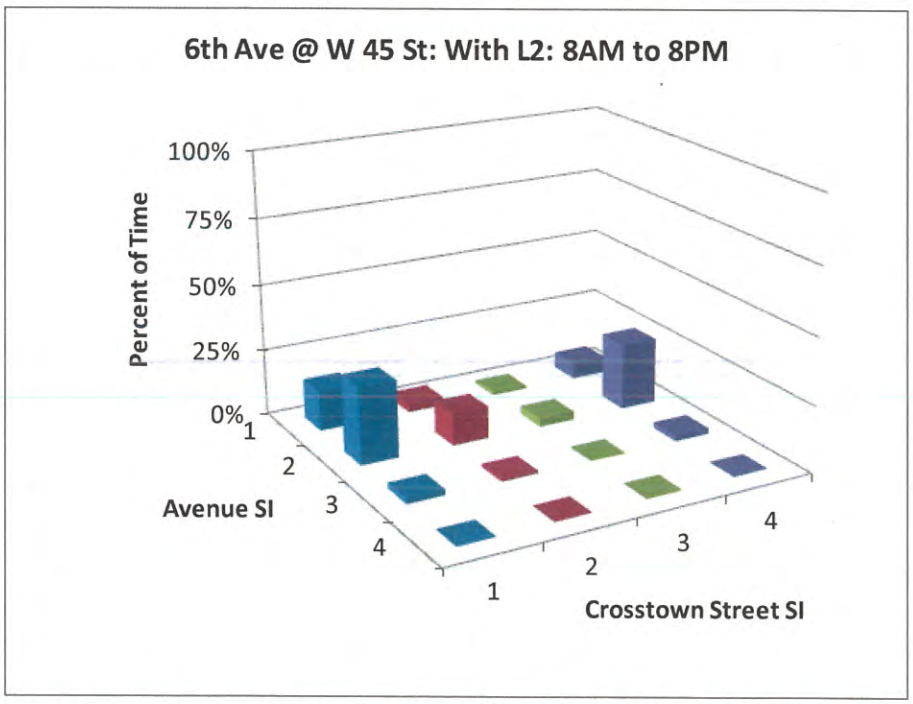


Figure 3-7 – SI Distribution Charts for 6th Avenue @ W 45St (8AM to 8PM)

The following observations can be made from Table 3-10:

- Lexington Avenue @ E 54 Street
  - The equity ratio is better suggesting balanced operations
  - L2 is active resulting in a different signal split from the existing two-thirds of the time
- Lexington Avenue @ E 50 Street
  - The equity ratio is better suggesting balanced operations
  - The average SI for the cross street is better with comparable SI for the avenue
  - L2 is active resulting in a different signal split from the existing half of the time
- Lexington Avenue @ E 46 Street
  - The equity ratio is better suggesting balanced operations
  - The average SI for the cross street is better with comparable SI for the avenue
  - L2 is active resulting in a different signal split from the existing three-quarters of the time
- 6th Avenue @ W 53 Street
  - The equity ratio is better suggesting balanced operations
  - The average SI for the avenue is better
  - L2 is active resulting in a different signal split most of the time
- 6th Avenue @ W 45 Street
  - The average SI for the cross street is better with higher SI for the avenue

By analyzing the log of signal timing changes as a result of Level 2 Control, we can assess the responsiveness of the system. Table 3-11 shows the percentage of time the signal timing changes were applied and if those favored the Avenue or the Cross Street. Based on Table 3-11, it appears that Level 2 has been active to different degrees at each intersection, and with different remedies (for instance, at one intersection, changes favored the venue; at another, it was balanced; at three, the cross street was given the extra green when the need & opportunity arose).

Table 3-11 – Level 2 Control -- Signal Timing Changes

Intersection	% Active	% Favor Avenue	% Favor Cross St
Lex Ave @ E 54 St	67%	26%	40%
Lex Ave @ E 50 St	57%	18%	38%
Lex Ave @ E 46 St	73%	17%	56%
6 Ave @ W 53 St	93%	92%	2%
6 Ave @ W 45 St	83%	41%	42%
% Active – represents the percentage of time signal splits were changed compared to the baseline % Favor Avenue – Represents the percentage of time signal splits for the Avenue were increased % Favor Cross St – Represents the percentage of time signal splits for the Cross St were increased			

Overall, Level 2 helped reducing the extent of congestion and achieving equity during the period. The results are not uniform at all intersections. The implementation of Level 2 suggests that there are intervals wherein the splits can be adjusted to better service needs to either the avenue or the crosstown street, which is part of the objectives of the active traffic management system. Parts of the system (approaches to the zone) were in the process of being upgraded resulting in down time for the detectors. This has impacted the sampling rates as seen in Table 3-10. Further analysis will be

conducted after the upgrades are complete. The Level 2 results are based on the prevailing traffic demand, with the intent of achieving equity and avoiding or balancing severity (that is, queue as a percentage of block length).

4 TAXI GPS DATA

NYCDOT is analyzing the taxi trip GPS database for the MIM zone and a surrounding, larger area of Midtown Manhattan to investigate changes in vehicle mobility. This includes analysis of taxi travel speeds from 2009 to 2011 as part of the system evaluation and it is currently in progress. As part of the coordinated efforts, the ETC travel time data, system implementation log, and TMC log are being provided on a routine basis.

5 NEXT STEPS

Study Area

NYCDOT intends to expand the study area in additional phases as shown in Figure 5-1. The next steps associated with these efforts will be focused on deploying the vehicle sensors effectively based on the experiences from this current system. Also, the database management system will be enhanced with post processing tools, to handle the additional data, and generate reports.

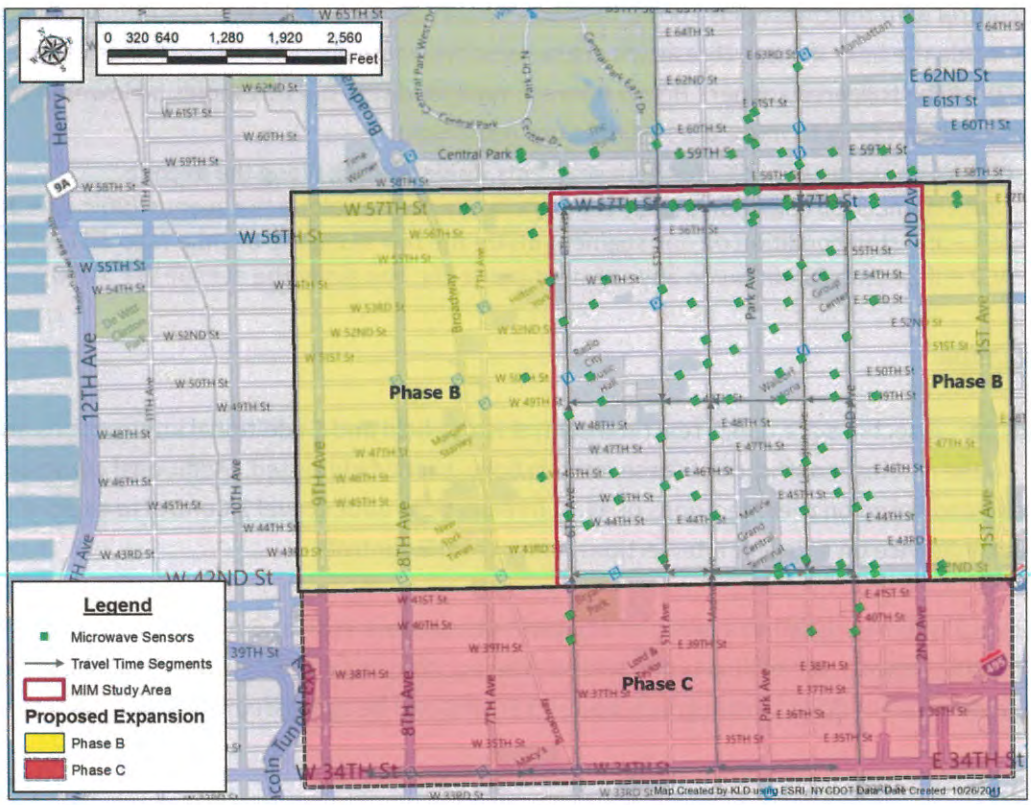


Figure 5-1 – MIM Phases Planned

Level 1 Control

An enhancement that will be investigated is the change of the Level 1 thresholds. Currently the thresholds are based on an estimate of number of stops using the median travel time on a given segment.

Median travel time along 7 or 8 blocks (approximately 2000 ft) is about 50 seconds (using an average travel speed between 25mph and 30mph) with no stops. Considering *N* number of stops the travel time will be 50 + N * 90. As the equation implies, the median travel time increases by a cycle length as the number of stops increases. The Level 1 thresholds are defined to separate these conditions.

For example, the threshold to separate one stop condition from two stop condition can be defined by taking the average of the median travels times for both conditions. That is, {(50 + 1 * 90) + (50 + 2 * 90)} / 2 = 185. For purposes of running the system, 180 seconds was selected in the current set of thresholds. All the other thresholds are defined in the same way, and following are the current thresholds and the associated signal timing plans:

- CTOD – one or less stop (TT < 180) for both segments inside the box along the avenue
- NBP – if two stop condition on any segment inside the box along the avenue (180 < TT < 270)
- AC1 – if 3 stop condition on any segment inside the box along the avenue (270 < TT < 360)
- AC2 – if 3+ stop condition on any segment inside the box along the avenue (TT > 360)

Level 1 control with the thresholds above, has shown improvement of the flow conditions along the avenues inside the box. If these thresholds are lowered the more aggressive signal timing plans (AC1/AC2) will be triggered sooner. Hence it is recommended that the thresholds be lowered by 90 seconds as shown below to make the system more responsive:

- CTOD – zero stop (TT < 90) for both segments inside the box along the avenue
- NBP – if one stop condition on any segment inside the box along the avenue (90 < TT < 180)
- AC1 – if 2 stop condition on any segment inside the box along the avenue (180 < TT < 270)
- AC2 – if 2+ stop condition on any segment inside the box along the avenue (TT > 270)

Level 2 Control

Currently 7 intersections are under real time control in the field and 6 additional intersections are under testing. In the coming months, all of these intersections will be field tested. Additional constraints will be investigated based on the operations of all 13 intersections under Level 2 Control to explore systematic influence on adjacent intersections under Level 2 control.

When Level 2 is to be applied to a group of adjacent intersections such as 6 Ave @ E45 St and 5 Ave @ E45 St, the adjustments will be fine tuned to minimize any coupling impact such as increase of upstream green and decrease of downstream green along 45 St. This will be addressed in the next update.

Learning System

An analysis of the recommendations of the system and actions taken by the TMC needs to be performed to investigate if there are patterns in the recommendations by specific time of day. If such patterns exist, they will be assimilated into the CTOD plans. This learning and assimilation will be a continual process that will meet the overall objective of being responsive under the Active Traffic Management architecture.

On a continual basis the state of the sensor network will be monitored to alert NYCDOT regarding offline detectors or communication failures to ensure minimal disruptions to system operations. Also, monitoring signal timing changes via the NYC_TCS will be continued to improve system efficiency.

6 CONCLUSIONS

The MIM project, in its first five months of operation, has demonstrated feasibility and effectiveness of deploying adaptive signal controls to better manage traffic operations in the highly congested urban roadway network of midtown Manhattan. Utilizing a system of roadway sensors, a reliable communications system and sophisticated traffic signal controls, NYCDOT is able to measure traffic conditions and take corrective actions.

MIM has shown to be effective in improving traffic operations on the avenues within the midtown core (study zone) by better managing the flow of traffic entering the core.

MIM is also showing promise in improving traffic operations at specific intersection when one or both approaches experience congestion. Parts of the system (approaches to the zone) were in the process of being upgraded resulting in down time for the detectors and this affected the sampling rates. Further analysis will be conducted after the upgrades are complete. Also, refinements to the algorithm to take into account adjacent intersections that are both under Level 2 control will be considered to improve the effectiveness.

We can anticipate the preservation of speeds on the avenues approaching the zone through future expansions of MIM when they are included in the zone (for instance, 34th to 42nd Streets). The objective will remain using active traffic management to avoid cascading problems within the zone that will detrimentally affect both the traffic in the zone and on its approaches, if left unaddressed.

7 ACKNOWLEDGEMENTS

The system exists in the operational mode because of the smooth and cooperative work by JHK/TransCore and the feedback and guidance received from NYCDOT management. It has truly been a team effort.

8 REFERENCES

[1] Office of the Mayor of New York City, PR-257-11, July 2011. *MAYOR BLOOMBERG ANNOUNCES NEW, REAL-TIME TRAFFIC MANAGEMENT SYSTEM TO REDUCE CONGESTION IN MIDTOWN MANHATTAN. Cameras, Microwave Motion Sensors and E-ZPass Readers Provide Real-Time Information Used in Wireless Adjustments to Traffic Signals.*

[2] KLD (August 2011). *Active Traffic Management Through Adaptive Signal Control in Midtown Manhattan – Status Report*.

APPENDIX A DATES AND INTERVALS FOR LEVEL 1 ANALYSIS

The following table presents the list of periods by segment that were excluded ("X") from the analysis.

Table A-1 – Dates and Intervals for Level 1 Analysis

Date	Period	6Ave (34St to 42St)	6Ave (42St to 49St)	6Ave (49St to 57St)	5Ave (49St to 42St)	5Ave (57St to 49St)	5Ave (72St to 57St)	Madison (34St to 42 St)	Madison (42St to 49St)	Madison (49St to 57St)	Lexington (49St to 42St)	Lexington (57St to 49St)	Lexington (72St to 57St)	3rdAve (34St to 42St)	3rdAve (42St to 49St)	3rdAve (49St to 57St)
Note: X = Interval excluded from the analysis. Pre-Existing Control (6/2-6/8), Real Time Control (6/20-11/3).																
6/2/2011	AM	X	X													
	MD	X	X													
	PM															
6/3/2011	AM						X									
	MD															
	PM															
6/6/2011	AM															
	MD												X			
	PM															
6/7/2011	AM															
	MD															
	PM															
6/8/2011	AM															
	MD													X		
	PM	X	X											X		
6/20/11	AM										X					
	MD															X
	PM													X		X
6/21/11	AM			X												
	MD			X												
	PM															
6/22/11	AM	X														
	MD	X			X											
	PM															
6/23/11	AM				X	X										
	MD															
	PM		X	X	X				X					X	X	X
6/24/11	AM															
	MD															

Table A-1 – Dates and Intervals for Level 1 Analysis

Date	Period	6Ave (34St to 42St)	6Ave (42St to 49St)	6Ave (49St to 57St)	5Ave (49St to 42St)	5Ave (57St to 49St)	5Ave (72St to 57St)	Madison (34St to 42 St)	Madison (42St to 49St)	Madison (49St to 57St)	Lexington (49St to 42St)	Lexington (57St to 49St)	Lexington (72St to 57St)	3rdAve (34St to 42St)	3rdAve (42St to 49St)	3rdAve (49St to 57St)
Note: X = Interval excluded from the analysis. Pre-Existing Control (6/2-6/8), Real Time Control (6/20-11/3).																
	PM				X									X		
6/27/11	AM											X		X		
	MD															
	PM			X												
6/28/11	AM											X				
	MD		X		X	X										
	PM															
6/29/11	AM	X				X	X							X		
	MD															
	PM							X						X		
6/30/11	AM															
	MD															
	PM															
7/1/11	AM	X				X	X									
	MD	X	X				X							X		
	PM			X									X			
7/5/11	AM	X				X	X									
	MD	X	X			X	X									
	PM					X	X									
7/6/11	AM					X	X						X	X		X
	MD					X	X									
	PM					X	X									
7/7/11	AM															
	MD															
	PM				X											
7/8/11	AM										X					
	MD			X												
	PM												X	X		
7/11/11	AM	X												X		
	MD															
	PM															X
7/12/11	AM							X								
	MD															

Table A-1 – Dates and Intervals for Level 1 Analysis

Date	Period	6Ave (34St to 42St)	6Ave (42St to 49St)	6Ave (49St to 57St)	5Ave (49St to 42St)	5Ave (57St to 49St)	5Ave (72St to 57St)	Madison (34St to 42 St)	Madison (42St to 49St)	Madison (49St to 57St)	Lexington (49St to 42St)	Lexington (57St to 49St)	Lexington (72St to 57St)	3rdAve (34St to 42St)	3rdAve (42St to 49St)	3rdAve (49St to 57St)
Note: X = Interval excluded from the analysis. Pre-Existing Control (6/2-6/8), Real Time Control (6/20-11/3).																
	PM												X			
7/13/11	AM						X									
	MD					X	X									
	PM					X	X									
7/14/11	AM			X							X					
	MD			X			X		X							
	PM						X						X			
7/15/11	AM		X			X										
	MD															
	PM															
7/18/11	AM															
	MD															
	PM															
7/19/11	AM															
	MD															
	PM													X		
7/20/11	AM								X					X		
	MD					X			X	X					X	X
	PM					X										
7/21/11	AM	X	X		X						X				X	
	MD					X					X					
	PM			X								X				
7/22/11	AM							X	X							
	MD					X	X	X	X					X		
	PM										X	X	X	X	X	
7/25/11	AM											X				
	MD															
	PM															
7/26/11	AM	X				X										
	MD	X											X			
	PM		X	X		X	X						X			
7/27/11	AM					X						X				
	MD					X			X		X			X		

Table A-1 – Dates and Intervals for Level 1 Analysis

Date	Period	6Ave (34St to 42St)	6Ave (42St to 49St)	6Ave (49St to 57St)	5Ave (49St to 42St)	5Ave (57St to 49St)	5Ave (72St to 57St)	Madison (34St to 42 St)	Madison (42St to 49St)	Madison (49St to 57St)	Lexington (49St to 42St)	Lexington (57St to 49St)	Lexington (72St to 57St)	3rdAve (34St to 42St)	3rdAve (42St to 49St)	3rdAve (49St to 57St)
Note: X = Interval excluded from the analysis. Pre-Existing Control (6/2-6/8), Real Time Control (6/20-11/3).																
	PM				X	X	X									
7/28/11	AM										X					
	MD		X													
	PM					X					X		X			
7/29/11	AM		X													
	MD		X			X					X					
	PM										X					
8/1/11	AM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	MD						X									
	PM															
8/2/11	AM															
	MD													X		
	PM													X		
8/3/11	AM			X												
	MD	X														
	PM						X									
8/4/11	AM															
	MD															
	PM															
8/5/11	AM															
	MD															
	PM									X						
8/8/11	AM									X		X				
	MD									X						
	PM												X			X
8/9/11	AM				X						X					
	MD							X								
	PM						X									
8/10/11	AM								X					X		
	MD					X			X							
	PM		X	X		X										
8/11/11	AM					X								X		
	MD									X						

Table A-1 – Dates and Intervals for Level 1 Analysis

Date	Period	6Ave (34St to 42St)	6Ave (42St to 49St)	6Ave (49St to 57St)	5Ave (49St to 42St)	5Ave (57St to 49St)	5Ave (72St to 57St)	Madison (34St to 42 St)	Madison (42St to 49St)	Madison (49St to 57St)	Lexington (49St to 42St)	Lexington (57St to 49St)	Lexington (72St to 57St)	3rdAve (34St to 42St)	3rdAve (42St to 49St)	3rdAve (49St to 57St)
Note: X = Interval excluded from the analysis. Pre-Existing Control (6/2-6/8), Real Time Control (6/20-11/3).																
	PM		X	X	X		X	X	X	X			X	X	X	
8/12/11	AM									X						
	MD															
	PM															
8/15/11	AM	X	X		X					X					X	
	MD	X	X													
	PM															
8/16/11	AM															
	MD															
	PM				X	X										
8/17/11	AM				X											
	MD															
	PM															
8/18/11	AM	X	X													
	MD	X	X	X												
	PM	X	X											X		
8/19/11	AM	X	X													
	MD	X	X				X									
	PM	X	X													
8/22/11	AM	X	X		X	X										
	MD	X	X		X								X			
	PM	X	X													X
8/23/11	AM	X	X					X		X						
	MD	X	X													
	PM															
8/24/11	AM				X			X			X					
	MD										X					
	PM															
8/25/11	AM									X						
	MD												X			
	PM		X	X									X			
8/26/11	AM									X						
	MD								X				X			

Table A-1 – Dates and Intervals for Level 1 Analysis

Date	Period	6Ave (34St to 42St)	6Ave (42St to 49St)	6Ave (49St to 57St)	5Ave (49St to 42St)	5Ave (57St to 49St)	5Ave (72St to 57St)	Madison (34St to 42 St)	Madison (42St to 49St)	Madison (49St to 57St)	Lexington (49St to 42St)	Lexington (57St to 49St)	Lexington (72St to 57St)	3rdAve (34St to 42St)	3rdAve (42St to 49St)	3rdAve (49St to 57St)
Note: X = Interval excluded from the analysis. Pre-Existing Control (6/2-6/8), Real Time Control (6/20-11/3).																
	PM	X	X	X		X	X			X			X			
8/29/11	AM	X	X		X	X			X	X						X
	MD					X			X						X	
	PM	X				X							X			
8/30/11	AM	X		X		X						X	X		X	
	MD								X							
	PM			X		X										
8/31/11	AM											X			X	
	MD															X
	PM															
9/1/11	AM												X	X		
	MD				X	X										
	PM															
9/2/11	AM	X				X										
	MD															
	PM												X			
9/6/11	AM	X	X													
	MD	X	X													
	PM	X	X				X						X		X	X
9/7/11	AM	X	X	X			X					X	X		X	
	MD												X			
	PM			X					X	X						
9/8/11	AM							X				X	X			
	MD															
	PM			X												
9/9/11	AM	X		X	X	X	X			X			X			
	MD	X		X	X	X	X			X	X	X	X			
	PM	X		X	X		X						X			
9/12/11	AM				X	X	X			X		X	X			
	MD											X				
	PM					X							X			X
9/13/11	AM	X	X		X								X			
	MD	X	X				X									

Table A-1 – Dates and Intervals for Level 1 Analysis

Date	Period	6Ave (34St to 42St)	6Ave (42St to 49St)	6Ave (49St to 57St)	5Ave (49St to 42St)	5Ave (57St to 49St)	5Ave (72St to 57St)	Madison (34St to 42 St)	Madison (42St to 49St)	Madison (49St to 57St)	Lexington (49St to 42St)	Lexington (57St to 49St)	Lexington (72St to 57St)	3rdAve (34St to 42St)	3rdAve (42St to 49St)	3rdAve (49St to 57St)
Note: X = Interval excluded from the analysis. Pre-Existing Control (6/2-6/8), Real Time Control (6/20-11/3).																
	PM				X											
9/14/11	AM	X	X		X				X							
	MD	X	X				X						X		X	
	PM									X						
9/15/11	AM	X	X						X							
	MD		X		X		X		X	X		X	X			
	PM	X	X	X					X						X	
9/16/11	AM								X	X						
	MD					X			X	X		X			X	
	PM			X									X			
9/26/11	AM	X		X					X	X						
	MD		X	X												
	PM									X						X
9/27/11	AM	X	X		X		X									
	MD												X	X		
	PM	X	X							X						
9/29/11	AM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	MD	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	PM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9/30/11	AM															
	MD															
	PM			X												X
10/3/11	AM	X	X									X				X
	MD	X	X													
	PM	X	X							X				X		X
10/4/11	AM	X	X	X			X									
	MD	X	X	X						X				X		
	PM				X		X									
10/5/11	AM															
	MD												X			
	PM													X		
10/6/11	AM									X						X
	MD															

Table A-1 – Dates and Intervals for Level 1 Analysis

Date	Period	6Ave (34St to 42St)	6Ave (42St to 49St)	6Ave (49St to 57St)	5Ave (49St to 42St)	5Ave (57St to 49St)	5Ave (72St to 57St)	Madison (34St to 42 St)	Madison (42St to 49St)	Madison (49St to 57St)	Lexington (49St to 42St)	Lexington (57St to 49St)	Lexington (72St to 57St)	3rdAve (34St to 42St)	3rdAve (42St to 49St)	3rdAve (49St to 57St)
Note: X = Interval excluded from the analysis. Pre-Existing Control (6/2-6/8), Real Time Control (6/20-11/3).																
	PM								X	X						
10/7/11	AM													X		
	MD	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	PM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
10/11/11	AM								X			X	X			
	MD								X	X		X	X	X		X
	PM													X		
10/12/11	AM								X	X				X		
	MD	X							X	X						X
	PM									X						X
10/13/11	AM							X								X
	MD															
	PM									X						X
10/14/11	AM			X										X		X
	MD													X		X
	PM															X
10/17/11	AM							X						X		X
	MD													X		X
	PM					X		X								X
10/18/11	AM	X								X				X		X
	MD	X	X					X					X	X		X
	PM									X			X			
10/19/11	AM	X				X	X						X			
	MD	X						X		X		X	X		X	
	PM	X						X		X					X	
10/20/11	AM	X									X					X
	MD												X			
	PM	X								X						
10/21/11	AM									X		X				X
	MD															
	PM							X		X	X	X		X		
10/24/11	AM					X	X							X		X
	MD													X		

Table A-1 – Dates and Intervals for Level 1 Analysis

Date	Period	6Ave (34St to 42St)	6Ave (42St to 49St)	6Ave (49St to 57St)	5Ave (49St to 42St)	5Ave (57St to 49St)	5Ave (72St to 57St)	Madison (34St to 42 St)	Madison (42St to 49St)	Madison (49St to 57St)	Lexington (49St to 42St)	Lexington (57St to 49St)	Lexington (72St to 57St)	3rdAve (34St to 42St)	3rdAve (42St to 49St)	3rdAve (49St to 57St)
Note: X = Interval excluded from the analysis. Pre-Existing Control (6/2-6/8), Real Time Control (6/20-11/3).																
	PM	X	X	X	X	X								X		X
10/25/11	AM													X		
	MD						X									
	PM									X						
10/26/11	AM													X		
	MD	X												X		X
	PM	X			X									X		
10/27/11	AM	X								X						
	MD	X					X	X					X			
	PM	X							X	X			X	X		
10/28/11	AM											X		X	X	X
	MD			X	X		X		X			X		X		
	PM	X										X		X	X	
10/31/11	AM				X	X										
	MD	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	PM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
11/1/11	AM	X														X
	MD								X							
	PM															X
11/2/11	AM															
	MD			X	X	X									X	X
	PM									X					X	
11/3/11	AM				X											X
	MD				X											X
	PM	X														X