Final Report

Development of Traffic Performance Metrics Using Real-time Traffic Data

Performing Organization: Polytechnic Institute of NYU

October 2013
University Transportation Research Center - Region 2

The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

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The research program objectives are (1) to develop a theme based transportation research program that is responsive to the needs of regional transportation organizations and stakeholders, and (2) to conduct that program in cooperation with the partners. The program includes both studies that are identified with research partners of projects targeted to the theme, and targeted, short-term projects. The program develops competitive proposals, which are evaluated to insure the mostresponsive UTRC team conducts the work. The research program is responsive to the UTRC theme: "Planning and Managing Regional Transportation Systems in a Changing World." The complex transportation system of transit and infrastructure, and the rapidly changing environment impacts the nation's largest city and metropolitan area. The New York/New Jersey Metropolitan has over 19 million people, 600,000 businesses and 9 million workers. The Region's intermodal and multimodal systems must serve all customers and stakeholders within the region and globally. Under the current grant, the new research projects and the ongoing research projects concentrate the program efforts on the categories of Transportation Systems Performance and Information Infrastructure to provide needed services to the New Jersey Department of Transportation, New York City Department of Transportation, New York Metropolitan Transportation Council, New York State Department of Transportation, and the New York State Energy and Research Development Authority and others, all while enhancing the center's theme.

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Project Date: October 2013

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Project's Website: http://www.utrc2.org/research/projects/traffic-performance-metrics

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FINAL REPORT

Traveler - Oriented Traffic Performance Metrics Using Real Time Traffic Data from the Midtown-in-Motion (MIM) Project in Manhattan, NY

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POLYTECHNIC INSTITUTE OF NYU

DEPARTMENT OF CIVIL AND URBAN ENGINEERING

Urban ITS Center

OCT 31, 2013
### Abstract

In a congested urban street network the average traffic speed is an inadequate metric for measuring speed changes that drivers can perceive from changes in traffic control strategies.

A driver–oriented metric is needed. Stop frequency distributions were developed for avenue segments in Manhattan, NYC, from known vehicle travel times for the am, midday, and pm peak hours.

The stop frequency metrics were developed from archived real-time data for twenty avenue segments in Midtown Manhattan. Additional data sources included ETC (EZ-Pass) readers, Google Earth, and records of Traffic Signal Strategies.

Using the stop frequency metric it is possible to evaluate the benefits of adaptive traffic control systems (ATCS) over pre-ATCS deployment, by comparing the number of vehicles stopping more than an acceptable number of stops. Relationships were developed between average speed and a stop frequency threshold representing driver’s perception of annoyance.

In a very dense traffic network, where competition for street space among a multiplicity of users is very intense (as in Manhattan), ATCS implementation needs to be combined with the deployment of active traffic enforcement.

To be able to measure the drivers’ benefits of ATCS deployment it is fundamental to collect robust pre-deployment data.
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The authors assume all responsibility for content and accuracy.
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A. INTRODUCTION

New York City Department of Transportation (NYCDOT) has been upgrading its Intelligent Transportation Systems (ITS) infrastructure. Specifically NYCDOT has been installing Advanced Solid State Traffic Controllers (ASTC), a city wide wireless network (NYCWiN), and a sophisticated Traffic Control System (TCS) in the Traffic Management Center (TMC). Capitalizing on the deployment of these new technologies, NYCDOT instituted the “Midtown in Motion” (MIM) project to enhance mobility in the Midtown Core of Manhattan in a 110 square block area of “box” from 2nd to 6th Avenues, 42nd to 57th Streets. MIM was announced by Mayor Michael Bloomberg on July 18, 2011. The project uses adaptive signal control systems. Adaptive control is generally characterized by adjusting the signal timing in response to changes in traffic using real-time data.

The MIM project utilizes “active traffic management” (ATM) and the full capabilities of the NYCDOT ITS infrastructure. The signal-timing measures applied by MIM complement other efforts by the City to improve traffic operations. As part of this project E-ZPass tag readers were installed to provide travel time data, and microwave sensors were deployed to provide flow/occupancy data, both in real time. The ATM is based on a two-level control strategy to improve mobility using both travel time and flow/occupancy data.

The real time data are being archived by NYCDOT and supplement other data warehouse including counts, volumes, and speeds, etc., which are collected as part of the DOT and other agency projects.
B. LITERATURE REVIEW

The federal highway administration (FHWA) defines adaptive signal control as technology that adjusts the timing of traffic signals in order to “accommodate changing traffic patterns” for the purpose of easing congestion [1].

Conventional pre-timed signal control uses fixed intervals of green, yellow, and red based on the time of day. The decision of what intervals to use are usually based on past history of traffic counts for that intersection.

The benefits of adaptive control over the fixed interval systems that use pretimed settings that do not change either all day or for large periods of the day are [1]:

1. Distributing green time equitably for all traffic movements, based on actual volumes moving through an intersection,
2. Improves travel time reliability by reducing the number of stops through a system,
3. Reducing congestion, and therefore pollution, and

Some example adaptive control systems include SCATS [2], SCOOT [3], UTOPIA [4], CRONOS [5], InSync [6], and ACS-Lite [7].

Many states are now using adaptive control to improve the movement of vehicles to reduce congestion. Florida, Minnesota, and Wisconsin DOTs were among the first states to experiment with adaptive control systems [8]. Each year, more and more states are converting systems, either for single intersections, arterials or entire grid systems, to adaptive control systems.

Colorado DOT is installing adaptive traffic control technology on the 10th street arterial, which is comprised of eleven intersections. The have installed video
detection cameras on all approaches to each intersection as well as a wireless radio communication system for each intersection’s controllers to communicate. The video and data information is then returned to the traffic management center [9].

Zhao and Tian [10] estimate that only 4% of signalized intersections in the US are under adaptive signal control systems, which is much lower than usage in other countries. The number of states using adaptive control is increasing, however. Table 1, abridged from Ref [10], gives a partial summary of where adaptive control systems have been implemented in the United States, with the percent of the signals in each area that are under adaptive control. Richmond and Petersburg, Virginia and Washington, DC have the highest percent of signals using adaptive control, with 34% and 35%, respectively. The next highest state is New York, with 16% of signals using adaptive control in Albany, Schenectady, and Troy.

### Table 1 Summary of Adaptive Signal Control Deployments in the U.S.

<table>
<thead>
<tr>
<th>Metropolitan Area</th>
<th>State</th>
<th>Percent Signalized Intersections deploying Adaptive Traffic Control Systems</th>
</tr>
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<tbody>
<tr>
<td>Albany, Schenctady, Troy</td>
<td>NY</td>
<td>16%</td>
</tr>
<tr>
<td>Atlanta</td>
<td>GA</td>
<td>1%</td>
</tr>
<tr>
<td>Chicago, Gary, Lake Country</td>
<td>IL</td>
<td>13%</td>
</tr>
<tr>
<td>Dayton, Springfield</td>
<td>OH</td>
<td>1%</td>
</tr>
<tr>
<td>Denver, Boulder</td>
<td>CO</td>
<td>1%</td>
</tr>
<tr>
<td>Detroit, Ann Arbor</td>
<td>MI</td>
<td>14%</td>
</tr>
<tr>
<td>Grand Rapids</td>
<td>MI</td>
<td>&lt;0.2%</td>
</tr>
<tr>
<td>Greensboro, Winston-Salem, High Point</td>
<td>NC</td>
<td>3%</td>
</tr>
<tr>
<td>Hampton Roads</td>
<td>VA</td>
<td>2%</td>
</tr>
<tr>
<td>Houston, Galveston, Brazoria</td>
<td>TX</td>
<td>1%</td>
</tr>
<tr>
<td>Jackson</td>
<td>MS</td>
<td>&lt;0.4%</td>
</tr>
<tr>
<td>Little Rock, North Little Rock</td>
<td>AR</td>
<td>1%</td>
</tr>
<tr>
<td>Los Angeles, Anaheim, Riverside</td>
<td>CA</td>
<td>3%</td>
</tr>
<tr>
<td>Milwaukee, Racine</td>
<td>WI</td>
<td>&lt;0.2%</td>
</tr>
<tr>
<td>Minneapolis, St. Paul</td>
<td>MN</td>
<td>&lt;0.2%</td>
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<tr>
<td>Modesto</td>
<td>CA</td>
<td>1%</td>
</tr>
<tr>
<td>NY, Northern NJ</td>
<td>NY</td>
<td>5%</td>
</tr>
<tr>
<td>City</td>
<td>State</td>
<td>Region</td>
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<tr>
<td>Orlando</td>
<td>FL</td>
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<td>Philadelphia, Wilmington, Trenton</td>
<td>PA</td>
<td></td>
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<tr>
<td>Providence, Pawtucket, Fall River</td>
<td>RI</td>
<td></td>
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<tr>
<td>Raleigh-Durham</td>
<td>NC</td>
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<td>Richmond, Petersburg</td>
<td>VA</td>
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<tr>
<td>San Diego</td>
<td>CA</td>
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<tr>
<td>San Francisco, Oakland, San Jose</td>
<td>CA</td>
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</tr>
<tr>
<td>Tampa, St. Petersburg, Clearwater</td>
<td>FL</td>
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<td>Tucson</td>
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<td>Tulsa</td>
<td>OK</td>
<td></td>
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<tr>
<td>Washington</td>
<td>DC</td>
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In Gresham, Oregon a major corridor deployed adaptive control and compared travel times on the corridor before and after the implementation. Significant improvement was found with the adaptive control system compared to the previous time-of-day system, and travel times were reduced to the lowest recorded levels [11].

Full scale adaptive control technologies are most often useful for large-scale systems and on grid systems [12], where large-scale is defined as at least 100 signals. These systems, in general, require much maintenance and oversight, but can offer substantial results due to continuous data collection and updating of the signal timing [12].

The system used in Los Angeles was initially implemented for the 1984 Olympics. The system controls over 17,000 detectors and over 3,000 signals. A 2001 study found travel times improving by 13%; stops were decreased by 31%, and delay decreased by 21% [12].
C. THE NEW YORK CITY DOT MIDTOWN-IN-MOTION PROJECT

1. PURPOSE

The Midtown in Motion (MIM) Project adopted in New York City was implemented for the purpose of reducing congestion, minimizing travel times along the arterials, (thereby reducing delay), improving the efficiency of traffic flow, and improving air quality by reducing the number of stops.

2. DEMONSTRATION STUDY AREA

The phase 1 Midtown in Motion (MIM) Project adopted in New York City was implemented in an area is bounded by 42nd Street, 57th Street, 3rd Avenue and 6th Avenue (the “box”).

The MIM project uses the new ITS environment described in the Introduction section of this report to actively manage traffic. The Real-time data are used to implement various control strategies. Traffic demand is regulated to limit the number of vehicles entering the “box” of the test area, and balance queues at critical intersections.

As part of this project, new control plans (signal timing plans) were designed for inside the box, which included the area from 42nd to 57th streets, between 6th Avenue and 3rd Avenue, as well as for arterials approaching the box, as shown in Figure 1. Implementation consists of a two-stage process [13].
Figure 1 Map of MIM Study Area
3. **TWO-STAGE IMPLEMENTATION STRATEGY**

Implementation consists of a two-stage process [13]. The first stage, (Level One Control) considers travel times, which are measured by the E-ZPass tag readers. Level One only considers travel times (and measures derived from travel time, such as stops) on the avenues (north/south arterials) located within in the box. A continuous monitoring of the differences in travel times alerts the Traffic Management Center (TMC) when the system is starting to deteriorate. At this point, one of the pre-made plans may be implemented to improve traffic flow, by limiting demand entering the box. The decision to change signal timing plan is made by the operator at the TMC. The operator looks at the monitors to determine if a change is needed. Is there something blocking the vehicles, for example, a traffic accident or a car double parked is blocking traffic. In that case the operator will call police to quickly clear the location. If however there is nothing obviously blocking traffic, then the operator decides ‘yes’ that a new signal-timing plan will be implemented. The system then picks the traffic plan to be implemented. Changes are made primarily to the signal plan approaching the box and less frequently changes are made to timing plans within the box.

The second stage, (Level Two of traffic control) uses the data from the microwave sensors that have been placed midblock, 110 feet from the intersection, to get volume and occupancy levels, that are aggregated in 30-second intervals. Level Two strategy consists of queue control by making signal adjustments (dynamically adjusting splits) to balance queue storage ratios, Qr, in order to prevent spillovers due to local queuing [12].

References [13] and [14] describe in detail the complete architecture implemented in the MIM project, the algorithms used, and the metrics developed for traffic management.
D. SCOPE OF THIS PROJECT

The Adaptive Traffic Control System (ATCS) of Midtown Manhattan is an integrated application of electronic sensors, video surveillance, real time algorithms, and real-time response to maximize the efficiency and throughput of the traffic signal system. The Manhattan application of ATCS is particularly effective in reducing delay from random incidents when used to proactively remove/correct random conditions that interfere with traffic flow.

This project is about the development and application of traffic performance measures that can inform how drivers are likely to perceive changes in their driving experience from the implementation of the Adaptive Traffic Control System (ATCS) in Midtown Manhattan.

Evaluating traffic performance from the driver’s perspective requires using metrics that reflect driver’s concerns.

Using the average or median traffic speed to describe changes in traffic performance resulting from changes from ATCS policies for Midtown Manhattan, although useful when measuring network performance, it is not useful as a measure to reflect drivers’ perceptions of these changes. This is because an improvement in average or median speeds from ATCS deployment in a congested network is likely to be too small (e.g., 1 or 2 mph) and well within the range in speeds drivers experience on a daily basis (see Figure 2).
Figure 2: Vehicle Speeds on Third Avenue, Traveling from 49th to 57th Street during the 8-10AM Peak Hours

In heavily congested street networks such as Midtown Manhattan, however, it is the stop-and-go frequency of movement that greatly upsets drivers caught in congested traffic. Therefore the number of vehicle stops and starts becomes a critical metric for evaluating the benefits from strategies aimed at reducing congestion – not only because measuring the frequency of stops to traverse a road segment actually reflect drivers’ experiences, but also because the number of stops impacts tail pipe
air pollutant emissions more so than speed. In the NCHRP Report 616 it was found that “stops” are the most important measure of quality of service to drivers (16).

E. ANALYSIS FRAMEWORK

The stop frequency metrics are developed from archived data representing pre-existing conditions (June 2011) and conditions resulting from the implemented adaptive traffic control strategies (May-June 2012, May-June 2013).

These metrics are shown for twenty avenues segments, during the peak hours of the morning (8-10am), midday (11am-1pm) and the evening (4-6pm).

In the next sections the data sources are described together with the methods used in calculating travel times, and for estimating the number of vehicle stops from real-time travel data and signal control policies along a street segment.

1. DATA SOURCES

The data that were collected during the MIM project and used by our research included data from:

- ETC (EZ-Pass Tag) Readers
- Google earth
- Records of Traffic Signal Strategy

The EZ-Pass tag readers capture individual trip travel duration and trip end time information when a vehicle is equipped with EZ-Pass device in-car and complete a journey fit the target Origin and Destination pair.

The Google Earth software is used to gather geographic information such as distance between intersections and between each origin and destination pair. An example of the distance between valid EZ Pass Tag Reader combinations is shown in Figure 13.
The Time-of-Day traffic signal plans, made available by the New York City Department of Transportation Traffic Management Center, were used to develop the time-space diagram to illustrate the progression pattern.
F. ESTIMATING THE FREQUENCY OF VEHICLE STOPS WHEN THE SEGMENT TRAVEL TIME IS KNOWN

Examples of the daily distribution of travel times collected from EZ Pass Tag Readers are shown in Figures 4, 5, and 6, for a segment of 3rd Avenue from 49th to 57th Street.

Figure 4 shows 2011 travel time data collected from June 2 to June 8 representing preexisting conditions. Figures 5 and 6 show 2012 and 2013 travel time data collected from May 26 to June 15, when the Adaptive Signal Control was operational.

Figure 4: Scatter Plot of Travel Time during the Week of June 2 to June 8 in 2011, Segment of 3rd Avenue from 49 ST to 57 Street
Figure 5: Scatter Plot of Travel Time during May 26 to June 15 in 2012, Segment of 3rd Avenue from 49 ST to 57 ST

Figure 6: Scatter Plot of Travel Time during the May 26 to June 15 in 2013, Segment of 3rd Avenue from 49 Street to 57 Street
These figures share strong commonalities in a number of areas: (1) there is a regular and predictable daily peaking of trip times, with the largest concentrated around the pm peak hours - with a varying magnitude of the daily peaks. However, within the patterns illustrated, there is great variability. This leads to radical differences on when specific plans are recommended and at which times. This variability from day to day is why the advanced technologies can make such a difference in stops and travel time for drivers; and

(2) at off-peak times of day some trips tend to take much longer than expected – this may be caused by vehicles that after entering the segment they park (or wait to serve customers) or are searching for a curb parking space within the segment before exiting the segment – an issue that will be addressed in the discussion of “outliers” (Step#3).

The overall distribution of travel times (including the sum total all days sampled) for three sample years (2011, 2012, and 2013) is shown in Figures 7-9. It should be noted that the hourly variability in travel times, measured by its standard deviation, is very large compared to the average value. However, this variability can be explained by travel time clusters which reflect different driving conditions – ranging from less than 100 seconds, to over 800 seconds. As shown in Step #3, the travel times in the cluster groups can be used as predictors of the number of stops involved in traversing the segment.
Figure 7: Frequency of Travel Time in June 2 – June 8 2011, Segment of 3rd. Avenue from 49 ST to 57 ST

Figure 8: Frequency of Travel Time in May 26 – Jun 15 2012, Segment of 3rd. Avenue from 49 ST to 57 ST
In order to estimate the number of stops made per vehicle on each segment, the following steps were used:

**STEP 1: SIGNAL TIMING PLANS**

Operator Logs were obtained for each intersection in the MIM study area from NYCDOT and the TMC center. The operator logs provided the signal timing plans.

The operator logs being applied in this research covers the periods of April, May and June 2013. According to the TMC logs, the Time-of-Day (TOD)* signal-timing strategies before fall 2012 are not archived in the database.

*However, the MIM Level One system does not operate signals according to a time of day pattern with fixed change times, but chooses the plan that best matches the demand during the operational hours (8am-8pm).
The operator logs obtained contain the cycle length, offset and detailed splits for the intersections in the study area (See Table 2). Based on the signal timing information, the time space diagrams were drawn.

Table 2: Example Signal Timing Plan from the TMC Logs

<table>
<thead>
<tr>
<th>Main St</th>
<th>Cross St</th>
<th>Cycle Length</th>
<th>Offset</th>
<th>S1</th>
<th>Amber</th>
<th>AR</th>
<th>S2</th>
<th>Am</th>
<th>AR</th>
<th>TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 AVE</td>
<td>49 ST</td>
<td>90</td>
<td>66 34</td>
<td>3</td>
<td>2 46</td>
<td>3</td>
<td>2</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 AVE</td>
<td>50 ST</td>
<td>90</td>
<td>73 40</td>
<td>3</td>
<td>2 40</td>
<td>3</td>
<td>2</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 AVE</td>
<td>51 ST &amp; 52 ST</td>
<td>90</td>
<td>80 48</td>
<td>3</td>
<td>4 30</td>
<td>0</td>
<td>5</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 AVE</td>
<td>51 ST</td>
<td>90</td>
<td>80 45</td>
<td>3</td>
<td>7 30</td>
<td>3</td>
<td>2</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 AVE</td>
<td>52 ST</td>
<td>90</td>
<td>88 49</td>
<td>3</td>
<td>2 31</td>
<td>3</td>
<td>2</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 AVE</td>
<td>53 ST</td>
<td>90</td>
<td>5 36</td>
<td>3</td>
<td>2 44</td>
<td>3</td>
<td>2</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 AVE</td>
<td>54 ST</td>
<td>90</td>
<td>11 36</td>
<td>3</td>
<td>2 44</td>
<td>3</td>
<td>2</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 AVE</td>
<td>55 ST</td>
<td>90</td>
<td>18 47</td>
<td>3</td>
<td>2 33</td>
<td>3</td>
<td>2</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 AVE</td>
<td>56 ST</td>
<td>90</td>
<td>24 45</td>
<td>3</td>
<td>2 35</td>
<td>3</td>
<td>2</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 AVE</td>
<td>57 ST</td>
<td>90</td>
<td>24 35</td>
<td>3</td>
<td>9 38</td>
<td>3</td>
<td>2</td>
<td>101</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: TP 101 is for Mon-Fri 8pm to 8am.
**STEP 2: TIME-SPACE DIAGRAM**

The adaptive signal system in Midtown-In-Motion project adopts time-space diagrams to relate stops to travel time. The number of stops corresponding to the median travel time value (of a 15 minutes rolling window) contributes to control level [14]. In this study, we specifically categorize each and every vehicle trip captured into an equivalent number of red traffic signals stop.

Time space diagrams were then created for each avenue segment in the study area. Table 3 lists each of the segments in the MIM study area.

**Table 3: Segments in the MIM Study Area for Which Data are Collected**

<table>
<thead>
<tr>
<th>3rd Avenue from 42nd to 49th Streets</th>
<th>3rd Avenue from 49th to 57th Streets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lexington Avenue from 57th to 49th Streets</td>
<td>Lexington Avenue from 49th to 42nd Streets</td>
</tr>
<tr>
<td>Madison Avenue from 42nd to 49th Streets</td>
<td>Madison Avenue from 49th to 57th Streets</td>
</tr>
<tr>
<td>5th Avenue from 57th to 49th Streets</td>
<td>5th Avenue from 49th to 42nd Streets</td>
</tr>
<tr>
<td>6th Avenue from 42nd to 49th Streets</td>
<td>6th Avenue from 49th to 57th Streets</td>
</tr>
</tbody>
</table>

Figure 10 shows an example time-space diagram of for 3rd Avenue from 49th street to 57th Street. Using the time space diagrams, estimates of the minimum and maximum travel time on each segment were determined.
Figure 10: Time-Space Diagram for 3rd Avenue from 49th Street to 57th Street
**STEP 3: FINDING TRAVEL TIME BOUNDARIES**

The time-space diagrams are used to determine the minimum and maximum travel time in the same manner for each of segments. After having the minimum and maximum travel time, the mid-point value between the maximum travel time value for n number of stops and the minimum travel time value for n+1 number of stops is adopted as the boundaries that normalize all vehicles’ travel time into equivalent number of red signal stops. Table 5 summarizes the analysis results for the same segment, 3rd Avenue from 49th Street to 57th Street.

**Table 4: Boundary Values for 3rd Avenue from 49th Street to 57th Street**

<table>
<thead>
<tr>
<th>NUMBER OF RED SIGNAL STOPS</th>
<th>FINAL TRAVEL TIME RANGE (second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZERO</td>
<td>24</td>
</tr>
<tr>
<td>ONE</td>
<td>95</td>
</tr>
<tr>
<td>TWO</td>
<td>185</td>
</tr>
<tr>
<td>THREE</td>
<td>275</td>
</tr>
<tr>
<td>FOUR</td>
<td>365</td>
</tr>
<tr>
<td>FIVE</td>
<td>455</td>
</tr>
<tr>
<td>SIX</td>
<td>545</td>
</tr>
<tr>
<td>SEVEN</td>
<td>635</td>
</tr>
<tr>
<td>EIGHT</td>
<td>725</td>
</tr>
<tr>
<td>NINE</td>
<td>815</td>
</tr>
<tr>
<td>TEN</td>
<td>905</td>
</tr>
<tr>
<td>ELEVEN &amp; MORE</td>
<td>995</td>
</tr>
<tr>
<td></td>
<td>1800</td>
</tr>
</tbody>
</table>

**Outliers**

The EZ Pass data source made available for this project does not contain trips longer 30 minutes. Within this set of trips we cleaned the data further:

(1) To eliminate suspiciously low travel times, twice the speed limit value has been adopted as the lower limit (in our example location, this criterion is 24 seconds). Further study reveals that the proportion of low travel time outliers is less than one percent.
(2) Aside from low travel time outliers, other outliers include excessively long travel times resulting from stops along the way to pick up and drop off people or goods, short-term loading and unloading, time spent searching for curb parking space, etc. These activities will lead to abnormally longer travel time. In these cases, the maximum number of red signal stops is introduced as the upper bar separating acceptable and unacceptable travel times. The method to determine maximum number of equivalent red signal stops is described below. In our example location, the maximum number of stops is ten stops, which makes the threshold 995 seconds (16.6 minutes). Thus, for the above cited reasons, trips that have travel time more than 995 seconds were excluded from the data set used in further calculation for segment of 3 AV from 49 ST to 57 ST.

**STEP 4. CALCULATING THE MAXIMUM NUMBER OF STOPS**

The maximum number of stops per block is calculated by determining the maximum queue length (N) on each link in the segment and dividing by the capacity in vehicles per cycle (N/c) that can be processed at the downstream intersection. Then a total sum is found for the segment. Thus the road segment’s physical maximum vehicle queue length and the maximum queue length the downstream intersection can discharge in one cycle are examined.

Equation 1 and Equation 2 show the formula to calculate the road segment’s physical maximum vehicle queue length and the maximum queue discharge rate, respectively.

**Equation 1**

\[ N = \frac{L}{L_p} \]
Equation 2

\[ c = s \times g = s \times (G + Y + AR - l_1 - l_2) = s \times (G - l_1 + s) \]

Where:

- \( N \) is the road segment’s physical maximum vehicle queue length, \( \text{in} \);
- \( L \) is Link Length, is distance a vehicle traveled from upstream intersection to of the road segment downstream intersection, \( \text{ft} \);
- \( L_v \) is average vehicle length, the default value is \( \text{veh} \);
- \( c \) is the capacity of the downstream intersection in vehicles/cycle;
- \( l_1 \) is the start-up lost time, the default value is \( \text{sec} \);
- \( s \) is the saturation flow rate, the value adopted is \( \text{veh} / \text{hr} \);
- \( \sigma \) is the encroachment of vehicles into yellow and all-red, the value adopted is \( \text{veh} / \text{hr} \).

Notice that most segments include one or more signalized intersection(s) between the entry (upstream) and exit (downstream) intersections, the total number of maximum possible stops is the aggregation of all the signalized intersections. One, two or three buffer cycle(s) might be added to the maximum number of stops per segment during the calculation process. The decision whether or not to add buffer cycle(s) is based on the geographical information of the road and the travel time frequency tables showing extra needed cycles. Additionally the implementation of level 2 control would deduct or add extra waiting time by adding more or less green time to the main phase.

**STEP 5: APPLY BOUNDARY VALUES IN DATA**

After computing the theoretical number of red signal stop boundaries, the results are applied to each data sample collected from the ETC readers. The cluster characteristics are obtained from the EZ-Pass data and as seen in Figure 12. In
addition, these frequency charts show the computed travel time boundaries from the methodology shown here as vertical lines with the boundaries labeled on the tops of each chart. It can be seen in these charts that the computed travel time boundaries fit very well with the cluster characteristics. Additional EZ Pass travel time data categorized by our calculated boundaries are available in APPENDIX A.

The travel time boundaries were calculated based on Spring 2013 signal timing (Figure 11) plans, and they fit very well for 2012 (Figure 2) and 2011 (Figure 13) data – even with the fact that the 2011 data was very limited. These data include trip samples from a 24 hour day, for the days indicated.

Figure 11: 2013 Travel Time Data Clusters and Travel Time Boundaries per Stop
Figure 12: 2012 Travel Time Data Clusters and Travel Time Boundaries per Stop
Figure 13: 2011 Travel Time Data Clusters and Travel Time Boundaries per Stop
G. USING STOP FREQUENCY TO MEASURE THE EFFECT OF TRAFFIC CONTROL POLICIES ON DRIVERS

Absent actual feedback from drivers, and after reviewing the stop frequency distributions for the three peak periods in each of the 20 analysis sections, we have assumed that having to stop four or more times in traversing an avenue segment (42nd – 49th or 49th-57th streets) would constitute the threshold of annoyance for most drivers traveling within the Manhattan CBD. Assuming this criterion, therefore, the goal of adaptive signal control is to minimize the number of drivers that fall in this category.

For each of the 20 avenue segments the frequency distribution of traffic stops was calculated for three time periods: 8-10 am; 11am – 1pm; and 4-6pm. The set of figures in Appendix B show the cumulative distribution of vehicles stop frequencies for the weekdays sampled in 2011, 2012, and 2013, and for 20 avenue segments. This appendix summarizes the results of the stop frequency analysis for the 20 avenue segments, for the three sample years, and for the three time periods. In total there are 30 graphs illustrating the cumulative distribution of stops.

The 5 weekdays in 2011 (June 2-8), represent the traffic conditions before the ATCS deployment, while the 43 weekdays (May1 – June30) in 2012, and the 42 weekdays in (May 1 - June 19) in 2013 represent traffic conditions during ATCS operations.

Although the sampled days for 2011, were only five (and subject to possible bias conditions), the number of vehicle trips sampled for each of the three time periods (8-10am, 11am- 1pm, 4-6pm) was large enough (at least 500 trips) to yield representative traffic condition for the five weekdays. For this reason observed differences in the metrics of the “before” and “after” conditions provide only
anecdotal insights and should not be regarded statistically valid. These observations are summarized below for the 2011, 2012 and 2013.

1. ANECDOTAL INSIGHTS

- There is no uniformity in the results: comparing 2011 stop frequency data with those resulting after ATCS implementation (2012 and 2013), the percent of vehicles stopping four or more times decreases at some locations and times (e.g., Third Ave. between 49 and 57 streets, 8-10am) and increases at other locations and times (e.g., Madison Avenue, between 49 and 57 streets, 4-6 pm).

- Although the key advantage of ATCS is in its pro-active behavior of expediting interventions that minimize the impacts of incidents, these events were not readily accessible for consideration in the analysis.

2. STATISTICAL INSIGHTS

As noted earlier, the 2012 and 2013 data are more representative of average weekday conditions throughout the year. For this reason the following observations represent objective statements of the similarities and differences between these two implementation years.

- There are significant similarities (e.g., 6th Avenue from 49th to 57th Street, midday peak period) and significant differences (e.g., Madison Avenue from 49th Street to 57 Street, pm peak) in the proportion of travelers stopping four or more times between 2012 and the 2013. Locations exhibiting different outcomes would require a site-specific review of the factors that contributed to these differences.

- The vehicle stop frequency distributions for the 20 segments reveal a number of similarities and differences between the 2012 and 2013
deployment years. Absent external events and assuming the same level of ATCS deployment in 2012 as in 2013, similar stop frequency distributions between the two years are to be expected at every location and time period.

- Locations with different stop frequency distributions in 2012 and 2013 would require monitoring the sources of these differences such as changes in traffic volume, changes in street capacity, or changes in ATCS deployment strategies. Factors such as street repairs, drivers adherence in not blocking traffic at the “gridlock box,” loading/unloading from the moving lanes, traffic and parking enforcement practices, changes in demand volume, changes in traffic management strategies, etc., they all impact on traffic performance and may mask the effect of a technology change in traffic control.

- It is necessary to distinguish between the evaluation of the traffic efficiency enabled by the traffic control technology, per se, and the evaluation of traveler benefits as the technology is deployed in specific driving environments. For example, we would expect that applying ATCS in a suburban low-density environment would yield substantial driver benefits in the form of reduced delays. But when the same technology is applied in a very dense network where competition for streets space among a multiplicity of users is very intense, the efficiencies brought about an advanced technology may not be as effective in reducing traveler delay.

- In these cases ATCS implementation needs to be coordinated with the deployment of active traffic enforcement to regulate street use and with effective training programs for traffic police and enforcement personnel.
H. APPLYING STOP METRICS AS AN EVALUATION TOOL

Using 2013 data, Figures 14–17 display the proportion of drivers stopping four or more times while traveling avenue segments bounded by 42-49 Streets, and 49-57 Streets. It can be seen that the proportion of vehicles stopping four times or more ranges from about 3% in the midday peak hours on the Lexington Ave. segment between 42 and 49 Streets, to 55% in the pm peak hours on the 3rd Avenue segment between 49 and 57 Street. This stop metric is seen to vary not only by time period, but also by location. The most congested sections for the three northbound avenues are from 49th street to 57th Street – reflecting the influence of the Ed Koch (59th Street) Bridge that often creates traffic queues extending into “gridlock” boxes.
Figure 14: Percent of Vehicles Stopped Four Times or More – Third Avenue, Madison Avenue, and Sixth Avenues between 42nd and 49th Streets
Figure 15: Percent of Vehicles Stopped Four Times or More – Third, Madison, and Sixth Avenues, between 49th and 57th Street
Figure 16: Percent of Vehicles Stopped Four or More Times – Lexington and Fifth Avenues, between 57th and 49th Streets
Figure 17: Percent of Vehicles Stopped Four Times or More – Lexington and Fifth Avenues, between 49th and 42nd Streets

1. NORTHBOUND AVENUES: Third, Madison, Sixth

Drivers experience higher congestion when traveling from 49th to 57th Street than when traveling from 42nd to 49th Street. This is largely attributable to the influence of the Ed Koch (59th Street) Bridge that at times creates traffic queues extending into the “gridlock” boxes. This difference is most noticeable in the AM for Madison Ave. (from 10%, between 42nd and 49th Streets, to 30% from 49th to
57th Street); and in the PM for 3rd Ave. (from 8%, between 42nd and 49th Streets, to 55% from 49th and 57th Street).

2. SOUTHBOUND AVENUES: Lexington and Fifth

The delay pattern for southbound travelers is similar to that of northbound travelers: drivers experience higher congestion when traveling from 57th to 49th Street than from 49th to 42nd Street. This difference is most pronounced in the AM for Lexington Ave. (from 41% to 11%); and in the PM for 5th Ave. (from 27% 8%).

I. RELATIONSHIP BETWEEN TRAFFIC SPEED AND THE PROPORTION OF DRIVERS STOPPING FOUR OR MORE TIMES

Although aggregate traffic speed metrics are inadequate when used to quantify drivers’ benefits resulting from a change in traffic control strategies in a congested network, it is possible to convert the speed metric into a stopped frequency metric involving individual drivers.

Figure 18 show that there is a relationship between traffic speed and the proportion of drivers that stop four or more times to travel the segment.

For example, using estimates from Figure 18, it may be seen that a (congested) average speed of 5mph implies that 25% of the drivers are required to stop four or more times as they travel the avenue segments. Therefore an increase in average traffic speed from 5mph to 6mph, while not a perceivable speed change by drivers, can be translated into a metric that drivers perceive: in this case a one mph speed increase reduces the percentage of vehicles stopping four or more times from approximately 25% to 10%.
Figure 2: Relationship Between Traffic Speed and the Proportion of Drivers Stopping Four Times or More
J. CONCLUSIONS

Four key points that have emerged from this project:

1. The average speed or median traffic speed describes the speed for the period of interest of the average or middle vehicle in the network. Where a change in traffic control strategies produces a small change in average or median speed such that its value lies within the range of speeds of all vehicles in the street segment (see Figure 2), the average or median speed cannot be used to measure speed changes that drivers can perceive.

2. Using the stop frequency metric at the road segment level allows for a better descriptor of drivers’ experience. This research has shown that it is possible to use the network metric of speed to estimate the traveler-oriented metrics of stop frequency.

3. To evaluate drivers’ benefits from a change in traffic control strategies it is necessary to collect sufficient data of the “before conditions”. Using a limited number of “before” days we were able to provide only anecdotal insights on network performance changes: the ATCS deployment has reduced excessive stopping frequencies (four or more) for some segments, while others remained unchanged or had a worse performance (see Appendix B).

4. In evaluating the traffic impact of a specific change in traffic control strategy it is important to identify and monitor the external variables that may affect the results. From the two ATCS deployment years (2012 and 2013), it can be seen that traffic performance in a dense network can vary by year, by location, and by time period. (Appendix B). The causes of this variability need to be identified so that those factors that constrain the potential efficiency of the ATCS can be explained or mitigated.
K. REFERENCES


TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 3 AV, FROM: 42 ST, EXIT: 49 ST, PERIOD: 2012_MAY26-JUN15, WEEK: WEEKDAYS

EIGHT-STOPs
Mean = 759.07
Std. Dev. = 25.239
N = 167

FIVE-STOPs
Mean = 495.43
Std. Dev. = 24.912
N = 451

FOUR-STOPs
Mean = 402.47
Std. Dev. = 24.688
N = 688

NON-STOP
Mean = 57.68
Std. Dev. = 11.749
N = 16,377

ONE-STOP
Mean = 131.96
Std. Dev. = 20.325
N = 14,090

SEVEN-STOPs
Mean = 679.07
Std. Dev. = 26.333
N = 205

SIX-STOPs
Mean = 587.44
Std. Dev. = 25.15
N = 338

THREE-STOPs
Mean = 309.08
Std. Dev. = 21.329
N = 1,670

TWO-STOPs
Mean = 219.6
Std. Dev. = 19.717
N = 5,568
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 3 AV, FROM: 42 ST, EXIT: 49 ST, PERIOD: 2013_MAY26-JUN15, WEEK: WEEKDAYS

NUMBER OF EQUIVALENT RED SIGNAL STOPS

EIGHT-STOPS
Mean = 761.69
Std. Dev. = 23.821
N = 164

FIVE-STOPS
Mean = 490.43
Std. Dev. = 22.44
N = 494

FOUR-STOPS
Mean = 402.25
Std. Dev. = 22.803
N = 804

NON-STOP
Mean = 56.5
Std. Dev. = 11.777
N = 15,108

ONE-STOP
Mean = 128.52
Std. Dev. = 19.377
N = 13,072

SEVEN-STOPS
Mean = 670.37
Std. Dev. = 23.79
N = 273

SIX-STOPS
Mean = 583.04
Std. Dev. = 23.321
N = 350

THREE-STOPS
Mean = 312.63
Std. Dev. = 21.247
N = 1,692

TWO-STOPS
Mean = 220.49
Std. Dev. = 20.28
N = 4,033
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 3 AV, FROM: 49 ST, EXIT: 57 ST, PERIOD: 2011_JUN2-JUN8, WEEK: WEEKDAYS
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 3 AV, FROM: 49 ST, EXIT: 57 ST, PERIOD: 2013_MAY26-JUN15, WEEK: WEEKDAYS

<table>
<thead>
<tr>
<th>NUMBER_OF_EQUIVALENT_RED_SIGNAL_STOPS</th>
<th>FREQUENCY_PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIGHT_STOPS</td>
<td>8%</td>
</tr>
<tr>
<td>FIVE_STOPS</td>
<td>6%</td>
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<tr>
<td>ONE_STOP</td>
<td>4%</td>
</tr>
<tr>
<td>SEVEN_STOPS</td>
<td>2%</td>
</tr>
<tr>
<td>SIX_STOPS</td>
<td>2%</td>
</tr>
<tr>
<td>TEN_STOPS</td>
<td>2%</td>
</tr>
<tr>
<td>THREE_STOPS</td>
<td>2%</td>
</tr>
<tr>
<td>TWO_STOPS</td>
<td>2%</td>
</tr>
</tbody>
</table>

TRAVEL_TIME

Mean: 771.29
Std. Dev.: 18.779
N = 392

FIVE_STOPS
Mean: 498.3
Std. Dev.: 17.982
N = 1476

FOUR_STOPS
Mean: 438.43
Std. Dev.: 16.732
N = 2,467

NINE_STOPS
Mean: 899.41
Std. Dev.: 19.227
N = 337

NON_STOP
Mean: 63.1
Std. Dev.: 8.612
N = 15,716

ONE_STOP
Mean: 136.17
Std. Dev.: 14.667
N = 19,045

SEVEN_STOPS
Mean: 679.66
Std. Dev.: 18.256
N = 629

SIX_STOPS
Mean: 586.03
Std. Dev.: 16.131
N = 892

TEN_STOPS
Mean: 980.73
Std. Dev.: 19.59
N = 208

THREE_STOPS
Mean: 319.47
Std. Dev.: 16.567
N = 3,006

TWO_STOPS
Mean: 224.62
Std. Dev.: 16.451
N = 7,624
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 5 AV, FROM: 49 ST, EXIT: 42 ST, PERIOD: 2011_JUN2-JUN8, WEEK: WEEKDAYS

NUMBER_OF_EQUIVALENT_RED_SIGNAL_STOPS

<table>
<thead>
<tr>
<th>STOP</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIGHT-STOP</td>
<td>759.6</td>
<td>24.37</td>
<td>88</td>
</tr>
<tr>
<td>FIVE-STOP</td>
<td>477.65</td>
<td>20.23</td>
<td>419</td>
</tr>
<tr>
<td>FOUR-STOP</td>
<td>388.85</td>
<td>19.69</td>
<td>1,121</td>
</tr>
<tr>
<td>THREE-STOP</td>
<td>298.93</td>
<td>19.113</td>
<td>2,851</td>
</tr>
<tr>
<td>TWO-STOP</td>
<td>212.1</td>
<td>18.916</td>
<td>6,171</td>
</tr>
<tr>
<td>ONE-STOP</td>
<td>127.35</td>
<td>17.403</td>
<td>10,073</td>
</tr>
<tr>
<td>SEVEN-STOP</td>
<td>699.24</td>
<td>21.429</td>
<td>145</td>
</tr>
<tr>
<td>SIX-STOP</td>
<td>569.4</td>
<td>22.141</td>
<td>219</td>
</tr>
<tr>
<td>TEN-STOP</td>
<td>932.61</td>
<td>22.881</td>
<td>71</td>
</tr>
</tbody>
</table>

Frequency Percent
0% 1% 2% 3% 4% 5% 6%
0s 50s 100s 150s 200s 250s 300s 350s 400s 450s 500s 550s 600s 650s 700s 750s 800s 850s 900s 950s 1,000s 1,050s 1,100s 1,150s 1,200s
TRAVEL_TIME
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 5 AV, FROM: 49 ST, EXIT: 42 ST, PERIOD: 2012_MAY26-JUN15, WEEK: WEEKDAYS
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 5 AV, FROM: 57 ST, EXIT: 49 ST, PERIOD: 2011_JUN2-JUN8, WEEK: WEEKDAYS

NUMBER_OF_EQUVALENT_RED_SIGNAL_STOPS

- EIGHT-STOPS
  - Mean: 757.05
  - Std. Dev.: 26.358
  - N = 63

- FIVE-STOPS
  - Mean: 490.03
  - Std. Dev.: 24.022
  - N = 423

- FOUR-STOPS
  - Mean: 394.26
  - Std. Dev.: 23.939
  - N = 782

- THREE-STOPS
  - Mean: 300.93
  - Std. Dev.: 23.699
  - N = 1,412

- TWO-STOPS
  - Mean: 213.87
  - Std. Dev.: 22.163
  - N = 2,776

NON-STOP

- Mean: 863.71
- Std. Dev.: 27.492
- N = 48

ONE-STOPS

- Mean: 124.66
- Std. Dev.: 19.896
- N = 4,793

SEVEN-STOPS

- Mean: 603.02
- Std. Dev.: 24.834
- N = 97

SIX-STOPS

- Mean: 572.29
- Std. Dev.: 23.991
- N = 182

TEN-STOPS

- Mean: 934.97
- Std. Dev.: 27.461
- N = 32

THREE-STOPS

- Mean: 300.93
- Std. Dev.: 23.699
- N = 1,412

TWO-STOPS

- Mean: 213.87
- Std. Dev.: 22.163
- N = 2,776

TRAVEL_TIME

Frequency Percent

0% 1% 2% 3% 4% 5%
0s 50s 100s 150s 200s 250s 300s 350s 400s 450s 500s 550s 600s 650s 700s 750s 800s 850s 900s 950s 1,000s 1,050s 1,100s 1,150s 1,200s
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 5 AV, FROM: 57 ST, EXIT: 49 ST, PERIOD: 2012_MAY26-JUN15, WEEK: WEEKDAYS
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 5 AV, FROM: 57 ST, EXIT: 49 ST, PERIOD: 2013_MAY26-JUN15, WEEK: WEEKDAYS

<table>
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<tr>
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<th>EIGHT-STOPS</th>
<th>FIVE-STOPS</th>
<th>FOUR-STOPS</th>
<th>THREE-STOPS</th>
<th>TWO-STOPS</th>
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<tbody>
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<td>Mean</td>
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<td>481.00</td>
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<td>Mean</td>
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<table>
<thead>
<tr>
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<tr>
<td>Mean</td>
<td>570.52</td>
</tr>
<tr>
<td>Std. Dev.</td>
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<td>Std. Dev.</td>
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TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS - DATA COLLECTED BY EZPASS TAG READERS

AT: 6 AV, FROM: 42 ST, EXIT: 49 ST, PERIOD: 2011_JUN2-JUN8, WEEK: WEEKDAYS

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<th>ONE-STOP</th>
<th>FIVE-STOP</th>
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<tr>
<td>EIGHT-STOP</td>
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TRAVEL_TIME

Frequency Percent

0% 2% 4% 6%

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TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS -DATA COLLECTED BY EZPASS TAG READERS


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<tr>
<th>NUMBER OF EQUIVALENT RED_SIGNAL_STOPS</th>
<th>EIGHT-STOP</th>
<th>FIVE-STOP</th>
<th>FOUR-STOP</th>
<th>ONE-STOP</th>
<th>NON-STOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>756.46</td>
<td>483.24</td>
<td>392.00</td>
<td>121.59</td>
<td>52.45</td>
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<tr>
<td>Std. Dev.</td>
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<td>23.724</td>
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<td>15.801</td>
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<td>381</td>
<td>14,110</td>
<td>10,089</td>
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<th>Std. Dev.</th>
<th>N</th>
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TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


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<td>FIVE-STOP</td>
<td>Mean = 480</td>
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<tr>
<td>FOUR-STOP</td>
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<td>Std. Dev. = 22.029</td>
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Frequency Percent

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<td>100s</td>
<td>150s</td>
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TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


TRAVEL_TIME

0s  50s  100s  150s  200s  250s  300s  350s  400s  450s  500s  550s  600s  650s  700s  750s  800s  850s  900s  950s  1,000s  1,050s  1,100s  1,150s  1,200s

Frequency Percent

0%  1%  2%  3%  4%  5%

NUMBER_OF
EQUIVALENT_RED_SIGNAL_STOPS

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<tr>
<th>Category</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>N</th>
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<tr>
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<tr>
<td>FIVE-STOPS</td>
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<td>215.67</td>
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TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


NUMBER OF EQUIVALENT RED SIGNAL STOPS

- EIGHT-STOPS
  - Mean = 759.01
  - Std. Dev. = 23.83
  - N = 236

- ELEVEN-STOPS
  - Mean = 1027.38
  - Std. Dev. = 23.927
  - N = 153

- FIVE-STOPS
  - Mean = 489.98
  - Std. Dev. = 21.543
  - N = 888

- FOUR-STOPS
  - Mean = 352.45
  - Std. Dev. = 21.451
  - N = 1,435

- NINE-STOPS
  - Mean = 947.08
  - Std. Dev. = 23.979
  - N = 173

- NON-STOP
  - Mean = 54.72
  - Std. Dev. = 10.515
  - N = 6,479

- ONE-STOP
  - Mean = 127.81
  - Std. Dev. = 18.547
  - N = 9,829

- SEVEN-STOPS
  - Mean = 660.72
  - Std. Dev. = 21.554
  - N = 334

- SIX-STOPS
  - Mean = 575.1
  - Std. Dev. = 20.904
  - N = 576

- TEN-STOPS
  - Mean = 937.75
  - Std. Dev. = 23.768
  - N = 174

- THREE-STOPS
  - Mean = 302.92
  - Std. Dev. = 20.776
  - N = 2,825

- TWO-STOPS
  - Mean = 21.6
  - Std. Dev. = 21.11
  - N = 1,150

TRAVEL_TIME
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


NUMBER OF EQUIVALENT RED SIGNAL STOPS

EIGHT-STOPS
Mean = 753.24
Std. Dev. = 20.674
N = 233

ELEVEN-STOPS
Mean = 1029.06
Std. Dev. = 21.198
N = 116

FIVE-STOPS
Mean = 481.39
Std. Dev. = 20.856
N = 846

FOUR-STOPS
Mean = 361.86
Std. Dev. = 20.451
N = 1,807

NINE-STOPS
Mean = 944.31
Std. Dev. = 18.53
N = 173

NON-STOP
Mean = 55.28
Std. Dev. = 10.197
N = 6,094

ONE-STOP
Mean = 127.12
Std. Dev. = 18.619
N = 9,987

SEVEN-STOPS
Mean = 660.31
Std. Dev. = 21.251
N = 316

SIX-STOPS
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Std. Dev. = 21.692
N = 474

TEN-STOPS
Mean = 939.89
Std. Dev. = 21.407
N = 126

THREE-STOPS
Mean = 301.69
Std. Dev. = 19.857
N = 4,193

TWO-STOPS
Mean = 215.92
Std. Dev. = 13.23
N = 1
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: LEXINGTON AV, FROM: 49 ST, EXIT: 42 ST, PERIOD: 2011_JUN2-JUN8, WEEK: WEEKDAYS

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<th>Frequency Percent</th>
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<td>FOUR-STOP</td>
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<td>ONE-STOP</td>
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<tr>
<td>NINE-STOP</td>
<td>2%</td>
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<tr>
<td>NON-STOP</td>
<td>1%</td>
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- EIGHT-STOPS
  - Mean = 759.34
  - Std. Dev. = 25.185
  - N = 109

- FIVE-STOPS
  - Mean = 480.72
  - Std. Dev. = 23.81
  - N = 337

- FOUR-STOPS
  - Mean = 385.02
  - Std. Dev. = 23.143
  - N = 995

- ONE-STOP
  - Mean = 121.93
  - Std. Dev. = 19.246
  - N = 9,705

- SEVEN-STOPS
  - Mean = 665.21
  - Std. Dev. = 24.852
  - N = 177

- SIX-STOPS
  - Mean = 572.88
  - Std. Dev. = 24.341
  - N = 229

- THREE-STOPS
  - Mean = 292.5
  - Std. Dev. = 20.896
  - N = 2,266

- TWO-STOPS
  - Mean = 204.35
  - Std. Dev. = 21.367
  - N = 8,543
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: LEXINGTON AV, FROM: 49 ST, EXIT: 42 ST, PERIOD: 2013_MAY26-JUN15, WEEK: ...

NUMBER OF EQUIVALENT RED SIGNAL STOPS

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<th>Std. Dev.</th>
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Frequency Percent

TRAVEL_TIME

0s  50s  100s  150s  200s  250s  300s  350s  400s  450s  500s  550s  600s  650s  700s  750s  800s  850s  900s  950s  1,000s  1,050s  1,100s  1,150s
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


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<th>Five-Stops</th>
<th>One-Stops</th>
<th>Seven-Stops</th>
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<td>315.36</td>
<td>22.115</td>
<td></td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>22.976</td>
<td>24.904</td>
<td>24.904</td>
<td>5,051</td>
<td>5,051</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>2,115</td>
<td>2,115</td>
<td>2,115</td>
<td>2,115</td>
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</tr>
</tbody>
</table>

0s, 50s, 100s, 150s, 200s, 250s, 300s, 350s, 400s, 450s, 500s, 550s, 600s, 650s, 700s, 750s, 800s, 850s, 900s, 950s, 1,000s, 1,050s, 1,100s, 1,150s, 1,200s

Frequency Percent
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: LEXINGTON AV, FROM: 57 ST, EXIT: 49 ST, PERIOD: 2012_MAY26-JUN15, WEEK: ...

<table>
<thead>
<tr>
<th>NUMBER_OF_EQUIVALENT_RED_SIGNAL_STOPS</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIGHT-STOPS</td>
<td>763.46</td>
<td>23.092</td>
<td>280</td>
</tr>
<tr>
<td>FIVE-STOPS</td>
<td>493.48</td>
<td>21.064</td>
<td>1,209</td>
</tr>
<tr>
<td>FOUR-STOPS</td>
<td>425</td>
<td>20.76</td>
<td>2,050</td>
</tr>
<tr>
<td>NINE-STOPS</td>
<td>866.73</td>
<td>23.2</td>
<td>180</td>
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<tr>
<td>NON-STOP</td>
<td>63.47</td>
<td>13.888</td>
<td>13,298</td>
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<tr>
<td>ONE-STOP</td>
<td>137.88</td>
<td>18.372</td>
<td>20,528</td>
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<tr>
<td>SEVEN-STOPS</td>
<td>674.69</td>
<td>21.195</td>
<td>398</td>
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<tr>
<td>SIX-STOPS</td>
<td>583.29</td>
<td>22.093</td>
<td>664</td>
</tr>
<tr>
<td>TEN-STOPS</td>
<td>945.43</td>
<td>22.813</td>
<td>152</td>
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<tr>
<td>THREE-STOPS</td>
<td>313.4</td>
<td>21.204</td>
<td>3,449</td>
</tr>
<tr>
<td>TWO-STOPS</td>
<td>221.37</td>
<td>20.081</td>
<td>9,300</td>
</tr>
</tbody>
</table>
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: LEXINGTON AV, FROM: 57 ST, EXIT: 49 ST, PERIOD: 2013_MAY26-JUN15, WEEK: ...
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: MADISON AV, FROM: 42 ST, EXIT: 49 ST, PERIOD: 2011_JUN2-JUN8, WEEK: WEEKDAYS

<table>
<thead>
<tr>
<th>NUMBER OF EQUIVALENT RED SIGNAL STOPS</th>
<th>Frequency Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIGHT-STOPST</td>
<td>6%</td>
</tr>
<tr>
<td>FIVE-STOPST</td>
<td>5%</td>
</tr>
<tr>
<td>FOUR-STOPST</td>
<td>4%</td>
</tr>
<tr>
<td>THREE-STOPST</td>
<td>3%</td>
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<tr>
<td>TWO-STOPST</td>
<td>2%</td>
</tr>
<tr>
<td>ONE-STOPST</td>
<td>1%</td>
</tr>
<tr>
<td>NON-STOPST</td>
<td>0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STOPST TYPE</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIGHT-STOPST</td>
<td>743.29</td>
<td>26.217</td>
<td>17</td>
</tr>
<tr>
<td>FIVE-STOPST</td>
<td>490.23</td>
<td>23.967</td>
<td>30</td>
</tr>
<tr>
<td>FOUR-STOPST</td>
<td>360.35</td>
<td>25.252</td>
<td>71</td>
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<tr>
<td>THREE-STOPST</td>
<td>298.32</td>
<td>23.281</td>
<td>192</td>
</tr>
<tr>
<td>TWO-STOPST</td>
<td>209.36</td>
<td>24.965</td>
<td>578</td>
</tr>
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</table>
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


| NUMBER OF EQUIVALENT RED SIGNAL STOPS | EIGHT-STOP Mean = 754.16  
  |                                | Std. Dev. = 27.574  
  |                                | N = 30  
|                                  | FIVE-STOP Mean = 487.1  
|                                  | Std. Dev. = 24.92  
|                                  | N = 92  
|                                  | FOUR-STOP Mean = 393.11  
|                                  | Std. Dev. = 23.758  
|                                  | N = 132  
| NON-STOP Mean = 53.91  
| Std. Dev. = 12.521  
| N = 5,640  
| ONE-STOP Mean = 115.92  
| Std. Dev. = 19.34  
| N = 3,798  
| SEVEN-STOP Mean = 669.43  
| Std. Dev. = 27.575  
| N = 46  
| SIX-STOP Mean = 577.7  
| Std. Dev. = 26.975  
| N = 53  
| THREE-STOP Mean = 303.5  
| Std. Dev. = 21.526  
| N = 240  
| TWO-STOP Mean = 209.72  
| Std. Dev. = 21.34  
| N = 690  

TRAVEL_TIME

Frequency Percent

0% 2% 4% 6% 8% 10%
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


<table>
<thead>
<tr>
<th>NUMBER_OF_EQUIVALENT_RED_SIGNAL_STOPS</th>
<th>Frequency Percent</th>
</tr>
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<tbody>
<tr>
<td>EIGHT-STOPS</td>
<td>6%</td>
</tr>
<tr>
<td>FIVE-STOPS</td>
<td>4%</td>
</tr>
<tr>
<td>FOUR-STOPS</td>
<td>2%</td>
</tr>
<tr>
<td>NON-STOP</td>
<td>0%</td>
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<table>
<thead>
<tr>
<th>EIGHT-STOPS</th>
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<tbody>
<tr>
<td>Mean: 762.84</td>
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<tr>
<td>Std. Dev.: 26.718</td>
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<tbody>
<tr>
<td>Mean: 481.57</td>
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<tr>
<td>Std. Dev.: 24.897</td>
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<tr>
<td>N: 135</td>
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<table>
<thead>
<tr>
<th>FOUR-STOPS</th>
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<tbody>
<tr>
<td>Mean: 394.35</td>
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<tr>
<td>Std. Dev.: 23.325</td>
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<tbody>
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<td>Mean: 56.26</td>
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<tr>
<td>Std. Dev.: 12.998</td>
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<tbody>
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<td>Mean: 131.1</td>
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<td>Std. Dev.: 20.704</td>
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<table>
<thead>
<tr>
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<tr>
<td>Mean: 670.98</td>
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<td>Std. Dev.: 27.7</td>
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<table>
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<tr>
<th>SIX-STOPS</th>
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<tr>
<td>Mean: 574.97</td>
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<td>Std. Dev.: 26.152</td>
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<table>
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<tr>
<th>THREE-STOPS</th>
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<tbody>
<tr>
<td>Mean: 302.88</td>
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<td>Std. Dev.: 22.19</td>
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<tr>
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<table>
<thead>
<tr>
<th>TWO-STOPS</th>
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<tbody>
<tr>
<td>Mean: 210.62</td>
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<tr>
<td>Std. Dev.: 21.103</td>
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<tr>
<td>N: 1,535</td>
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TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


TRAVEL_TIME

NUMBER_OF_EQUIVALENT_RED_SIGNAL_STOPS

EIGHT-STOPS
Mean = 760.07
Std. Dev. = 26.04
N = 59

ELEVEN-STOPS
Mean = 1032
Std. Dev. = 22.031
N = 77

FIVE-STOPS
Mean = 465.83
Std. Dev. = 20.194
N = 250

FOUR-STOPS
Mean = 395.29
Std. Dev. = 21.296
N = 682

NINE-STOPS
Mean = 855.4
Std. Dev. = 23.999
N = 35

NON-STOP
Mean = 57.19
Std. Dev. = 10.051
N = 338

ONE-STOP
Mean = 132.6
Std. Dev. = 19.897
N = 422

SEVEN-STOPS
Mean = 671.42
Std. Dev. = 23.555
N = 53

SIX-STOPS
Mean = 572.89
Std. Dev. = 24.854
N = 98

TEN-STOPS
Mean = 941.07
Std. Dev. = 24.227
N = 28

THREE-STOPS
Mean = 304.45
Std. Dev. = 21.399
N = 1,048

TWO-STOPS
Mean = 471.01
Std. Dev. = 24.035
N = 1,203
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


TRAVEL_TIME

EIGHT-STOPS
Mean = 767.19
Std. Dev. = 21.413
N = 313

ELEVEN-STOPS
Mean = 1034.15
Std. Dev. = 22.902
N = 88

FIVE-STOPS
Mean = 487.74
Std. Dev. = 19.795
N = 1,585

FOUR-STOPS
Mean = 388.96
Std. Dev. = 19.957
N = 2,247

NINE-STOPS
Mean = 851.43
Std. Dev. = 21.799
N = 162

NON-STOP
Mean = 56.19
Std. Dev. = 10.29
N = 10,030

ONE-STOP
Mean = 129.37
Std. Dev. = 17.978
N = 9,788

SEVEN-STOPS
Mean = 698.83
Std. Dev. = 21.464
N = 482

SIX-STOPS
Mean = 576.84
Std. Dev. = 20.318
N = 988

TEN-STOPS
Mean = 938.72
Std. Dev. = 20.635
N = 135

THREE-STOPS
Mean = 309.96
Std. Dev. = 20.296
N = 3,235

TWO-STOPS
Mean = 418.20
Std. Dev. = 20.828
N = 3,853

...
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
- DATA COLLECTED BY EZPASS TAG READERS

AVENUE: 3 AV, FROM: 42 ST, EXIT: 49 ST, WEEK: WEEKDAYS, PERIOD: 2011 JUN2-JUN8

NUMBER OF EQUIVALENT RED SIGNAL STOPS
- EIGHT-STOPS
- FIVE-STOPS
- FOUR-STOPS
- NON-STOP
- ONE-STOP

EIGHT-STOPS
Mean = 770.69
Std. Dev. = 26.957
N = 108

FIVE-STOPS
Mean = 489.02
Std. Dev. = 23.231
N = 441

FOUR-STOPS
Mean = 401.49
Std. Dev. = 22.449
N = 880

NON-STOP
Mean = 59.71
Std. Dev. = 11.875
N = 6,951

ONE-STOP
Mean = 120.5
Std. Dev. = 19.32
N = 7,461

SEVEN-STOPS
Mean = 672.88
Std. Dev. = 24.988
N = 141

SIX-STOPS
Mean = 581.11
Std. Dev. = 29.59
N = 269

THREE-STOPS
Mean = 312.77
Std. Dev. = 21.464
N = 1,344

TWO-STOPS
Mean = 219.73
Std. Dev. = 21.249
N = 2,631
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 3 AV, FROM: 42 ST, EXIT: 49 ST, PERIOD: 2012_MAY26-JUN15, WEEK: WEEKDAYS

TRAVEL_TIME

- EIGHT-STOP MEAN = 759.07
- EIGHT-STOP STDEV = 25.239
- EIGHT-STOP N = 167

- FIVE-STOP MEAN = 496.43
- FIVE-STOP STDEV = 24.912
- FIVE-STOP N = 451

- FOUR-STOP MEAN = 402.47
- FOUR-STOP STDEV = 24.688
- FOUR-STOP N = 688

- NON-STOP MEAN = 57.69
- NON-STOP STDEV = 11.749
- NON-STOP N = 16,377

- ONE-STOP MEAN = 131.96
- ONE-STOP STDEV = 20.325
- ONE-STOP N = 14,000

- SEVEN-STOP MEAN = 679.07
- SEVEN-STOP STDEV = 26.333
- SEVEN-STOP N = 205

- SIX-STOP MEAN = 587.44
- SIX-STOP STDEV = 26.16
- SIX-STOP N = 338

- THREE-STOP MEAN = 359.08
- THREE-STOP STDEV = 21.329
- THREE-STOP N = 1,670

- TWO-STOP MEAN = 219.6
- TWO-STOP STDEV = 19.717
- TWO-STOP N = 5,568
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 3 AV, FROM: 42 ST, EXIT: 49 ST, PERIOD: 2013_MAY26-JUN15, WEEK: WEEKDAYS

NUMBER OF EQUIVALENT RED SIGNAL STOPS

- EIGHT-STOPs
- FIVE-STOPs
- FOUR-STOPs
- THREE-STOPs
- TWO-STOPs
- ONE-STOPs
- NON-STOPs

Frequency Percent

TRAVEL_TIME

EIGHT-STOPs
Mean = 761.69
Std. Dev. = 23.821
N = 164

FIVE-STOPs
Mean = 490.43
Std. Dev. = 22.44
N = 494

FOUR-STOPs
Mean = 402.35
Std. Dev. = 22.803
N = 804

ONE-STOPs
Mean = 59.5
Std. Dev. = 11.777
N = 15,108

NON-STOPs
Mean = 59.5
Std. Dev. = 11.777
N = 15,108

SEVEN-STOPs
Mean = 670.37
Std. Dev. = 23.79
N = 273

SIX-STOPs
Mean = 583.04
Std. Dev. = 23.321
N = 350

THREE-STOPs
Mean = 312.63
Std. Dev. = 21.247
N = 1,692

TWO-STOPs
Mean = 220.49
Std. Dev. = 20.28
N = 4,033
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL Stops
- DATA COLLECTED BY EZPASS TAG READERS

AT: 3 AV, FROM: 49 ST, EXIT: 57 ST, PERIOD: 2011_JUN2-JUN8, WEEK: WEEKDAYS

NUMBER OF EQUIVALENT RED SIGNAL Stops

- EIGHT-STOPS
- FIVE-STOPS
- FOUR-STOPS
- THREE-STOPS
- TWO-STOPS
- THREE-STOPS
- TWO-STOPS
- ONE-STOP
- NON-STOP

EIGHT-STOPS
Mean = 769.25
Std. Dev. = 19.743
N = 174

FIVE-STOPS
Mean = 498.61
Std. Dev. = 18.76
N = 650

FOUR-STOPS
Mean = 406.41
Std. Dev. = 18.575
N = 1,246

THREE-STOPS
Mean = 359.98
Std. Dev. = 18.655
N = 465

TWO-STOPS
Mean = 227.27
Std. Dev. = 22.429
N = 5,006

NON-STOP
Mean = 857.69
Std. Dev. = 22.206
N = 128

ONE-STOP
Mean = 137.71
Std. Dev. = 19.005
N = 9,902

SEVEN-STOPS
Mean = 679.63
Std. Dev. = 19.66
N = 201

SIX-STOPS
Mean = 589.52
Std. Dev. = 19.655
N = 465

TEN-STOPS
Mean = 962.98
Std. Dev. = 20.802
N = 98
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
DATA COLLECTED BY EZPASS TAG READERS

AT: 3 AV, FROM: 49 ST, EXIT: 57 ST, PERIOD: 2013_MAY26-JUN15, WEEK: WEEKDAYS

NUMBER OF EQUIVALENT RED SIGNAL STOPS

EIGHT-STOP
Mean = 771.29
Std. Dev. = 18.779
N = 392

FIVE-STOP
Mean = 498.3
Std. Dev. = 17.592
N = 1476

FOUR-STOP
Mean = 482.43
Std. Dev. = 16.732
N = 2467

THREE-STOP
Mean = 482.43
Std. Dev. = 16.732
N = 2467

TWO-STOP
Mean = 482.43
Std. Dev. = 16.732
N = 2467

ONE-STOP
Mean = 136.17
Std. Dev. = 14.697
N = 19,645

SEVEN-STOP
Mean = 679.66
Std. Dev. = 18.236
N = 629

SIX-STOP
Mean = 588.03
Std. Dev. = 16.131
N = 892

FIVE-STOP
Mean = 498.3
Std. Dev. = 17.592
N = 1476

EIGHT-STOP
Mean = 771.29
Std. Dev. = 18.779
N = 392

NON-STOP
Mean = 859.41
Std. Dev. = 19.227
N = 337

Five axes graph showing frequency percent distribution of travel time.
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 5 AV, FROM: 49 ST, EXIT: 42 ST, PERIOD: 2011_JUN2-JUN8, WEEK: WEEKDAYS

TRAVEL TIME

NUMBER OF EQUIVALENT RED SIGNAL STOPS
- EIGHT-STOP
- FIVE-STOP
- ONE-STOP
- SEVEN-STOP
- NINE-STOP
- NON-STOP

EIGHT-STOP
Mean = 759.6
Std. Dev. = 24.37
N = 88

FIVE-STOP
Mean = 477.65
Std. Dev. = 20.233
N = 419

FOUR-STOP
Mean = 389.85
Std. Dev. = 19.699
N = 1,121

NINE-STOP
Mean = 962.9
Std. Dev. = 23.96
N = 61

NON-STOP
Mean = 92.25
Std. Dev. = 11.319
N = 10,454

ONE-STOP
Mean = 127.35
Std. Dev. = 17.403
N = 10,083

SEVEN-STOP
Mean = 699.24
Std. Dev. = 21.429
N = 145

SIX-STOP
Mean = 569.4
Std. Dev. = 22.141
N = 219

TEN-STOP
Mean = 932.61
Std. Dev. = 22.881
N = 71

THREE-STOP
Mean = 239.93
Std. Dev. = 19.113
N = 2,881

TWO-STOP
Mean = 412.1
Std. Dev. = 18.916
N = 6,171

Frequency Percent

0s 50s 100s 150s 200s 250s 300s 350s 400s 450s 500s 550s 600s 650s 700s 750s 800s 850s 900s 950s 1,000s 1,050s 1,100s 1,150s 1,200s

TRAVEL_TIME
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: 5 AV, FROM: 49 ST, EXIT: 42 ST, PERIOD: 2012_MAY26-JUN15, WEEK: WEEKDAYS

NUMBER_OF_EQUVALENT_RED_SIGNAL_STOPS

- EIGHT-STOP
- FIVE-STOP
- FOUR-STOP
- THREE-STOP
- TWO-STOP
- ONE-STOP
- NON-STOP
- NINE-STOP

EIGHT-STOP
Mean = 746.57
Std. Dev. = 22.744
N = 310

FIVE-STOP
Mean = 476.28
Std. Dev. = 20.278
N = 1.035

FOUR-STOP
Mean = 387.93
Std. Dev. = 19.987
N = 2.255

THREE-STOP
Mean = 308.02
Std. Dev. = 19.35
N = 5.442

TWO-STOP
Mean = 207.71
Std. Dev. = 18.797
N = 15.185

NON-STOP
Mean = 941.95
Std. Dev. = 23.87
N = 260

ONE-STOP
Mean = 124.34
Std. Dev. = 16.43
N = 90.670

SEVEN-STOP
Mean = 660.02
Std. Dev. = 21.958
N = 440

SIX-STOP
Mean = 570.19
Std. Dev. = 21.552
N = 640

TEN-STOP
Mean = 932.14
Std. Dev. = 22.212
N = 222

0s 50s 100s 150s 200s 250s 300s 350s 400s 450s 500s 550s 600s 650s 700s 750s 800s 850s 900s 950s 1,050s 1,100s 1,150s 1,200s

TRAavel_TIME

Frequency Percent

0% 2% 4% 6%
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
DATA COLLECTED BY EZPASS TAG READERS

AT: 5 AV, FROM: 57 ST, EXIT: 49 ST, PERIOD: 2011_JUN2-JUN8, WEEK: WEEKDAYS

TRAVEL_TIME

NUMBER OF EQUIVALENT RED SIGNAL STOPS

- EIGHT-STOPS
- FIVE-STOPS
- FOUR-STOPS
- THREE-STOPS
- TWO-STOPS
- ONE-STOP
- NON-STOP
- NINE-STOPS

EIGHT-STOPS
Mean = 757.05
Std. Dev. = 26.358
N = 63

FIVE-STOPS
Mean = 480.05
Std. Dev. = 24.222
N = 423

FOUR-STOPS
Mean = 394.26
Std. Dev. = 23.999
N = 762

THREE-STOPS
Mean = 300.93
Std. Dev. = 23.099
N = 1,412

TWO-STOPS
Mean = 213.67
Std. Dev. = 22.163
N = 2,776

ONE-STOP
Mean = 124.66
Std. Dev. = 19.896
N = 4,793

NON-STOP
Mean = 52.76
Std. Dev. = 11.907
N = 3,319

NINE-STOPS
Mean = 843.71
Std. Dev. = 27.492
N = 48

0s 50s 100s 150s 200s 250s 300s 350s 400s 450s 500s 550s 600s 650s 700s 750s 800s 850s 900s 950s 1,000s 1,050s 1,100s 1,150s 1,200s

Frequency Percent

0% 1% 2% 3% 4% 5%
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS - DATA COLLECTED BY EZPASS TAG READERS

AT: 5 AV, FROM: 57 ST, EXIT: 49 ST, PERIOD: 2012_MAY26-JUN15, WEEK: WEEKDAYS

<table>
<thead>
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<th>Number of Equivalent Red Signal Stops</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIGHT-STOPS</td>
<td>749.19</td>
<td>27.12</td>
<td>186</td>
</tr>
<tr>
<td>FIVE-STOPS</td>
<td>483.89</td>
<td>24.859</td>
<td>1,001</td>
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<tr>
<td>FOUR-STOPS</td>
<td>391.96</td>
<td>24.773</td>
<td>1,719</td>
</tr>
<tr>
<td>THREE-STOPS</td>
<td>301.76</td>
<td>24.111</td>
<td>3,399</td>
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<tr>
<td>TWO-STOPS</td>
<td>212.99</td>
<td>23.974</td>
<td>5,919</td>
</tr>
<tr>
<td>ONE-STOP</td>
<td>126.67</td>
<td>22.174</td>
<td>8,520</td>
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<tr>
<td>NON-STOP</td>
<td>840.38</td>
<td>37.022</td>
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</tr>
<tr>
<td>NINE-STOPS</td>
<td>660.09</td>
<td>24.508</td>
<td>347</td>
</tr>
<tr>
<td>SIX-STOPS</td>
<td>570.7</td>
<td>24.551</td>
<td>595</td>
</tr>
<tr>
<td>TEN-STOPS</td>
<td>931.3</td>
<td>29.857</td>
<td>101</td>
</tr>
<tr>
<td>SEVEN-STOPS</td>
<td>660.09</td>
<td>24.508</td>
<td>347</td>
</tr>
</tbody>
</table>

Diagram showing the distribution of travel time across different numbers of red signal stops.
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
DATA COLLECTED BY EZPASS TAG READERS

AT: 6 AV, FROM: 42 ST, EXIT: 49 ST, PERIOD: 2011_JUN2-JUN8, WEEK: WEEKDAYS

EIGHT-STOPS
Mean = 755.69
Std. Dev. = 22.131
N = 48

FIVE-STOPS
Mean = 485.04
Std. Dev. = 23.105
N = 74

FOUR-STOPS
Mean = 389.90
Std. Dev. = 20.092
N = 155

NON-STOP
Mean = 51.38
Std. Dev. = 10.461
N = 3,583

ONE-STOP
Mean = 121.96
Std. Dev. = 15.501
N = 5,523

SEVEN-STOPS
Mean = 659.96
Std. Dev. = 23.057
N = 54

SIX-STOPS
Mean = 569.96
Std. Dev. = 21.394
N = 80

THREE-STOPS
Mean = 294.5
Std. Dev. = 19.901
N = 442

TWO-STOPS
Mean = 104
Std. Dev. = 18.733
N = 1,762

TRAVEL_TIME

Frequency Percent

0% 2% 4% 6%
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


NUMBER_OF_EQUIVALENT_RED_SIGNAL_STOPS

EIGHT-STOPS
Mean = 756.46
Std. Dev. = 23.578
N = 123

FIVE-STOPS
Mean = 483.24
Std. Dev. = 23.724
N = 260

FOUR-STOPS
Mean = 392
Std. Dev. = 21.197
N = 381

ONE-STOP
Mean = 121.59
Std. Dev. = 15.801
N = 14,110

SEVEN-STOPS
Mean = 602.89
Std. Dev. = 22.631
N = 161

SIX-STOPS
Mean = 574.05
Std. Dev. = 23.266
N = 214

THREE-STOPS
Mean = 296.05
Std. Dev. = 18.76
N = 990

TWO-STOPS
Mean = 205.13
Std. Dev. = 18.453
N = 4,336

Frequency Percent

0% 1% 2% 3% 4% 5% 6%

0s 50s 100s 150s 200s 250s 300s 350s 400s 450s 500s 550s 600s 650s 700s 750s 800s 850s 900s 950s 1,000s 1,050s 1,100s 1,150s

TRAVEL_TIME
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


NUMBER OF EQUIVALENT RED SIGNAL STOPS

- EIGHT-STOPS
  - Mean = 751.06
  - Std. Dev. = 24.68
  - N = 139

- FIVE-STOPS
  - Mean = 483
  - Std. Dev. = 25.016
  - N = 224

- FOUR-STOPS
  - Mean = 387.98
  - Std. Dev. = 22.029
  - N = 365

- THREE-STOPS
  - Mean = 298.21
  - Std. Dev. = 16.554
  - N = 1,281

- TWO-STOPS
  - Mean = 204.86
  - Std. Dev. = 17.972
  - N = 5,288

NON-STOP
- Mean = 52.71
- Std. Dev. = 10.323
- N = 9,545

ONE-STOP
- Mean = 122.81
- Std. Dev. = 15.742
- N = 15,677

SEVEN-STOPS
- Mean = 862.3
- Std. Dev. = 25.248
- N = 190

SIX-STOPS
- Mean = 574.13
- Std. Dev. = 24.911
- N = 212

THREE-STOPS
- Mean = 298.21
- Std. Dev. = 16.554
- N = 1,281

TWO-STOPS
- Mean = 204.86
- Std. Dev. = 17.972
- N = 5,288
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


![Histogram of travel time frequency by number of red signal stops]
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


NUMBER OF EQUIVALENT RED SIGNAL STOPS

<table>
<thead>
<tr>
<th>Number of Stops</th>
<th>Mean</th>
<th>Std Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eight-Stops</td>
<td>759.01</td>
<td>23.83</td>
<td>236</td>
</tr>
<tr>
<td>Eleven-Stops</td>
<td>1027.38</td>
<td>23.927</td>
<td>153</td>
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<tr>
<td>Five-Stops</td>
<td>485.98</td>
<td>21.543</td>
<td>868</td>
</tr>
<tr>
<td>Four-Stops</td>
<td>352.45</td>
<td>21.451</td>
<td>1435</td>
</tr>
<tr>
<td>Nine-Stops</td>
<td>947.08</td>
<td>23.979</td>
<td>173</td>
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<tr>
<td>Non-Stop</td>
<td>54.72</td>
<td>10.515</td>
<td>6479</td>
</tr>
<tr>
<td>One-Stop</td>
<td>127.8</td>
<td>18.547</td>
<td>9829</td>
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<tr>
<td>Seven-Stops</td>
<td>663.72</td>
<td>21.554</td>
<td>334</td>
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<tr>
<td>Six-Stops</td>
<td>575.1</td>
<td>20.904</td>
<td>576</td>
</tr>
<tr>
<td>Ten-Stops</td>
<td>937.75</td>
<td>23.768</td>
<td>174</td>
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<tr>
<td>Three-Stops</td>
<td>302.92</td>
<td>20.776</td>
<td>2855</td>
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TRAVEL_TIME

Frequency Percent

0% 1% 2% 3% 4% 5%
0s 50s 100s 150s 200s 250s 300s 350s 400s 450s 500s 550s 600s 650s 700s 750s 800s 850s 900s 950s 1,000s 1,050s 1,100s 1,150s 1,200s
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


NUMBER_OF_EQUIVALENT_RED_SIGNAL_STOPS

- EIGHT-STOPS
  - Mean = 753.24
  - Std. Dev. = 20.674
  - N = 233

- ELEVEN-STOPS
  - Mean = 1029.06
  - Std. Dev. = 21.198
  - N = 116

- FIVE-STOPS
  - Mean = 481.39
  - Std. Dev. = 20.856
  - N = 845

- FOUR-STOPS
  - Mean = 361.89
  - Std. Dev. = 20.451
  - N = 1,807

- NINE-STOPS
  - Mean = 944.31
  - Std. Dev. = 18.53
  - N = 173

- NON-STOP
  - Mean = 55.28
  - Std. Dev. = 10.197
  - N = 6,094

- ONE-STOP
  - Mean = 127.12
  - Std. Dev. = 18.619
  - N = 9,987

- SEVEN-STOPS
  - Mean = 660.31
  - Std. Dev. = 21.251
  - N = 316

- SIX-STOPS
  - Mean = 573.99
  - Std. Dev. = 21.692
  - N = 474

- TEN-STOPS
  - Mean = 939.88
  - Std. Dev. = 21.407
  - N = 139

- THREE-STOPS
  - Mean = 301.69
  - Std. Dev. = 19.857
  - N = 4,193

- TWO-STOPS
  - Mean = 215.52
  - Std. Dev. = 19.223
  - N = 13

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### Travel Time Frequency and Marked by Number of Red Signal Stops

**Data Collected by EZPass Tag Readers**

**At:** Lexington Av, From: 49 St, Exit: 42 St, Period: 2011_JUN2-JUN8, Week: Weekdays

#### Frequency Percent

<table>
<thead>
<tr>
<th>Number of Equivalent Red Signal Stops</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eight-Stops</td>
<td>759.34</td>
<td>25.185</td>
<td>109</td>
</tr>
<tr>
<td>Five-Stops</td>
<td>480.72</td>
<td>23.81</td>
<td>337</td>
</tr>
<tr>
<td>Four-Stops</td>
<td>385.02</td>
<td>23.143</td>
<td>954</td>
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<tr>
<td>Non-Stop</td>
<td>896.34</td>
<td>24.508</td>
<td>90</td>
</tr>
<tr>
<td>One-Stop</td>
<td>121.93</td>
<td>19.246</td>
<td>976</td>
</tr>
<tr>
<td>Seven-Stops</td>
<td>695.21</td>
<td>24.852</td>
<td>177</td>
</tr>
<tr>
<td>Six-Stops</td>
<td>572.88</td>
<td>24.341</td>
<td>258</td>
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<tr>
<td>Three-Stops</td>
<td>292.5</td>
<td>20.896</td>
<td>229</td>
</tr>
<tr>
<td>Two-Stops</td>
<td>204.35</td>
<td>21.367</td>
<td>8543</td>
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TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: LEXINGTON AV, FROM: 49 ST, EXIT: 42 ST, PERIOD: 2013_MAY26-JUN15, WEEK: ...

<table>
<thead>
<tr>
<th>NUMBER OF EQUIVALENT RED SIGNAL STOPS</th>
<th>Eight-Stops</th>
<th>Five-Stops</th>
<th>Four-Stops</th>
<th>Three-Stops</th>
<th>Two-Stops</th>
<th>One-Stop</th>
<th>Seven-Stops</th>
<th>Nine-Stops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>751.86</td>
<td>478.93</td>
<td>367.03</td>
<td>295.02</td>
<td>203.5</td>
<td>119.93</td>
<td>861.03</td>
<td>949.42</td>
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<tr>
<td>N</td>
<td>274</td>
<td>886</td>
<td>1,796</td>
<td>40,430</td>
<td>529</td>
<td>17,130</td>
<td>320</td>
<td>201</td>
</tr>
</tbody>
</table>

Frequency Percent

TRAVEL_TIME

0s 50s 100s 150s 200s 250s 300s 350s 400s 450s 500s 550s 600s 650s 700s 750s 800s 850s 900s 950s 1,000s 1,050s 1,100s 1,150s

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TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


TRAVEL_TIME

NUMBER_OF_EQUIVALENT_RED_SIGNAL_STOPS

EIGHT-STOPS
Mean = 764.78
Std. Dev. = 23.447
N = 85

FIVE-STOPS
Mean = 494.35
Std. Dev. = 22.434
N = 400

FOUR-STOPS
Mean = 403.07
Std. Dev. = 21.426
N = 985

NINE-STOPS
Mean = 859.2
Std. Dev. = 26.161
N = 65

NON-STOP
Mean = 83.52
Std. Dev. = 13.76
N = 8,573

ONE-STOP
Mean = 137.79
Std. Dev. = 21.353
N = 9,890

SEVEN-STOPS
Mean = 679.98
Std. Dev. = 25.735
N = 130

SIX-STOPS
Mean = 585.57
Std. Dev. = 23.699
N = 190

TEN-STOPS
Mean = 947.13
Std. Dev. = 25.843
N = 60

THREE-STOPS
Mean = 315.36
Std. Dev. = 22.976
N = 2,115

TWO-STOPS
Mean = 225.7
Std. Dev. = 24.904
N = 5,051

Frequency Percent

0s  50s  100s  150s  200s  250s  300s  350s  400s  450s  500s  550s  600s  650s  700s  750s  800s  850s  900s  950s  1,000s  1,050s  1,100s  1,150s  1,200s
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: LEXINGTON AV, FROM: 57 ST, EXIT: 49 ST, PERIOD: 2012_MAY26-JUN15, WEEK: ...

<table>
<thead>
<tr>
<th>NUMBER OF EQUIVALENT RED SIGNAL STOPS</th>
<th>TRAVEL TIME</th>
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<tbody>
<tr>
<td>EIGHT-STOPS</td>
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<td>120s - 240s</td>
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<td>ONE-STOP</td>
<td>240s - 360s</td>
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<tr>
<td>SEVEN-STOPS</td>
<td>360s - 480s</td>
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<tr>
<td>NINE-STOPS</td>
<td>480s - 600s</td>
</tr>
<tr>
<td>NON-STOP</td>
<td>600s - 720s</td>
</tr>
<tr>
<td>ONE-STOP</td>
<td>720s - 840s</td>
</tr>
<tr>
<td>SIX-STOPS</td>
<td>840s - 960s</td>
</tr>
<tr>
<td>TEN-STOPS</td>
<td>960s - 1080s</td>
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<td>THREE-STOPS</td>
<td>1080s - 1200s</td>
</tr>
<tr>
<td>TWO-STOPS</td>
<td>1200s - 1320s</td>
</tr>
</tbody>
</table>

EIGHT-STOPS
Mean = 763.46
Std. Dev. = 23.092
N = 260

FIVE-STOPS
Mean = 430.68
Std. Dev. = 21.964
N = 1,209

ONE-STOP
Mean = 137.88
Std. Dev. = 18.372
N = 20,928

SEVEN-STOPS
Mean = 674.69
Std. Dev. = 21.195
N = 388

SIX-STOPS
Mean = 583.29
Std. Dev. = 22.093
N = 664

TEN-STOPS
Mean = 945.43
Std. Dev. = 22.813
N = 152

THREE-STOPS
Mean = 313.4
Std. Dev. = 21.204
N = 3,449

TWO-STOPS
Mean = 221.37
Std. Dev. = 20.081
N = 9,300
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: LEXINGTON AV, FROM: 57 ST, EXIT: 49 ST, PERIOD: 2013_MAY26-JUN15, WEEK: ...

TRAVEL_TIME

NUMBER OF EQUIVALENT RED SIGNAL STOPS

- EIGHT-STOP MEAN = 799.82, SD = 24.05, N = 295
- FIVE-STOP MEAN = 493.78, SD = 22.07, N = 1,124
- FOUR-STOP MEAN = 404.97, SD = 21.5, N = 2,275
- THREE-STOP MEAN = 315.73, SD = 21.2, N = 4,881
- TWO-STOP MEAN = 230.06, SD = 21.4, N = 10,542
- ONE-STOP MEAN = 138.78, SD = 20.2, N = 22,103
- NON-STOP MEAN = 65.46, SD = 14.17, N = 15,373

Frequency Percent

0% 1% 2% 3% 4%
0s 50s 100s 150s 200s 250s 300s 350s 400s 450s 500s 550s 600s 650s 700s 750s 800s 850s 900s 950s 1,000s 1,050s 1,100s 1,150s 1,200s

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TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

AT: MADISON AV, FROM: 42 ST, EXIT: 49 ST, PERIOD: 2011_JUN2-JUN8, WEEK: WEEKDAYS

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>MEAN</th>
<th>STD. DEV.</th>
<th>N</th>
</tr>
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<tr>
<td>EIGHT-STOPS</td>
<td>743.29</td>
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<td>FIVE-STOPS</td>
<td>480.23</td>
<td>23.907</td>
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<td>FOUR-STOPS</td>
<td>340.35</td>
<td>25.252</td>
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<td>NON-STOP</td>
<td>121.19</td>
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<tr>
<td>ONE-STOP</td>
<td>121.51</td>
<td>22.145</td>
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<td>SEVEN-STOPS</td>
<td>669.65</td>
<td>28.312</td>
<td>18</td>
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<td>SIX-STOPS</td>
<td>575.97</td>
<td>22.899</td>
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<td>THREE-STOPS</td>
<td>298.32</td>
<td>23.281</td>
<td>192</td>
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<tr>
<td>TWO-STOPS</td>
<td>309.36</td>
<td>24.965</td>
<td>578</td>
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</table>

Frequency Percent

TRAVEL_TIME

0s 50s 100s 150s 200s 250s 300s 350s 400s 450s 500s 550s 600s 650s 700s 750s 800s 850s 900s 950s 1,000s 1,050s 1,100s 1,150s 1,200s
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


<table>
<thead>
<tr>
<th>NUMBER OF EQUIVALENT RED SIGNAL STOPS</th>
<th></th>
</tr>
</thead>
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<tr>
<td>EIGHT-STOPST</td>
<td>NON-STOP</td>
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<tr>
<td>FIVE-STOPST</td>
<td>ONE-STOP</td>
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<tr>
<td>FOUR-STOPST</td>
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<table>
<thead>
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<th>FIVE-STOPST</th>
<th>FOUR-STOPST</th>
<th>NON-STOP</th>
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<tr>
<td>Mean = 754.16</td>
<td>Mean = 487.1</td>
<td>Mean = 382.11</td>
<td>Mean = 53.91</td>
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<tr>
<td>Std. Dev. = 27.574</td>
<td>Std. Dev. = 24.92</td>
<td>Std. Dev. = 23.758</td>
<td>Std. Dev. = 12.92</td>
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<td>N = 38</td>
<td>N = 92</td>
<td>N = 132</td>
<td>N = 5,640</td>
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<thead>
<tr>
<th>ONE-STOPST</th>
<th>SEVEN-STOPST</th>
<th>SIX-STOPST</th>
<th>THREE-STOPST</th>
<th>TWO-STOPST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean = 119.92</td>
<td>Mean = 669.43</td>
<td>Mean = 577.7</td>
<td>Mean = 303.5</td>
<td>Mean = 309.72</td>
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<tr>
<td>Std. Dev. = 19.34</td>
<td>Std. Dev. = 27.575</td>
<td>Std. Dev. = 26.975</td>
<td>Std. Dev. = 21.526</td>
<td>Std. Dev. = 21.34</td>
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<td>N = 3789</td>
<td>N = 46</td>
<td>N = 53</td>
<td>N = 240</td>
<td>N = 690</td>
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TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
DATA COLLECTED BY EZPASS TAG READERS


<table>
<thead>
<tr>
<th>NUMBER OF EQUIVALENT RED SIGNAL STOPS</th>
<th>EIGHT-STOPS</th>
<th>FIVE-STOPS</th>
<th>FOUR-STOPS</th>
<th>ONE-STOP</th>
<th>NON-STOP</th>
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<tbody>
<tr>
<td>Mean</td>
<td>762.84</td>
<td>481.57</td>
<td>394.35</td>
<td>133.1</td>
<td>12.89</td>
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<tr>
<td>Std. Dev.</td>
<td>28.71</td>
<td>24.807</td>
<td>23.325</td>
<td>5.915</td>
<td>12.968</td>
</tr>
<tr>
<td>N</td>
<td>68</td>
<td>135</td>
<td>221</td>
<td>83</td>
<td>5,476</td>
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<table>
<thead>
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<th>SEVEN-STOPS</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>670.98</td>
<td>27.7</td>
<td>63</td>
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<table>
<thead>
<tr>
<th>SIX-STOPS</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>574.97</td>
<td>28.152</td>
<td>110</td>
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<th>THREE-STOPS</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<td>302.88</td>
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<th>TWO-STOPS</th>
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<th>Std. Dev.</th>
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<td>210.62</td>
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TRAVEL_TIME
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


<table>
<thead>
<tr>
<th>NUMBER_OF_EQUIVALENT_RED_SIGNAL_STOPS</th>
<th>Summary Statistics</th>
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<tr>
<td>EIGHT-STOPS</td>
<td>Mean = 760.07, Std. Dev. = 26.04, N = 59</td>
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<td>Mean = 355.29, Std. Dev. = 21.296, N = 682</td>
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<td>ONE-STOP</td>
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<td>THREE-STOPS</td>
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<th>TRAVEL_TIME</th>
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<td>0s - 5s</td>
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TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
- DATA COLLECTED BY EZPASS TAG READERS


TRAVEL_TIME

0s  50s  100s  150s  200s  250s  300s  350s  400s  450s  500s  550s  600s  650s  700s  750s  800s  850s  900s  950s  1,000s  1,050s  1,100s  1,150s  1,200s

NUMBER_OF_EQUVALENT
RED_SIGNAL_STOPS

EIGHT-STOPS
Mean = 756.19
Std. Dev. = 21.413
N = 313

ELEVEN-STOPS
Mean = 1034.15
Std. Dev. = 22.302
N = 88

FIVE-STOPS
Mean = 487.84
Std. Dev. = 19.795
N = 1,585

FOUR-STOPS
Mean = 388.98
Std. Dev. = 19.557
N = 2,247

NINE-STOPS
Mean = 681.43
Std. Dev. = 21.799
N = 162

NON-STOP
Mean = 56.19
Std. Dev. = 10.29
N = 10,036

ONE-STOP
Mean = 129.37
Std. Dev. = 17.978
N = 9,788

SEVEN-STOPS
Mean = 698.83
Std. Dev. = 21.464
N = 492

SIX-STOPS
Mean = 576.84
Std. Dev. = 20.318
N = 898

TEN-STOPS
Mean = 939.72
Std. Dev. = 20.635
N = 135

THREE-STOPS
Mean = 309.08
Std. Dev. = 20.296
N = 3,235

TWO-STOPS
Mean = 418.93
Std. Dev. = 20.583
N = 883
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS


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<td>Std. Dev. = 22.092</td>
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<td>Std. Dev. = 14.69</td>
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<td>N = 6,056</td>
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APPENDIX B

Cumulative Distribution of Stops by Vehicles during the AM, Midday, and PM Peak Hours in five Avenue Segments
OD: 3 AV FROM 42 ST TO 49 ST, WEATHER: DRY, TIME: 4PM-6PM

PERIOD
- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: 3 AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 8AM-10AM

PERIOD

ALL WEEKDAYS IN 2011 JUN2-JUN8
ALL WEEKDAYS IN 2012 MAY1-JUN30
ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS

0% 20% 40% 60% 80% 100%
0 1 2 3 4 5 6 7 8 9 10
OD: 3 AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 11AM-1PM

PERIOD

ALL WEEKDAYS IN 2011 JUN2-JUN8
ALL WEEKDAYS IN 2012 MAY1-JUN30
ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: 3 AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 4PM-6PM

Period
- All Weekdays in 2011 Jun 2-Jun 8
- All Weekdays in 2012 May 1-Jun 30
- All Weekdays in 2013 May 1-Jun 19

Cumulative Sum of Percentage

Number of Equivalent Red Signal Stops
OD: 5 AV FROM 49 ST TO 42 ST, WEATHER: DRY, TIME: 8AM-10AM

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS

PERIOD
- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19
OD: 5 AV FROM 49 ST TO 42 ST, WEATHER: DRY, TIME: 11AM-1PM

PERIOD
- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: 5 AV FROM 57 ST TO 49 ST, WEATHER: DRY, TIME: 11AM-1PM

PERIOD

- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: 5 AV FROM 57 ST TO 49 ST, WEATHER: DRY, TIME: 4PM-6PM

PERIOD

- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: 6 AV FROM 42 ST TO 49 ST, WEATHER: DRY, TIME: 11AM-1PM

PERIOD
- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: 6 AV FROM 42 ST TO 49 ST, WEATHER: DRY, TIME: 4PM-6PM
OD: 6 AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 11AM-1PM

PERIOD
- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage vs. NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: 6 AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 4PM-6PM

PERIOD
- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL Stops
OD: LEXINGTON AV FROM 49 ST TO 42 ST, WEATHER: DRY, TIME: 8AM-10AM

PERIOD
- ALL WEEKDAYS IN 2011 JUN 7-JUN 13
- ALL WEEKDAYS IN 2012 MAY 1-JUN 30
- ALL WEEKDAYS IN 2013 MAY 1-JUN 19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: LEXINGTON AV FROM 49 ST TO 42 ST, WEATHER: DRY, TIME: 11AM-1PM

PERIOD
- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: LEXINGTON AV FROM 57 ST TO 49 ST, WEATHER: DRY, TIME: 8AM-10AM

PERIOD
- Blue line: ALL WEEKDAYS IN 2011 JUN2-JUN8
- Green line: ALL WEEKDAYS IN 2012 MAY1-JUN30
- Orange line: ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: LEXINGTON AV FROM 57 ST TO 49 ST, WEATHER: DRY, TIME: 11AM-1PM

PERIOD
- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: MADISON AV FROM 42 ST TO 49 ST, WEATHER: DRY, TIME: 8AM-10AM

PERIOD

ALL WEEKDAYS IN
2011 JUN2-JUN8
ALL WEEKDAYS IN
2012 MAY1-JUN30
ALL WEEKDAYS IN
2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: MADISON AV FROM 42 ST TO 49 ST, WEATHER: DRY, TIME: 11AM-1PM

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS

PERIOD
- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19

0% 20% 40% 60% 80% 100%

0 1 2 3 4 5 6 7 8
OD: MADISON AV FROM 42 ST TO 49 ST, WEATHER: DRY, TIME: 4PM-6PM

PERIOD

- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: MADISON AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 8AM-10AM

PERIOD

ALL WEEKDAYS IN
2011 JUN2-JUN8
ALL WEEKDAYS IN
2012 MAY1-JUN30
ALL WEEKDAYS IN
2013 MAY1-JUN19

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS
OD: MADISON AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 11AM-1PM

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS

PERIOD
- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19
OD: MADISON AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 4PM-6PM

Cumulative Sum of Percentage

NUMBER OF EQUIVALENT RED SIGNAL STOPS

PERIOD
- ALL WEEKDAYS IN 2011 JUN2-JUN8
- ALL WEEKDAYS IN 2012 MAY1-JUN30
- ALL WEEKDAYS IN 2013 MAY1-JUN19