University Transportation Research Center - Region 2

Final Report

Development of Traffic Performance Metrics Using Real-time Traffic Data

Performing Organization: Polytechnic Institute of NYU

October 2013

Sponsor:
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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.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

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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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16. 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 snesors 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
4. Higher customer satisfaction.

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 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 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.

Metropolitan Area	State	Percent Signalized Intersections deploying Adaptive Traffic Control Systems
Albany, Schenctady, Troy	NY	16%
Atlanta	GA	1%
Chicago, Gary, Lake Country	IL	13%
Dayton, Springfield	OH	1%
Denver, Boulder	CO	1%
Detroit, Ann Arbor	MI	14%
Grand Rapids	MI	<0.2%
Greensboro, Winston-Salem, High Point	NC	3%
Hampton Roads	VA	2%
Houston, Galveston, Brazoria	TX	1%
Jackson	MS	<0.4%
Little Rock, North Little Rock	AR	1%
Los Angeles, Anaheim, Riverside	CA	3%
Milwaukee, Racine	WI	<0.2%
Minneapolis, St.Paul	MN	<0.2%
Modesto	CA	1%
NY, Northern NJ	NY	5%

Orlando	FL	3%
Philadelphia, Wilmington, Trenton	PA	4%
Providence, Pawtucket, Fall River	RI	<0.2%
Raleigh-Durham	NC	1%
Richmond, Petersburg	VA	34%
San Diego	CA	<0.4%
San Francisco, Oakland, San Jose	CA	<0.4%
Tampa, St. Petersburg, Clearwater	FL	4%
Tucson	AZ	2%
Tulsa	OK	1%
Washington	DC	35%

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].

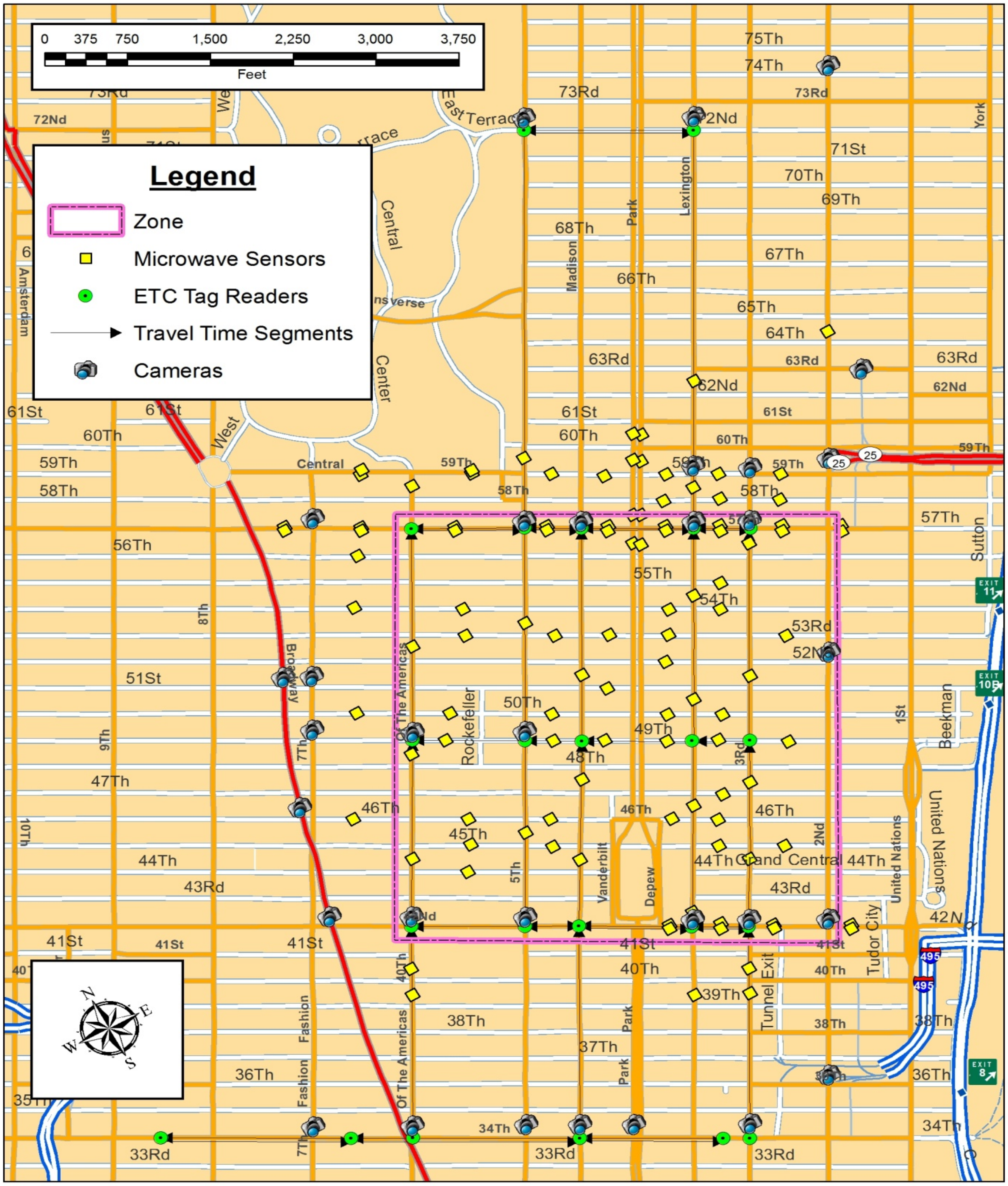

Figure 1 Map of MIM Study Area

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 <u>average</u> or <u>median</u> 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).

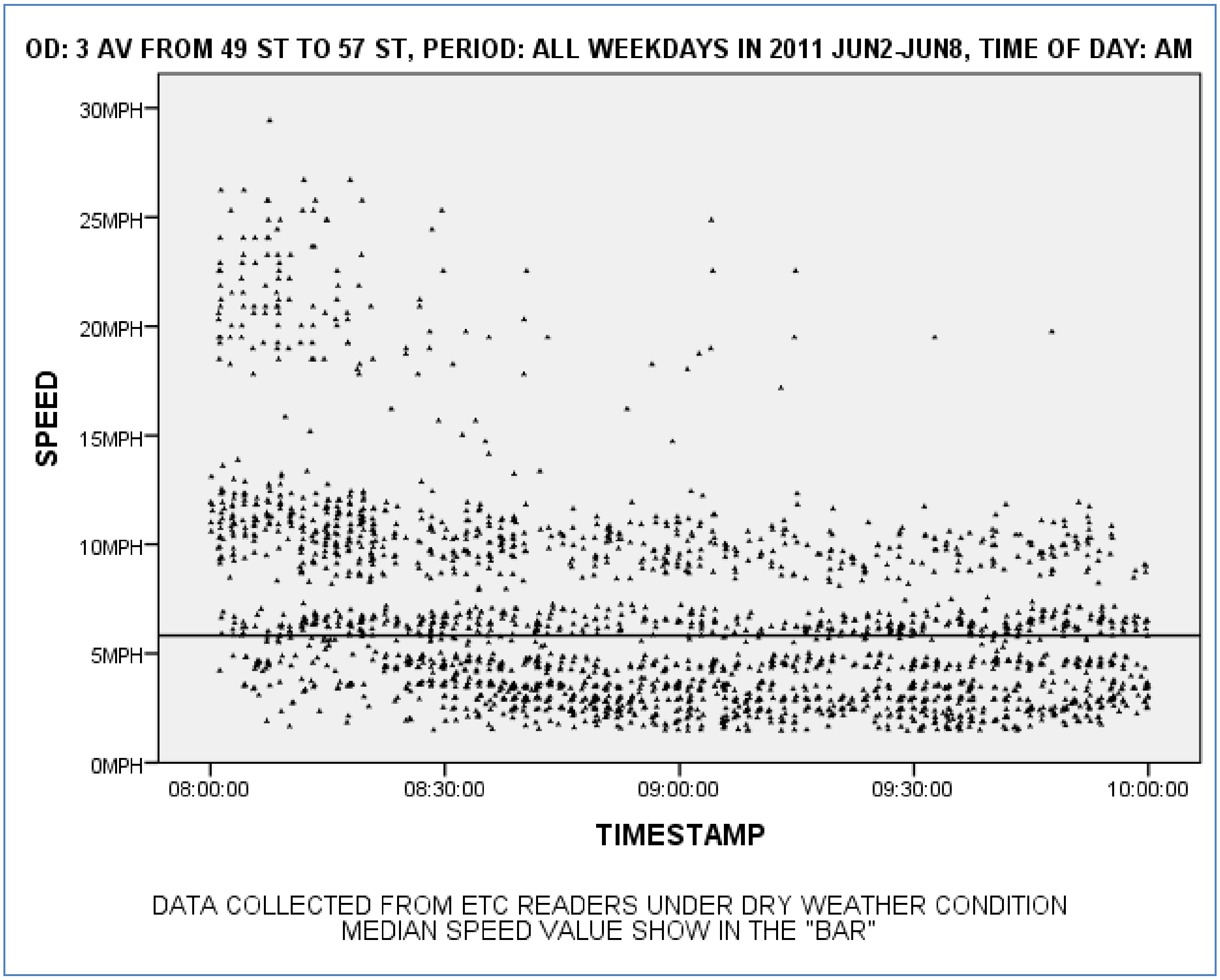

Figure 2: Vehicle Speeds on Third Avenue, Traveling from 49th to 57th Street during the 8-10AM Peak Hours

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 peal 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.

6 AV/57 ST	5 AV/57 ST	MADISON AV/57 ST	LEXINGTON AV/57 ST	3 AV/57 ST
2107 0.3990530	2106 0.3988636	2107 0.3990530	2124 0.4022727	2115 0.4005682
6 AV/49 ST	5 AV/49 ST	MADISON AV/49 ST	LEXINGTON AV/49 ST	3 AV/49 ST
1843 0.3490530	1847 0.3498106	1847 0.3498106	1853 0.3509470	1858 0.3518939
6 AV/42 ST	5 AV/42 ST	MADISON AV/42 ST	LEXINGTON AV/42 ST	3 AV/42 ST

NOTE: **** Distance in 'feet'
0.***** Distance in 'mile'

Figure 3: Distances of the Analysis Segments

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.

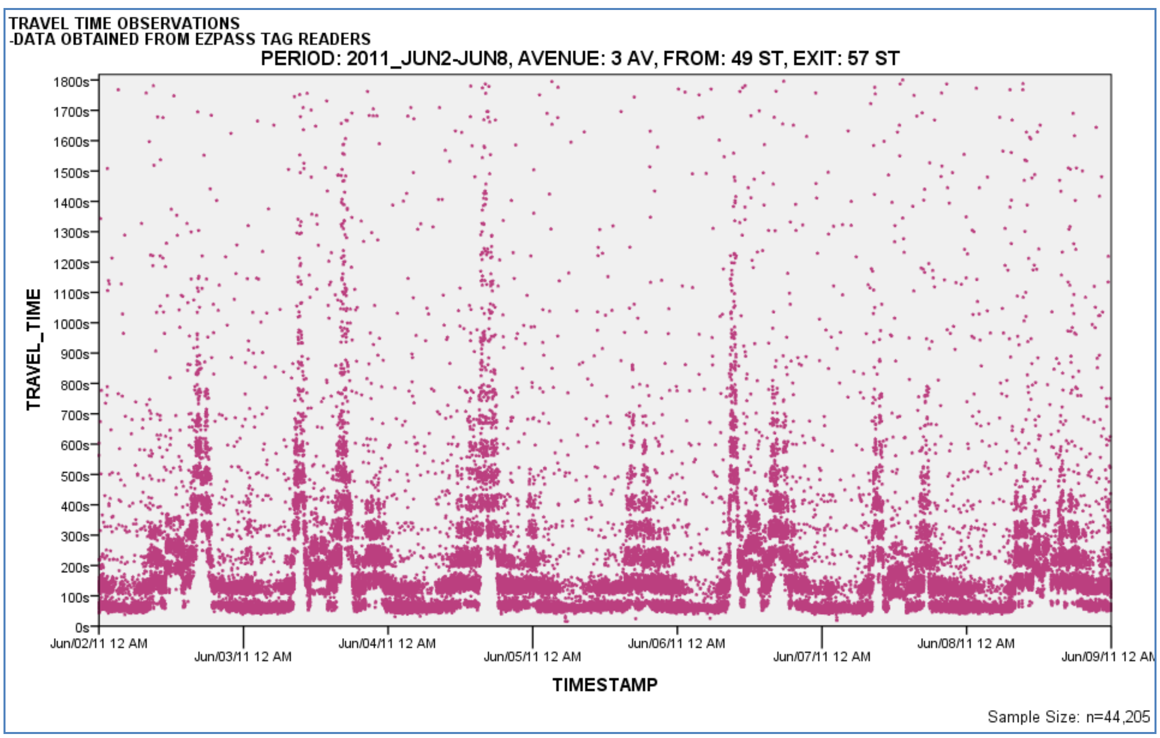

Figure 4: Scatter Plot of Travel Time during the Week of June 2 to June 8 in 2011, Segment of 3rd Avenue from 49 ST to 57 Street

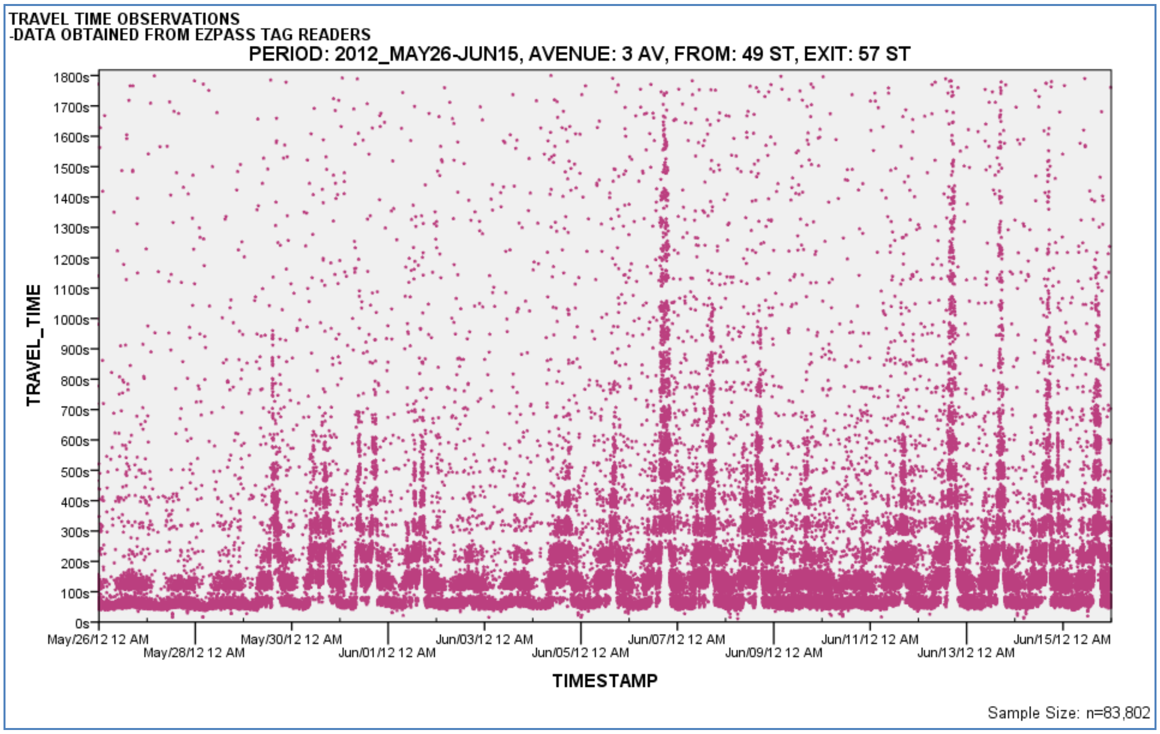

Figure 5: Scatter Plot of Travel Time during May 26 to June 15 in 2012, Segment of 3rd. Avenue from 49 ST to 57 ST

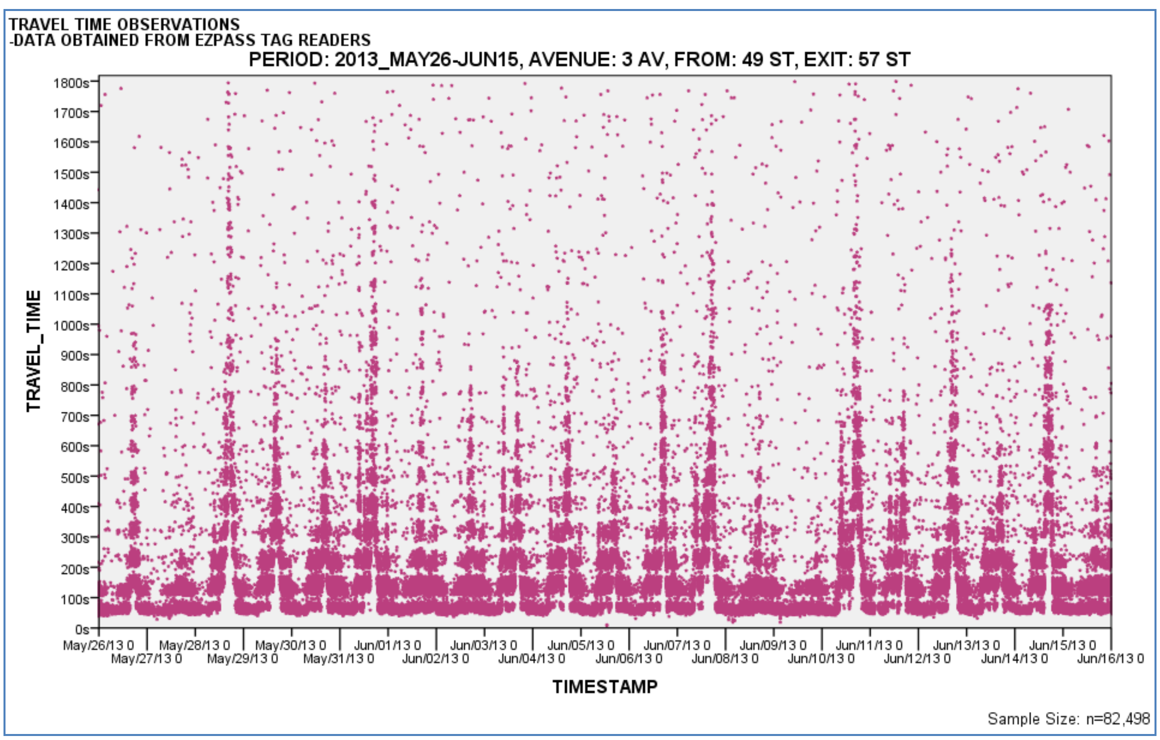

Figure 6: Scatter Plot of Travel Time during the May 26 to June 15 in 2013, Segment of 3rd. Avenue from 49 Street to 57 Street

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.

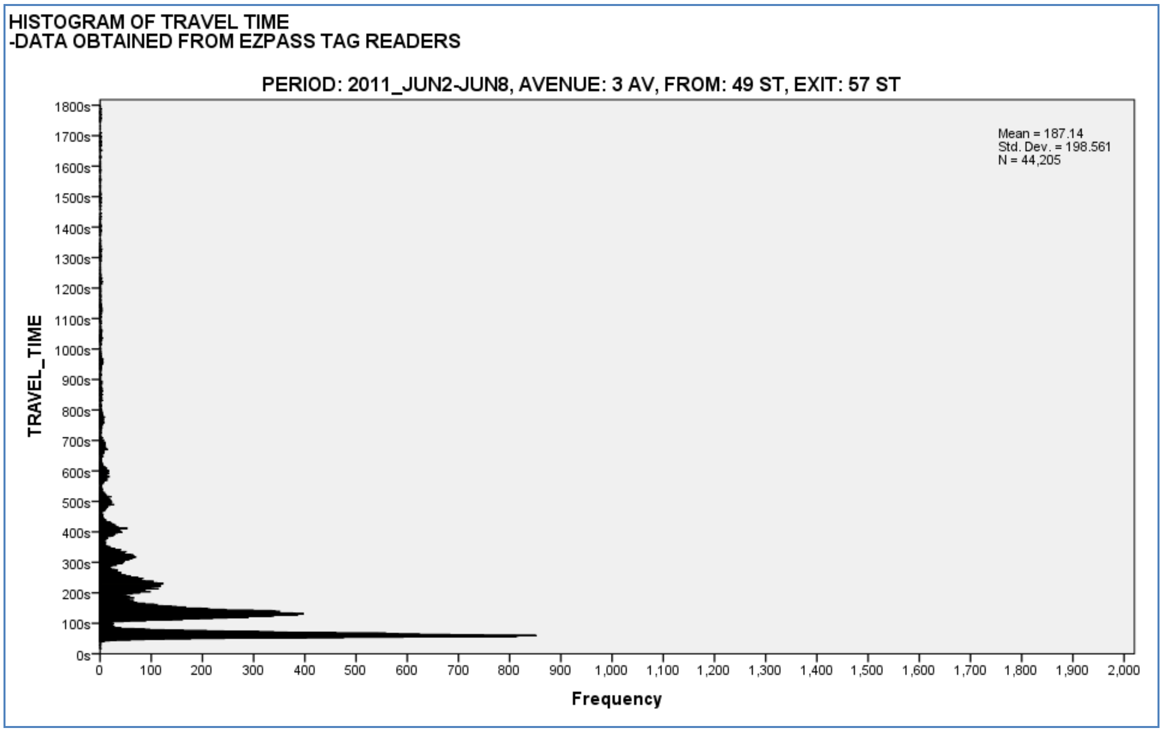

Figure 7: Frequency of Travel Time in June 2 – June 8 2011, Segment of 3rd. Avenue from 49 ST to 57 ST

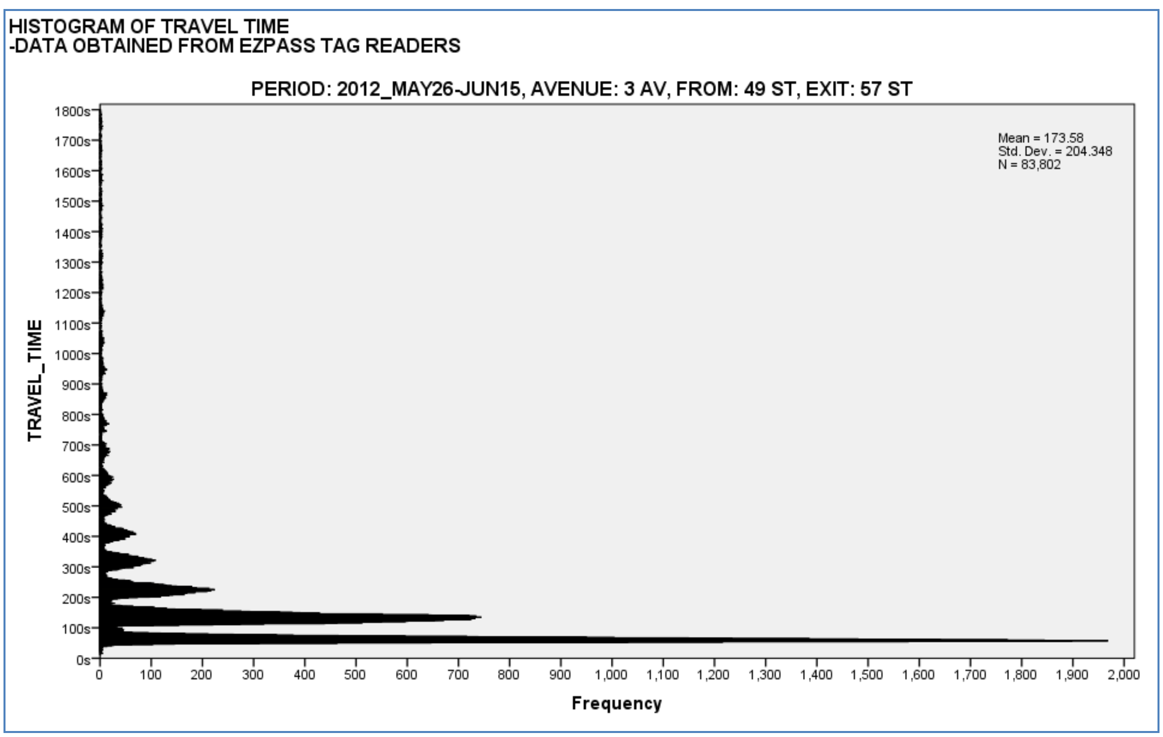

Figure 8: Frequency of Travel Time in May 26 – Jun 15 2012, Segment of 3rd. Avenue from 49 ST to 57 ST

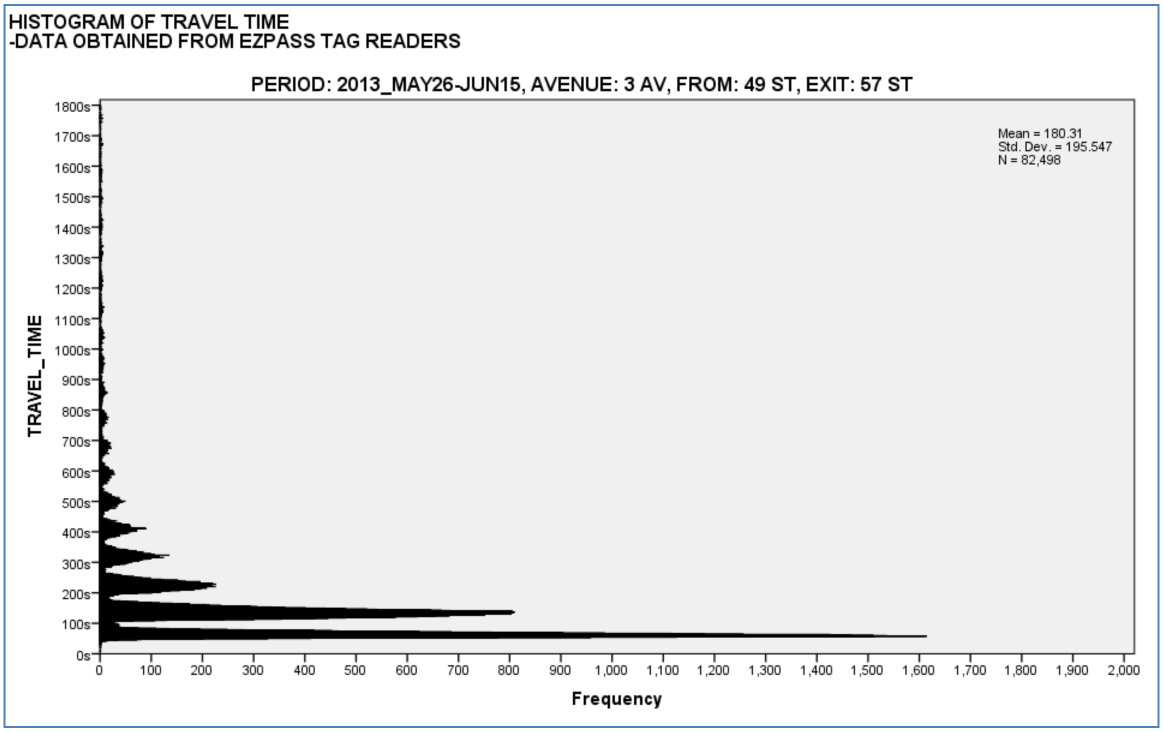

Figure 9: Frequency of Travel Time in May 26 – Jun 15 2012, Segment of 3rd. Avenue from 49 ST to 57 ST

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.

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* 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

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

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 a15 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

3rd Avenue from 42nd to 49th Streets	3rd Avenue from 49th to 57th Streets
Lexington Avenue from 57th to 49th Streets	Lexington Avenue from 49th to 42nd Streets
Madison Avenue from 42nd to 49th Streets	Madison Avenue from 49th to 57th Streets
5th Avenue from 57th to 49th Streets	5th Avenue from 49th to 42nd Streets
6th Avenue from 42nd to 49th Streets	6th Avenue from 49th to 57th Streets

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.

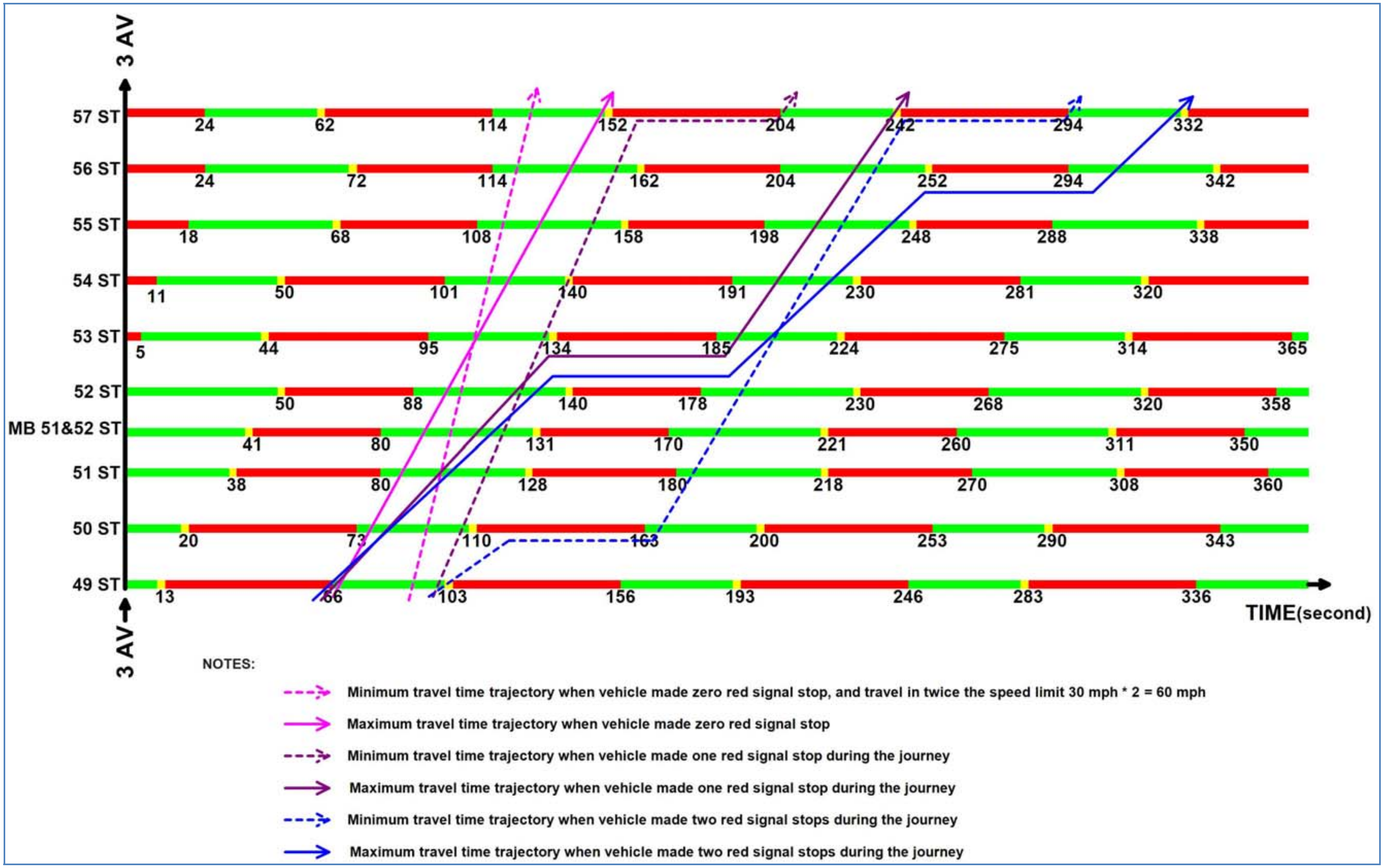

Figure 10: Time-Space Diagram for 3rd. Avenue from 49th Street to 57th Street

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

NUMBER OF RED SIGNAL STOPS	FINAL TRAVEL TIME RANGE (second)	
ZERO	**24**	**95**
ONE	**95**	**185**
TWO	**185**	**275**
THREE	**275**	**365**
FOUR	**365**	**455**
FIVE	**455**	**545**
SIX	**545**	**635**
SEVEN	**635**	**725**
EIGHT	**725**	**815**
NINE	**815**	**905**
TEN	**905**	**995**
ELEVEN & MORE	**995**	**1800**

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

$$N = \frac{L}{L_v}$$

Equation 2

$$c = s \times g = s \times (G + Y + AR - l_1 - l_2) = s * (G - l_1 + e)$$

Where:

N is the road segment's physical maximum vehicle queue length, $\frac{h}{\ln}$;
L is Link Length, is distance a vehicle traveled from upstream intersection to of the road segment downstream intersection, ft ;
L_v is average vehicle length, the default value is $\frac{25ft}{veh}$;
c is the capacity of the downstream intersection in vehicles/cycle;
l_1 is the start-up lost time, the default value is $\frac{2s}{phase}$;
s is the saturation flow rate, the value adopted is $\frac{\frac{1{,}450pc}{h}}{\ln}$
e is the encroachment of vehicles into yellow and all-red, the value adopted is $4s$.

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.

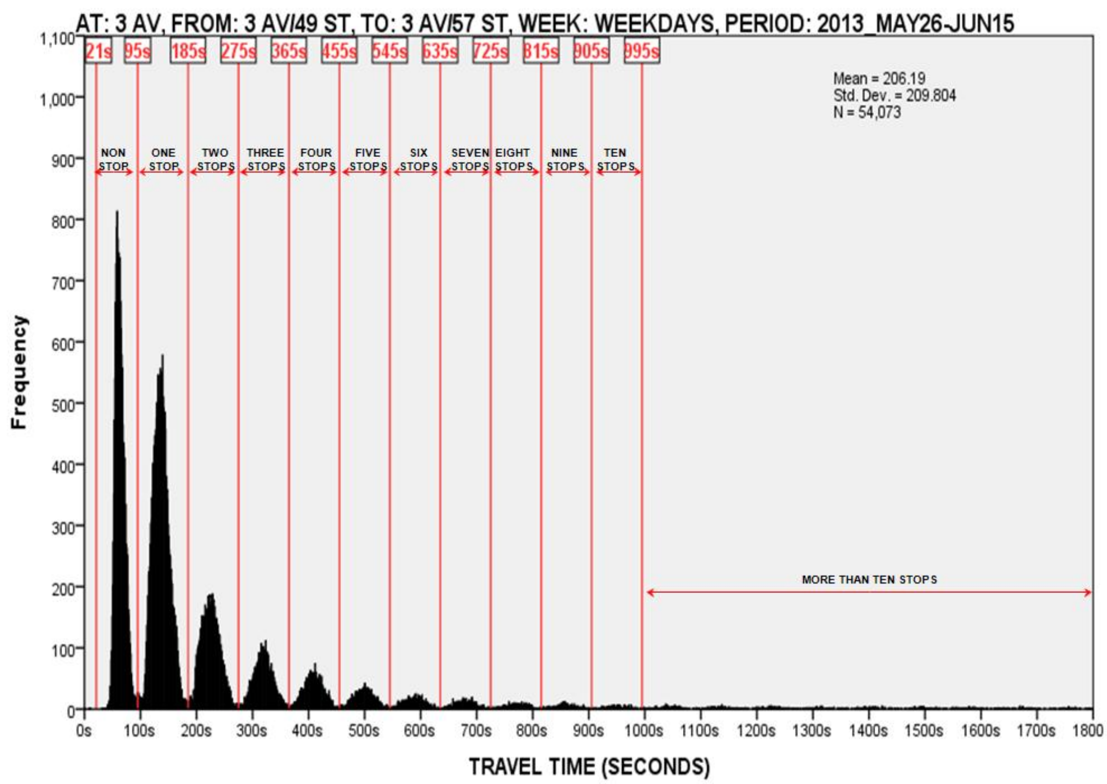

Figure 11: 2013 Travel Time Data Clusters and Travel Time Boundaries per Stop

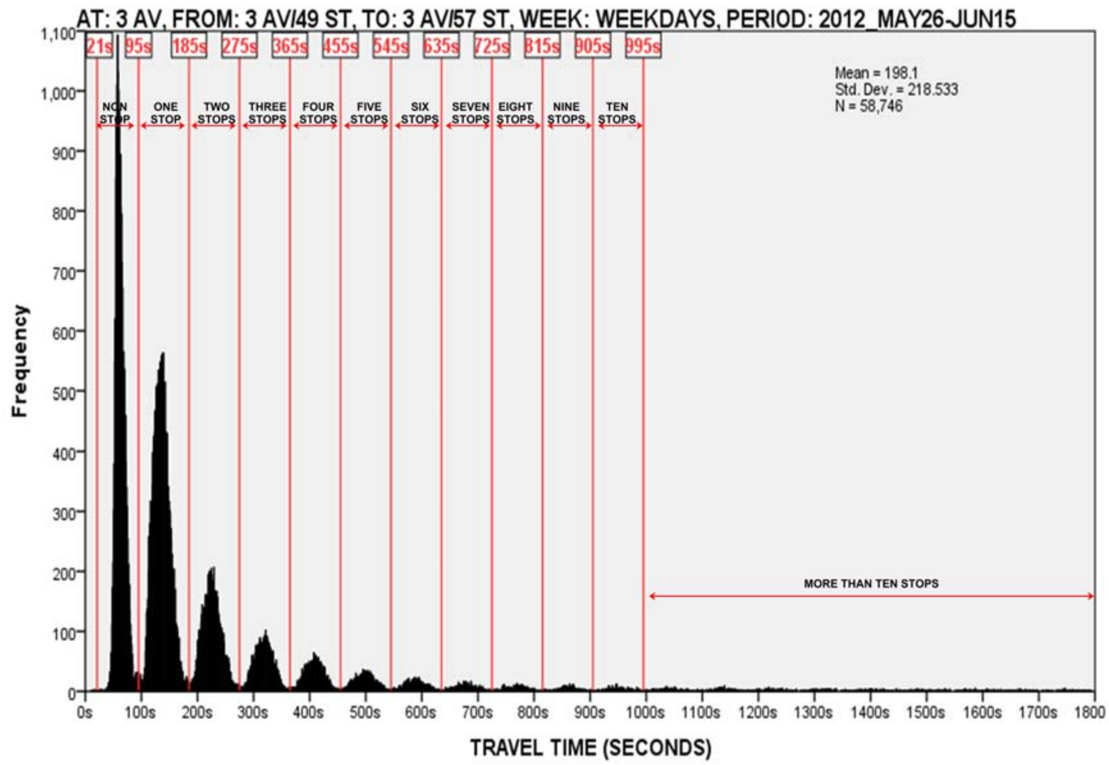

Figure 12: 2012 Travel Time Data Clusters and Travel Time Boundaries per Stop

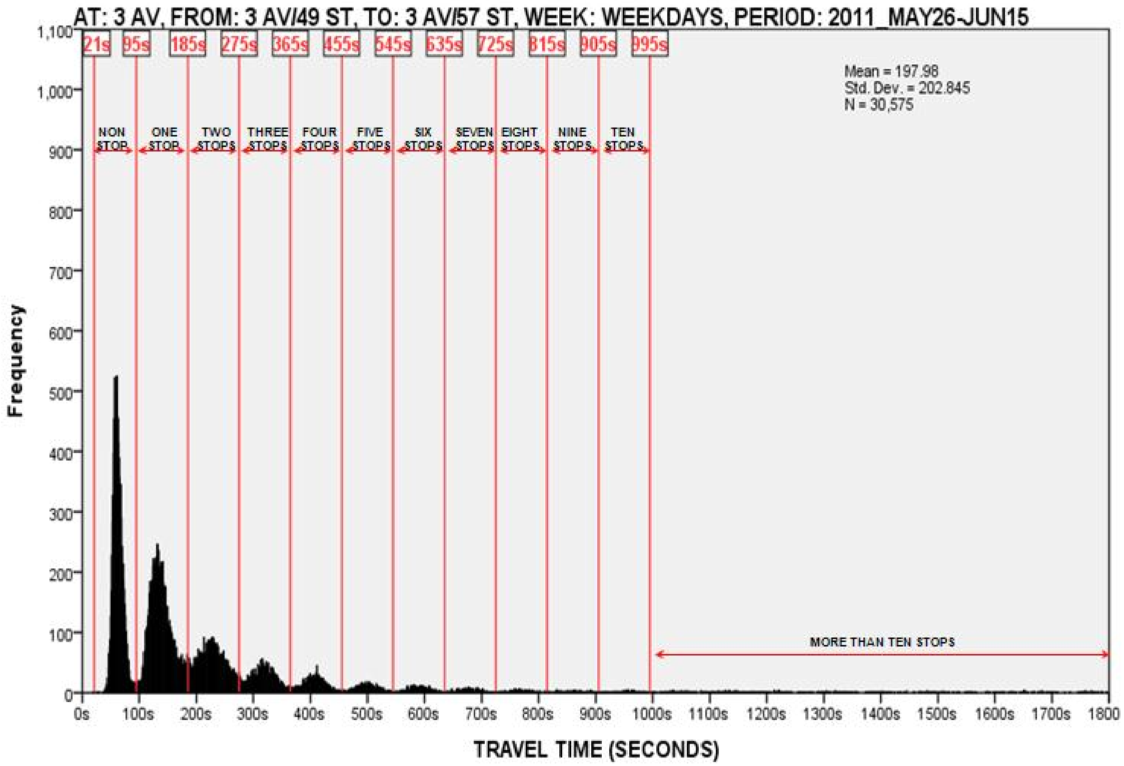

Figure 13: 2011 Travel Time Data Clusters and Travel Time Boundaries per Stop

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 (42^{nd} – 49^{th} or 49th-57^{th} 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.

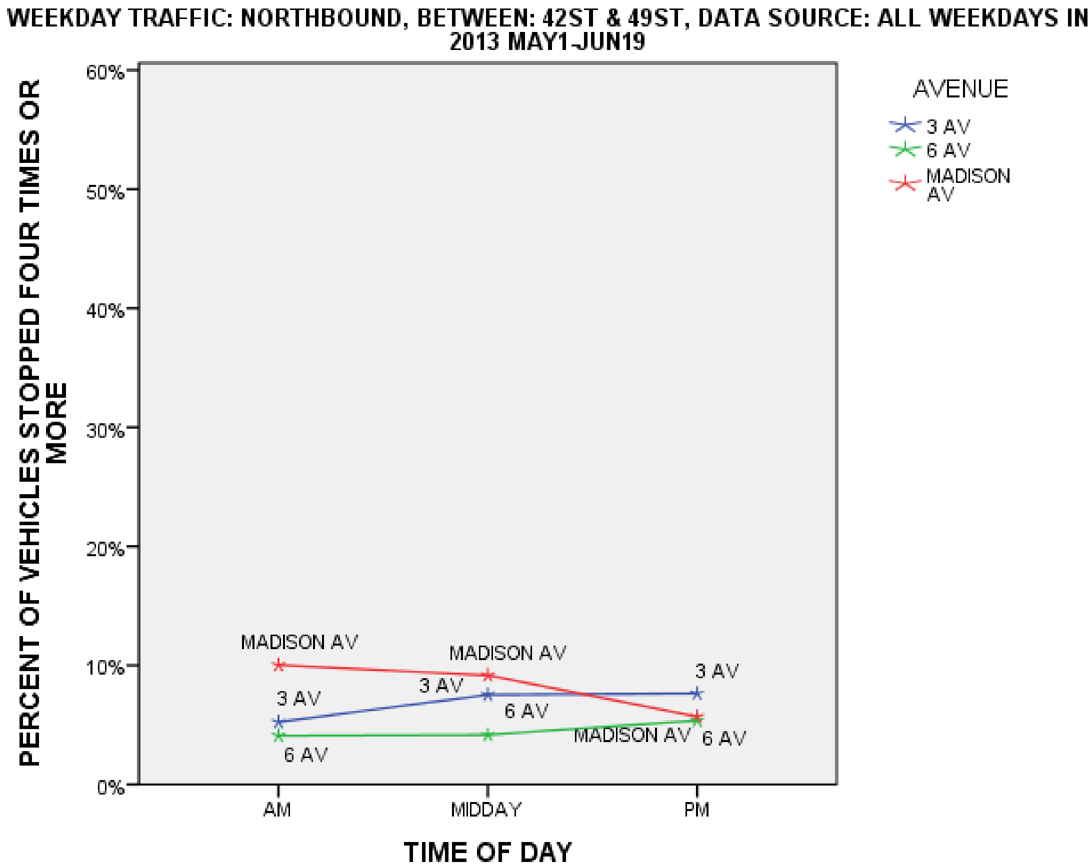

Figure 14: Percent of Vehicles Stopped Four Times or More – Third Avenue, Madison Avenue, and Sixth Avenues between 42nd and 49th Streets

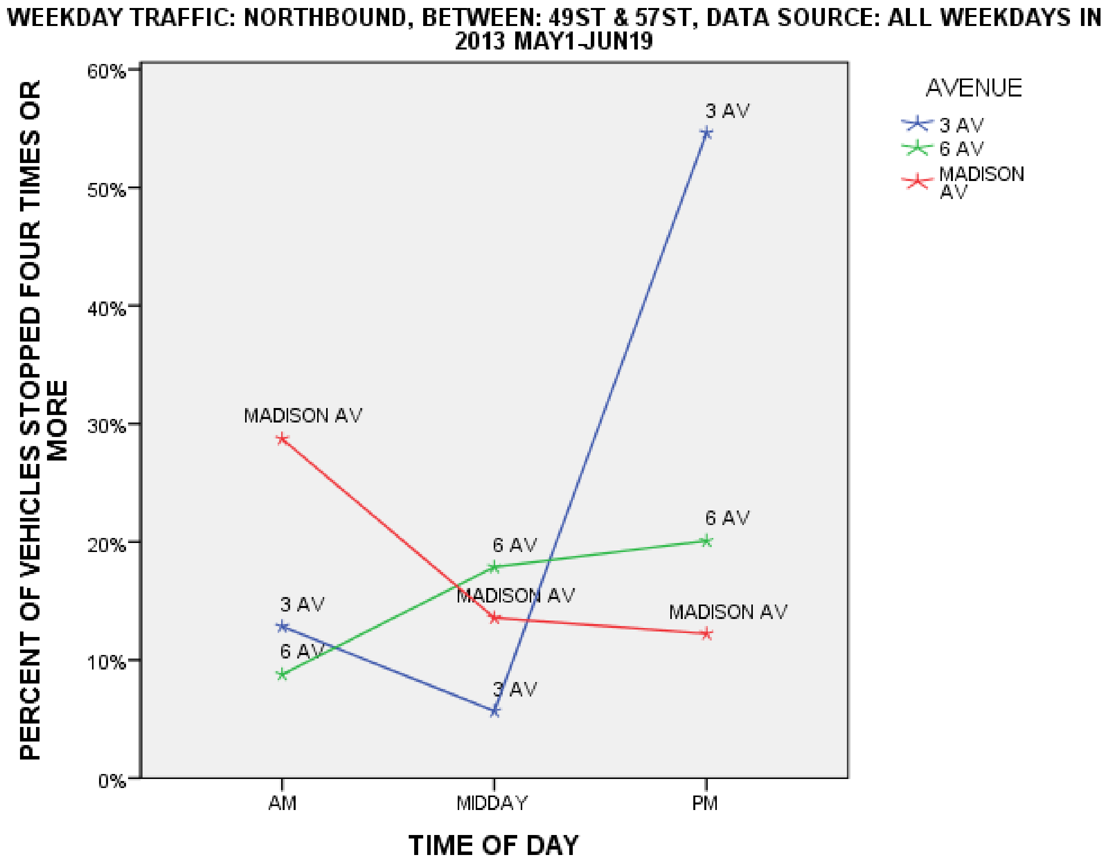

Figure 15: Percent of Vehicles Stopped Four Times or More – Third, Madison, and Sixth Avenues, between 49th and 57th Street

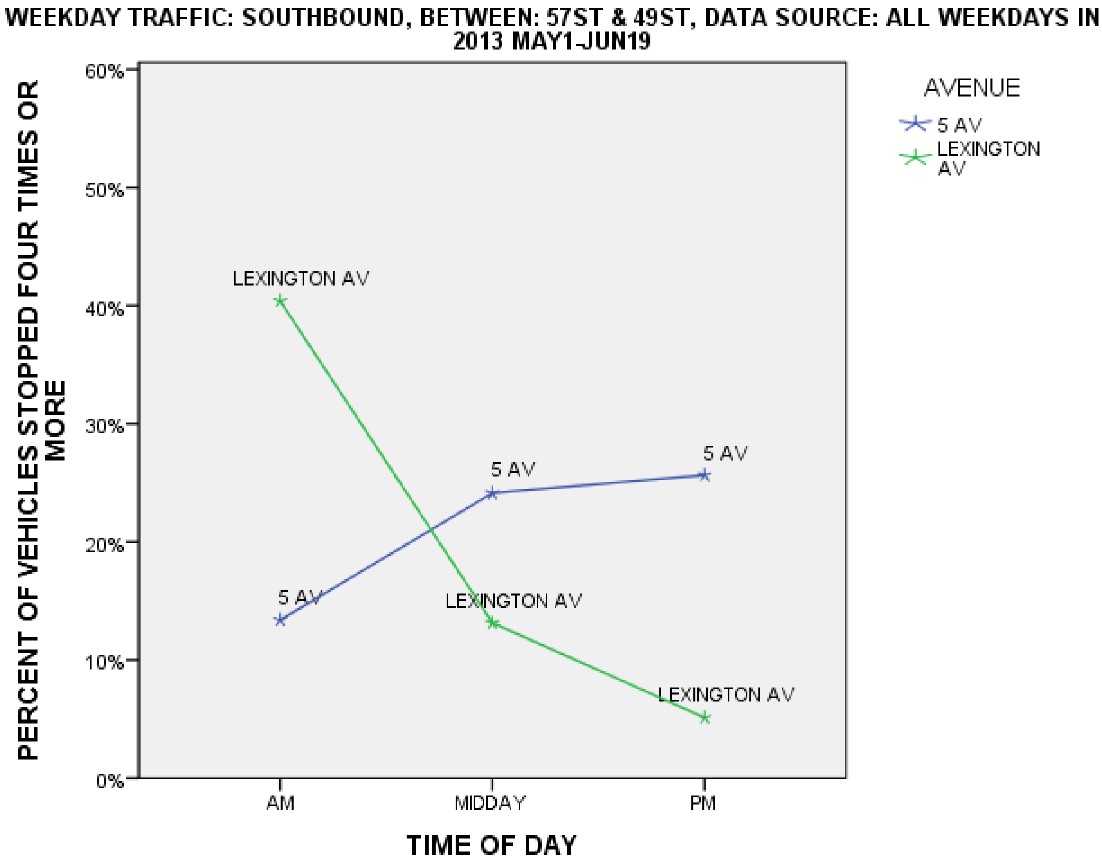

Figure 16: Percent of Vehicles Stopped Four or More Times – Lexington and Fifth Avenues, between 57th and 49th Streets

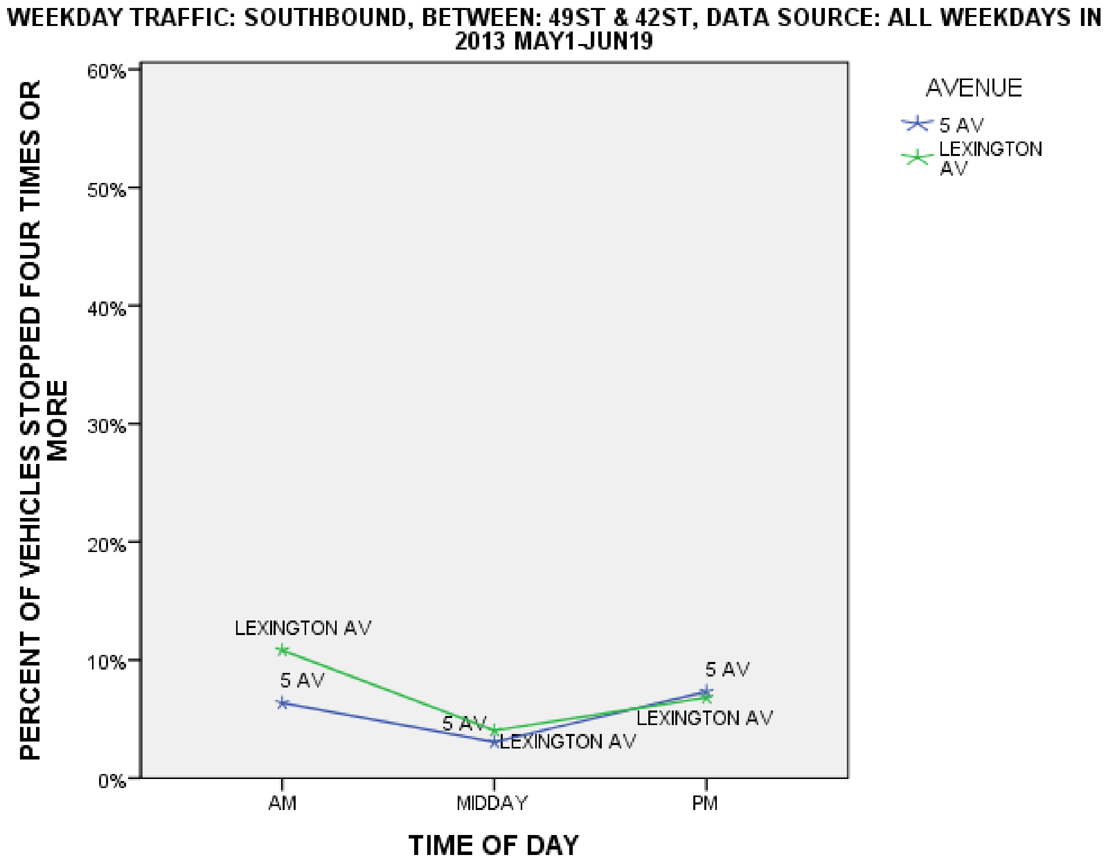

Figure 17: Percent of Vehicles Stopped Four Times or More – Lexington and Fifth Avenues, between 49th and 42nd Streets

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. (from41% 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%.

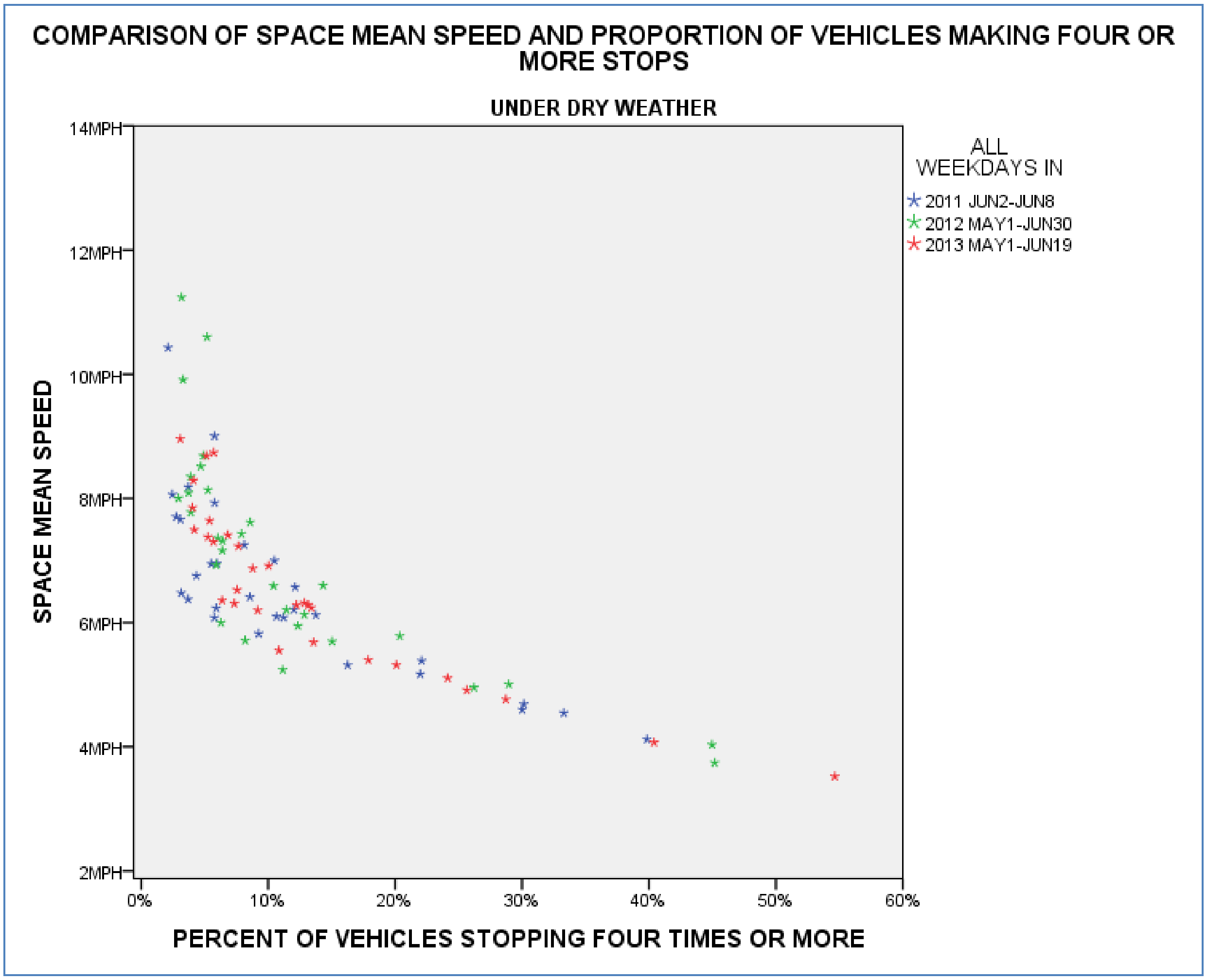

Figure 2: Relationship Between Traffic Speed and the Proportion of Drivers Stopping Four Times or More

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 <u>measure</u> 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 <u>external variables</u> 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.

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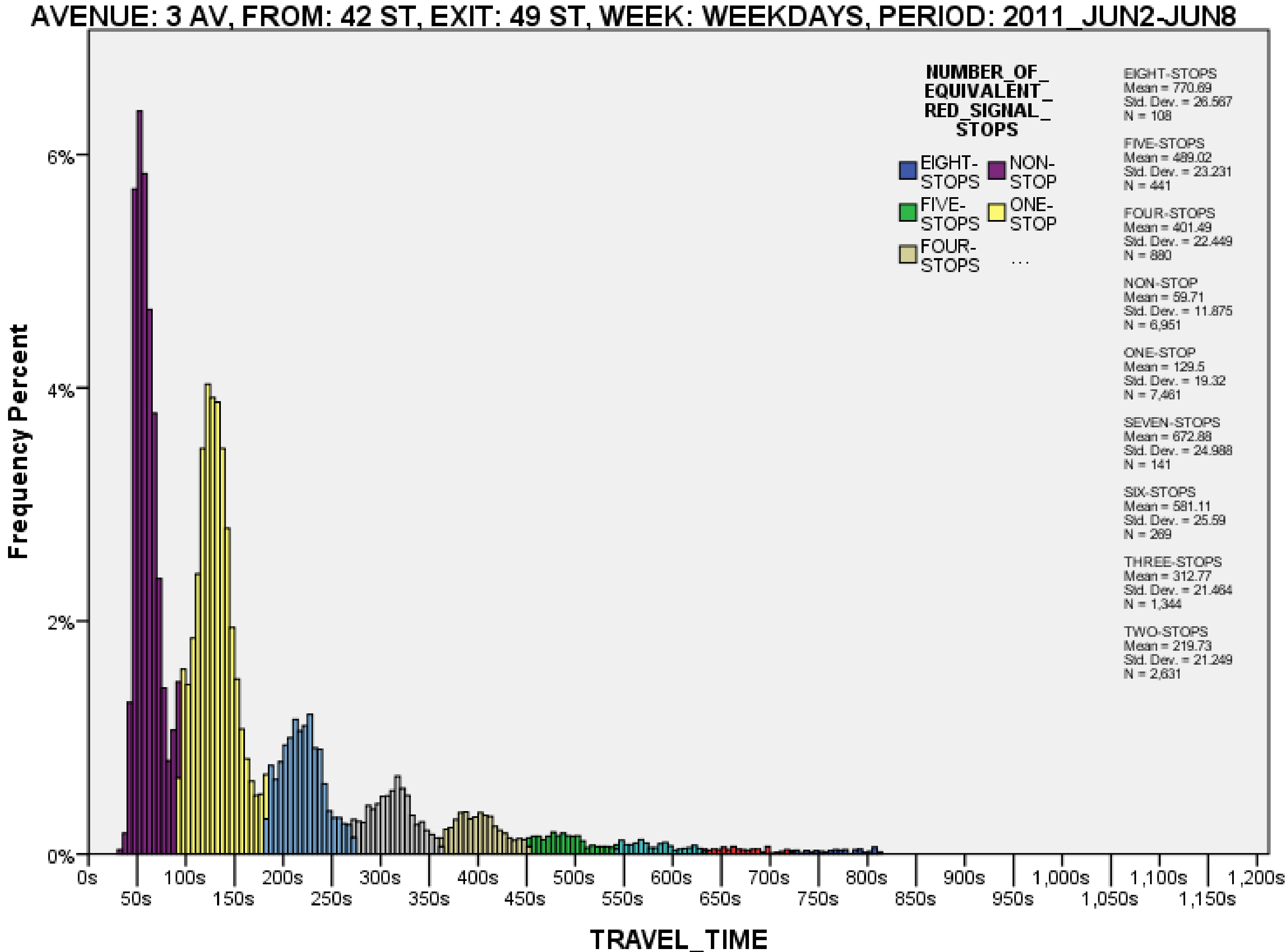
APPENDIX A

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



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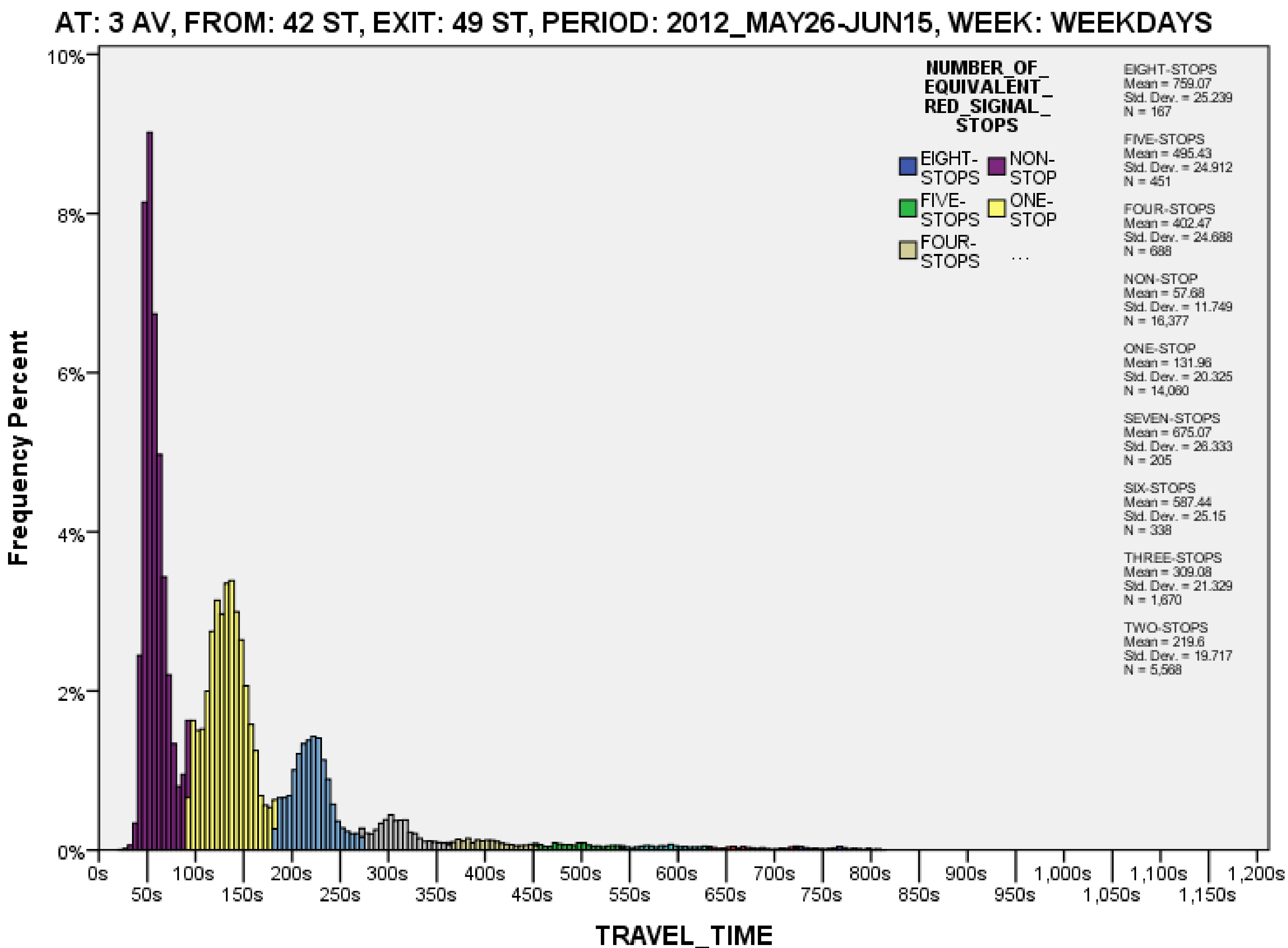

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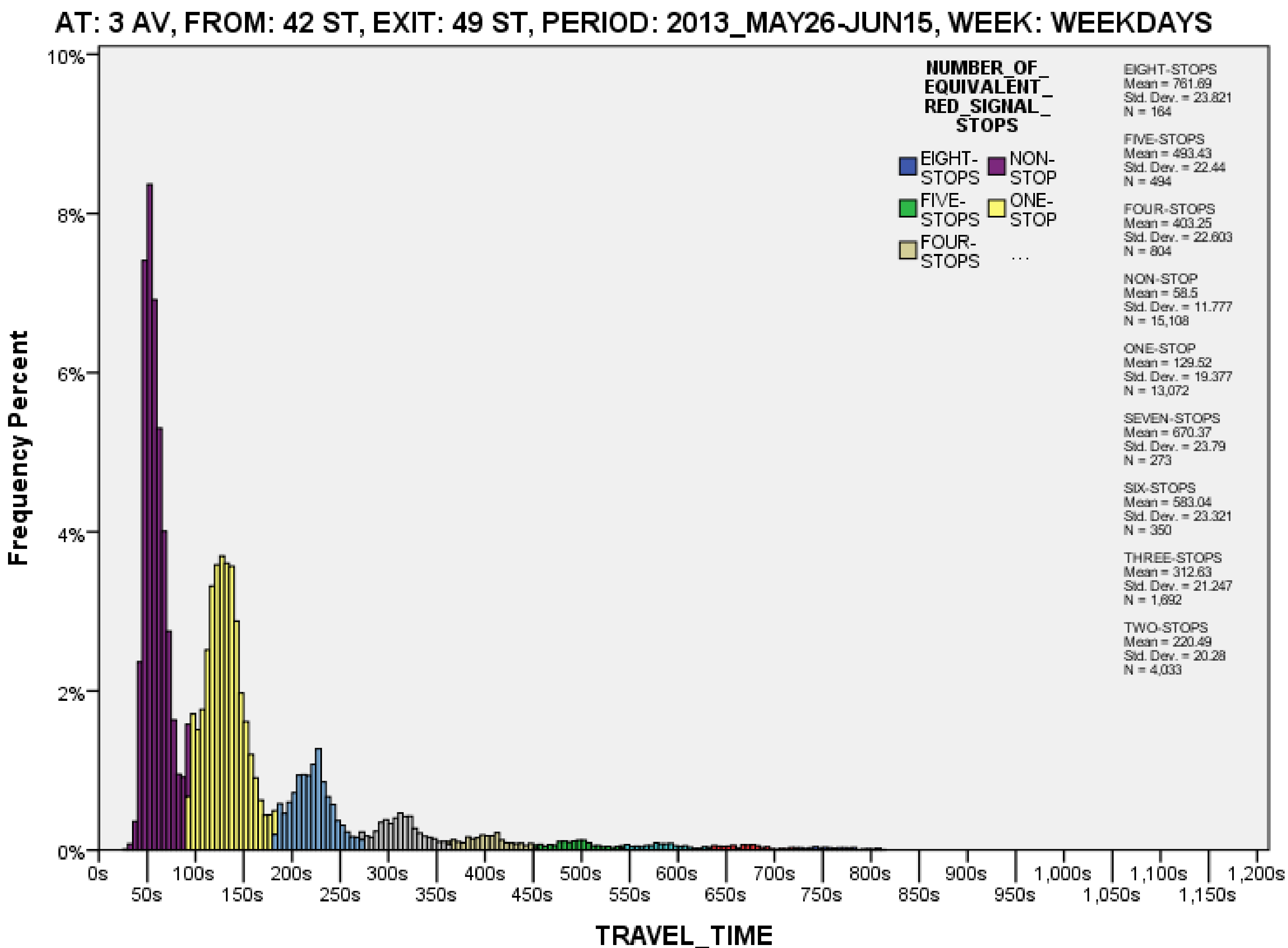

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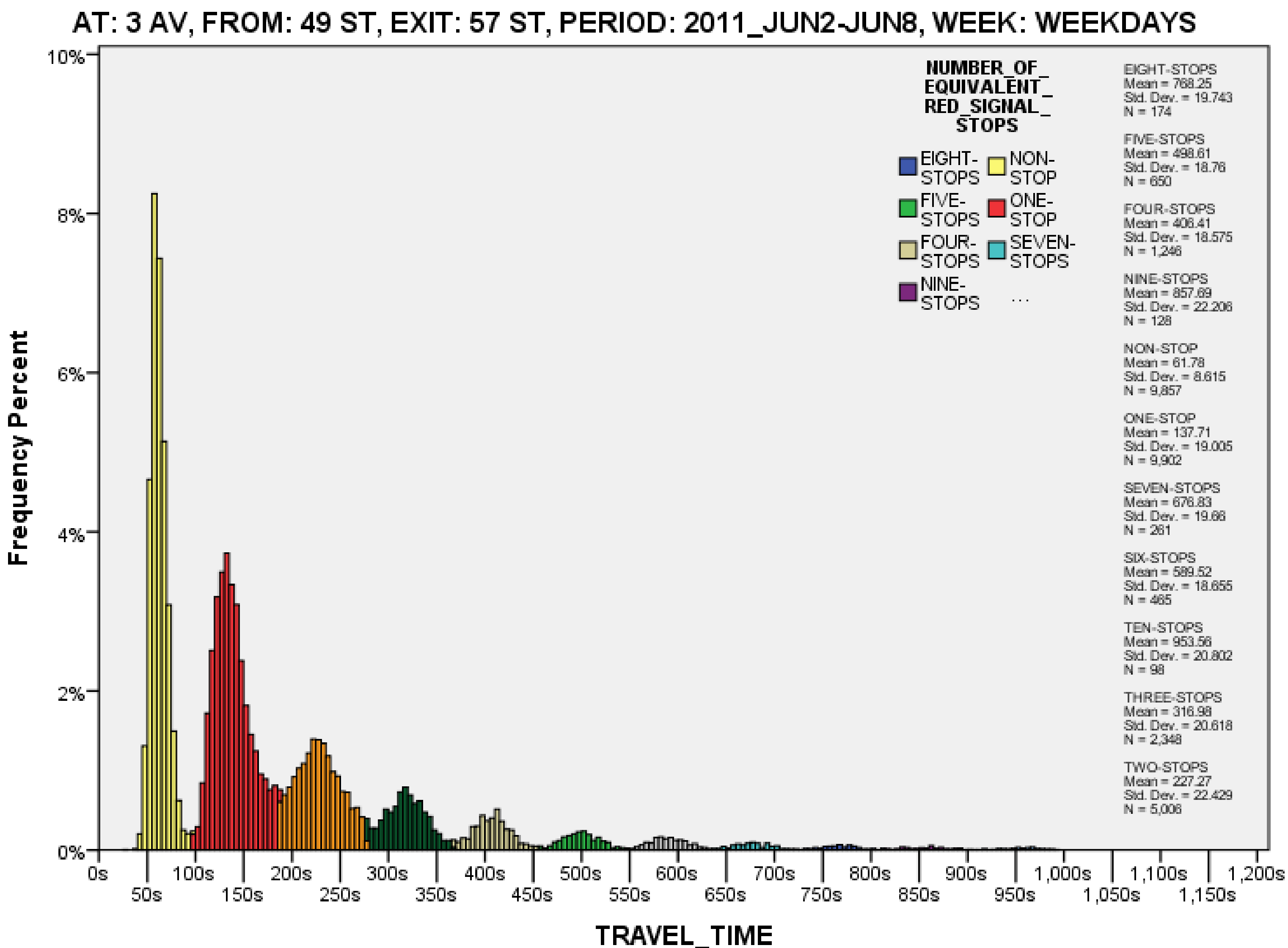

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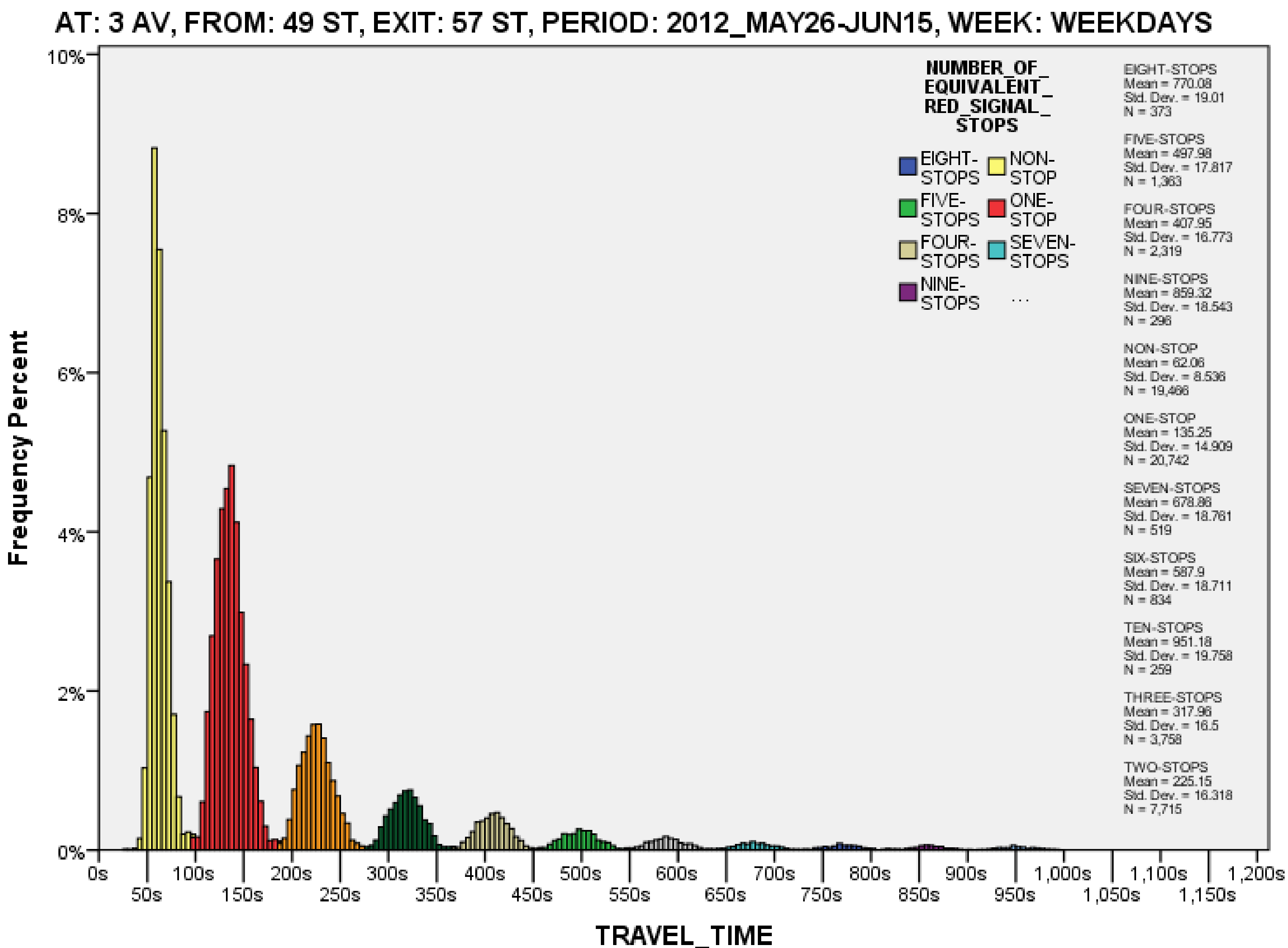

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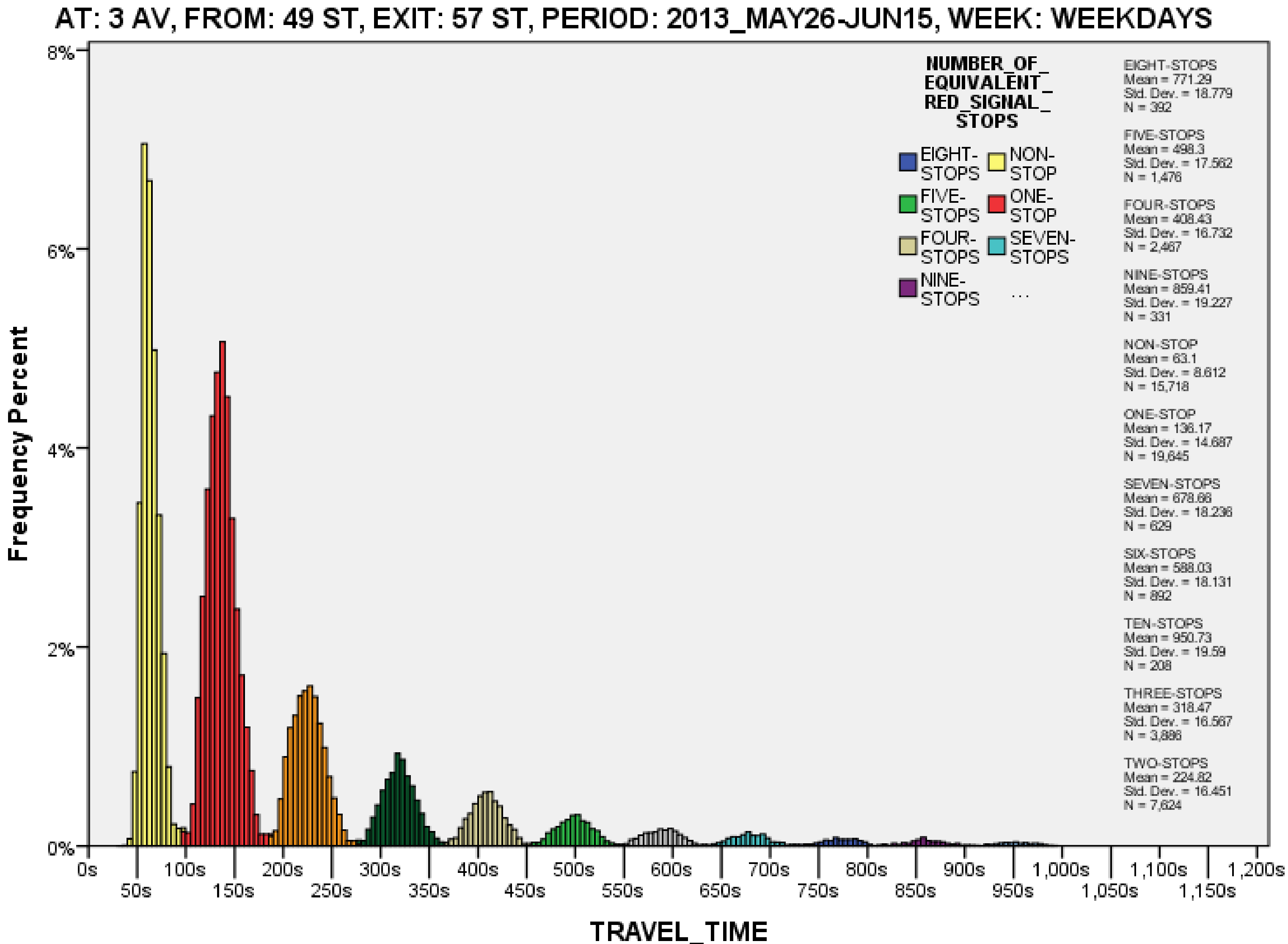

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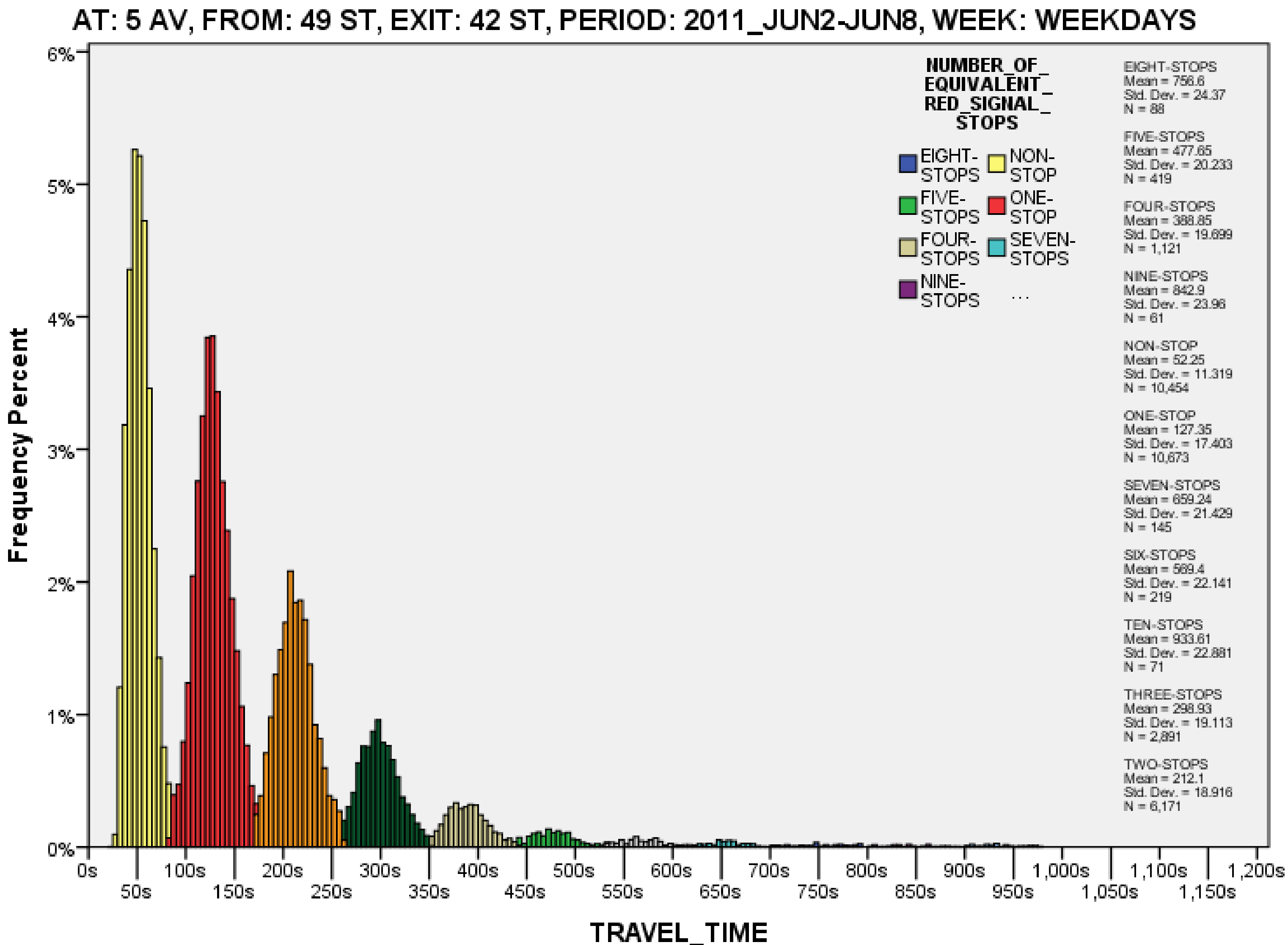

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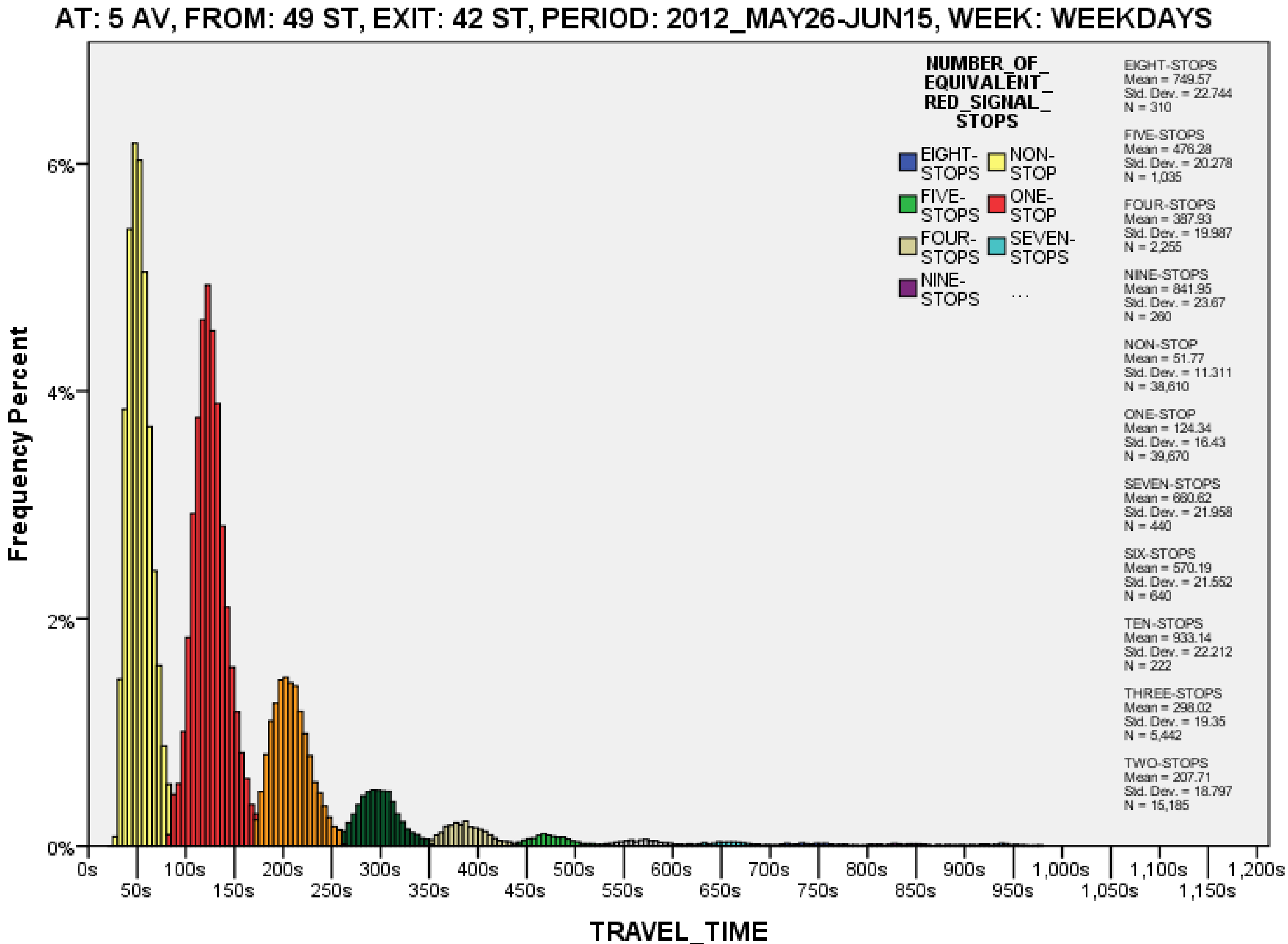

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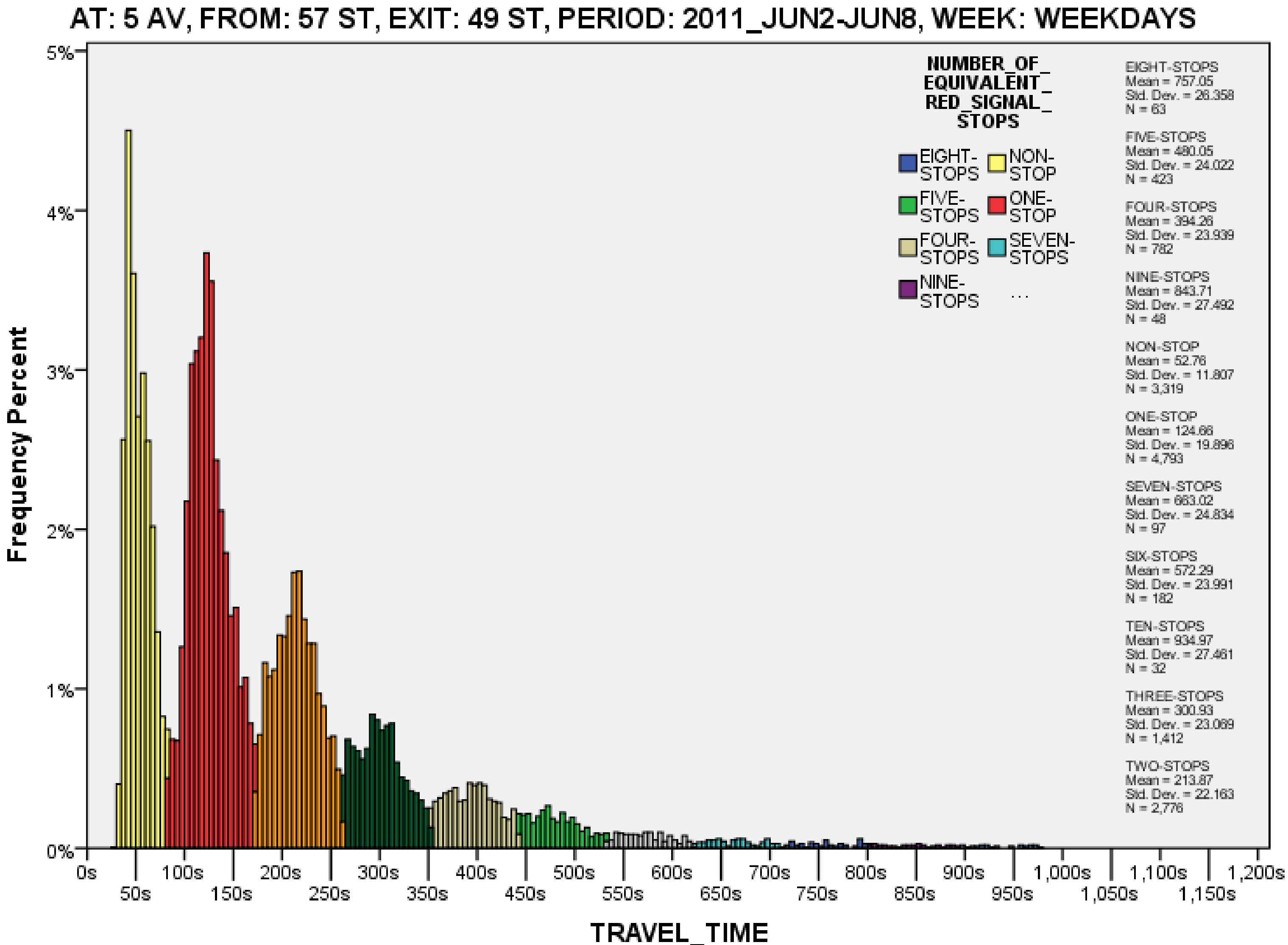

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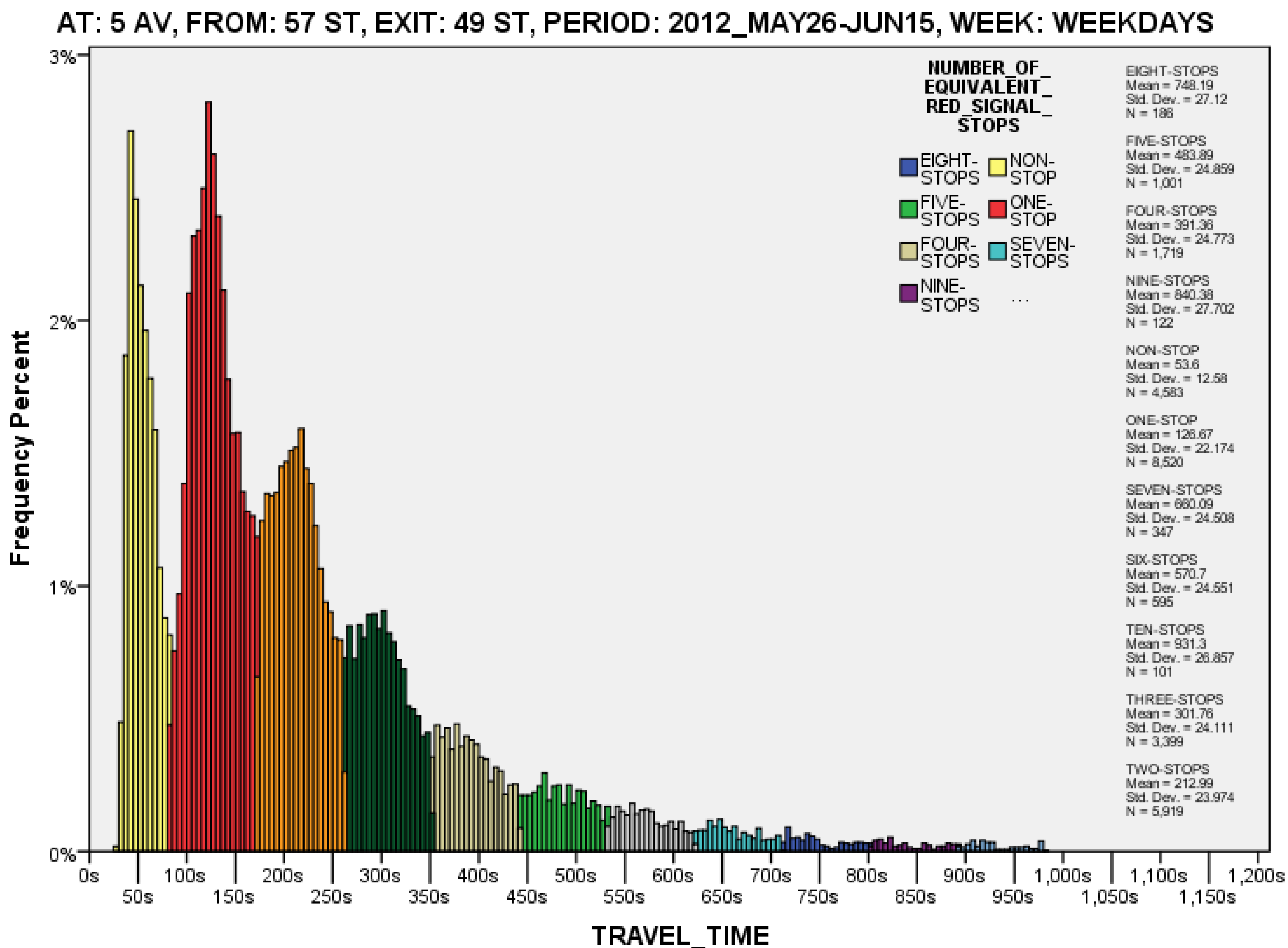

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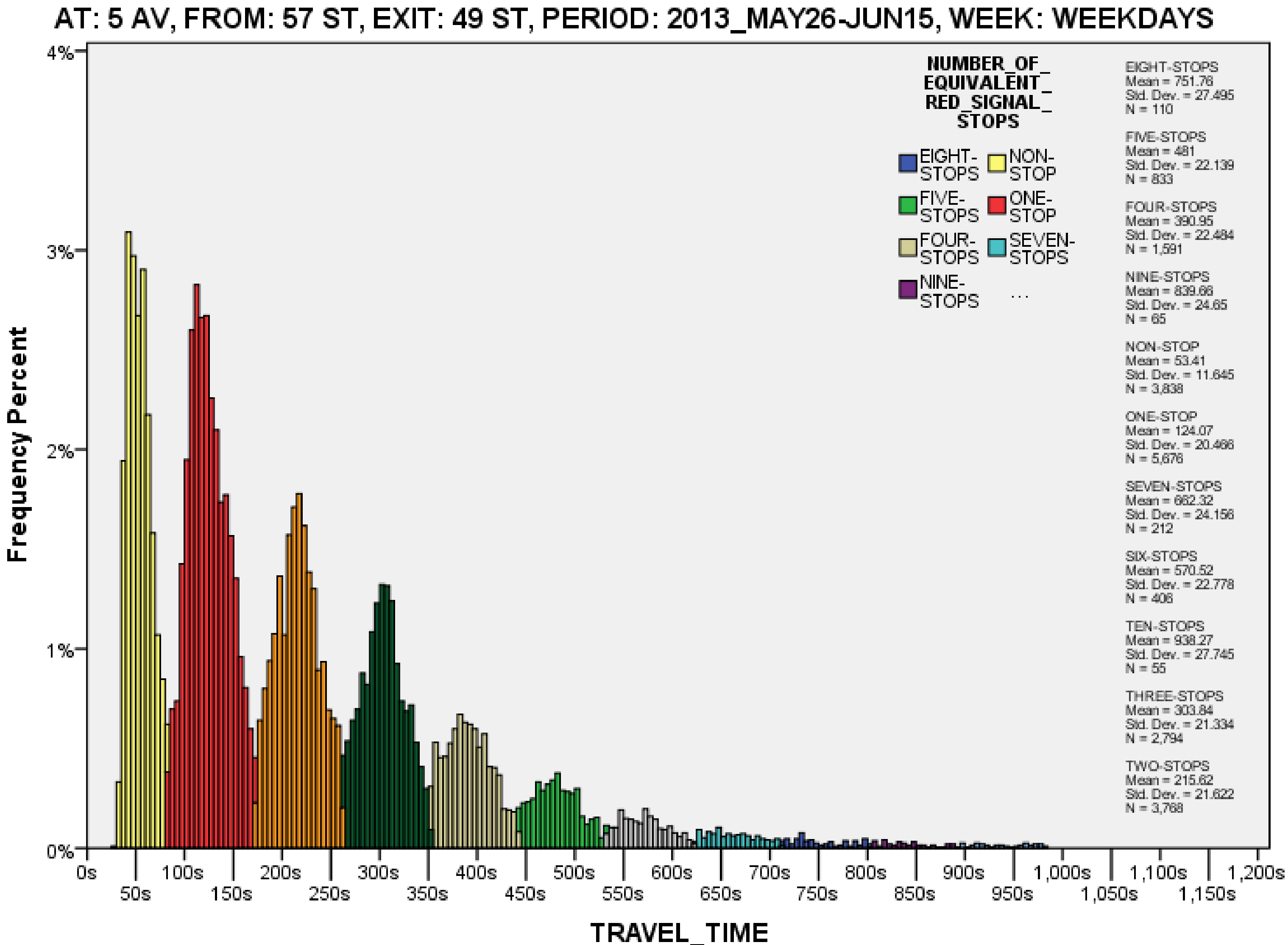

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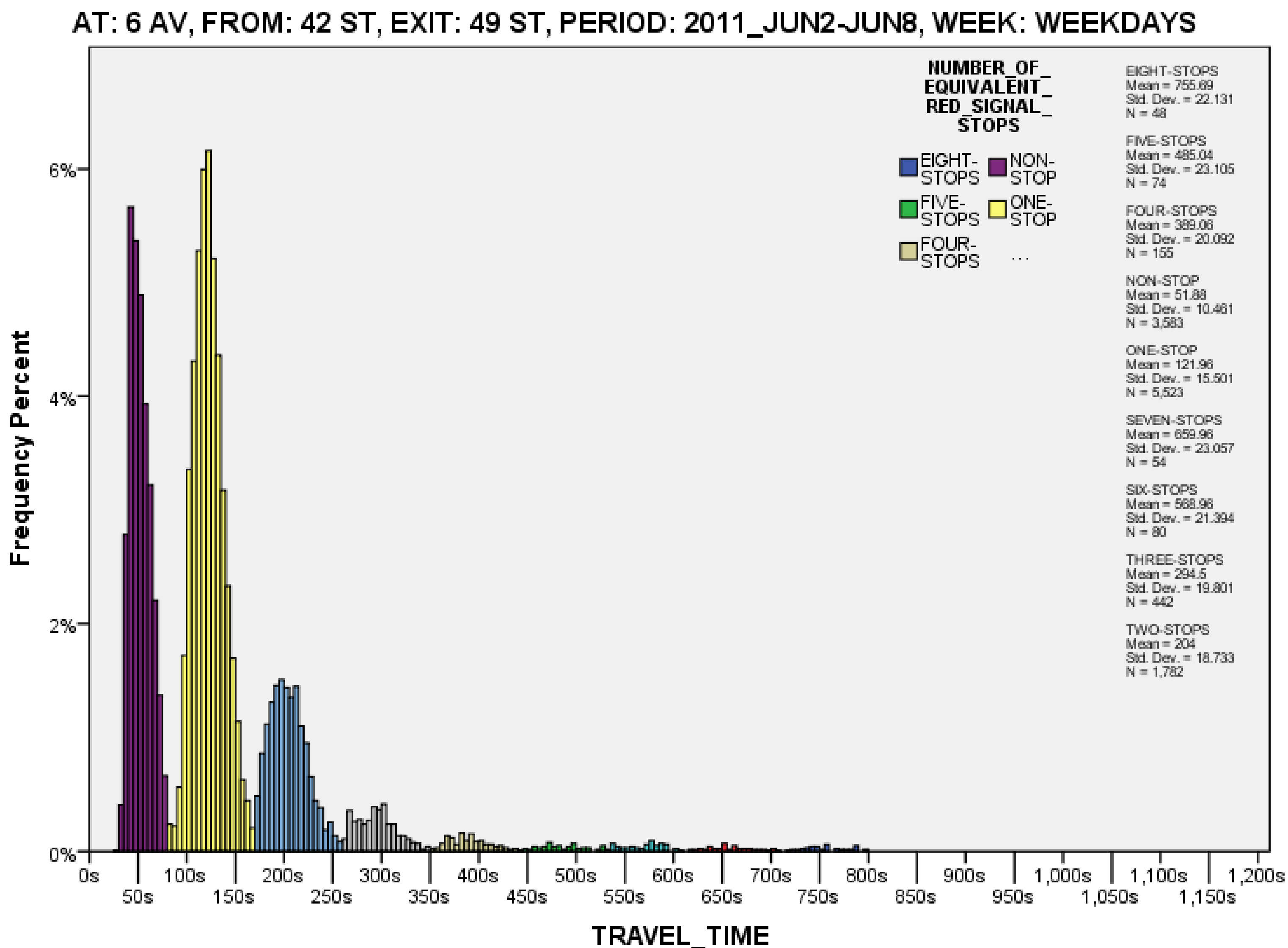

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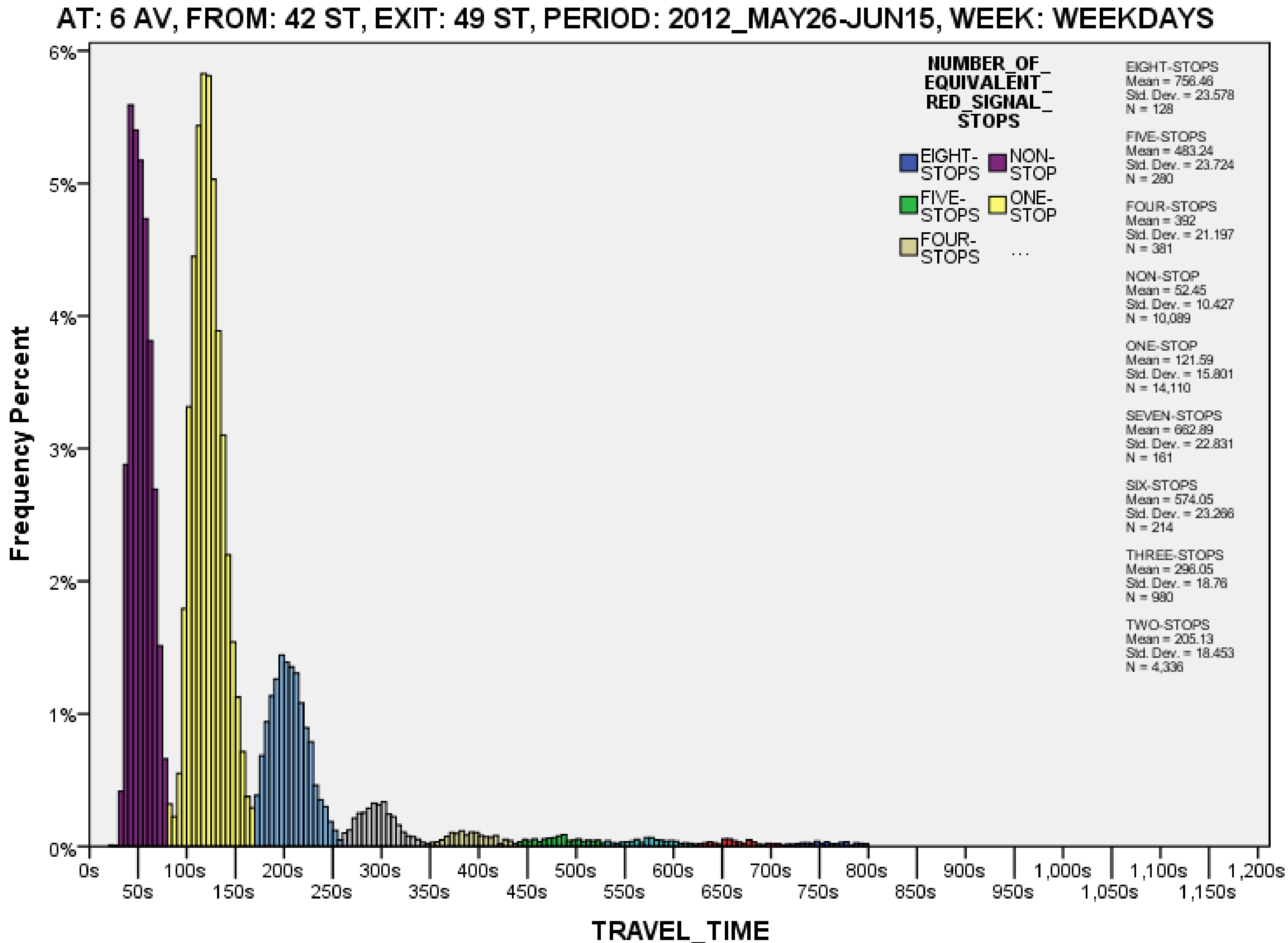

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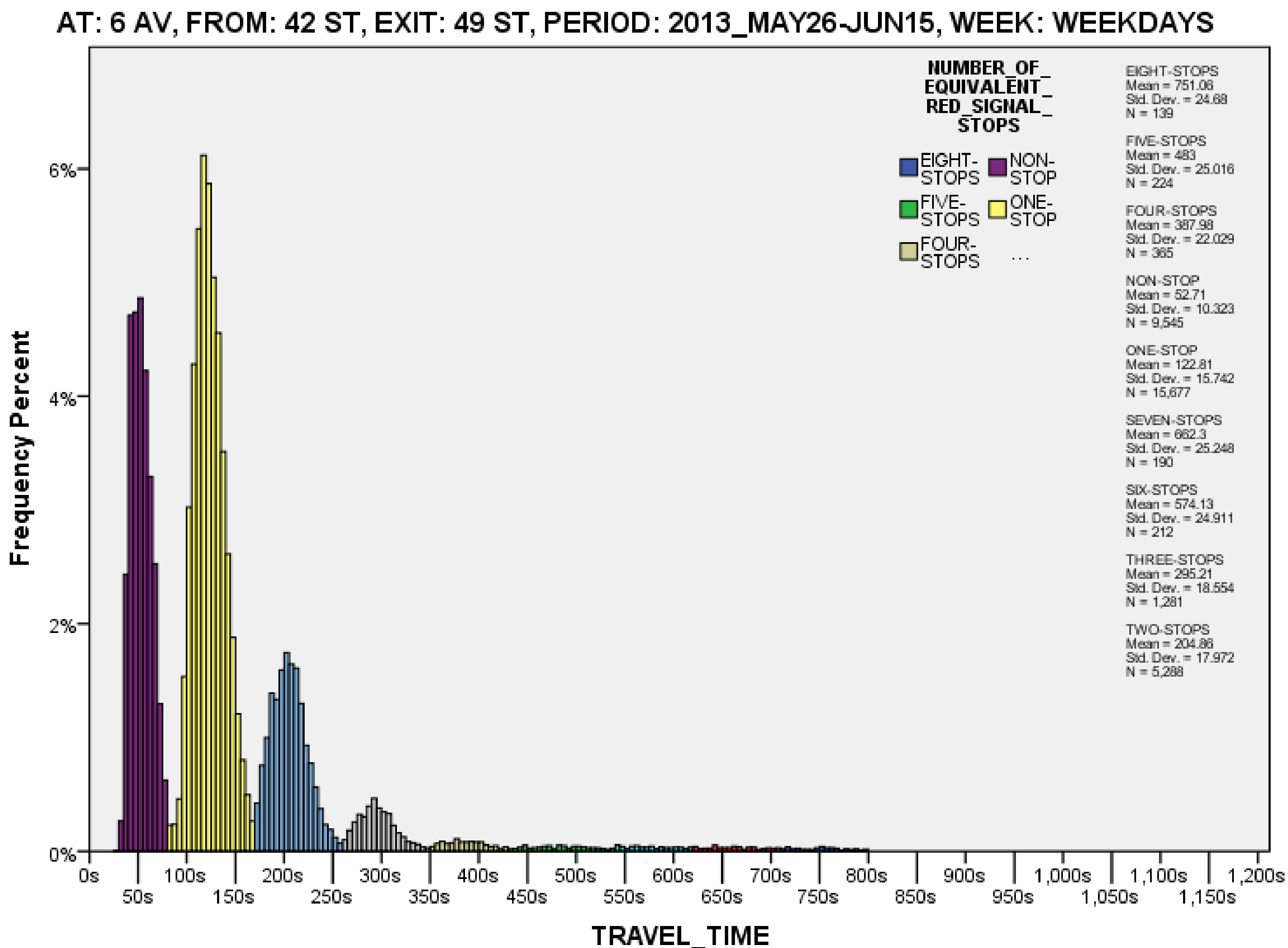

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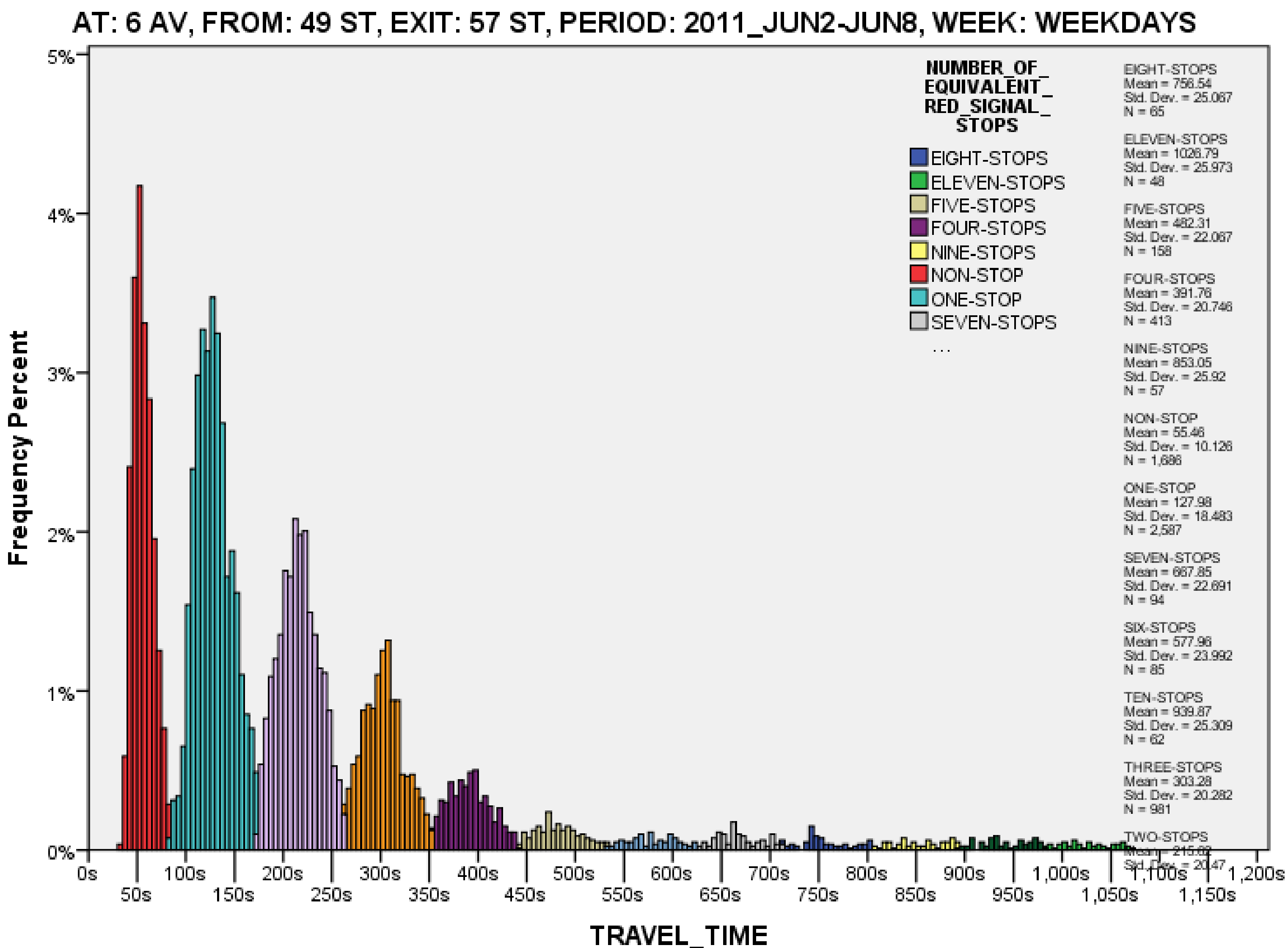

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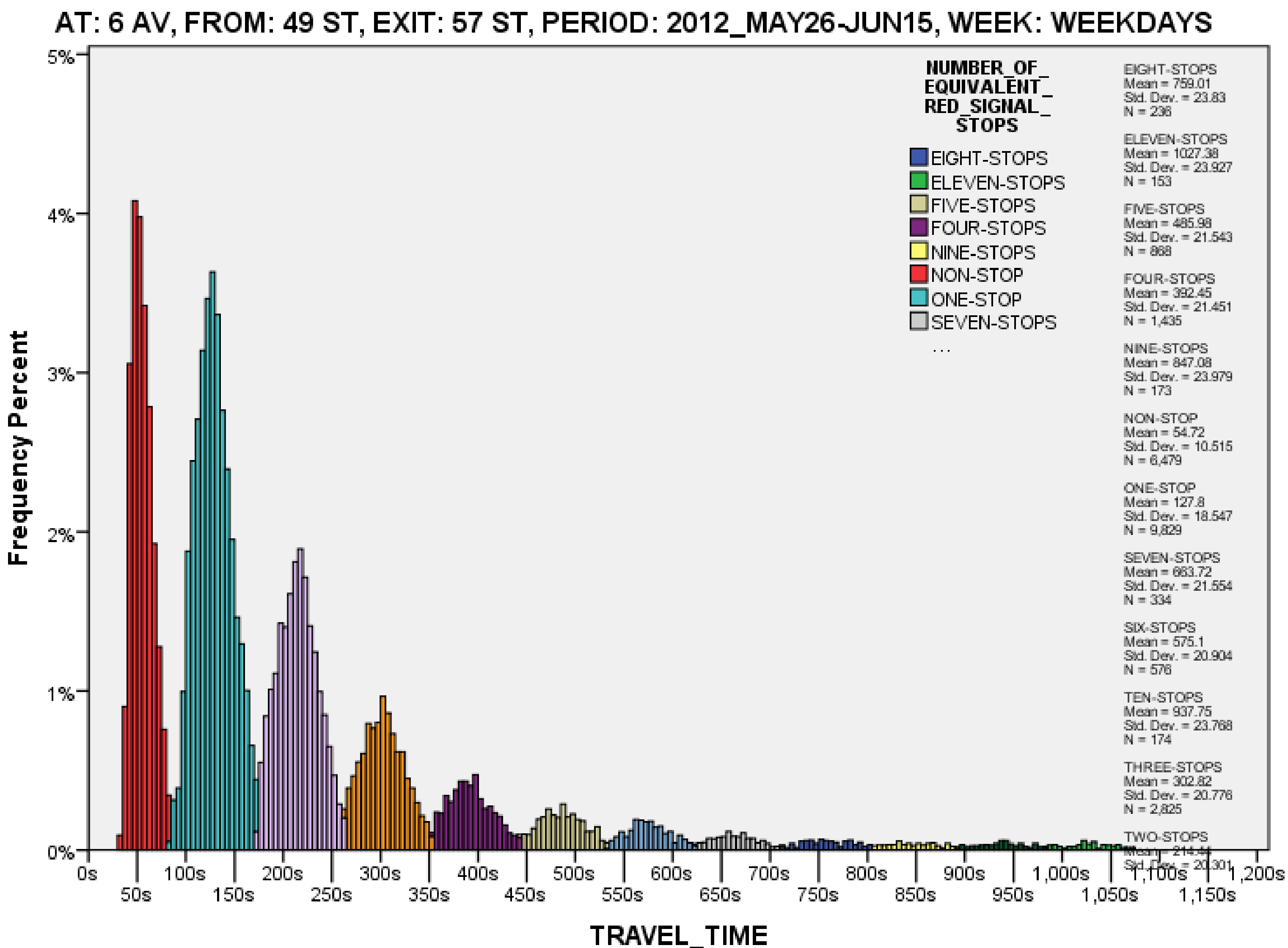

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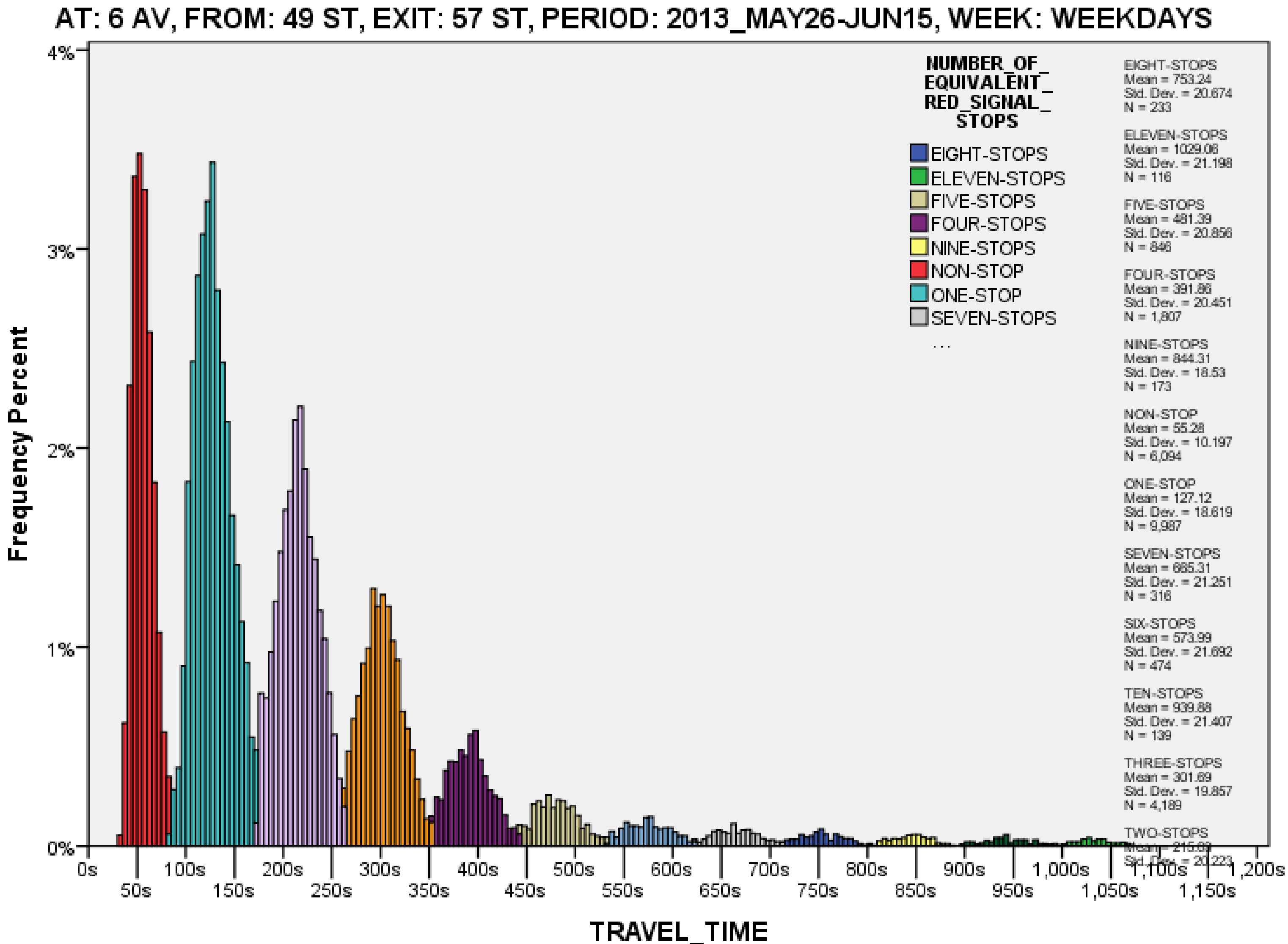
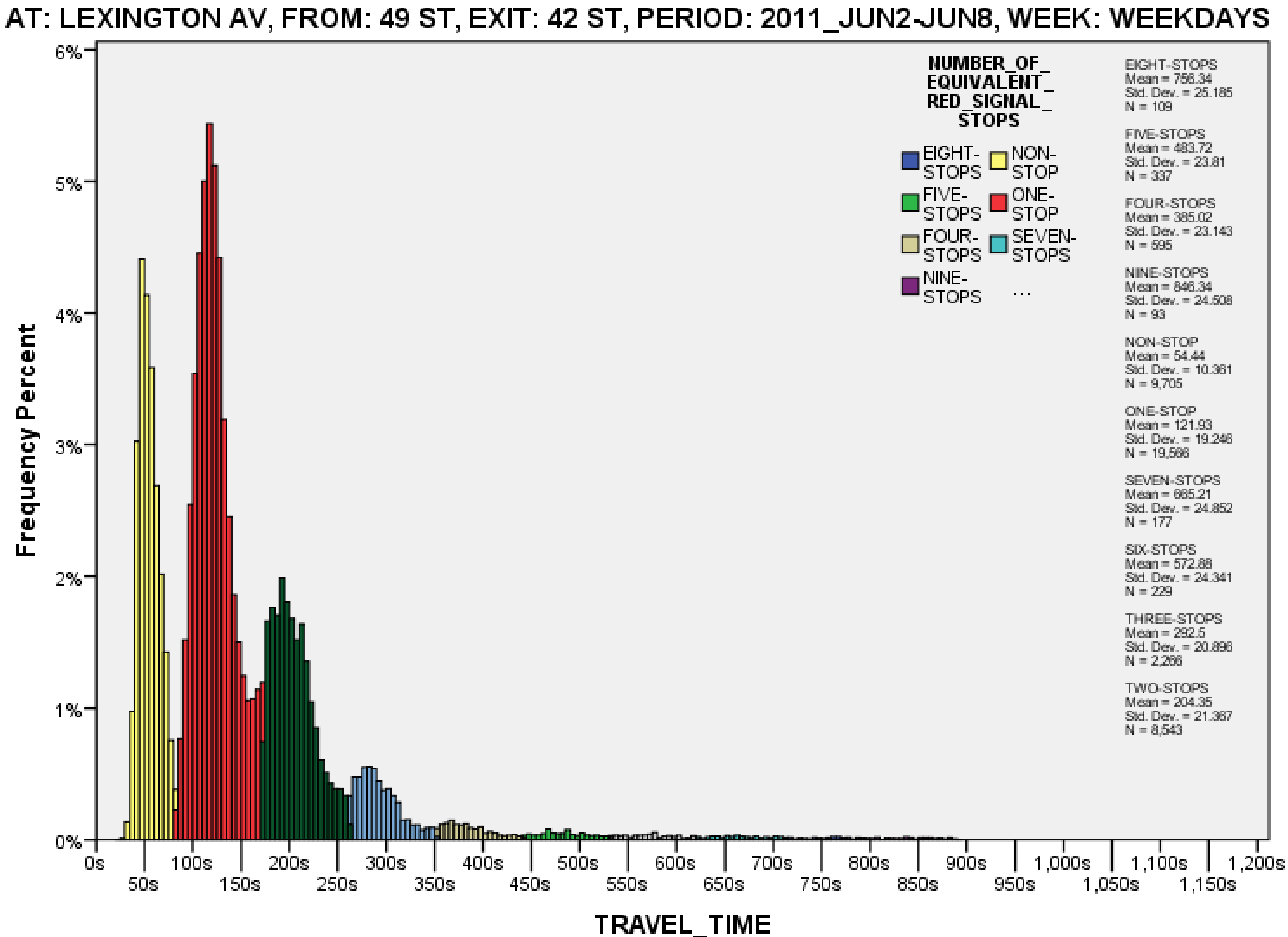
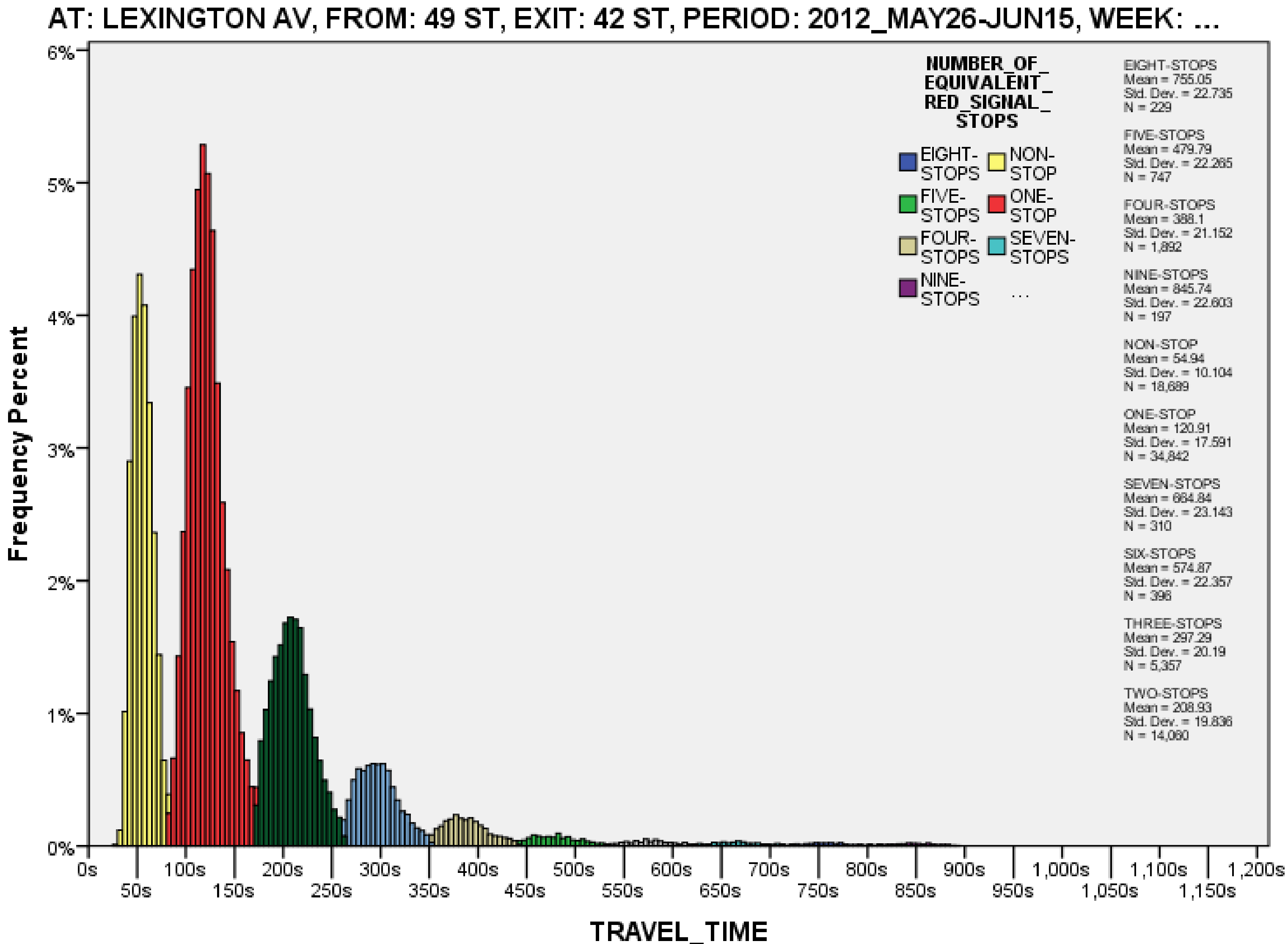
-DATA COLLECTED BY EZPASS TAG READERS



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



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



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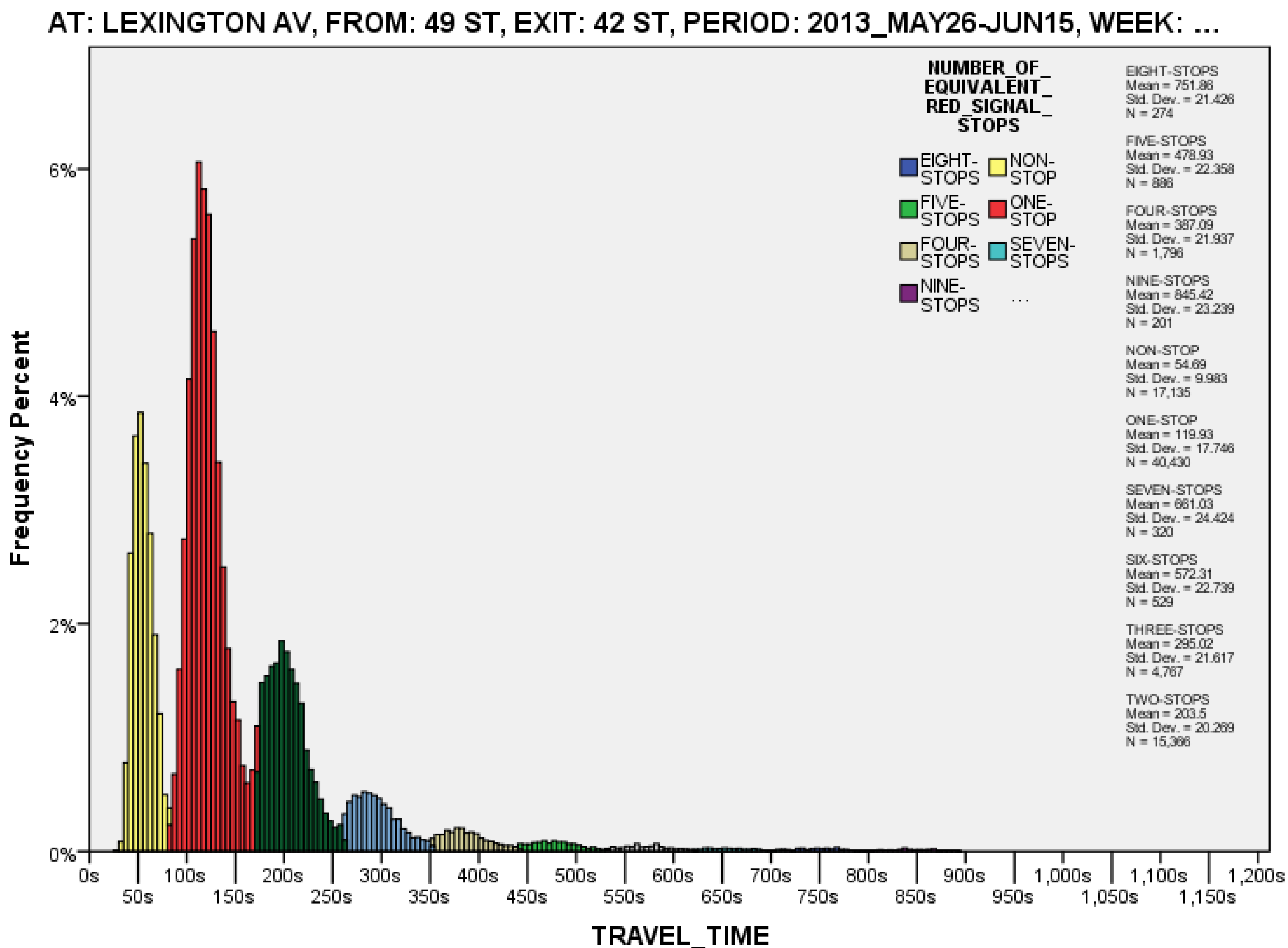
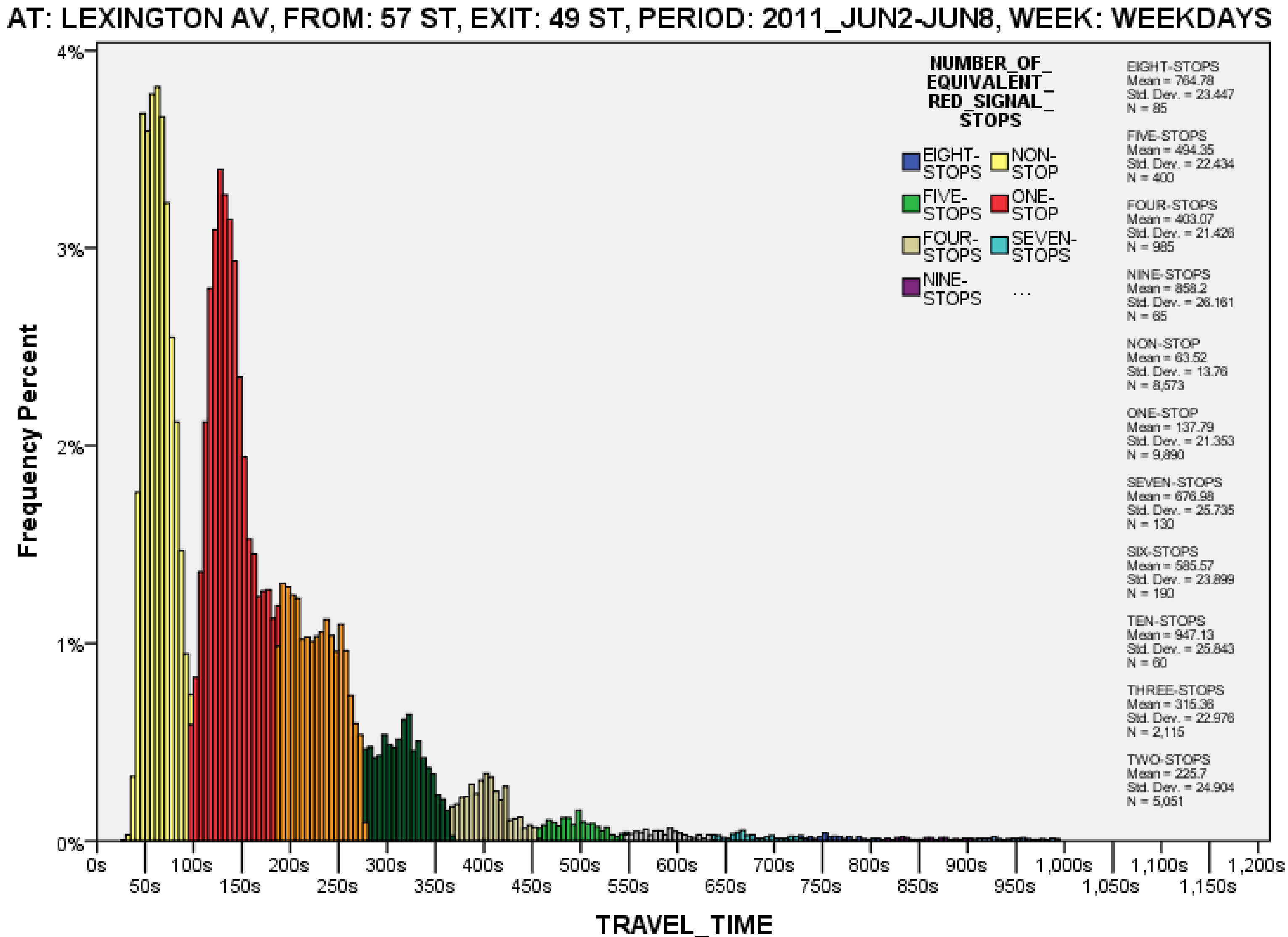
-DATA COLLECTED BY EZPASS TAG READERS



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



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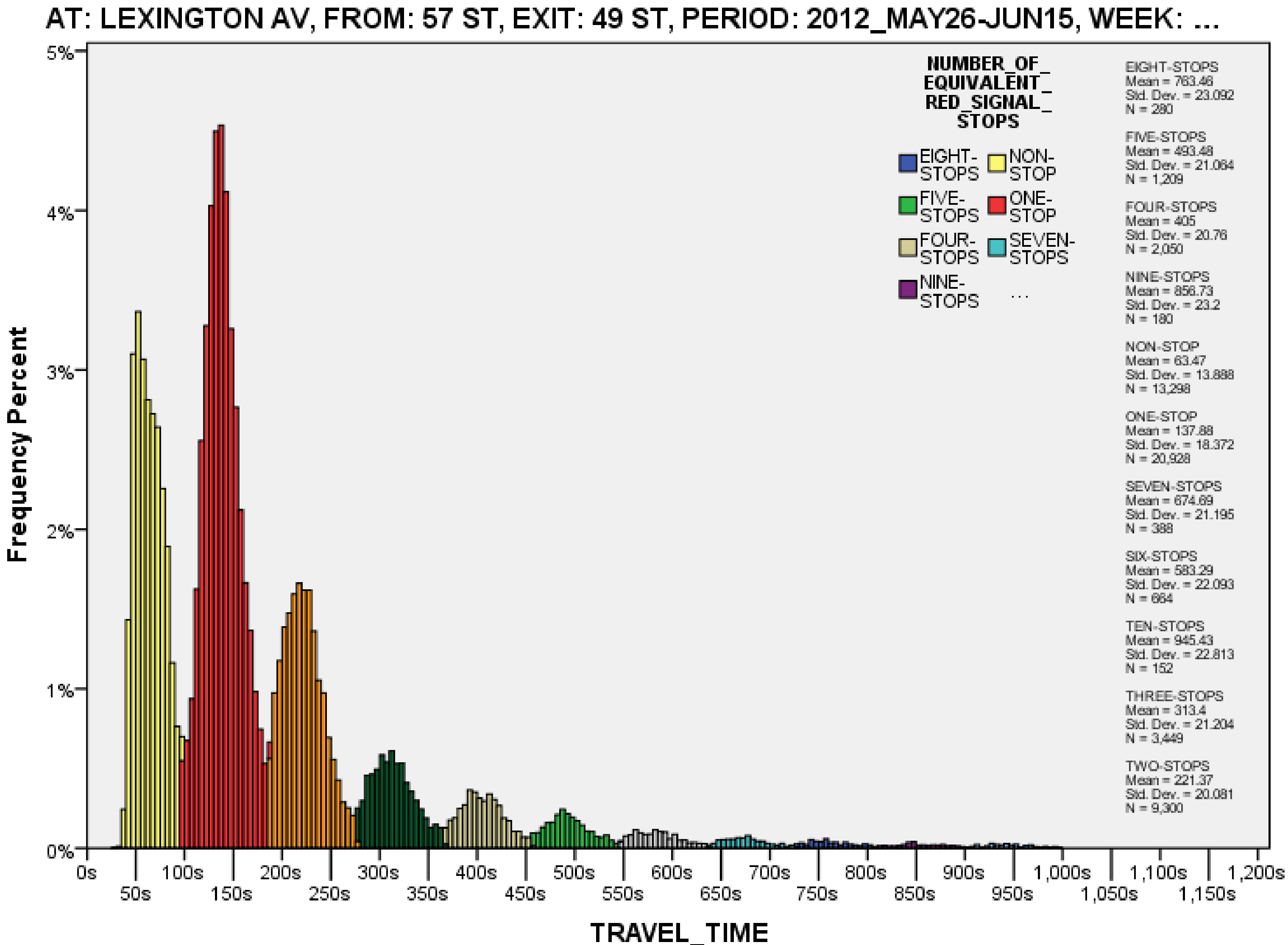
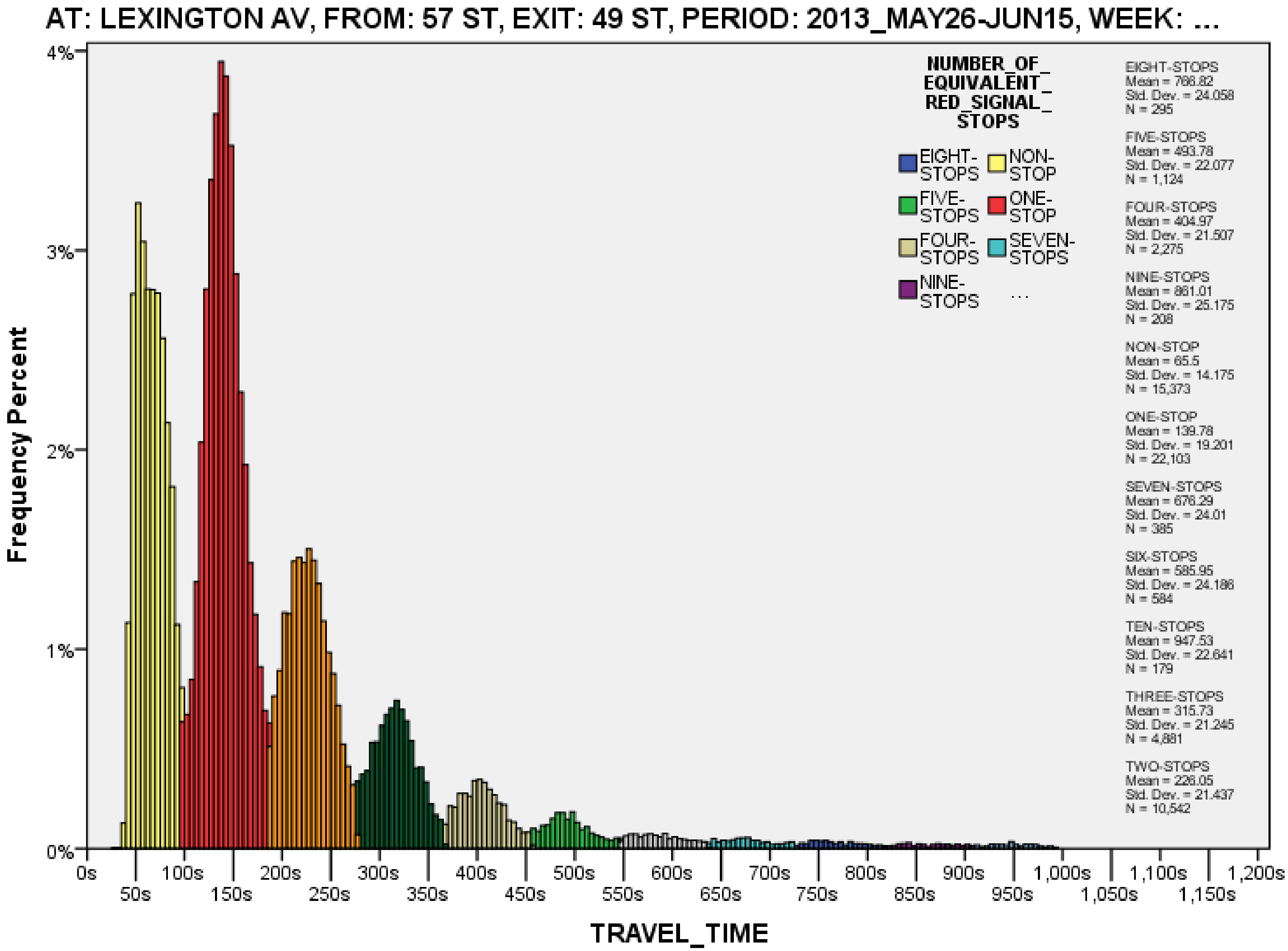
-DATA COLLECTED BY EZPASS TAG READERS



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



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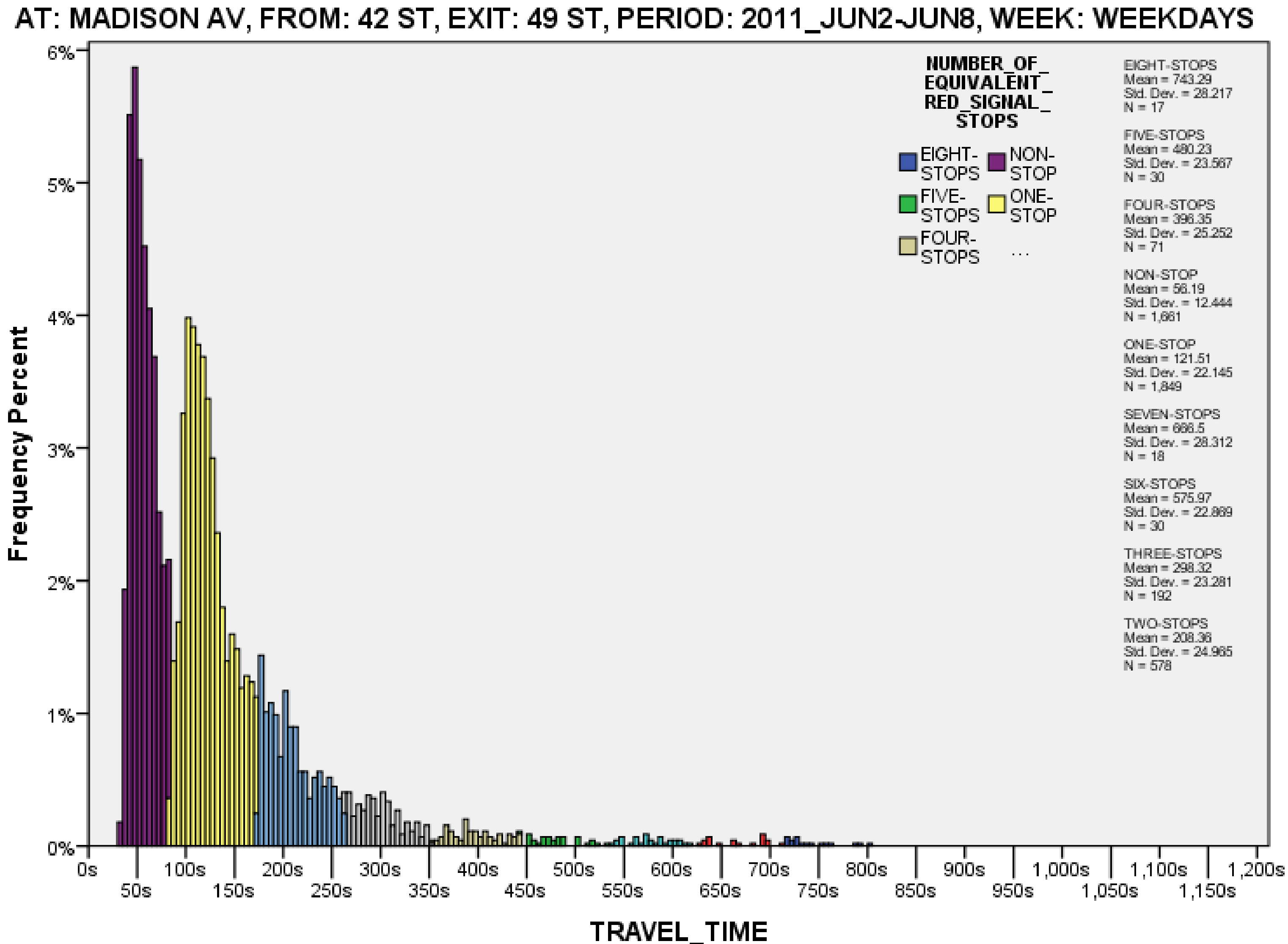
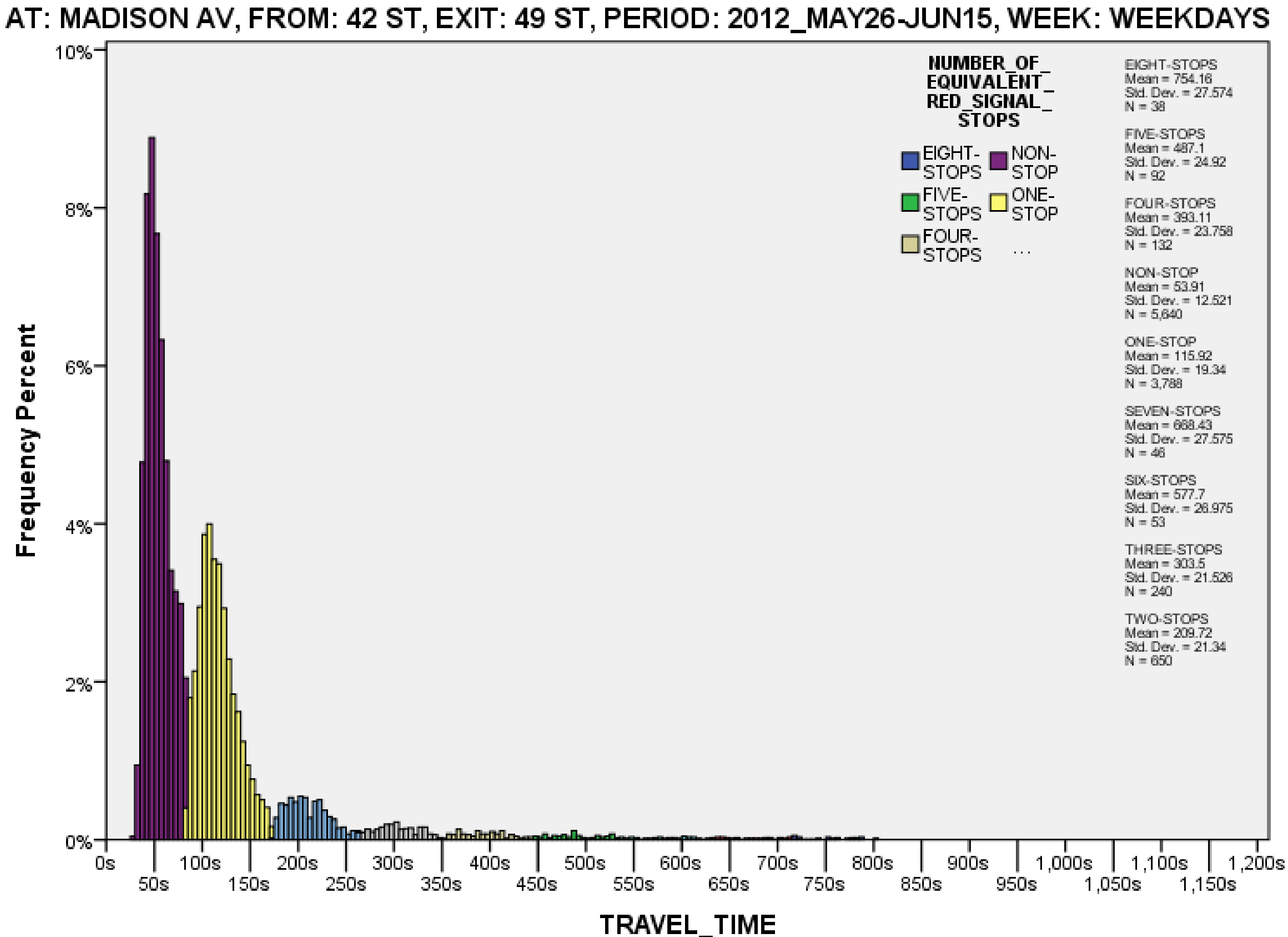
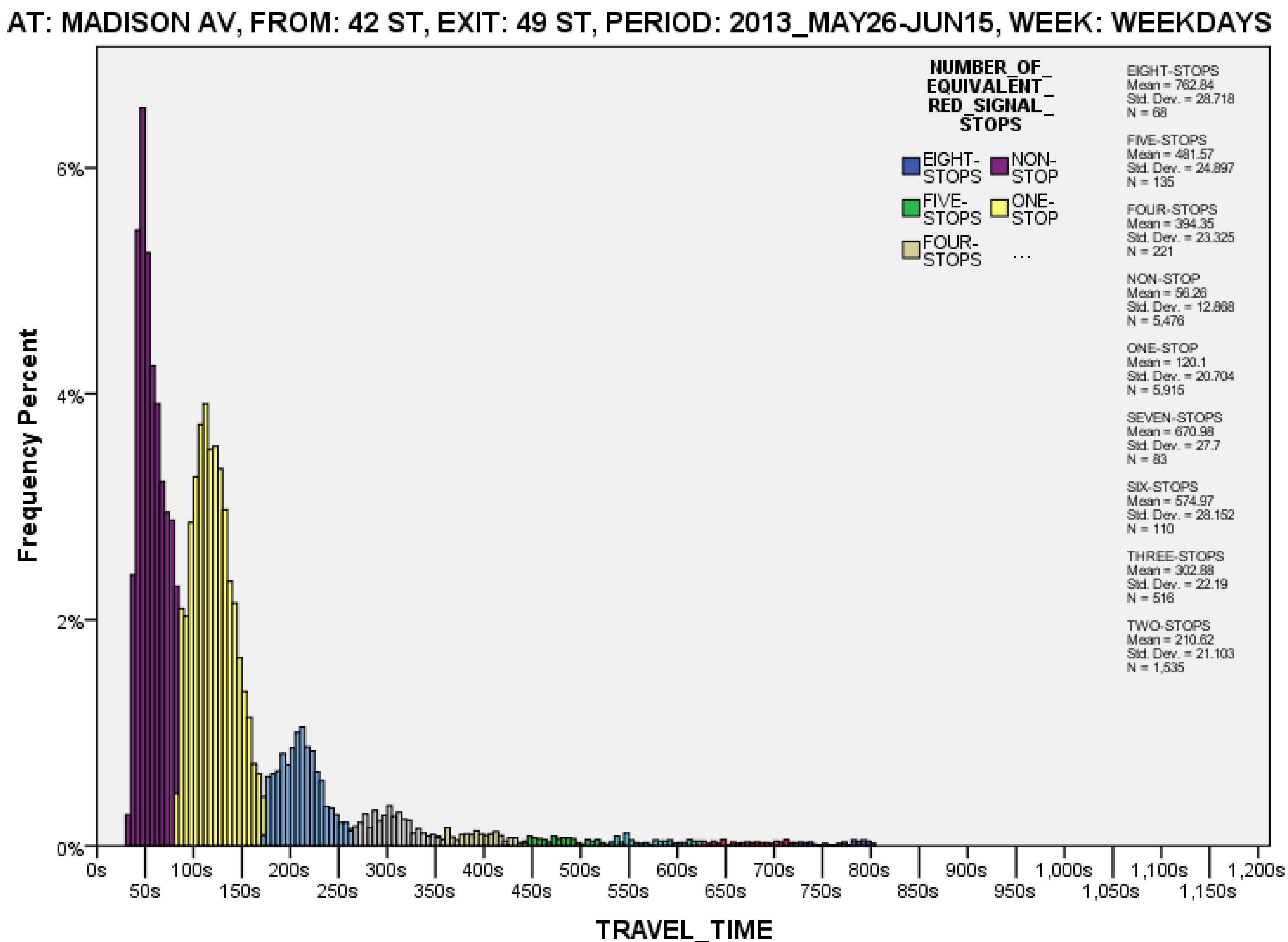
-DATA COLLECTED BY EZPASS TAG READERS



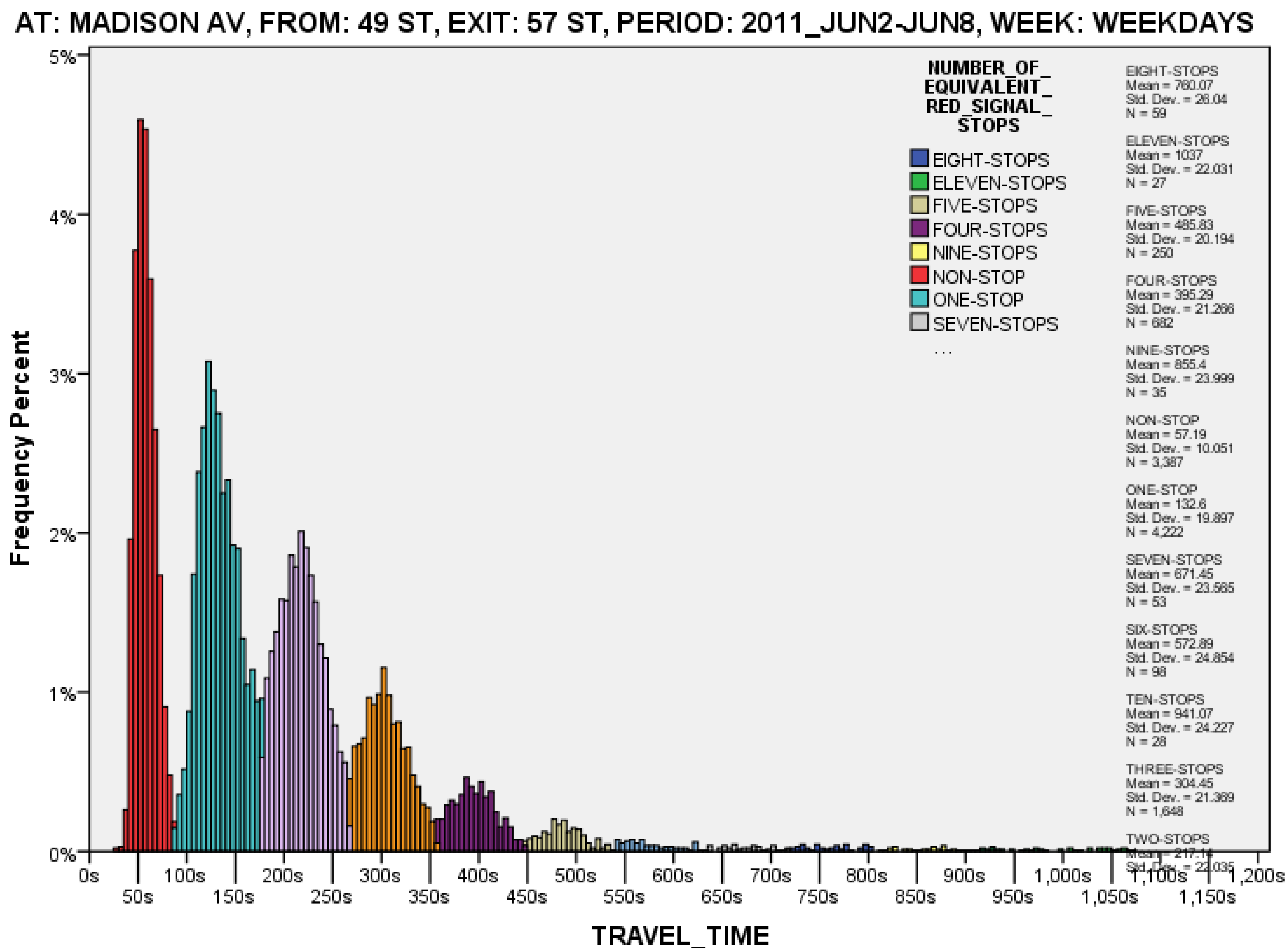
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



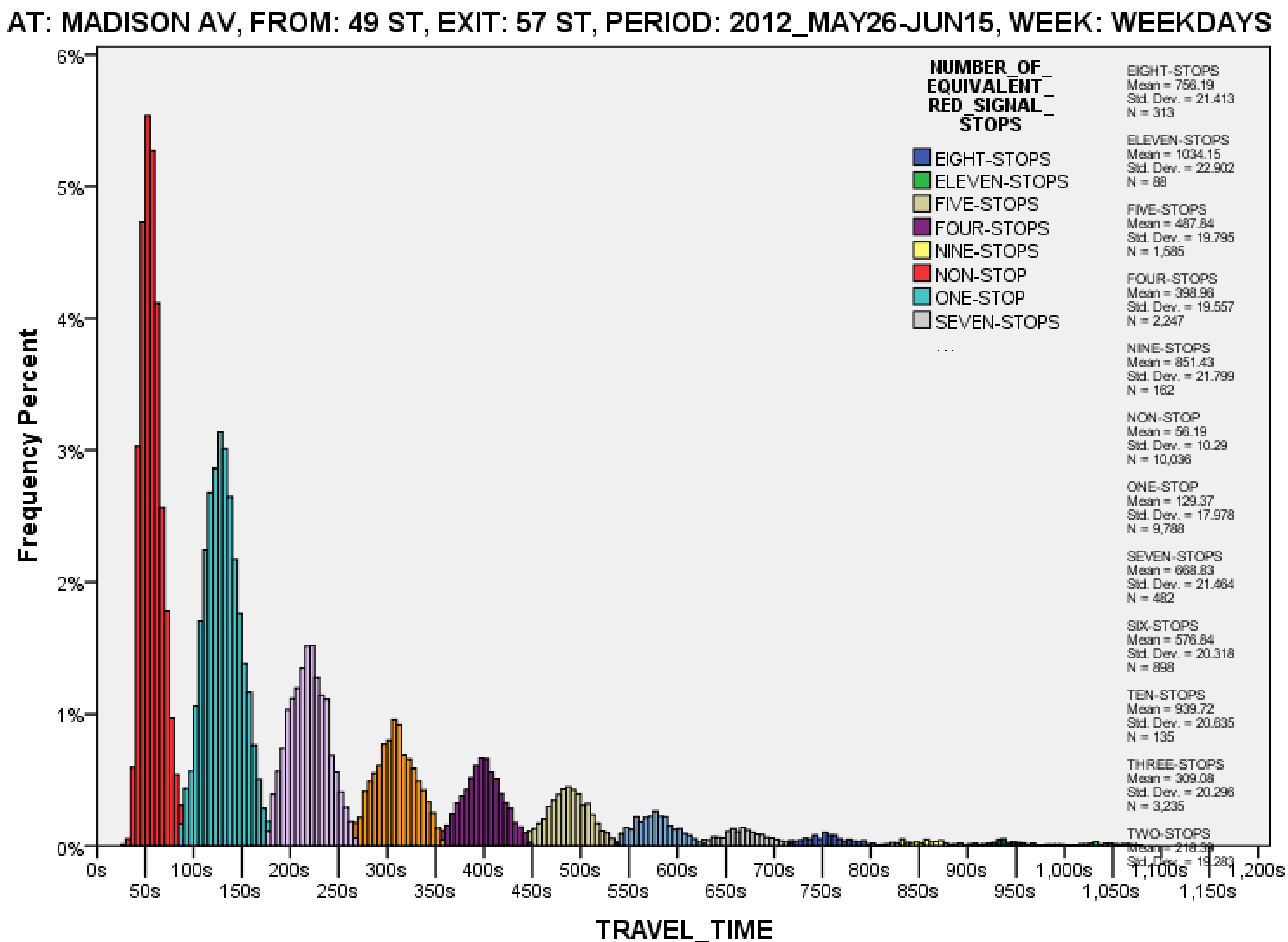
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



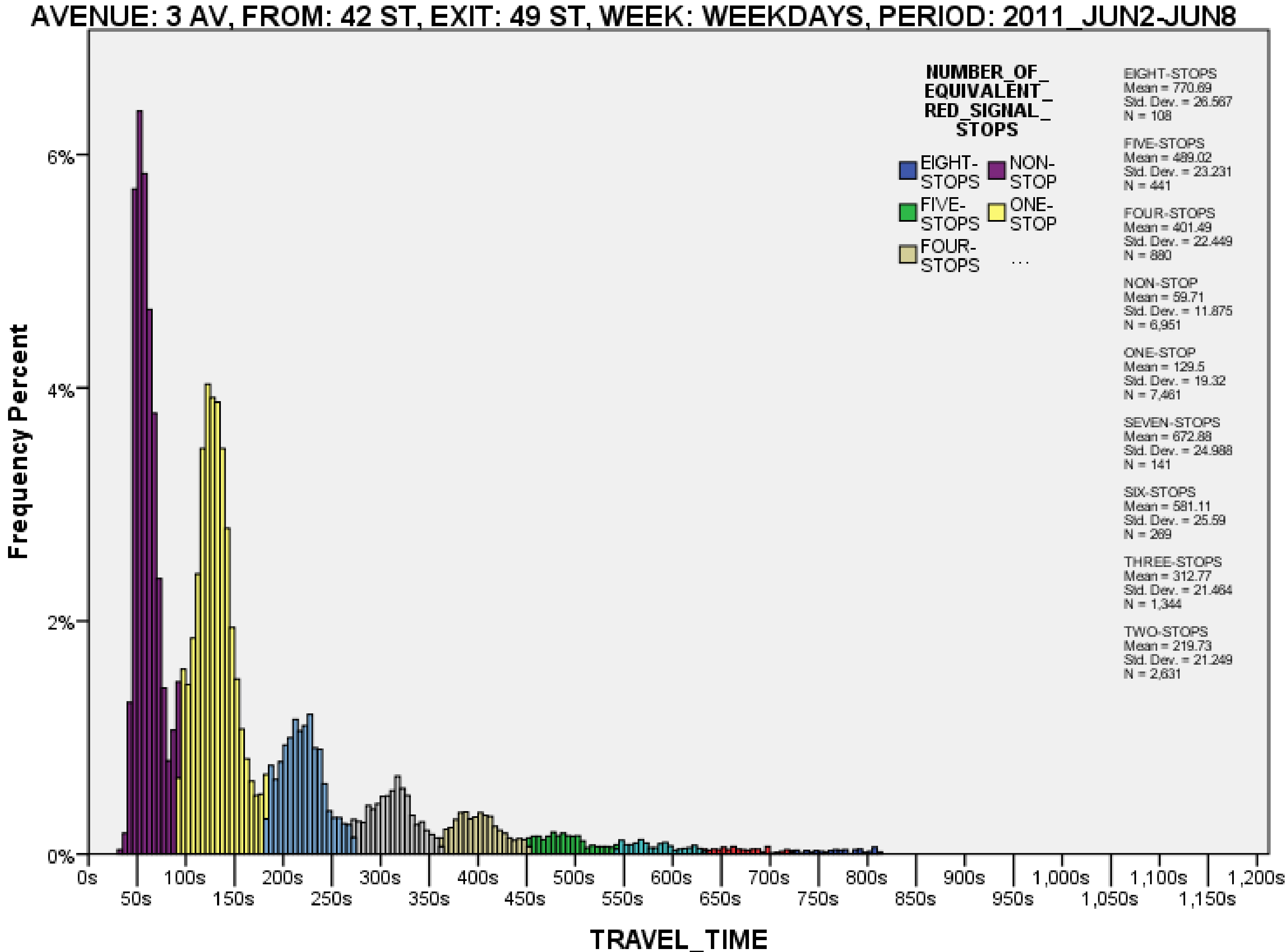
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



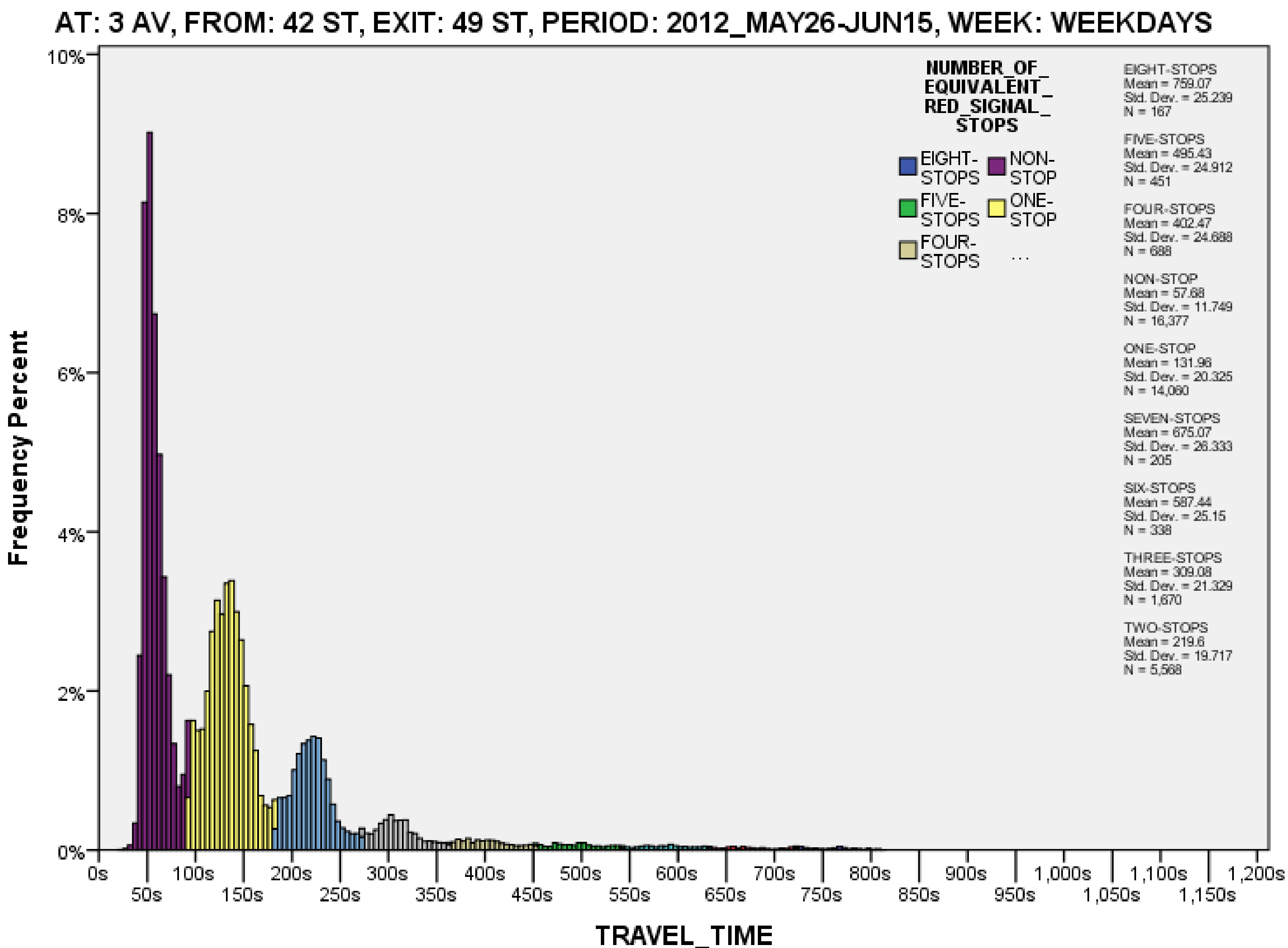
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



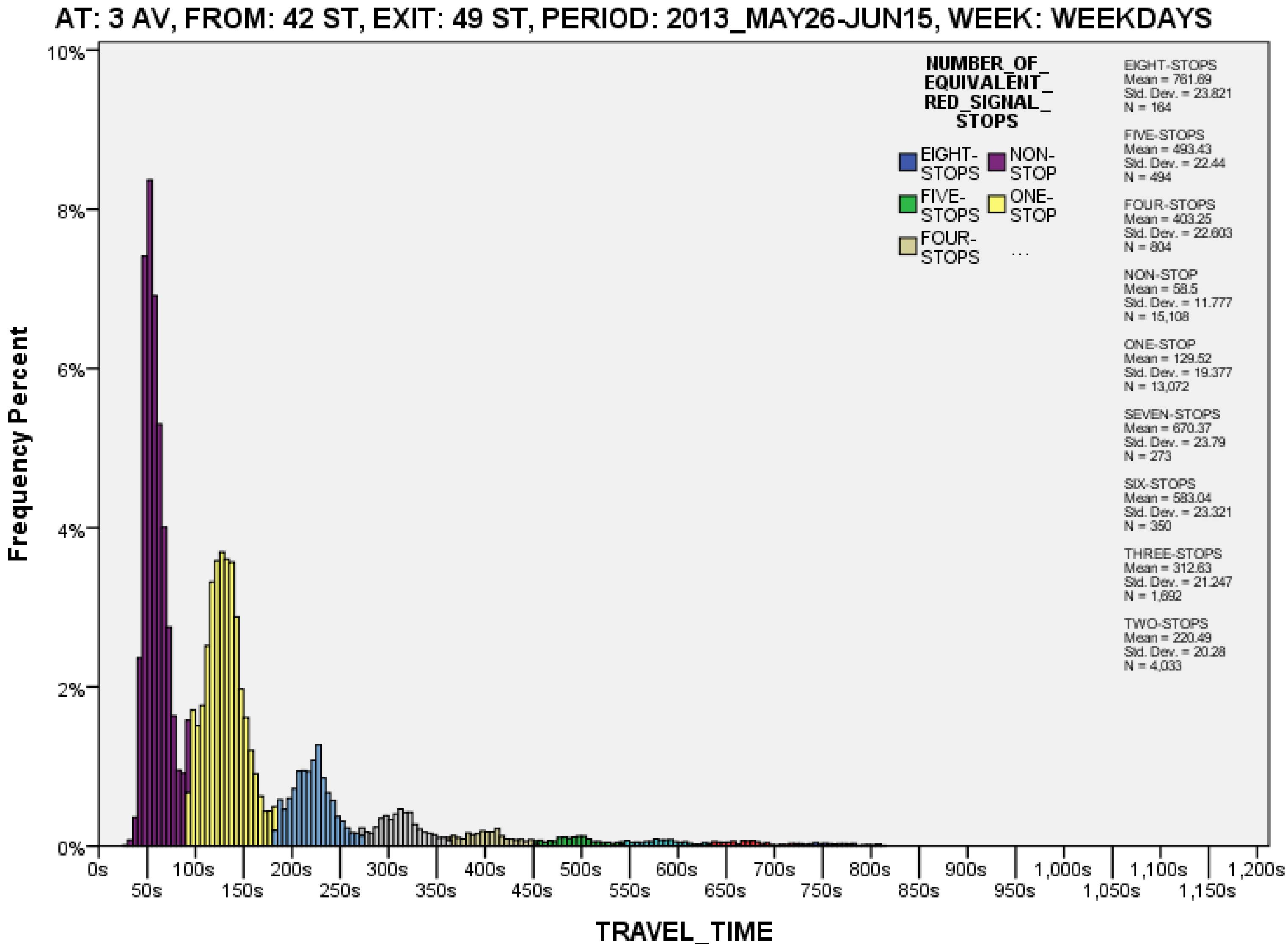
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



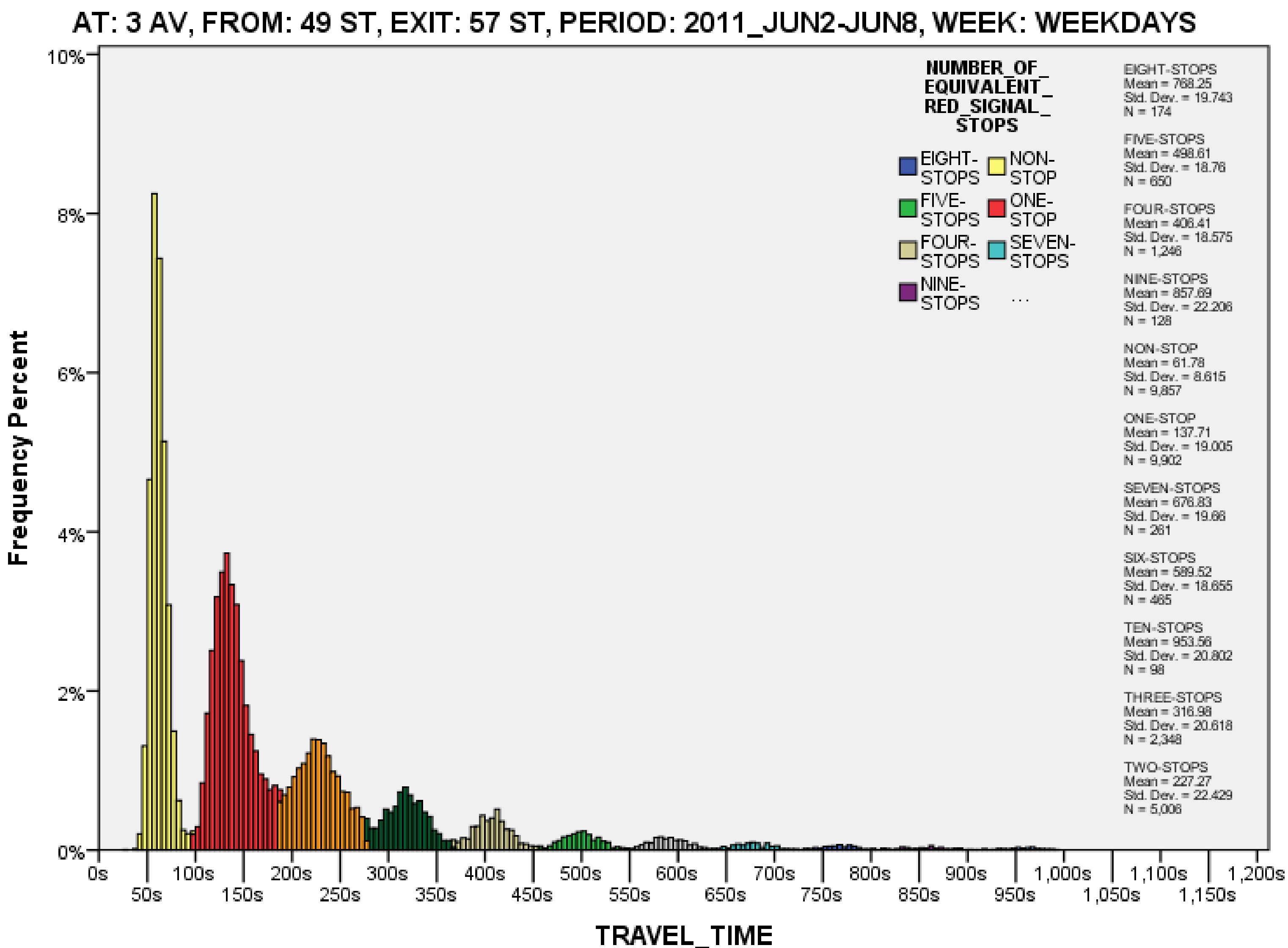
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



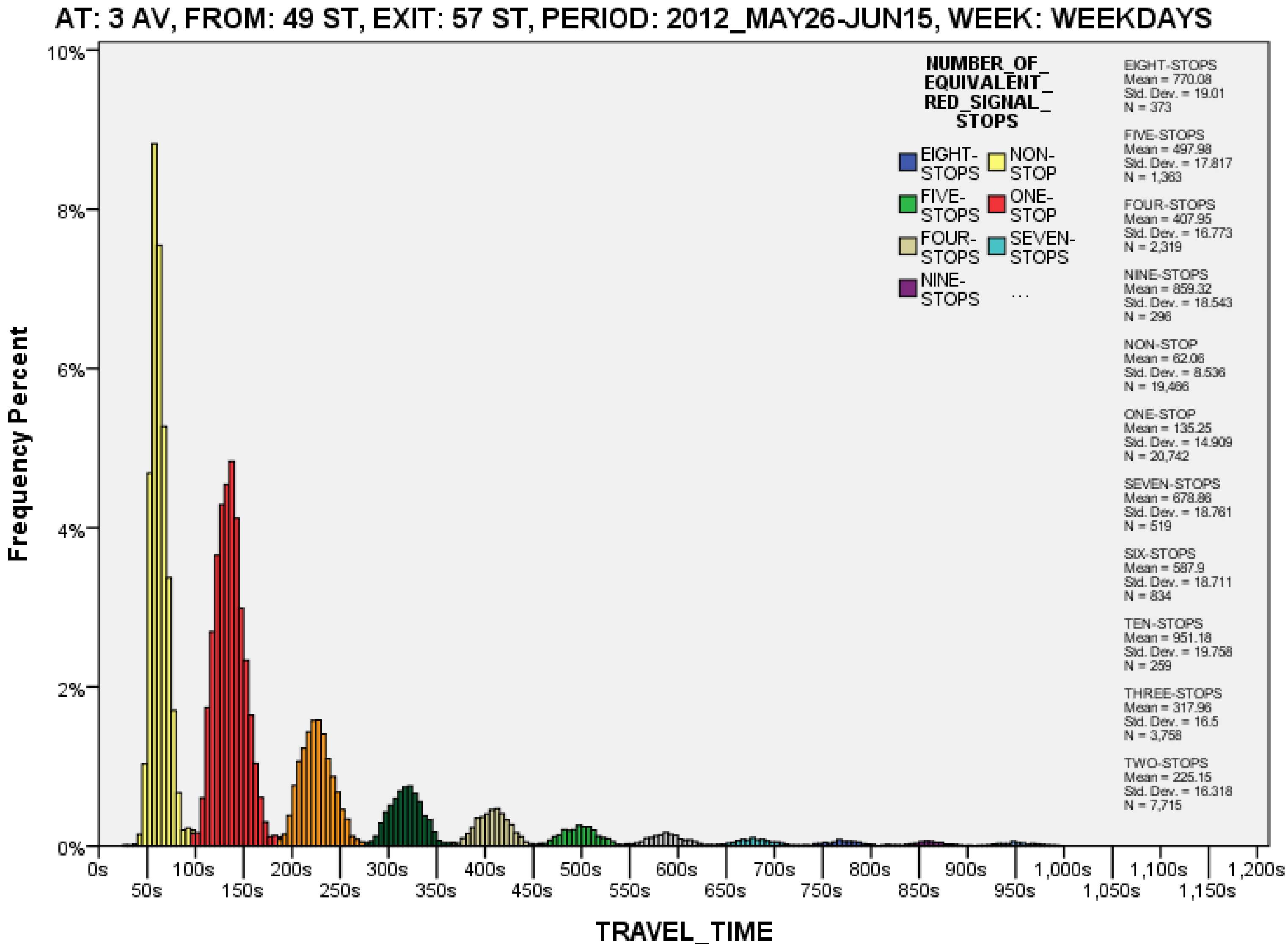
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



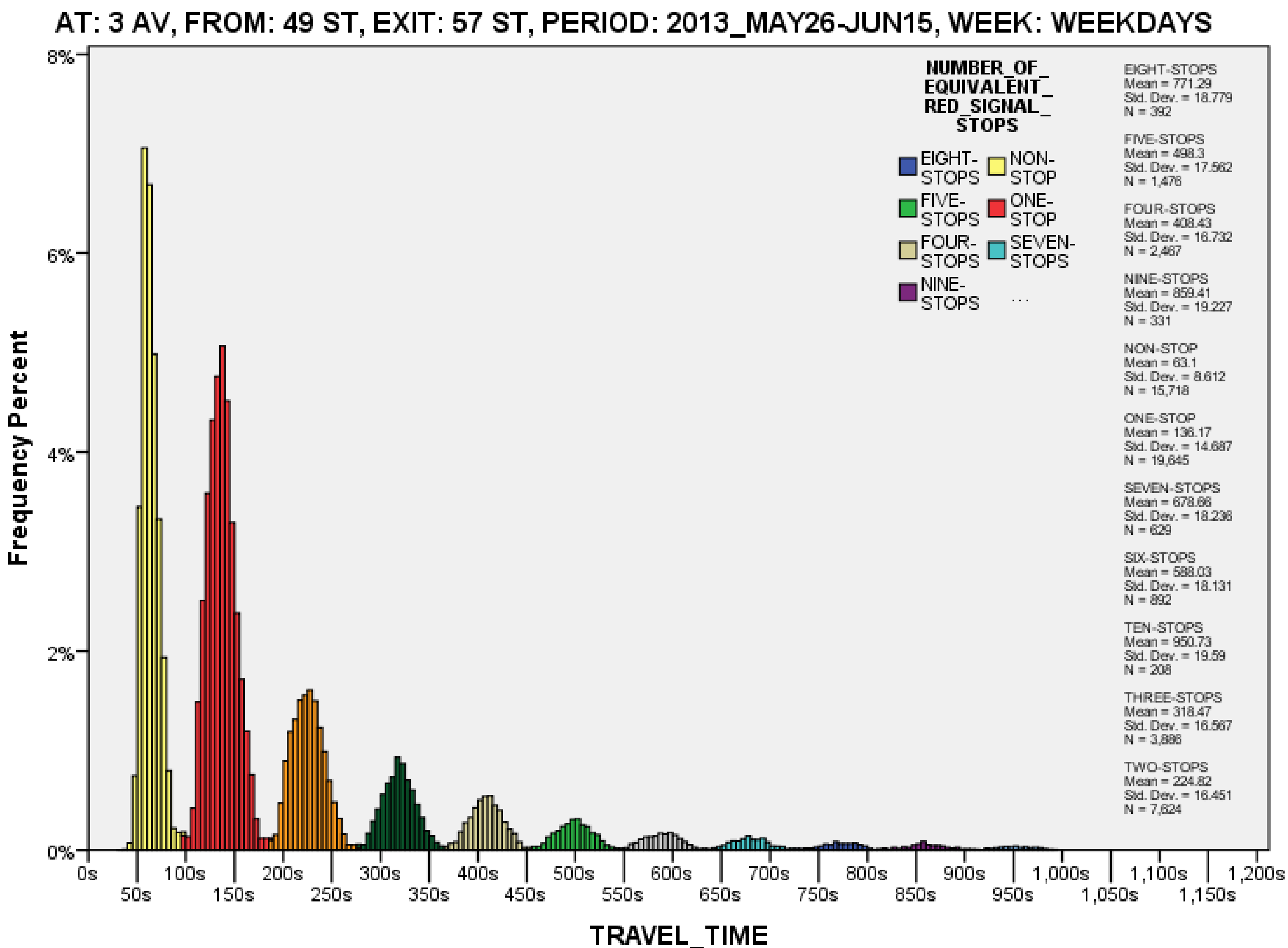
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS -DATA COLLECTED BY EZPASS TAG READERS



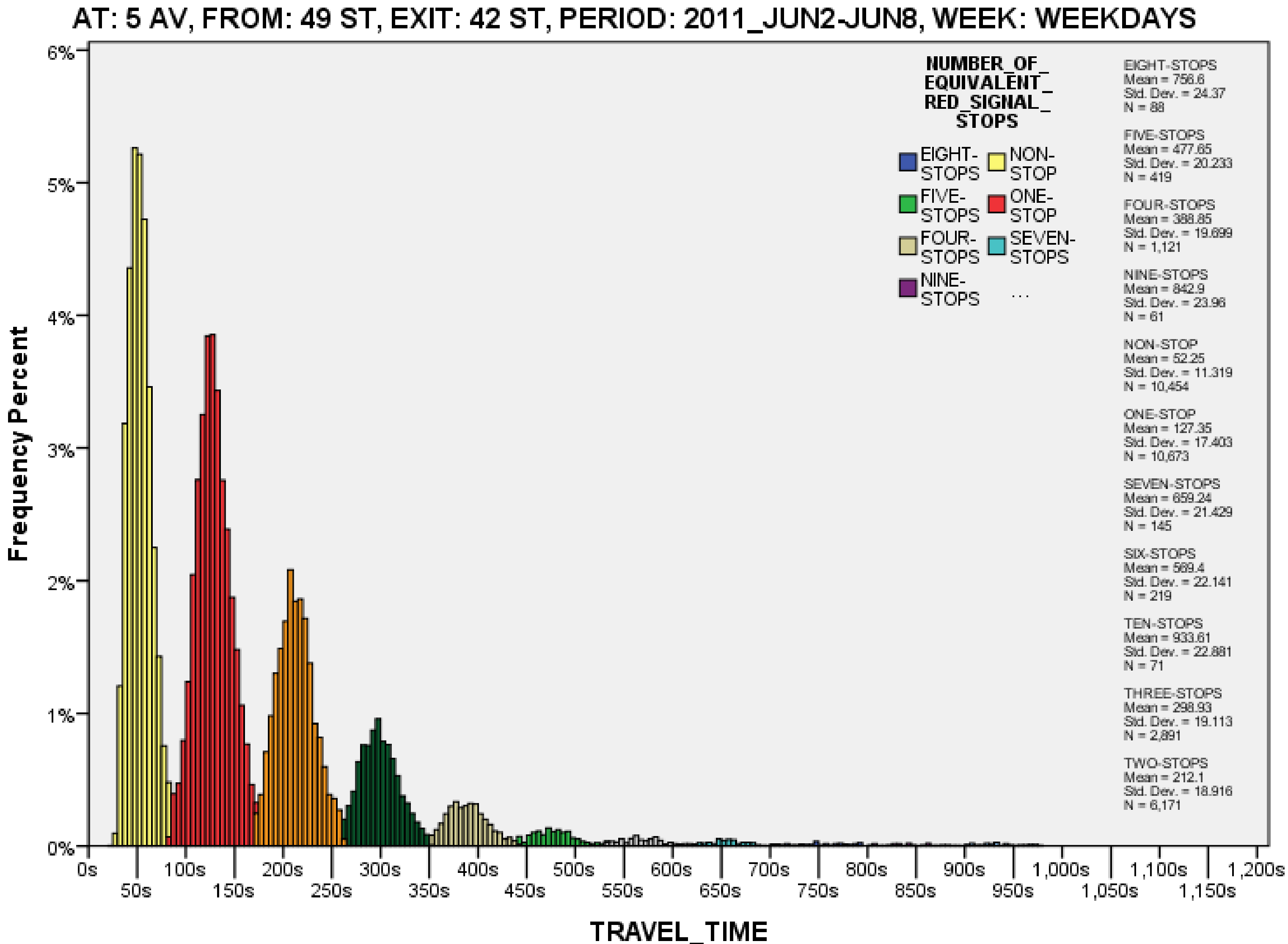
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



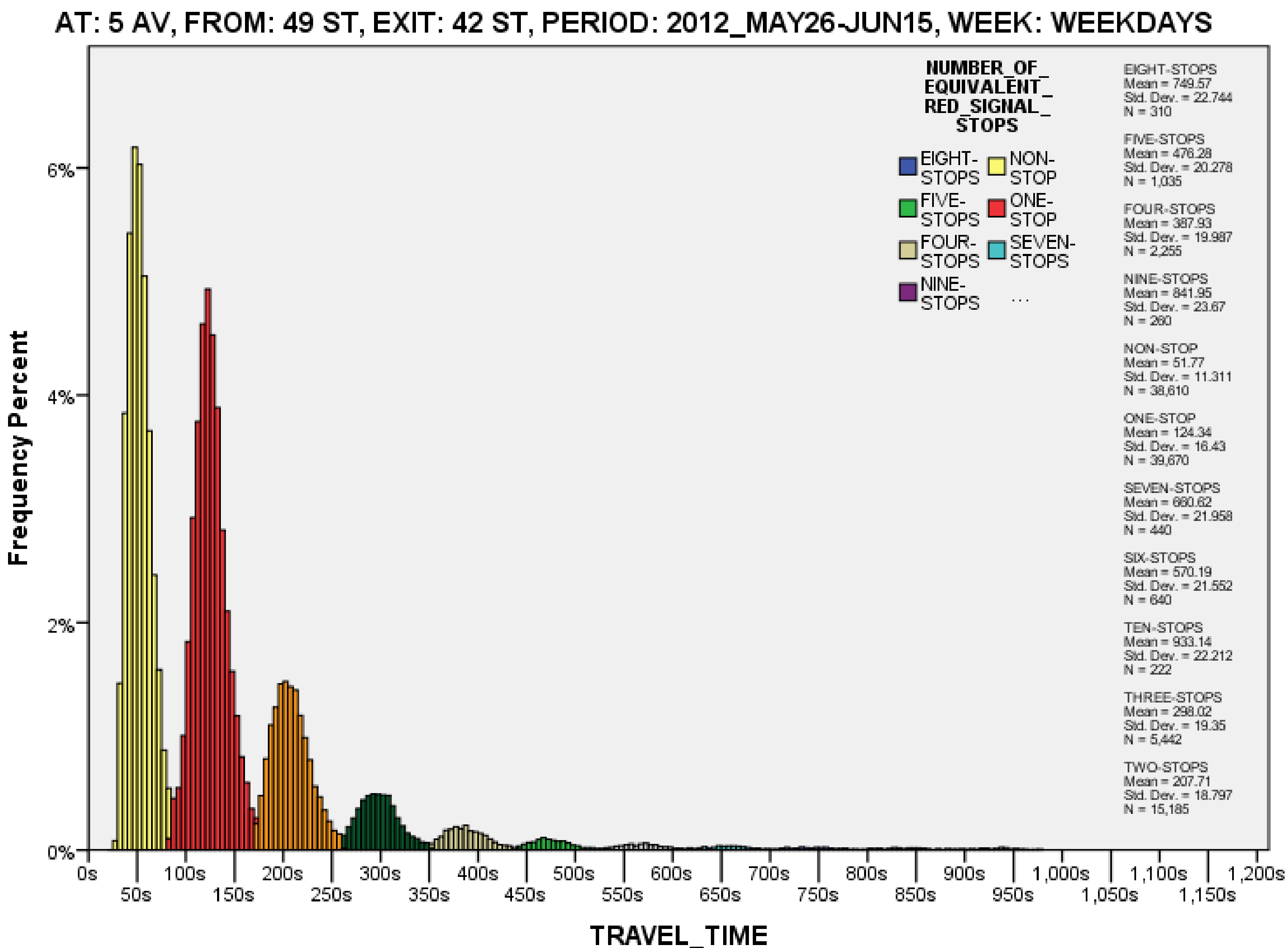
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



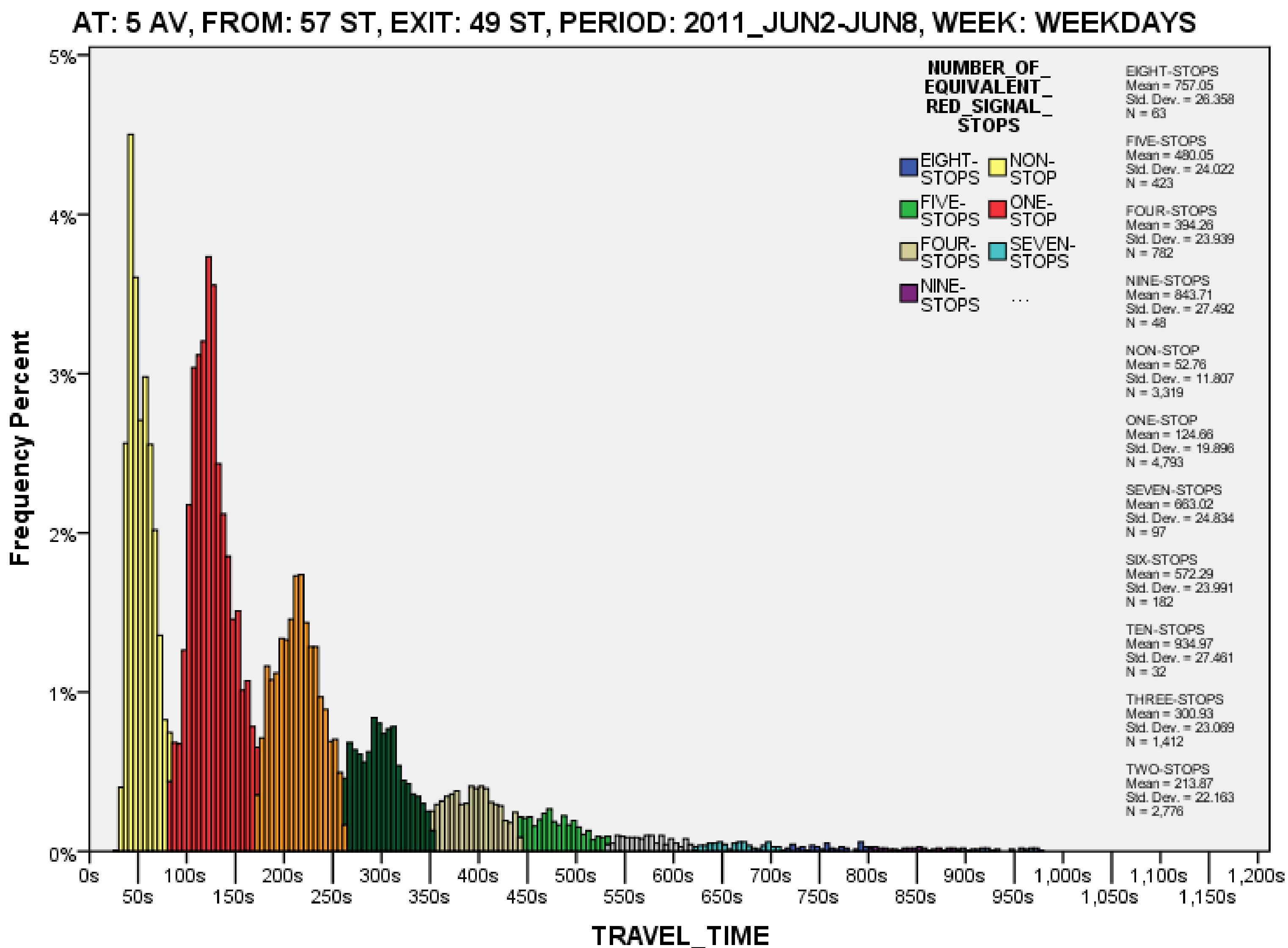
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



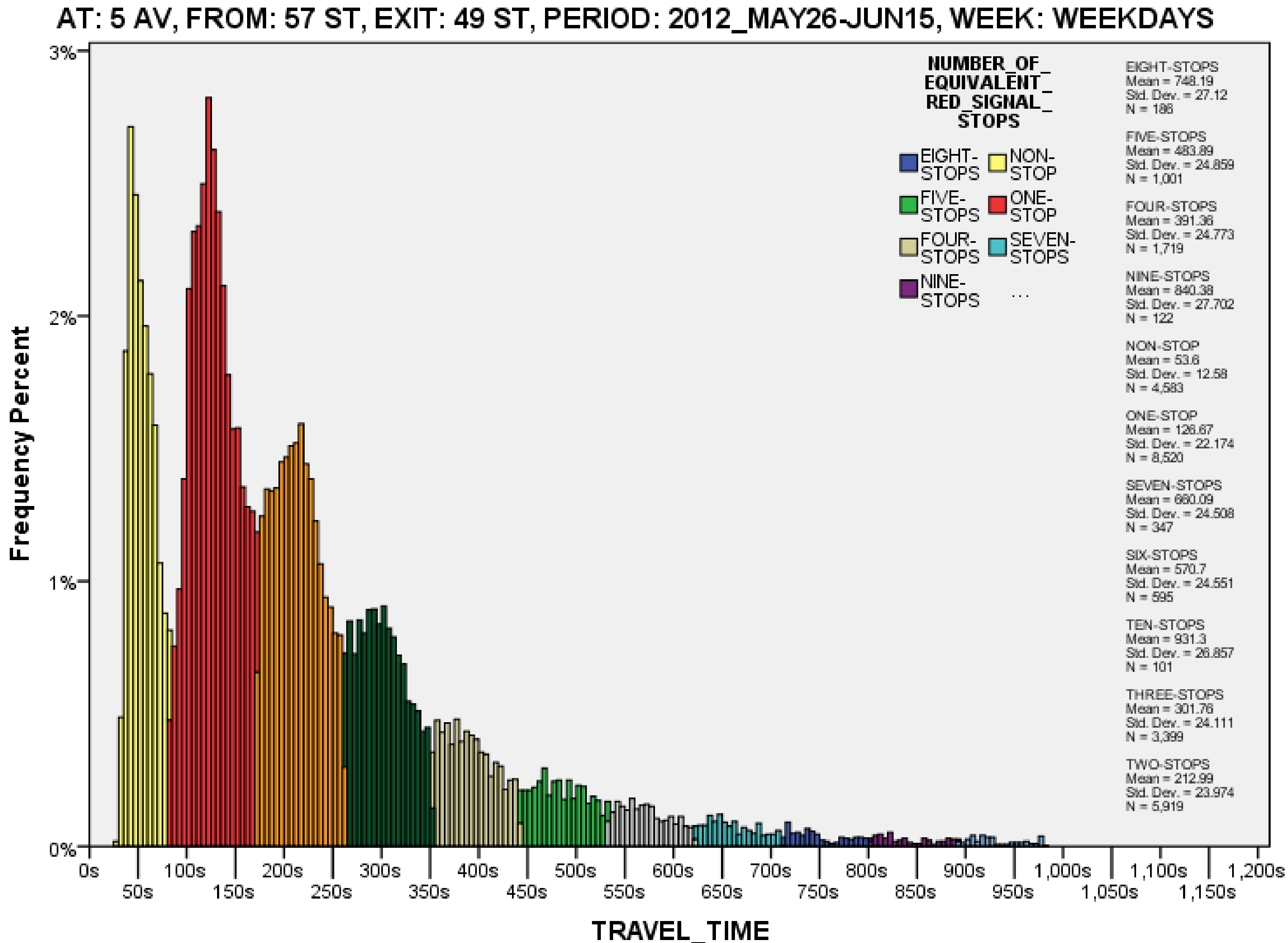
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



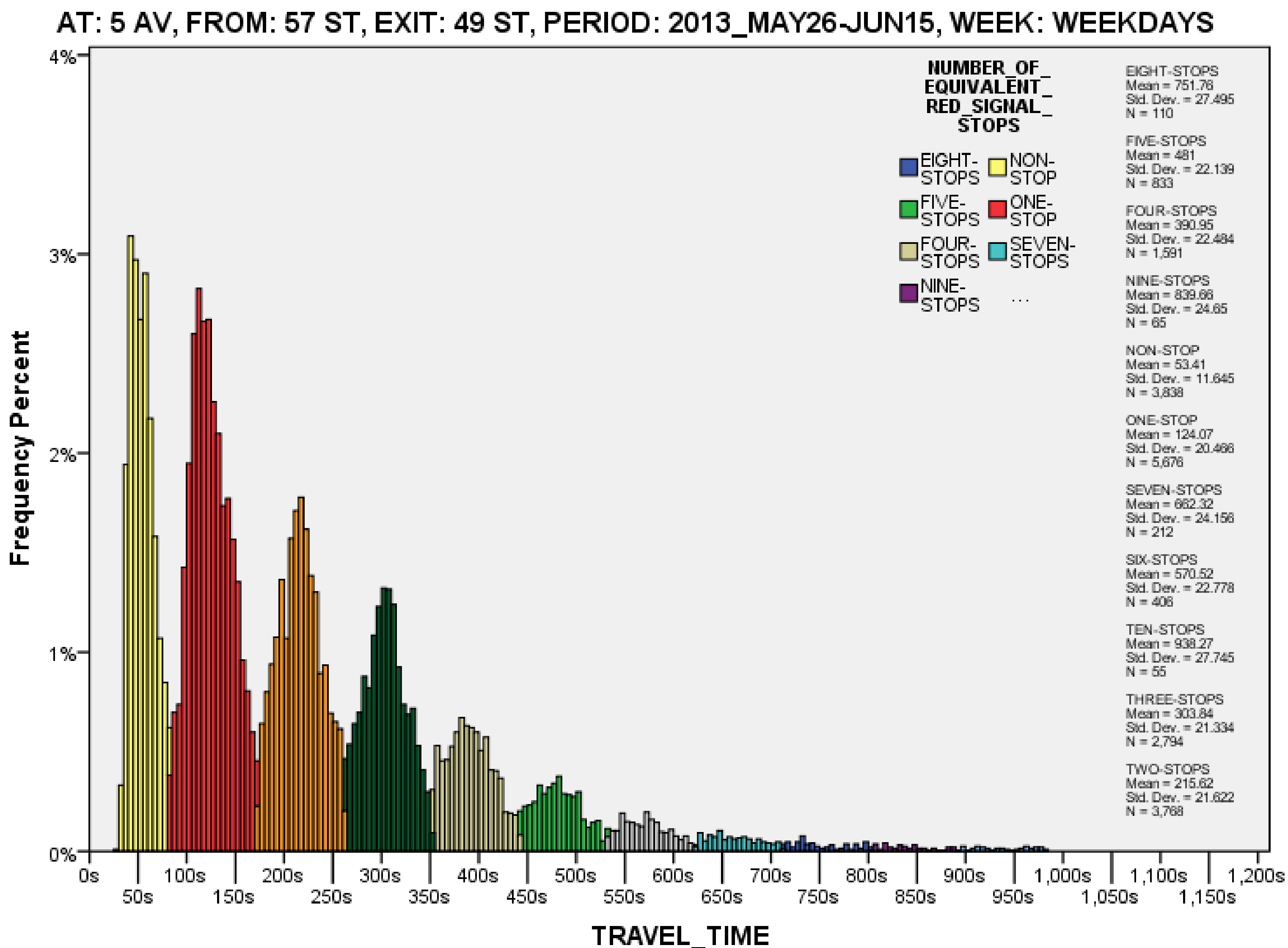
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



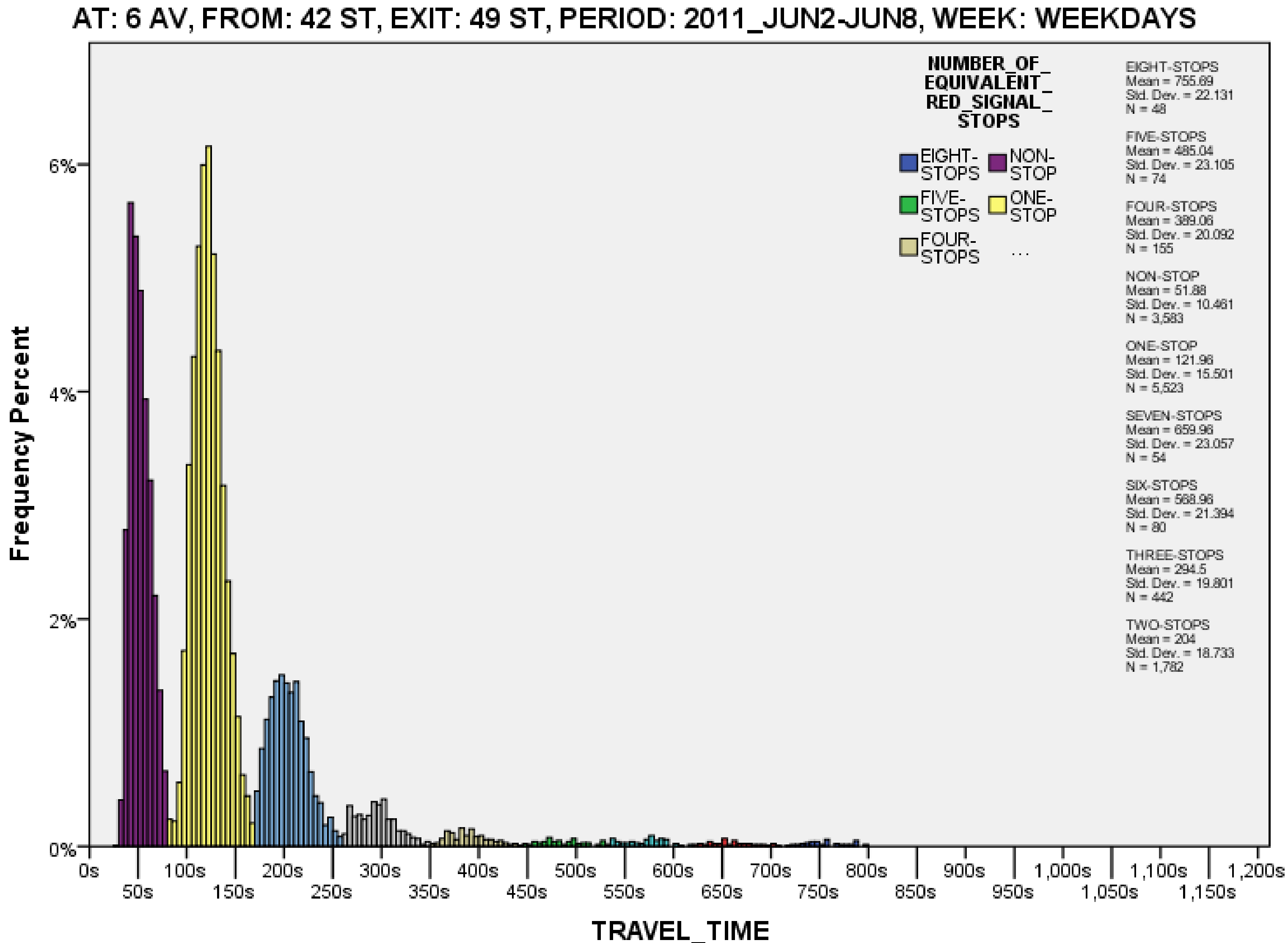
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



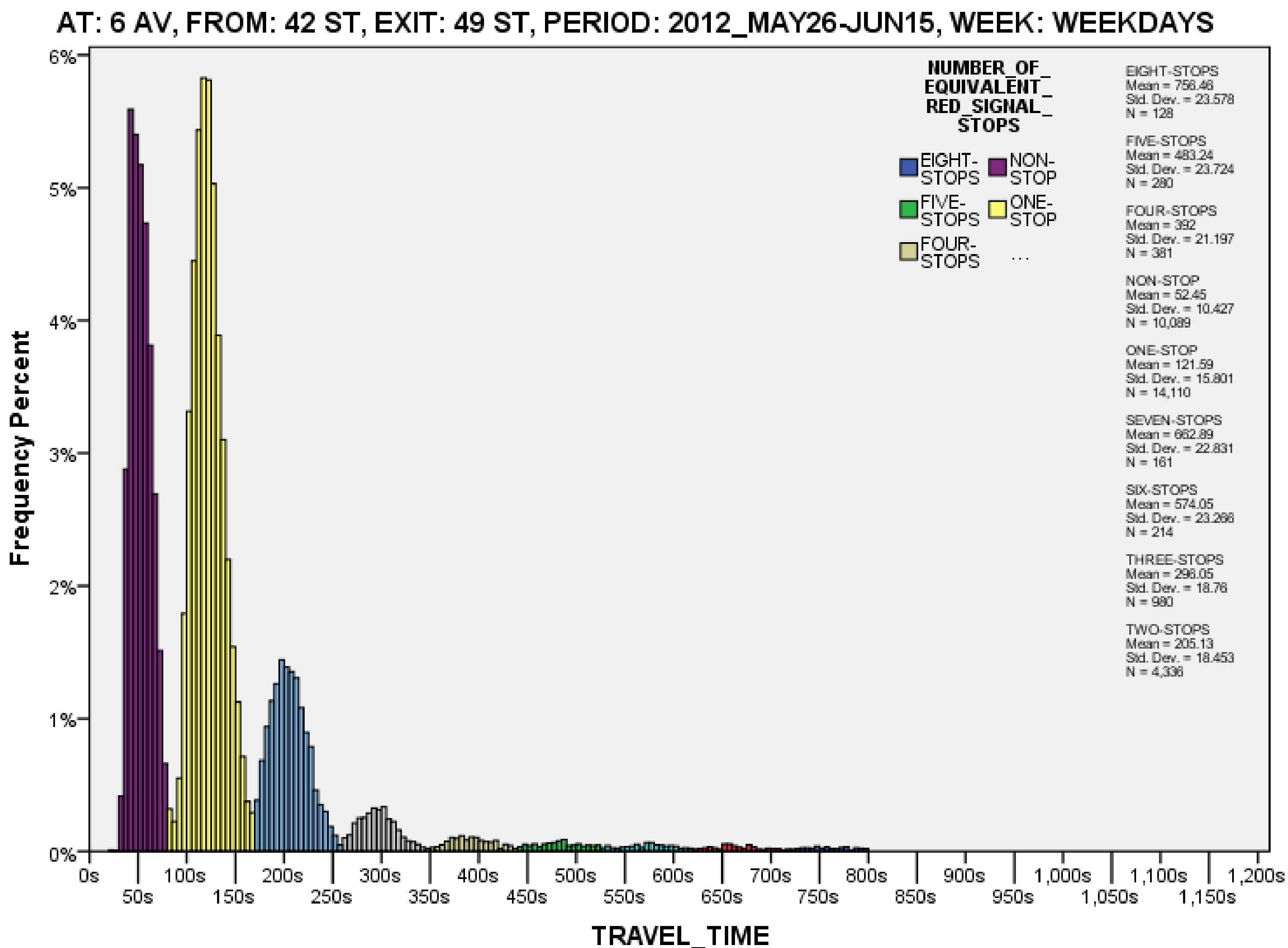
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



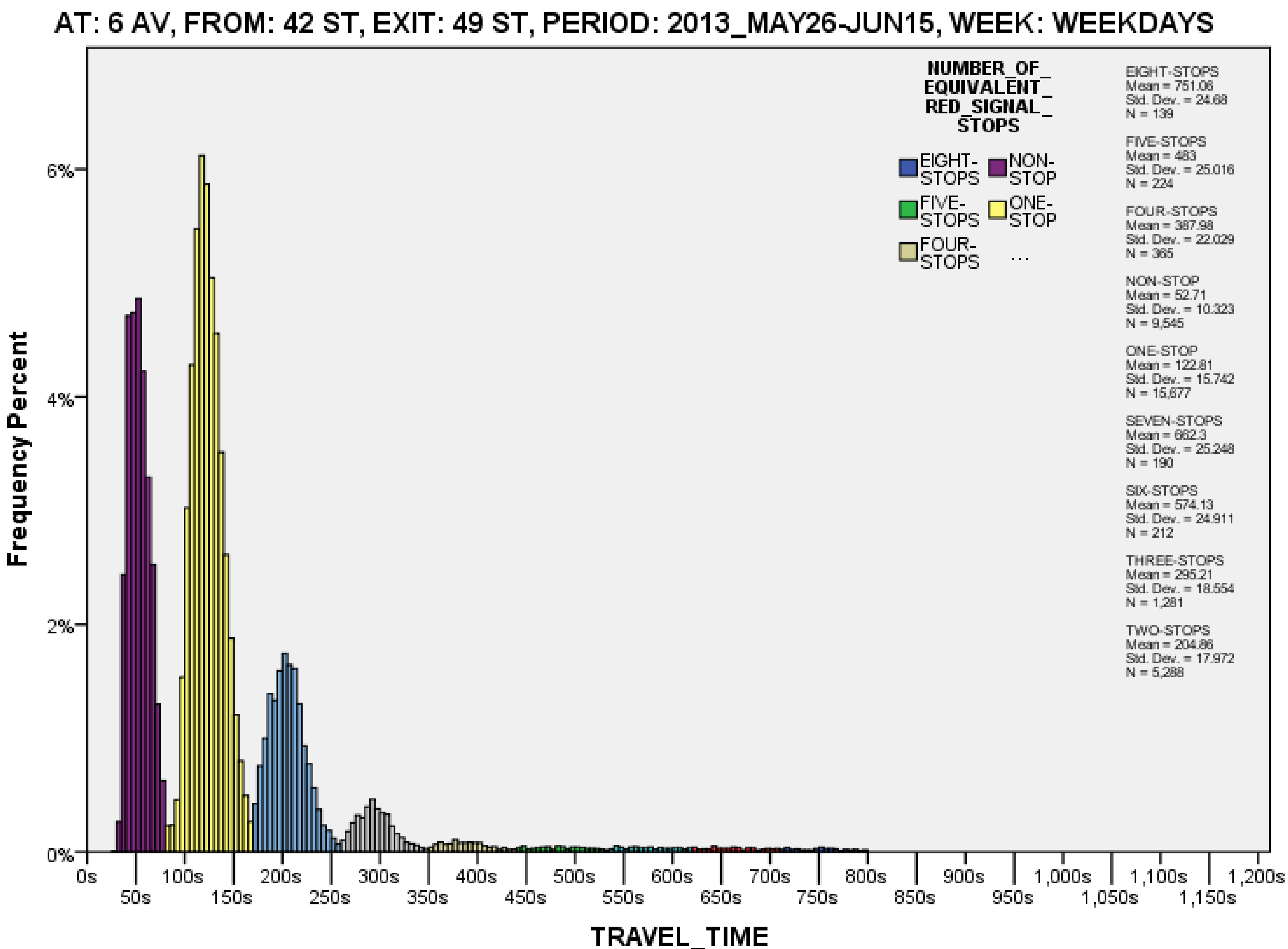
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



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



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



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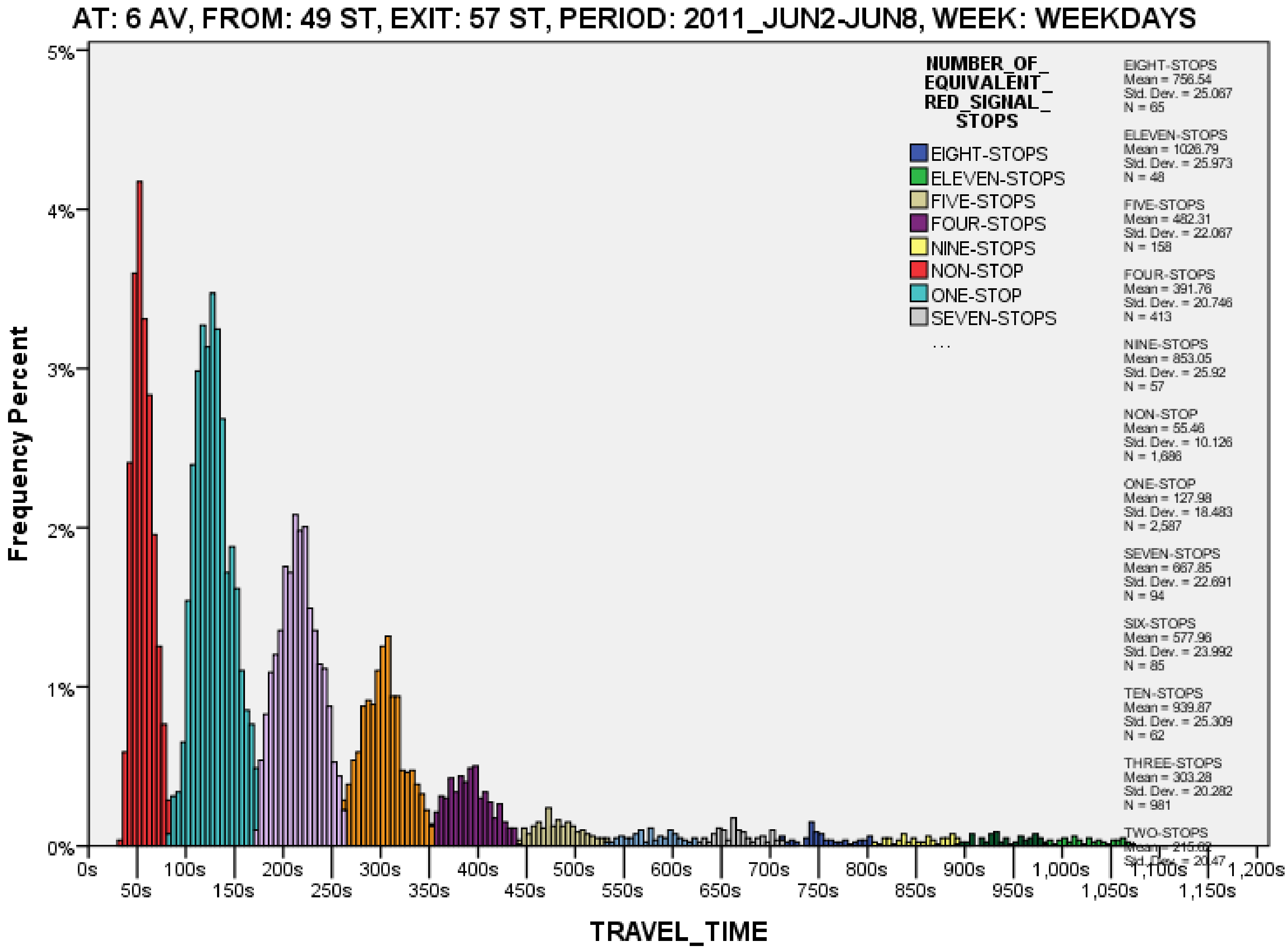
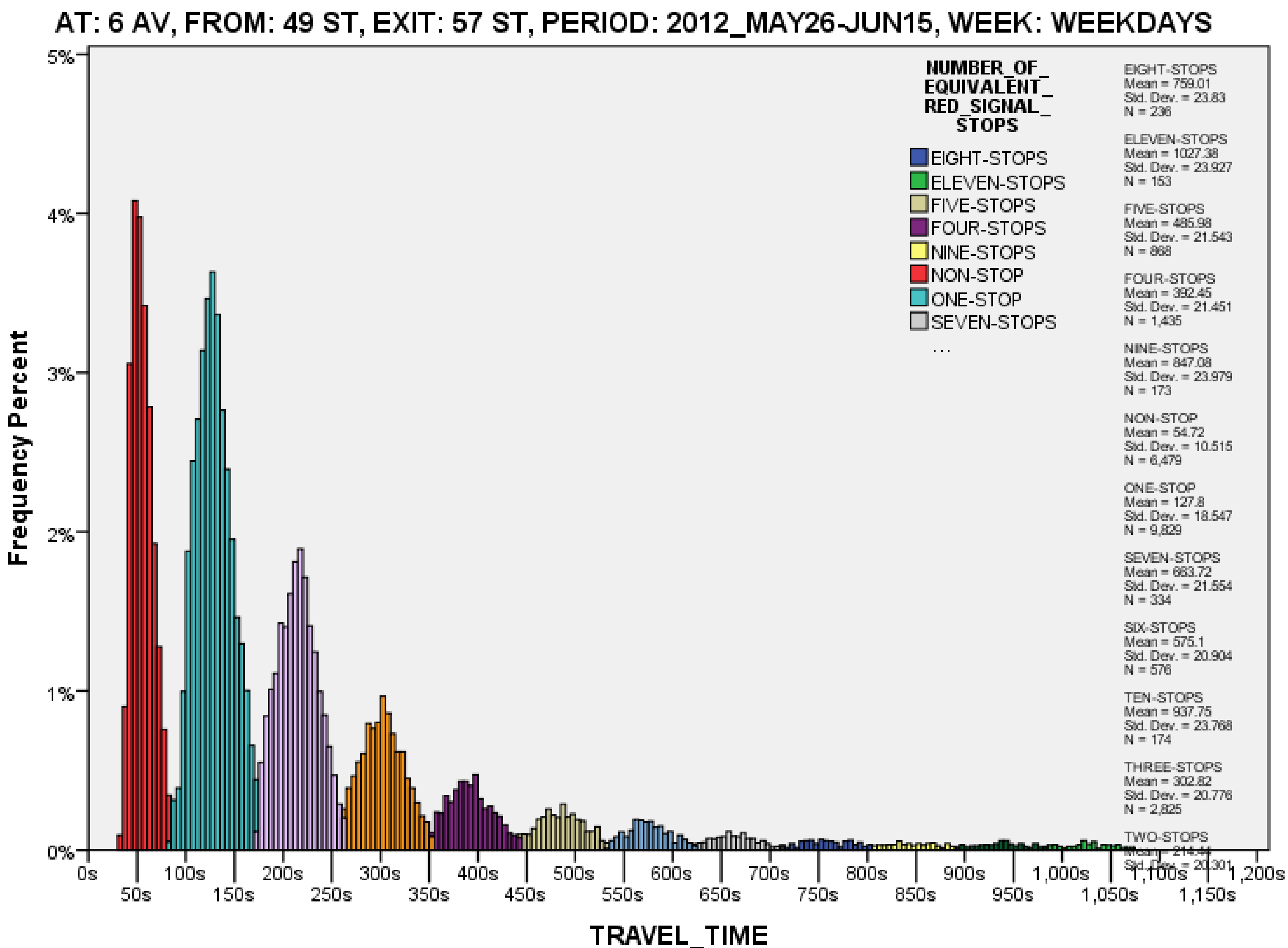
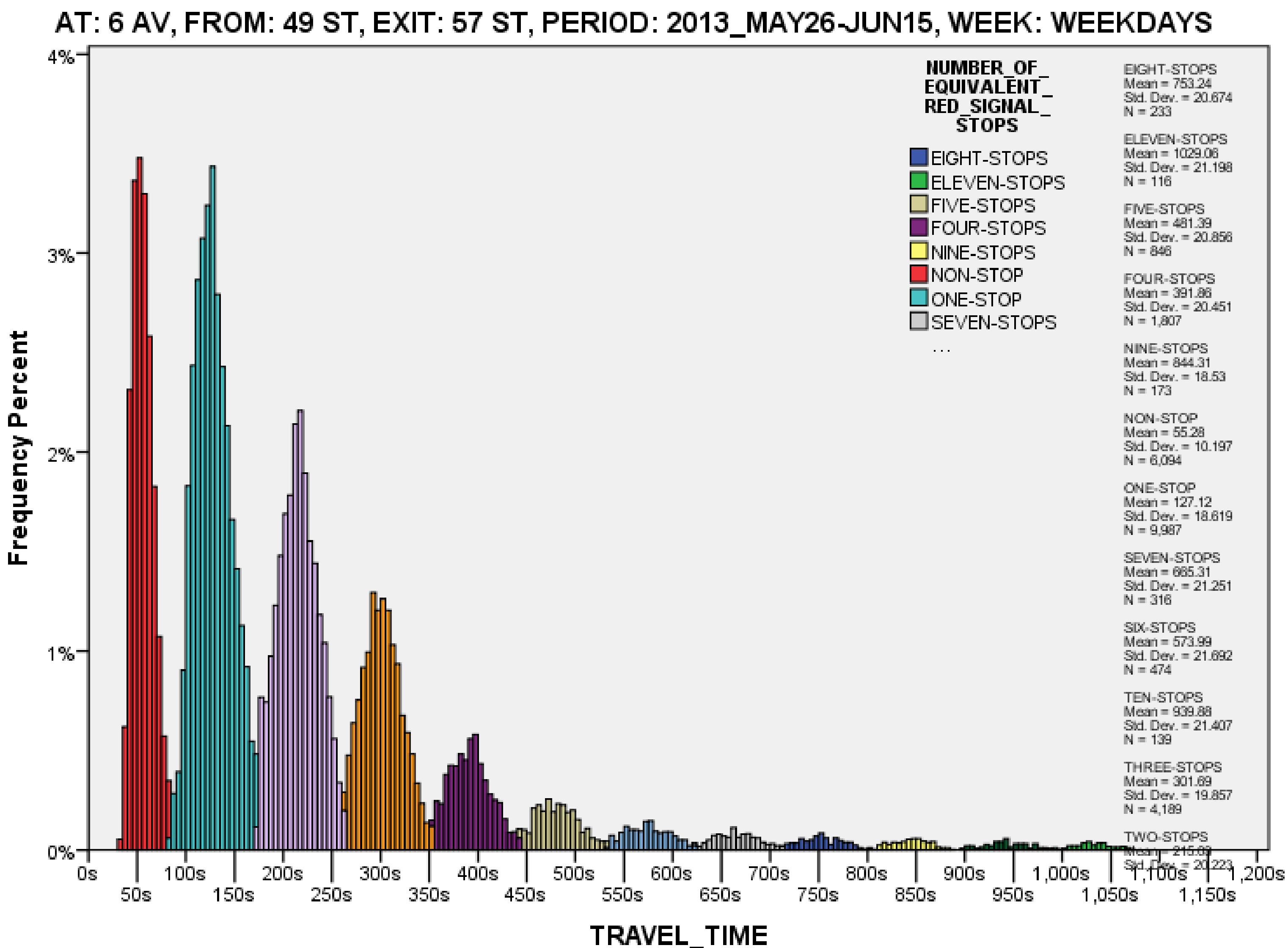
-DATA COLLECTED BY EZPASS TAG READERS



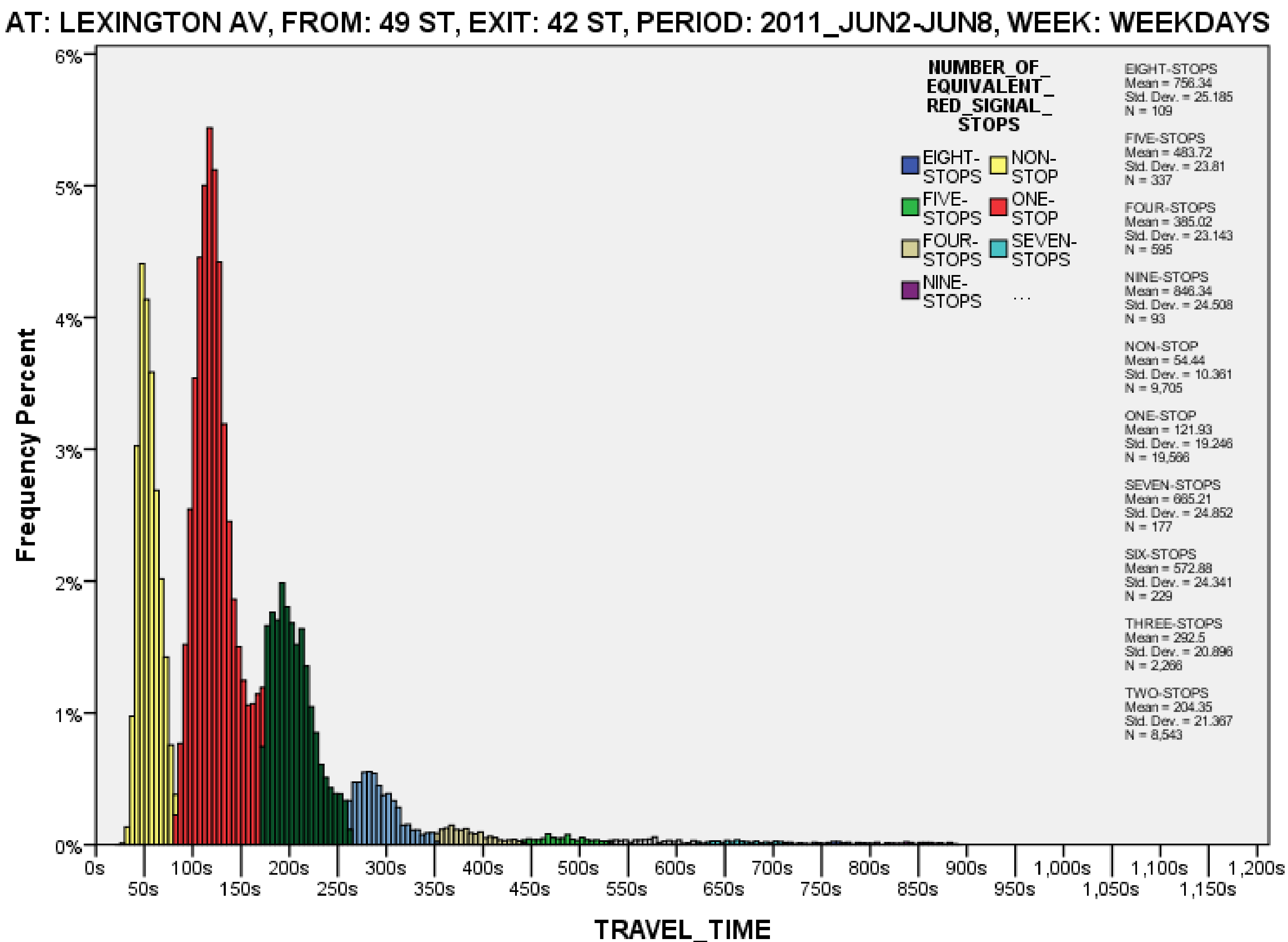
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



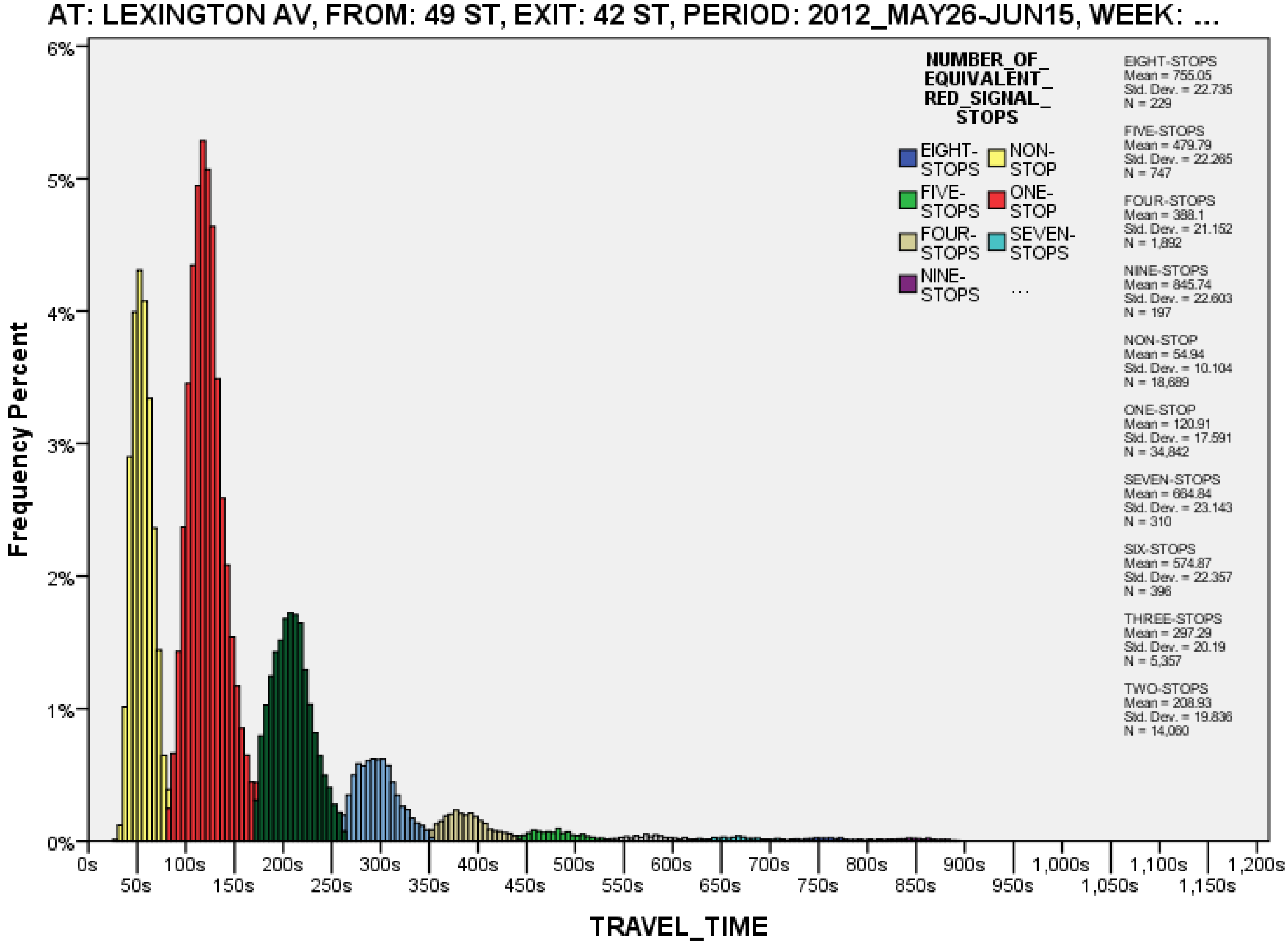
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



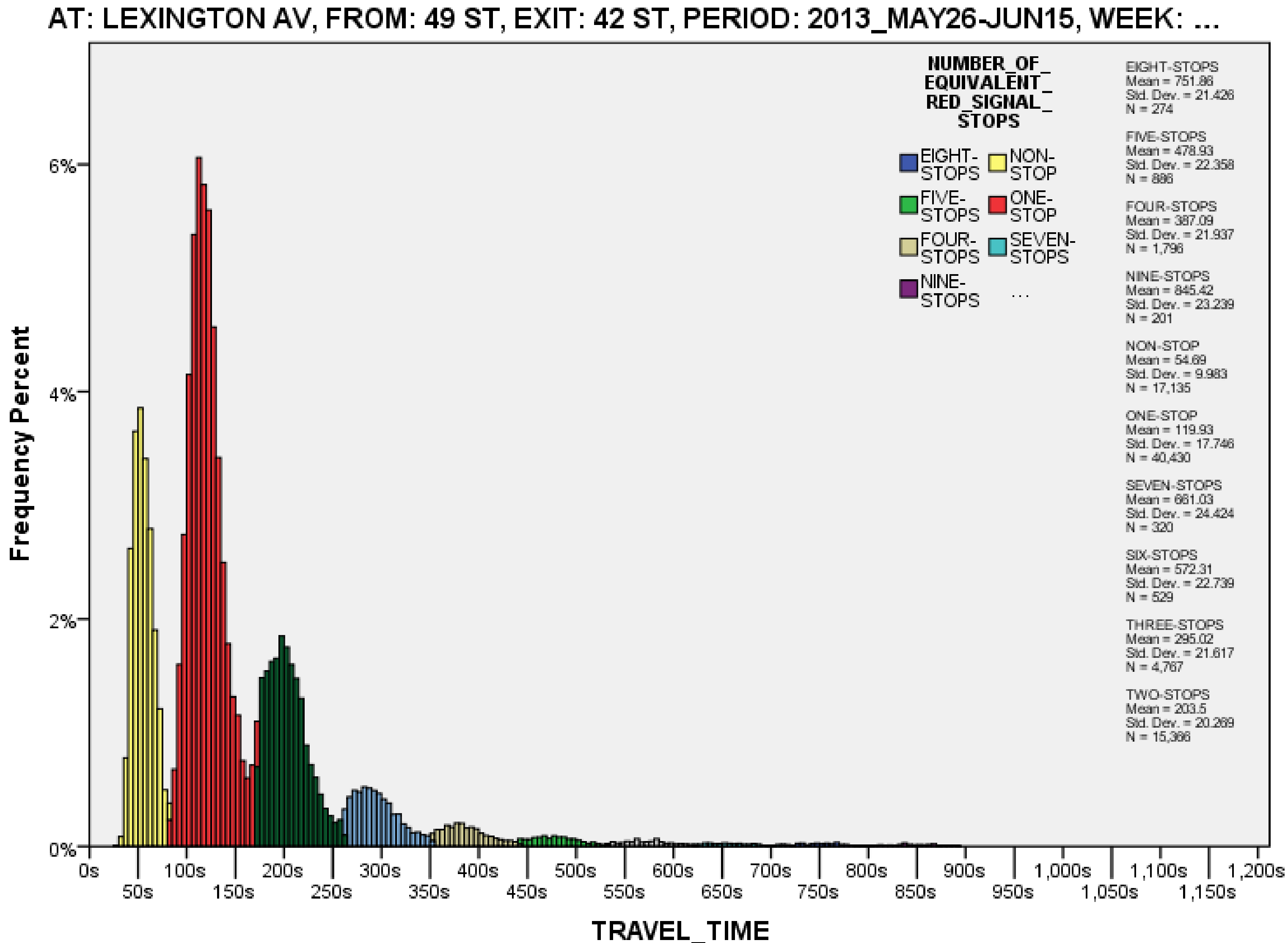
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



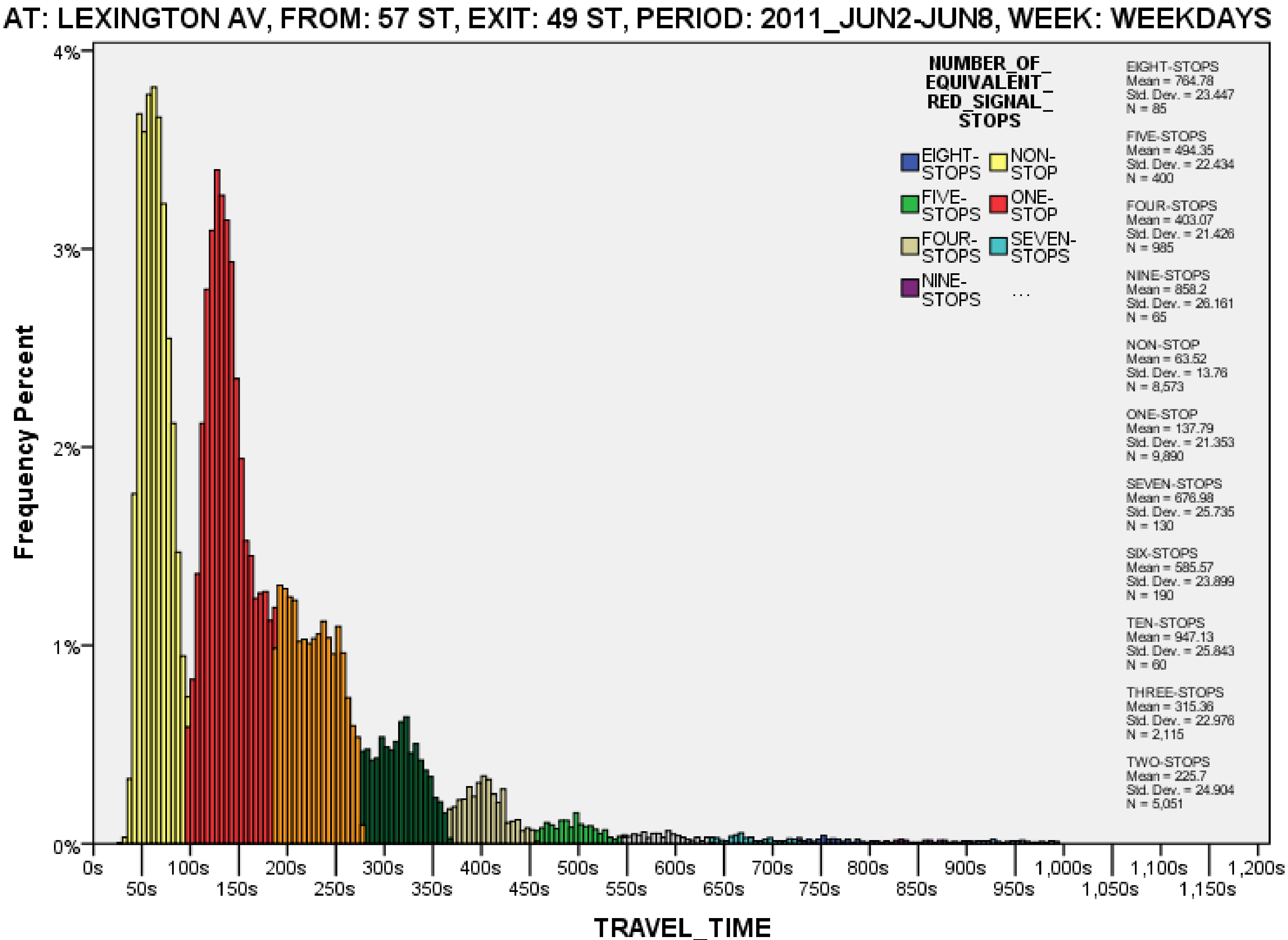
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



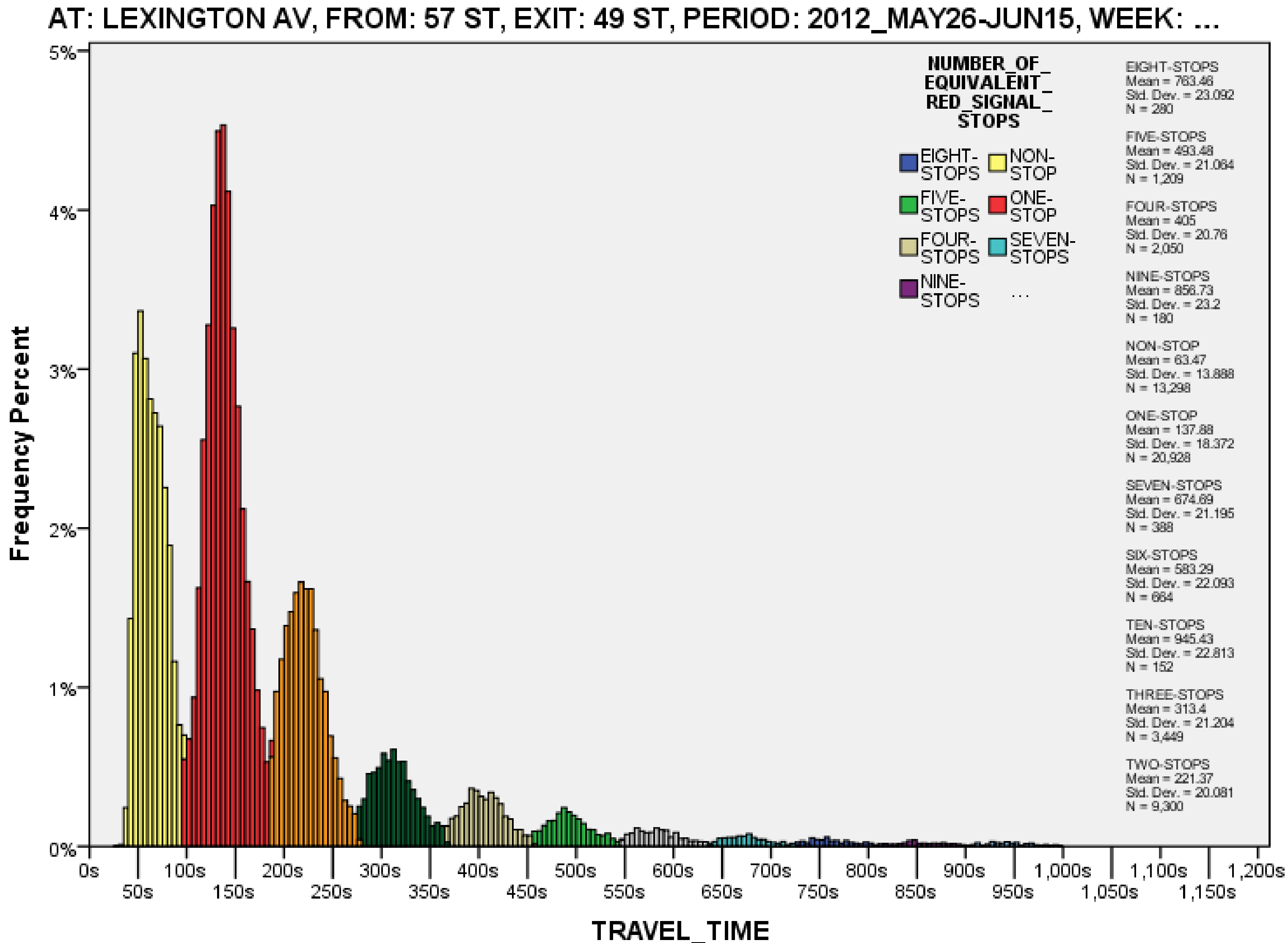
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



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



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



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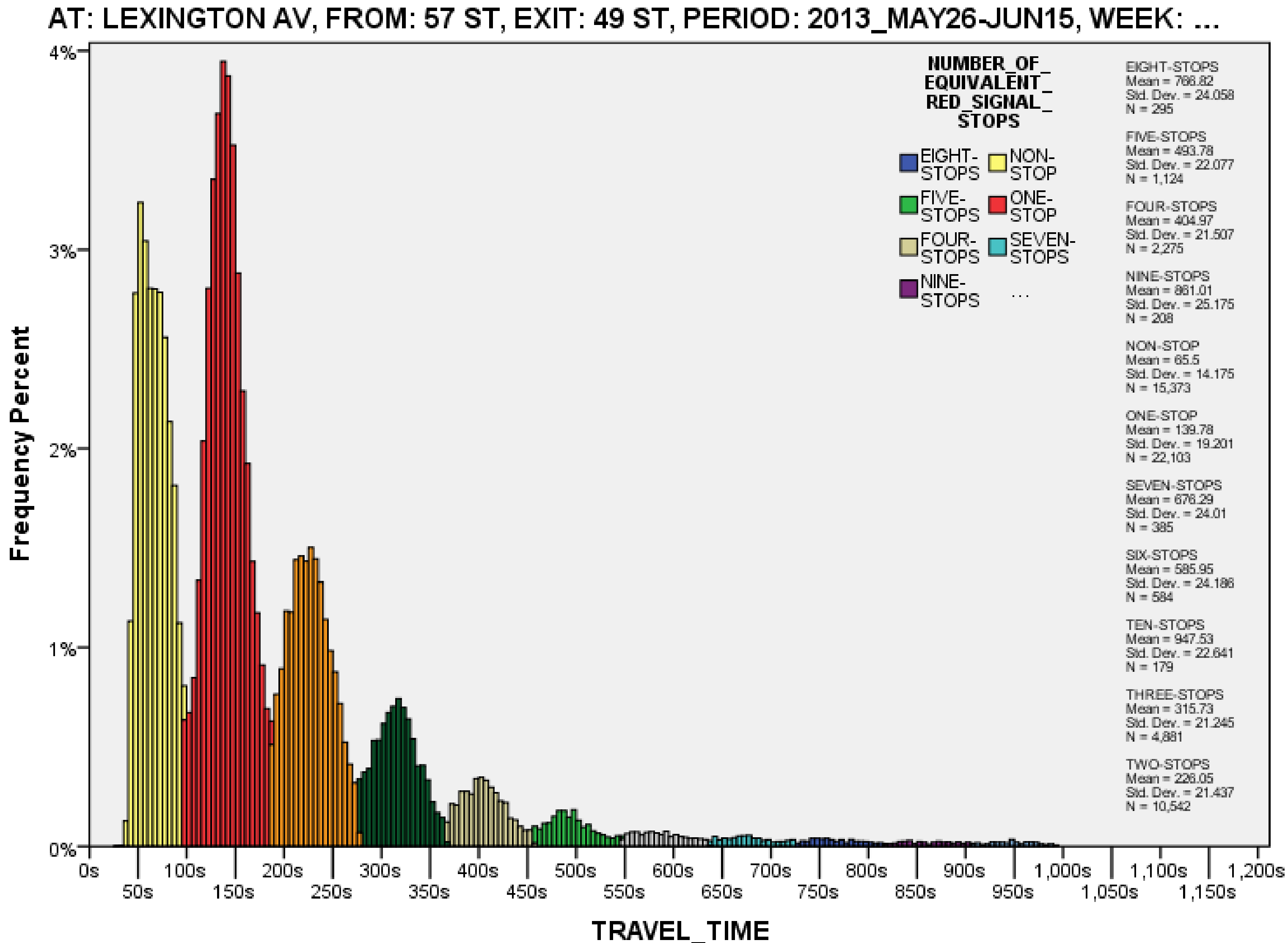
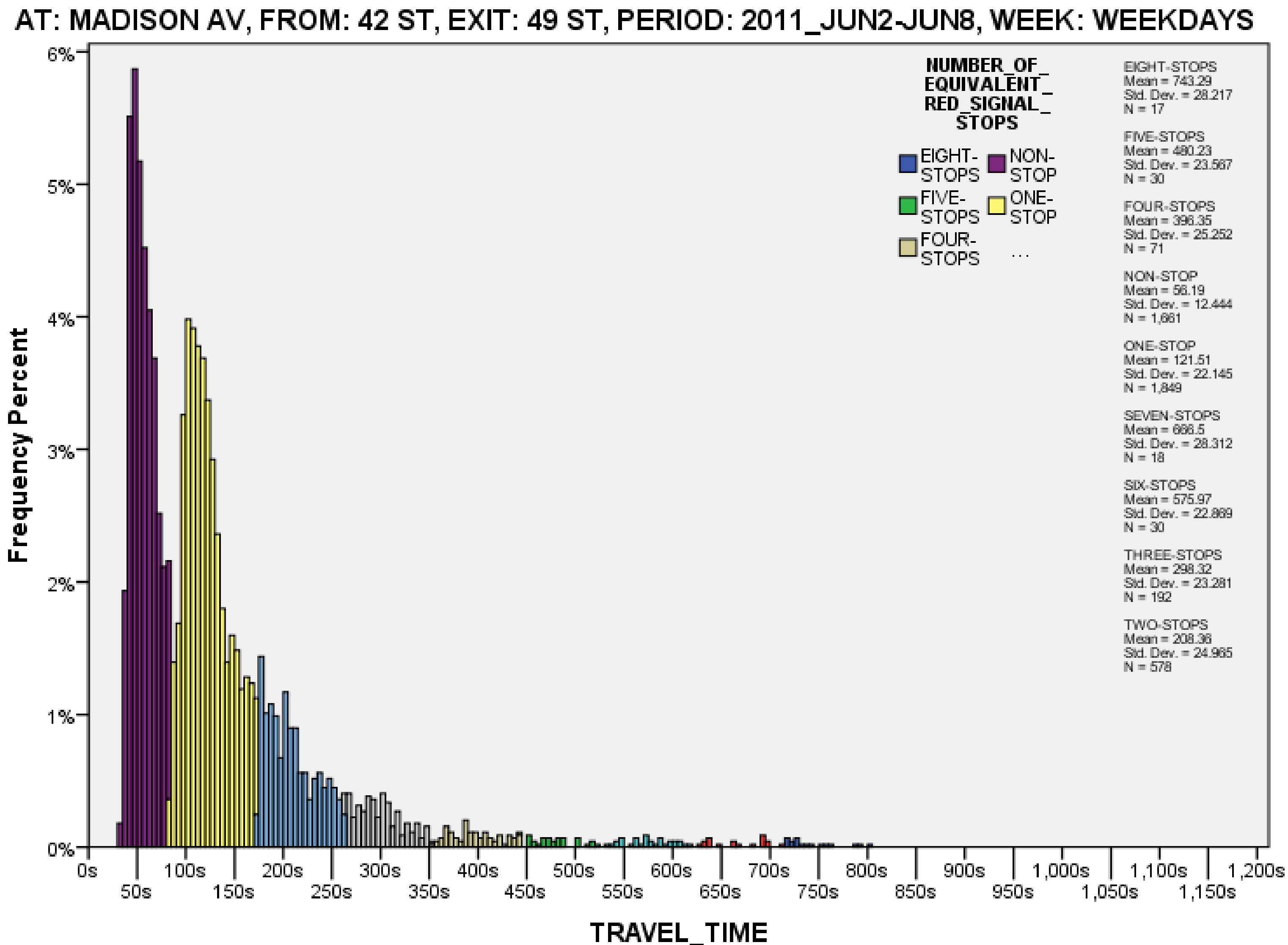
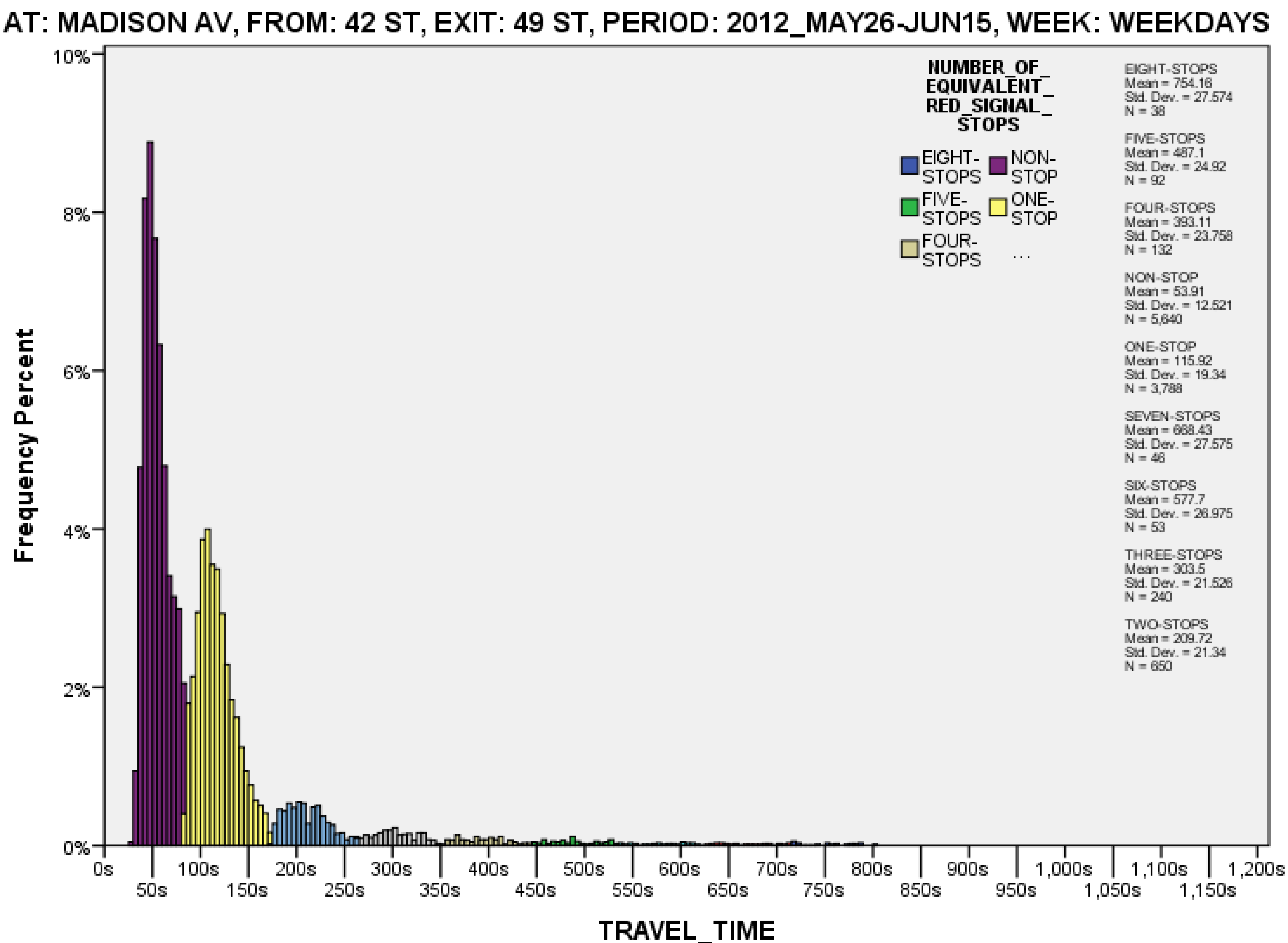
-DATA COLLECTED BY EZPASS TAG READERS



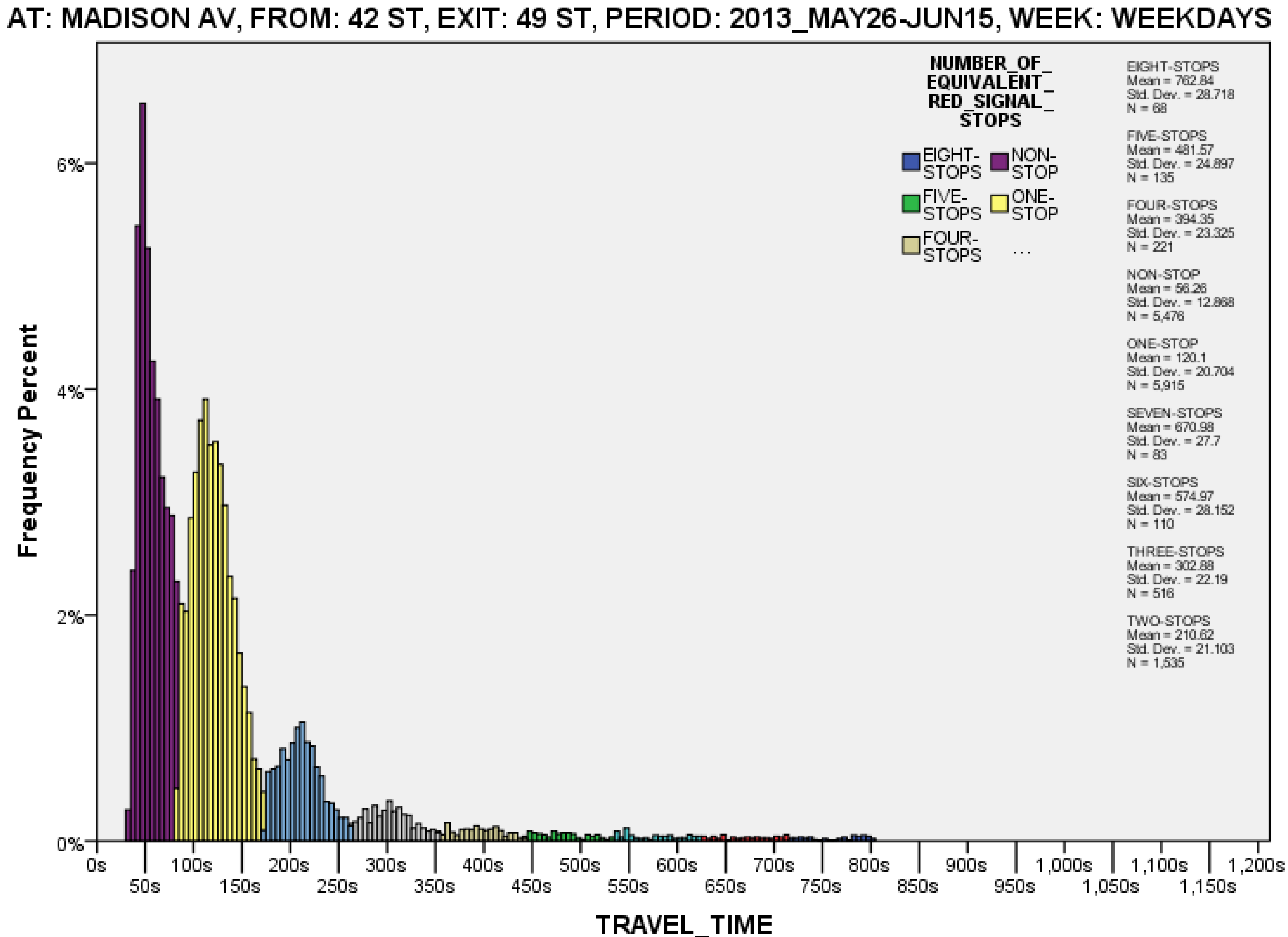
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



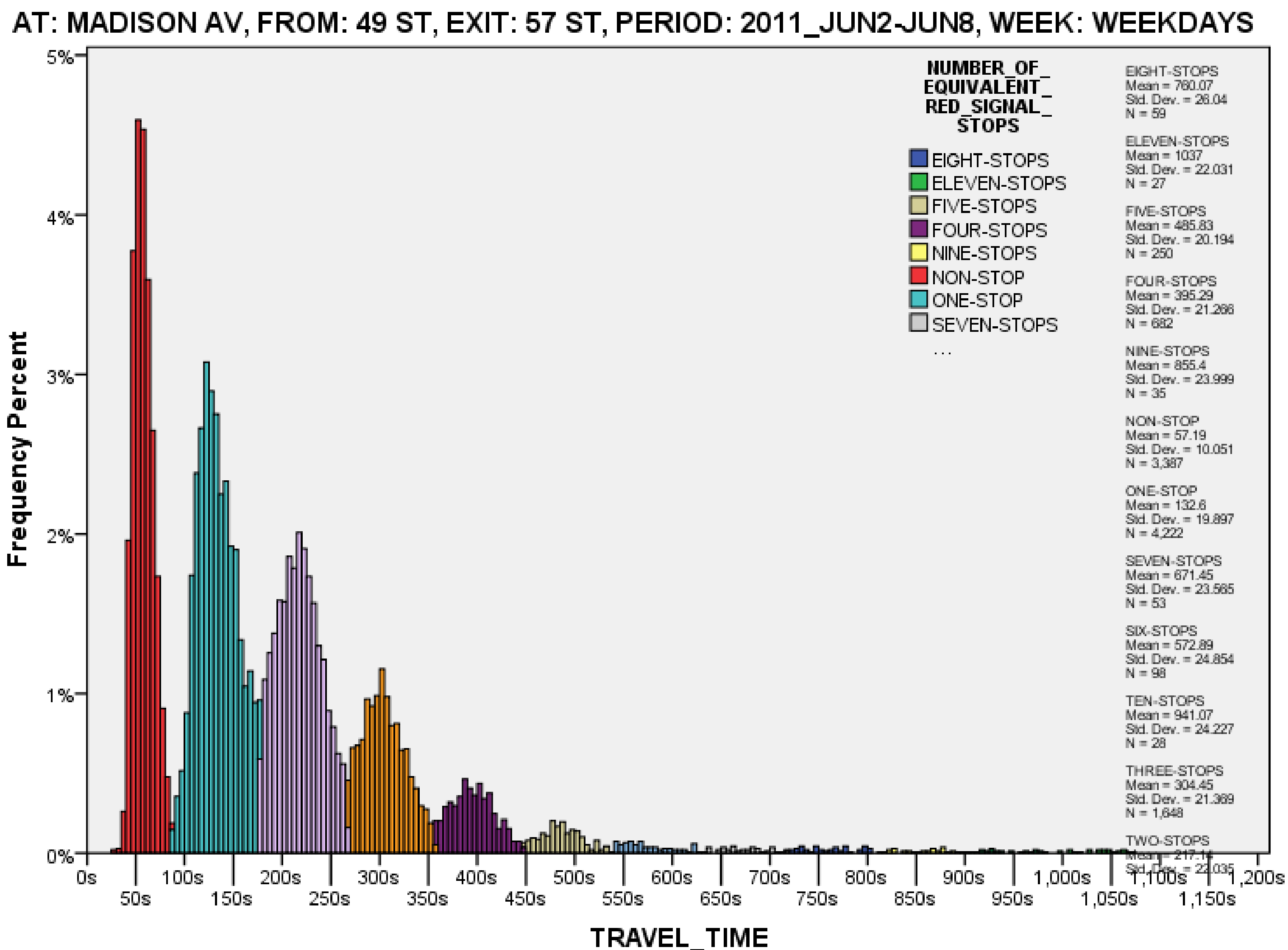
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



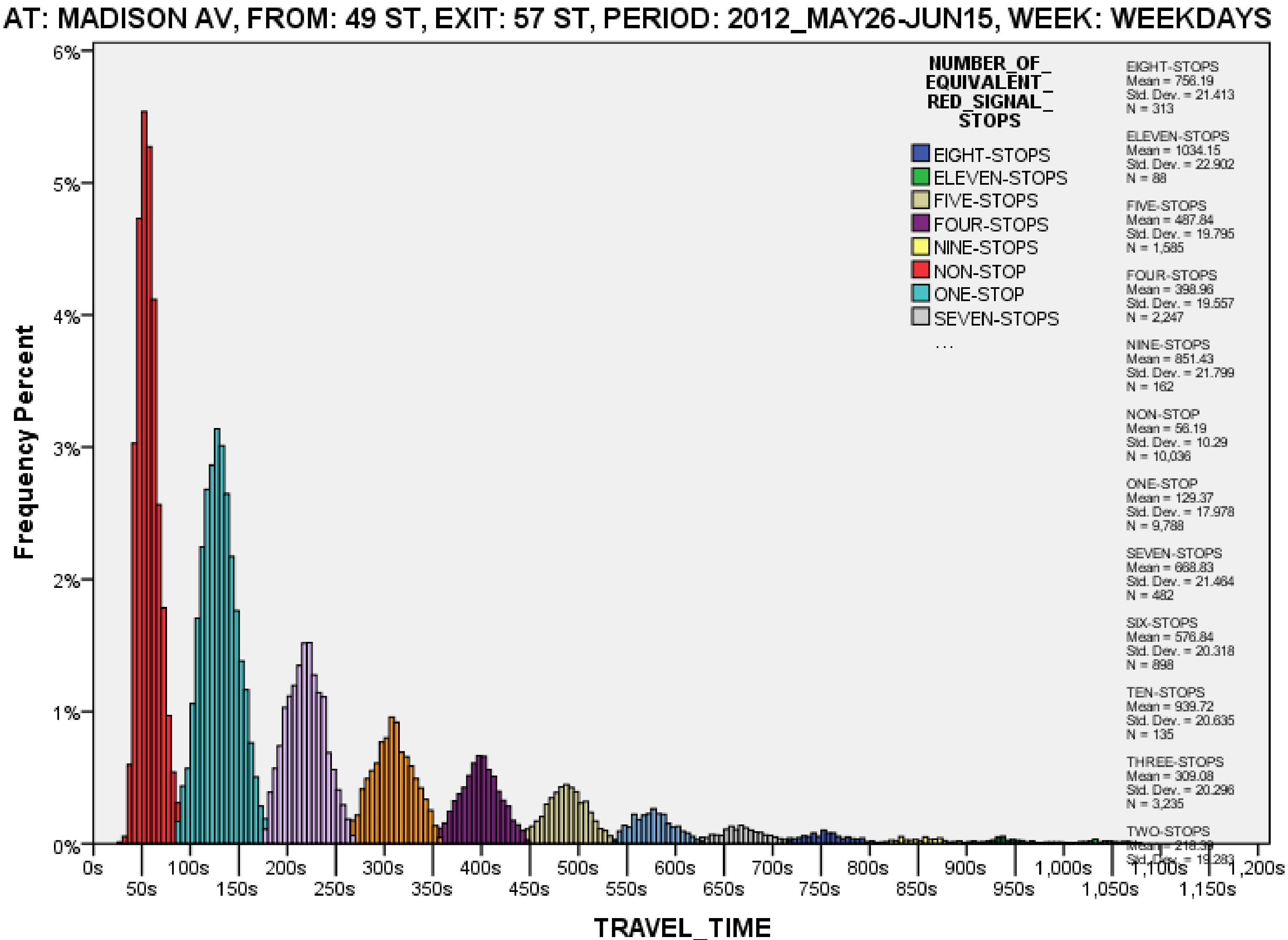
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



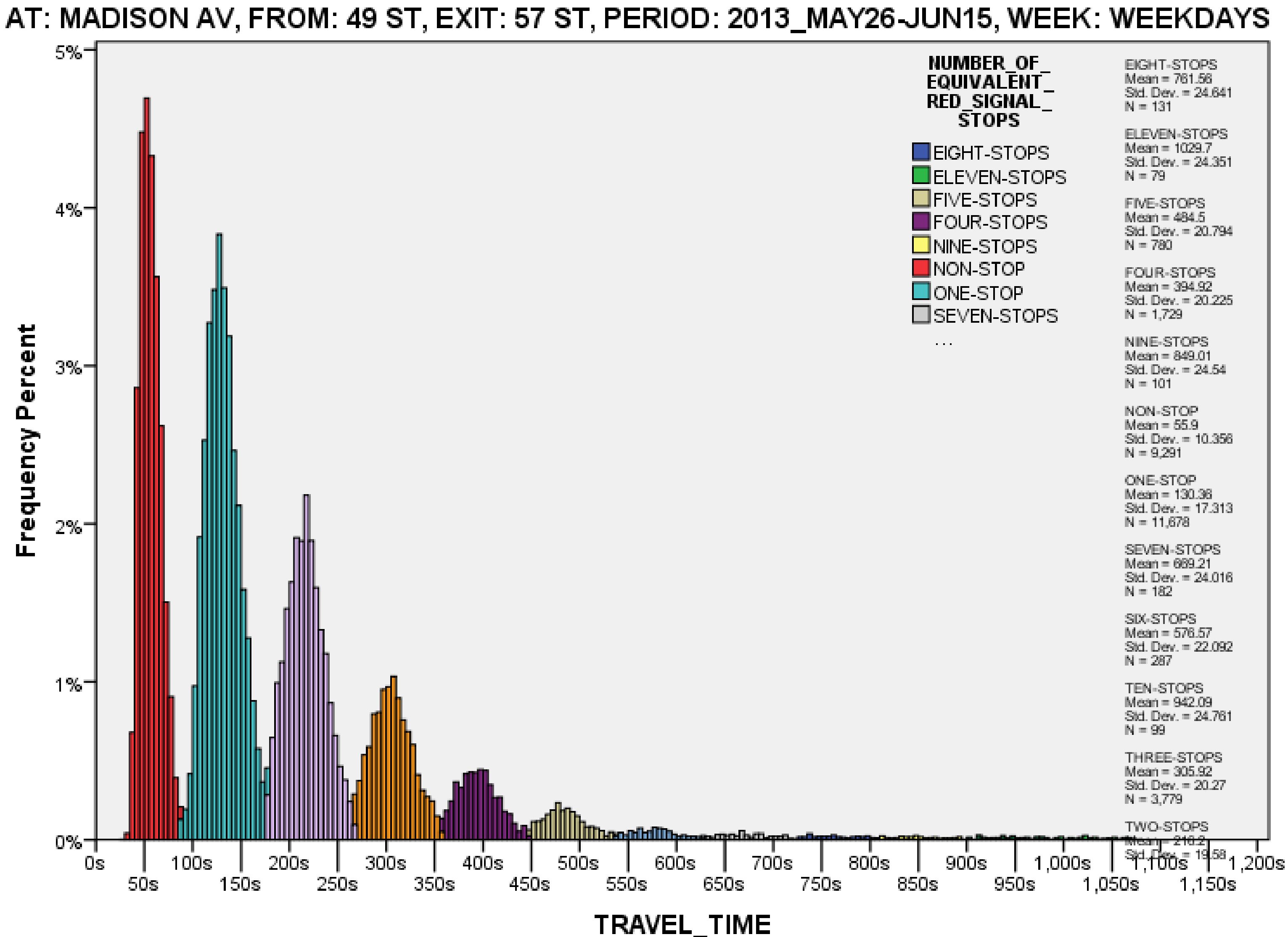
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS



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

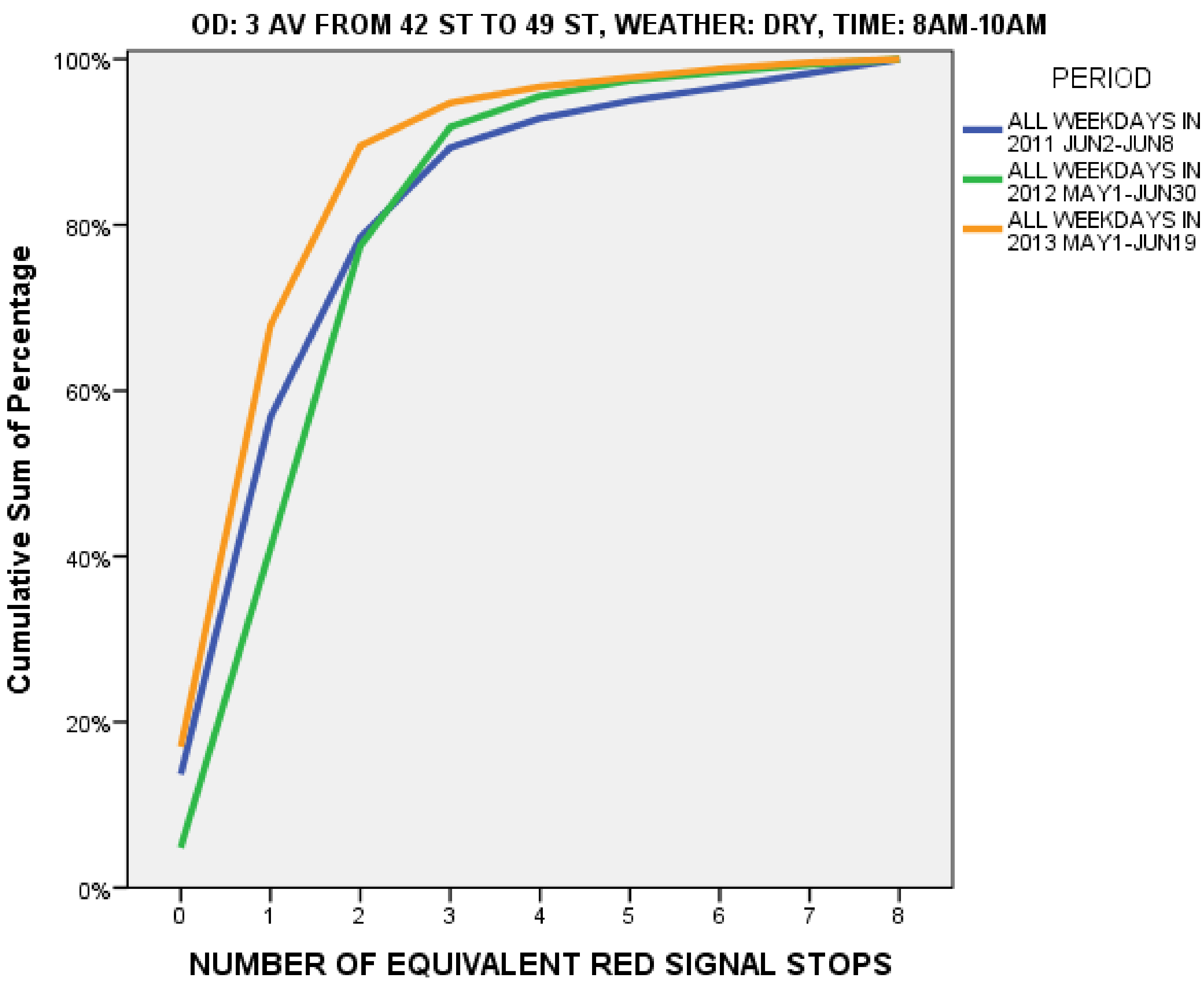


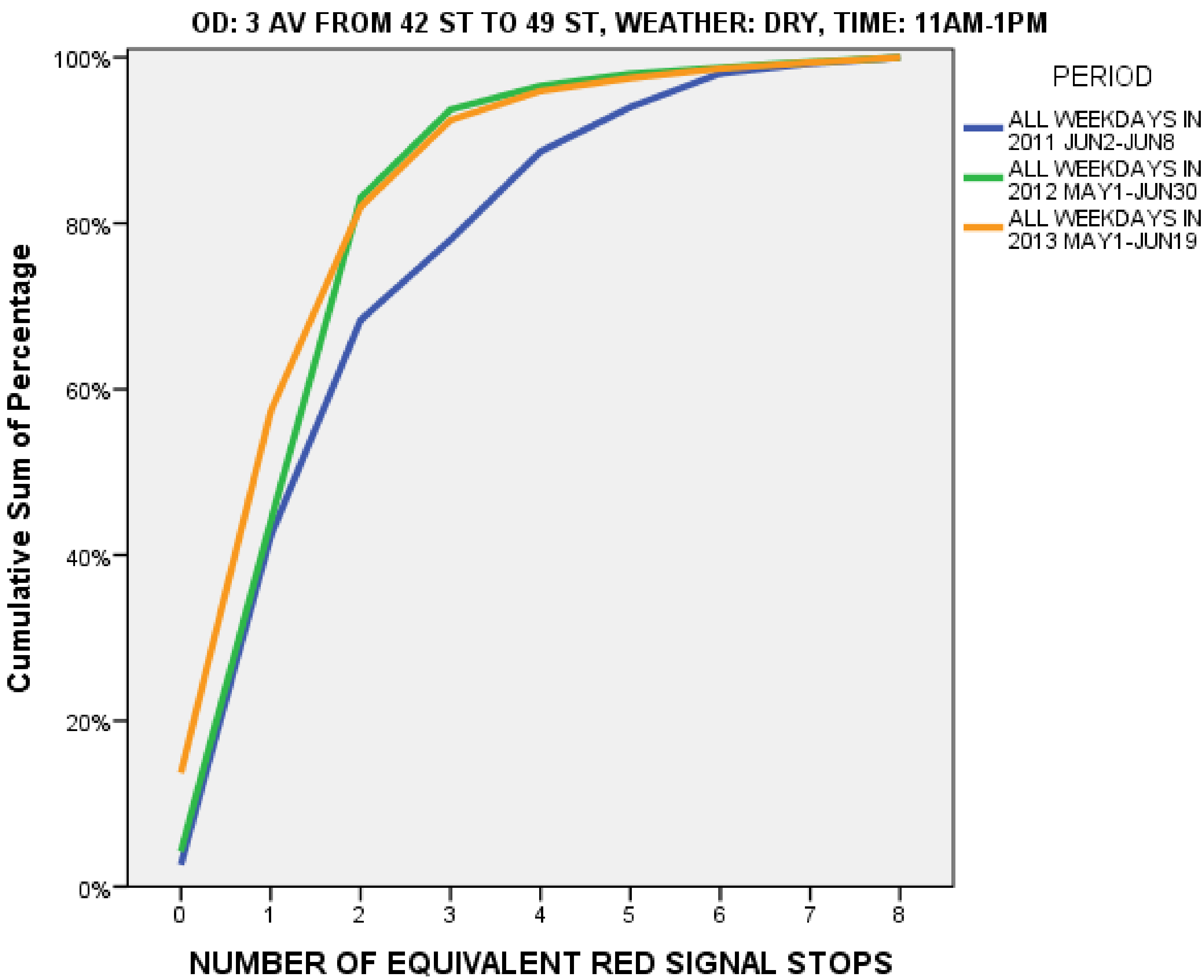
TRAVEL TIME FREQUENCY AND MARKED BY NUMBER OF RED SIGNAL STOPS
-DATA COLLECTED BY EZPASS TAG READERS

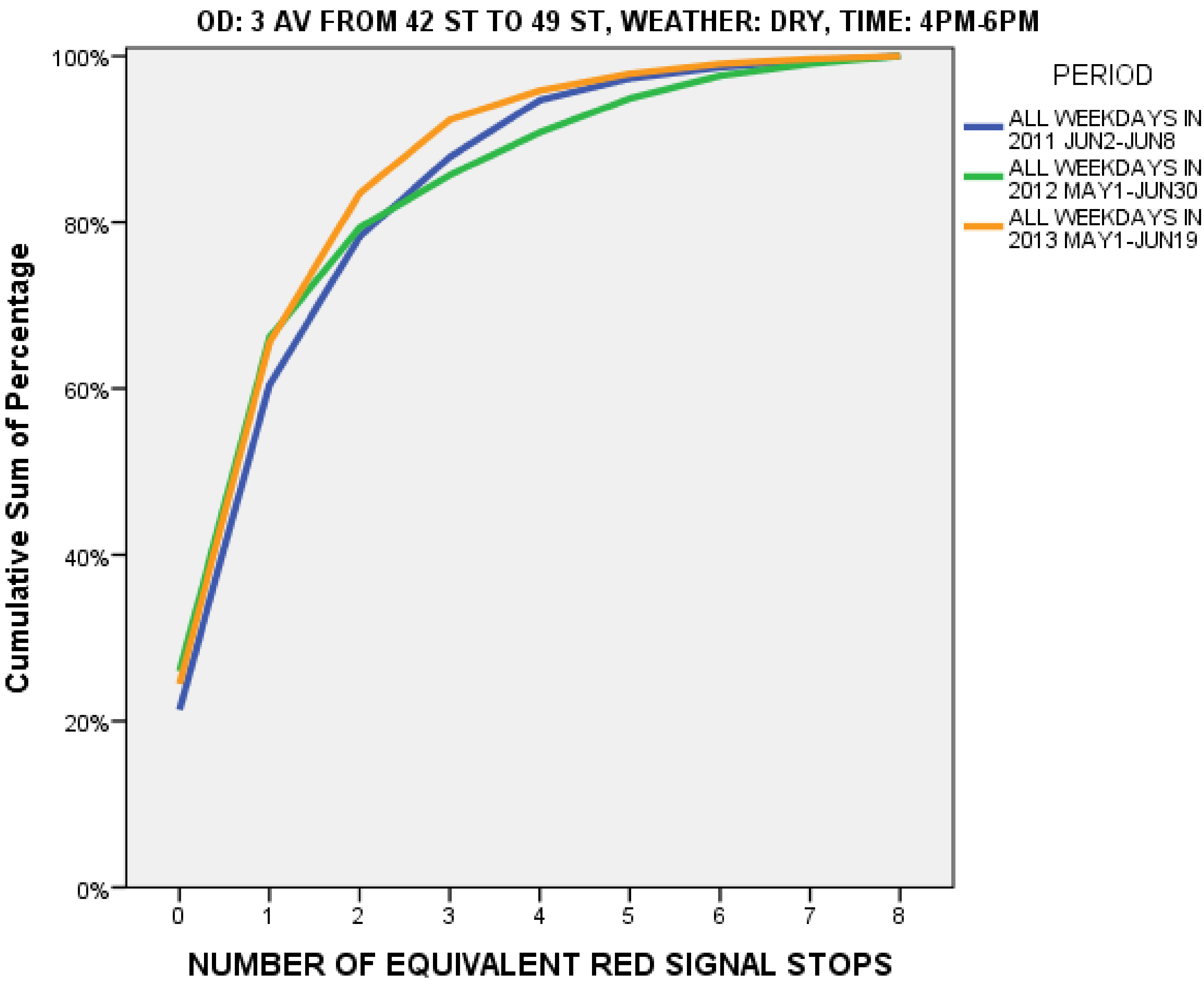


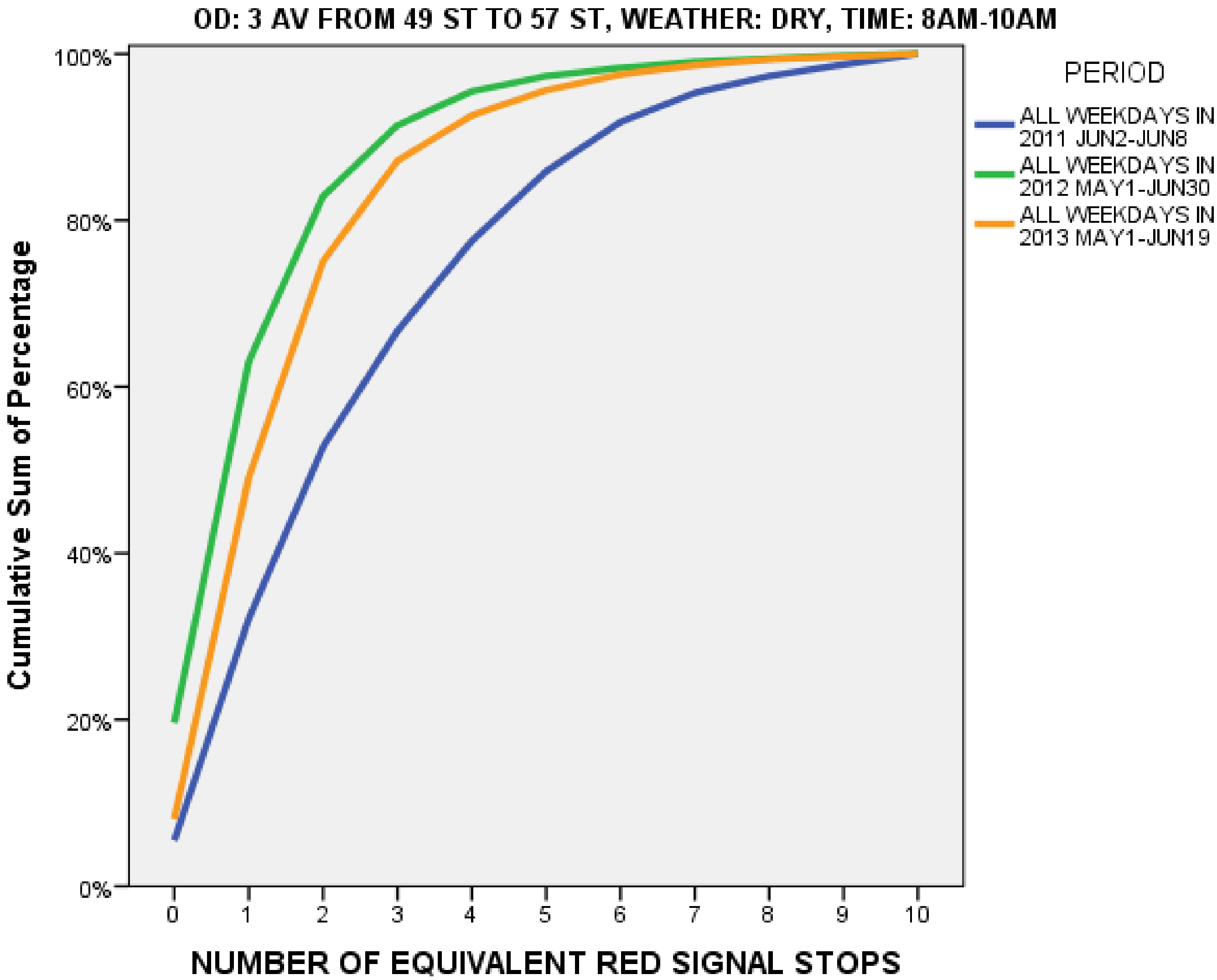
APPENDIX B

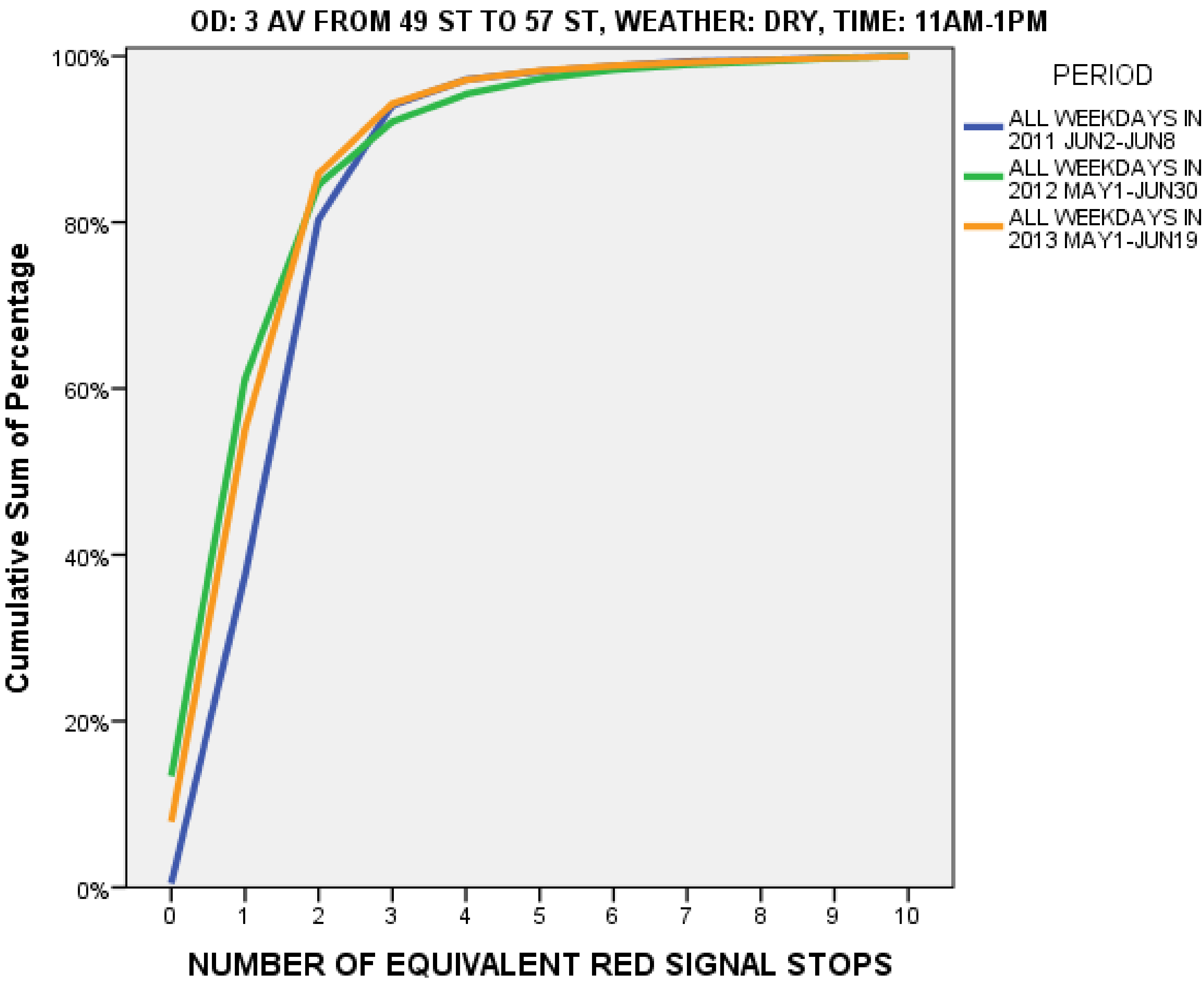
Cumulative Distribution of Stops by Vehicles during the AM, Midday, and PM Peak Hours in five Avenue Segments

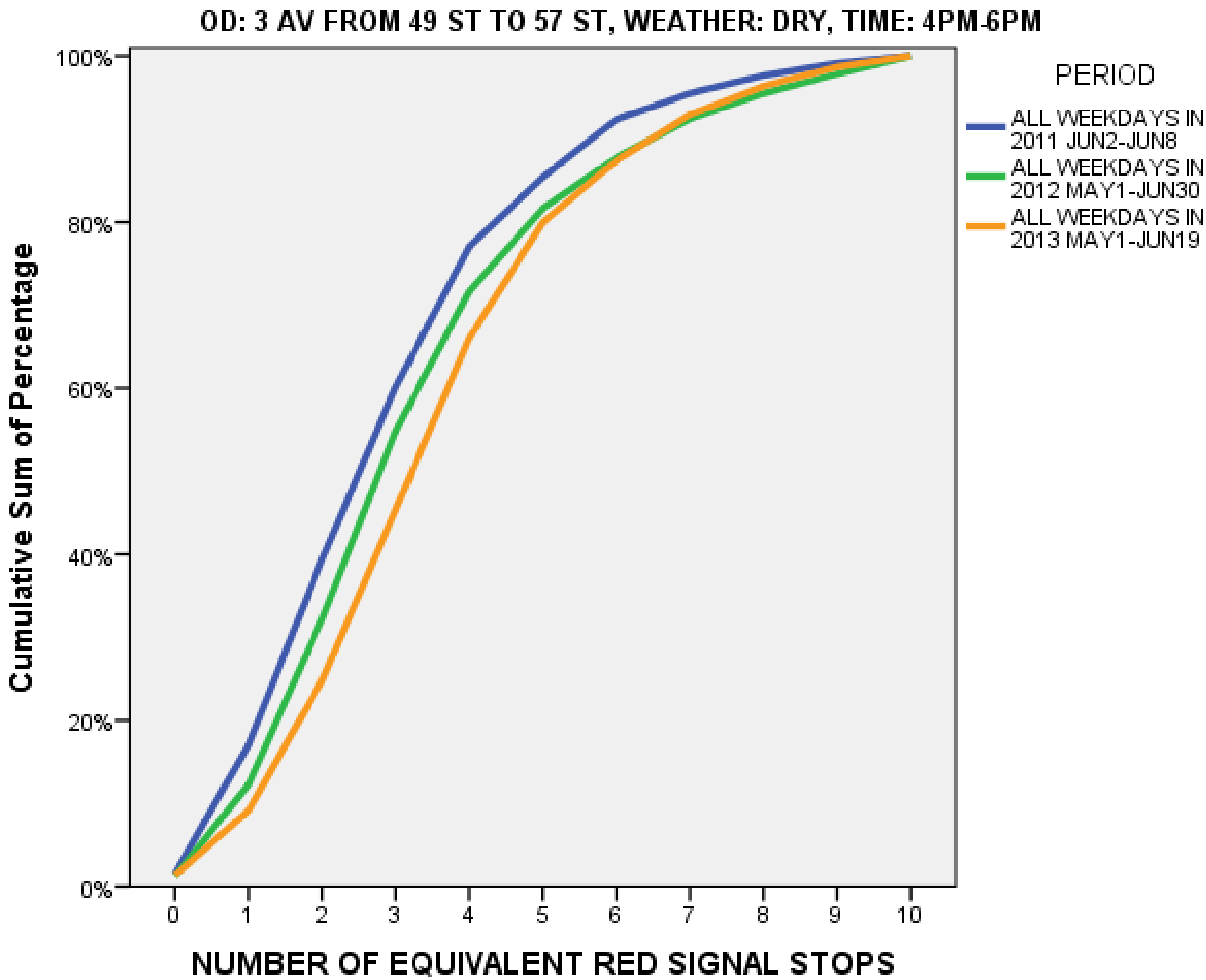



OD: 3 AV FROM 42 ST TO 49 ST, WEATHER: DRY, TIME: 11AM-1PM
Cumulative Sum of Percentage
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
6
7
8
NUMBER OF EQUIVALENT RED SIGNAL STOPS
PERIOD
ALL WEEKDAYS IN 2011 JUN2-JUN8
ALL WEEKDAYS IN 2012 MAY1-JUN30
ALL WEEKDAYS IN 2013 MAY1-JUN19

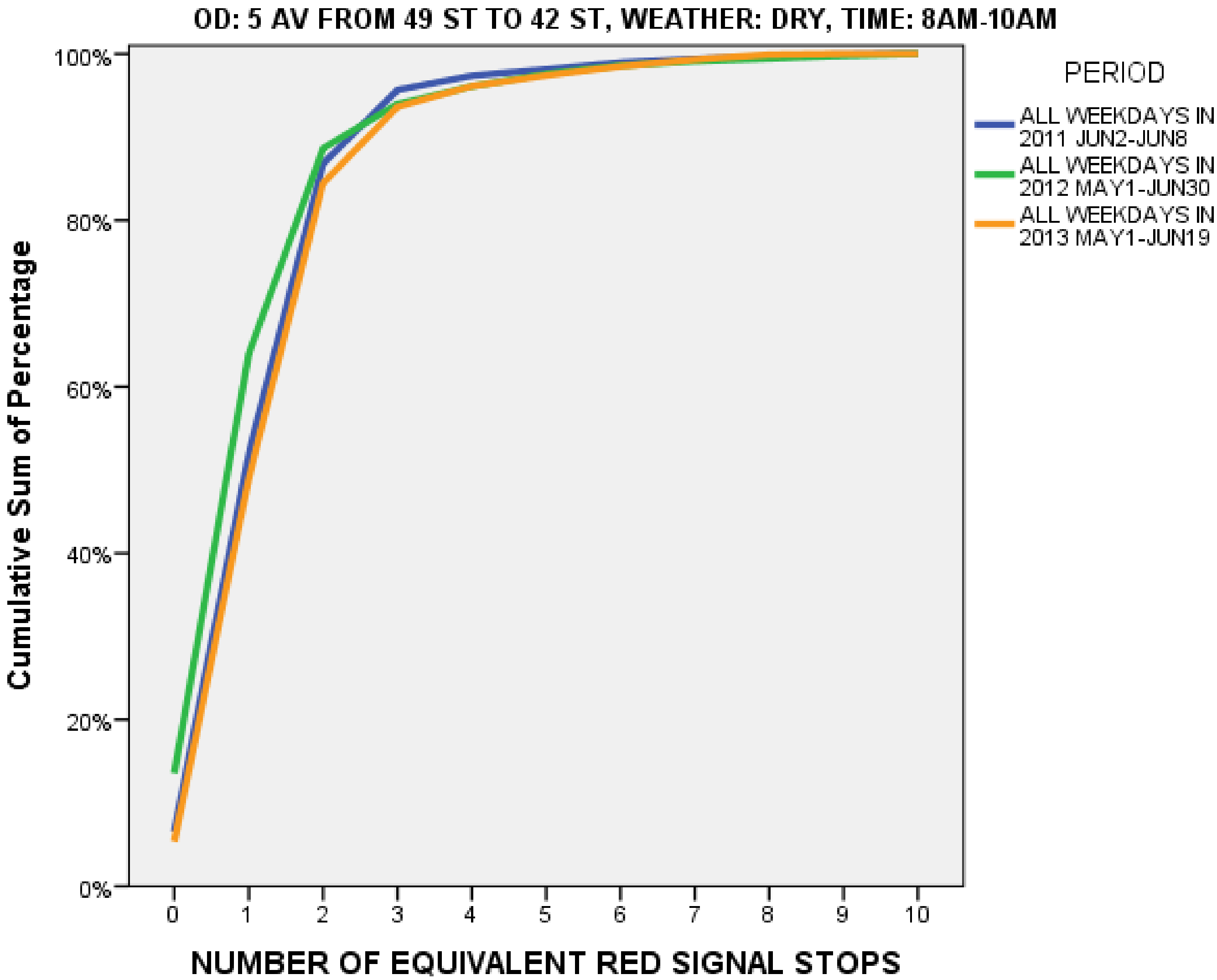

OD: 3 AV FROM 42 ST TO 49 ST, WEATHER: DRY, TIME: 4PM-6PM
Cumulative Sum of Percentage
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
6
7
8
NUMBER OF EQUIVALENT RED SIGNAL STOPS
PERIOD
ALL WEEKDAYS IN 2011 JUN2-JUN8
ALL WEEKDAYS IN 2012 MAY1-JUN30
ALL WEEKDAYS IN 2013 MAY1-JUN19

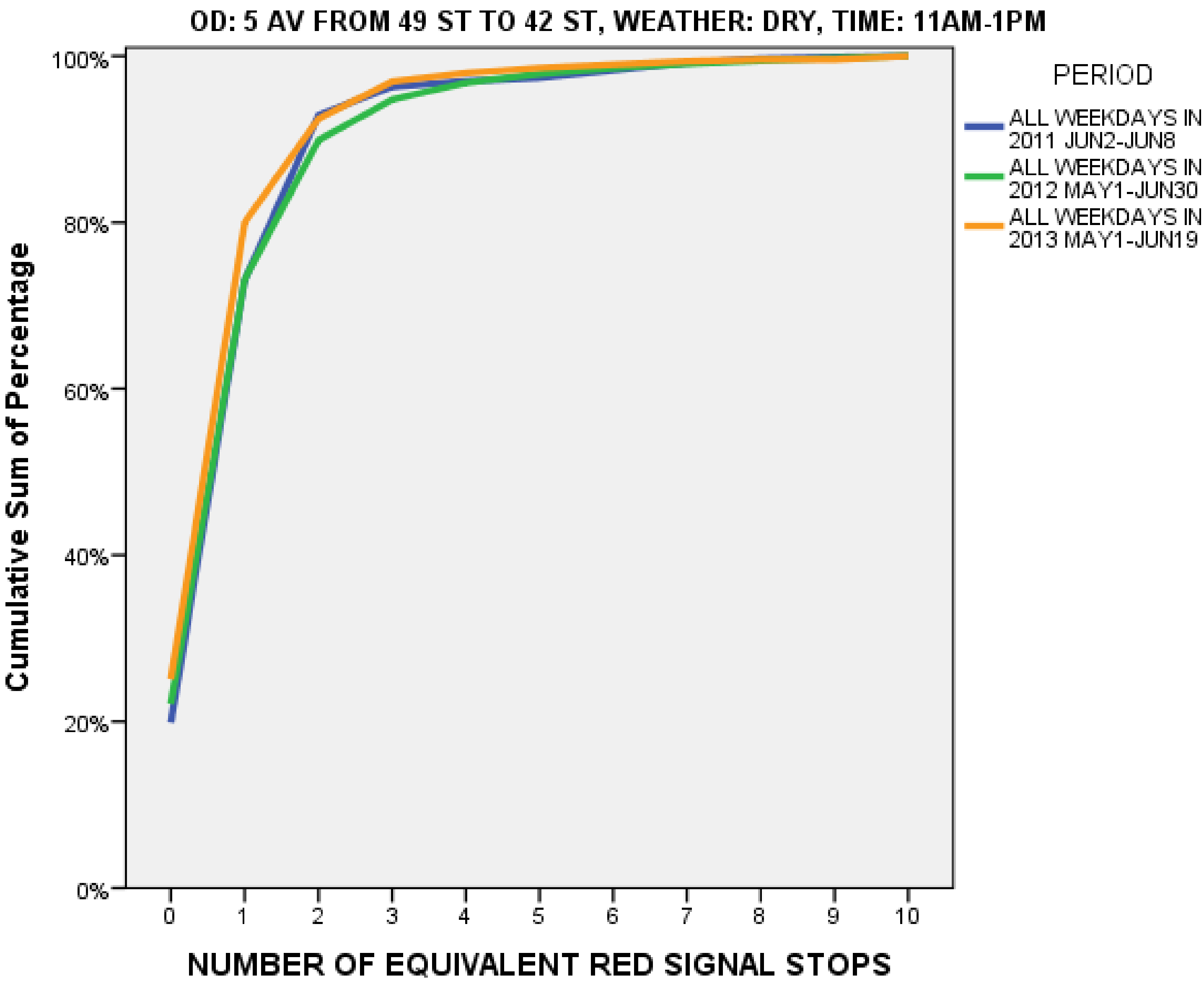

OD: 3 AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 8AM-10AM
Cumulative Sum of Percentage
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
6
7
8
9
10
NUMBER OF EQUIVALENT RED SIGNAL STOPS
PERIOD
ALL WEEKDAYS IN 2011 JUN2-JUN8
ALL WEEKDAYS IN 2012 MAY1-JUN30
ALL WEEKDAYS IN 2013 MAY1-JUN19

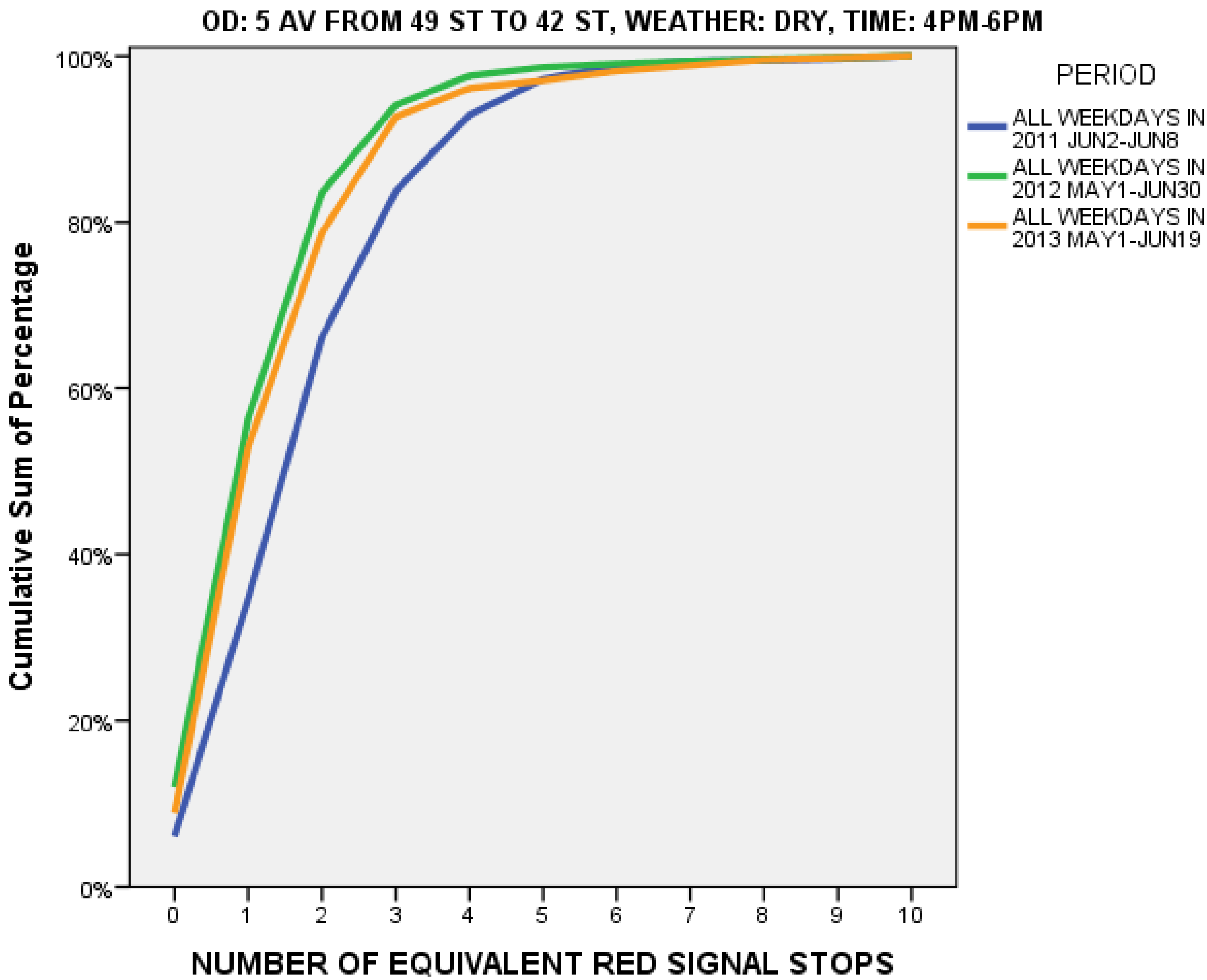

OD: 3 AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 11AM-1PM
Cumulative Sum of Percentage
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
6
7
8
9
10
NUMBER OF EQUIVALENT RED SIGNAL STOPS
PERIOD
ALL WEEKDAYS IN 2011 JUN2-JUN8
ALL WEEKDAYS IN 2012 MAY1-JUN30
ALL WEEKDAYS IN 2013 MAY1-JUN19

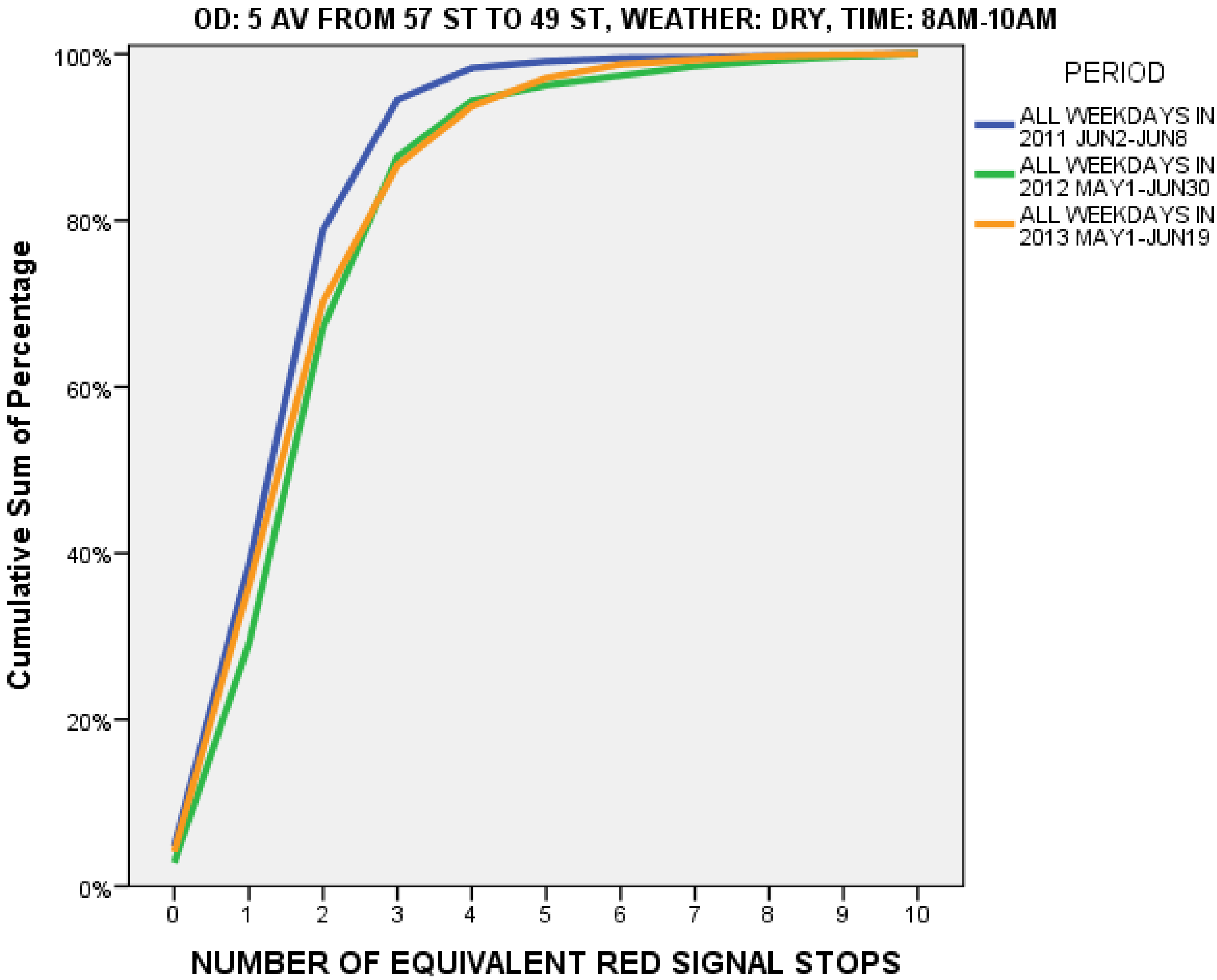


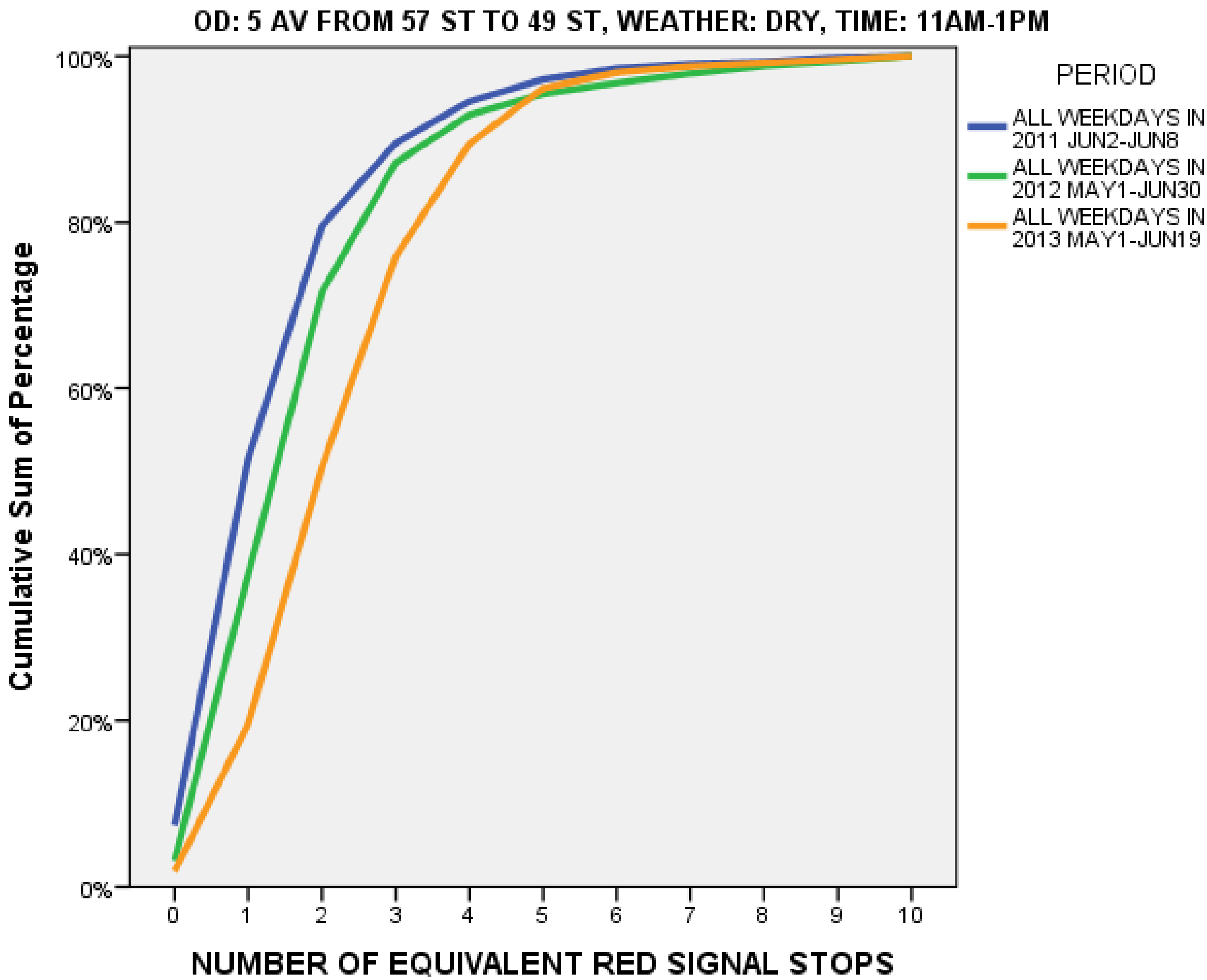
OD: 3 AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 4PM-6PM
Cumulative Sum of Percentage
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
6
7
8
9
10
NUMBER OF EQUIVALENT RED SIGNAL STOPS
PERIOD
ALL WEEKDAYS IN 2011 JUN2-JUN8
ALL WEEKDAYS IN 2012 MAY1-JUN30
ALL WEEKDAYS IN 2013 MAY1-JUN19


OD: 5 AV FROM 49 ST TO 42 ST, WEATHER: DRY, TIME: 8AM-10AM
Cumulative Sum of Percentage
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
6
7
8
9
10
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
Cumulative Sum of Percentage
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
6
7
8
9
10
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: 4PM-6PM
Cumulative Sum of Percentage
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
6
7
8
9
10
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 57 ST TO 49 ST, WEATHER: DRY, TIME: 8AM-10AM
Cumulative Sum of Percentage
100%
80%
60%
40%
20%
0%
0
1
2
3
4
5
6
7
8
9
10
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 57 ST TO 49 ST, WEATHER: DRY, TIME: 11AM-1PM
Cumulative Sum of Percentage
100%
80%
60%
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NUMBER OF EQUIVALENT RED SIGNAL STOPS
PERIOD
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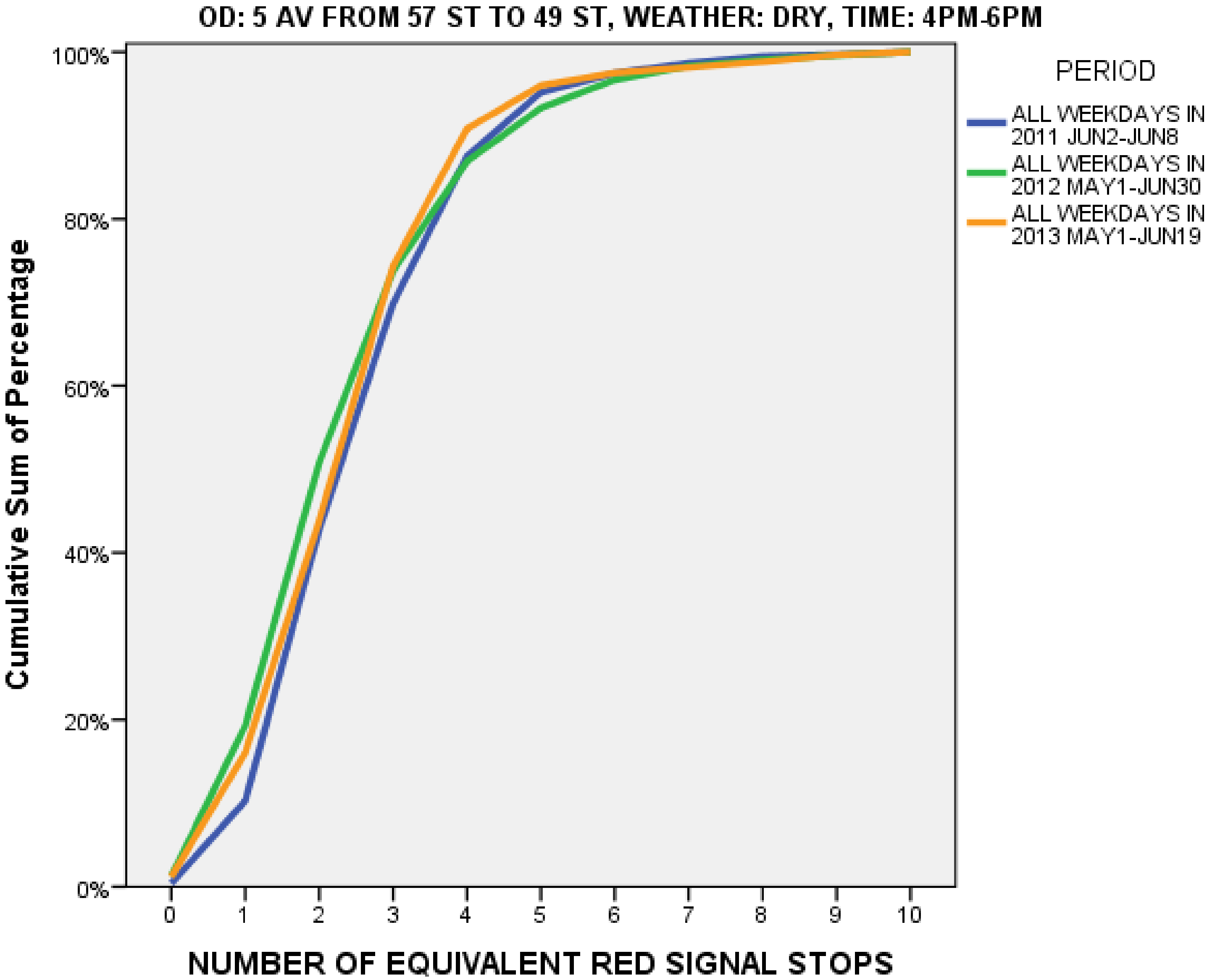
ALL WEEKDAYS IN 2012 MAY1-JUN30
ALL WEEKDAYS IN 2013 MAY1-JUN19



OD: 5 AV FROM 57 ST TO 49 ST, WEATHER: DRY, TIME: 4PM-6PM
Cumulative Sum of Percentage
100%
80%
60%
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NUMBER OF EQUIVALENT RED SIGNAL STOPS
PERIOD
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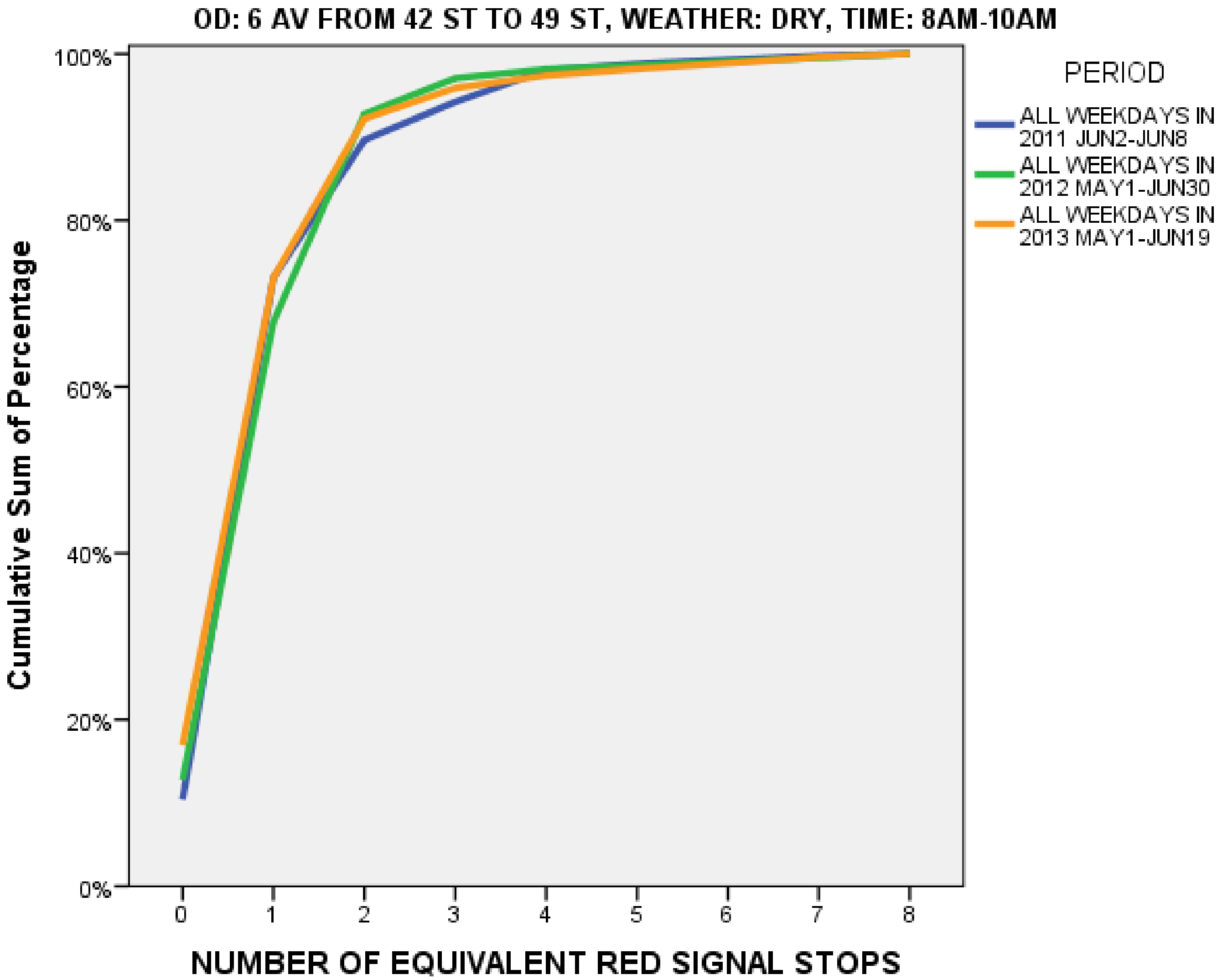
ALL WEEKDAYS IN 2013 MAY1-JUN19



OD: 6 AV FROM 42 ST TO 49 ST, WEATHER: DRY, TIME: 8AM-10AM
100%
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Cumulative Sum of Percentage
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NUMBER OF EQUIVALENT RED SIGNAL STOPS
PERIOD
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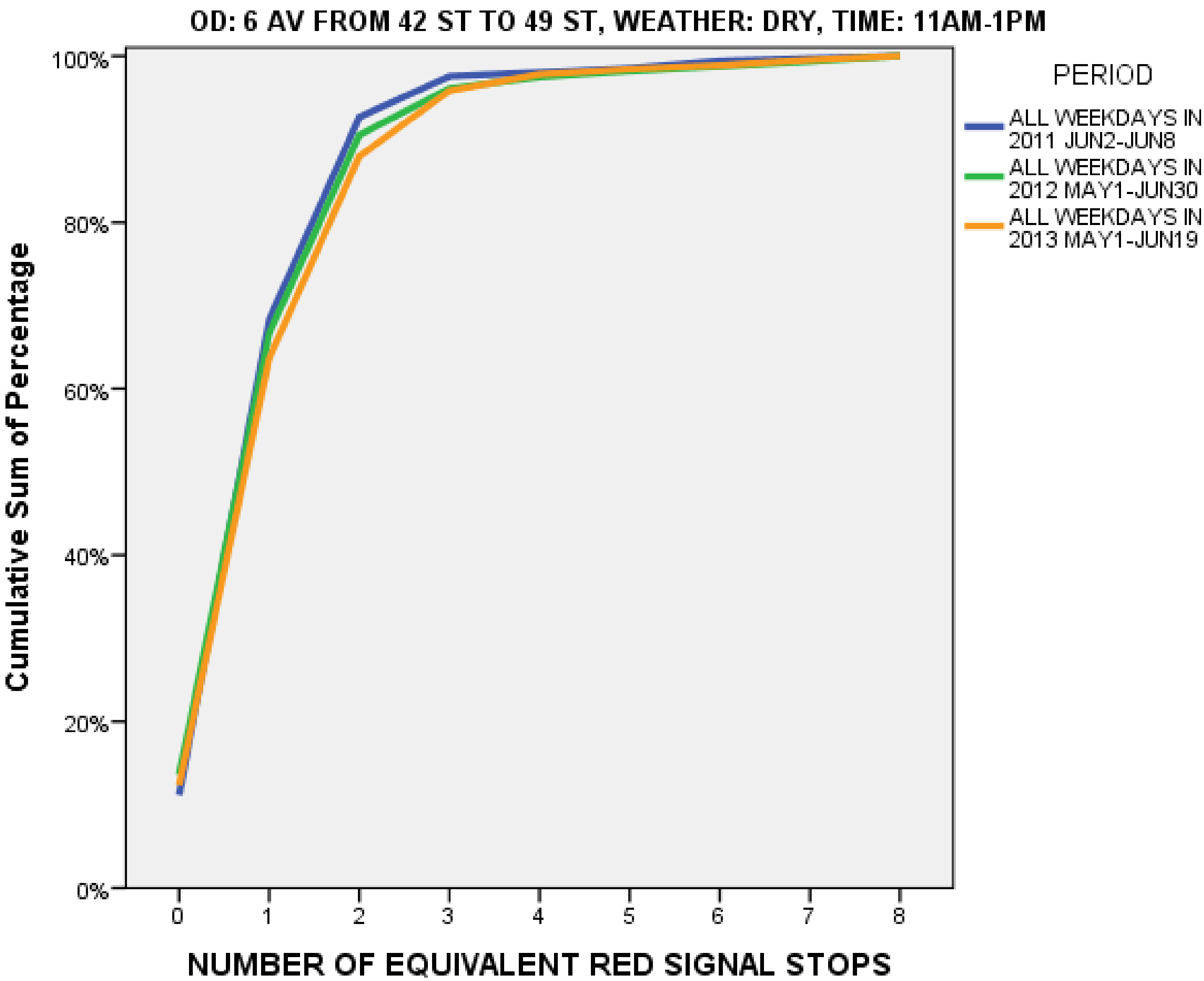
ALL WEEKDAYS IN 2013 MAY1-JUN19



OD: 6 AV FROM 42 ST TO 49 ST, WEATHER: DRY, TIME: 11AM-1PM
Cumulative Sum of Percentage
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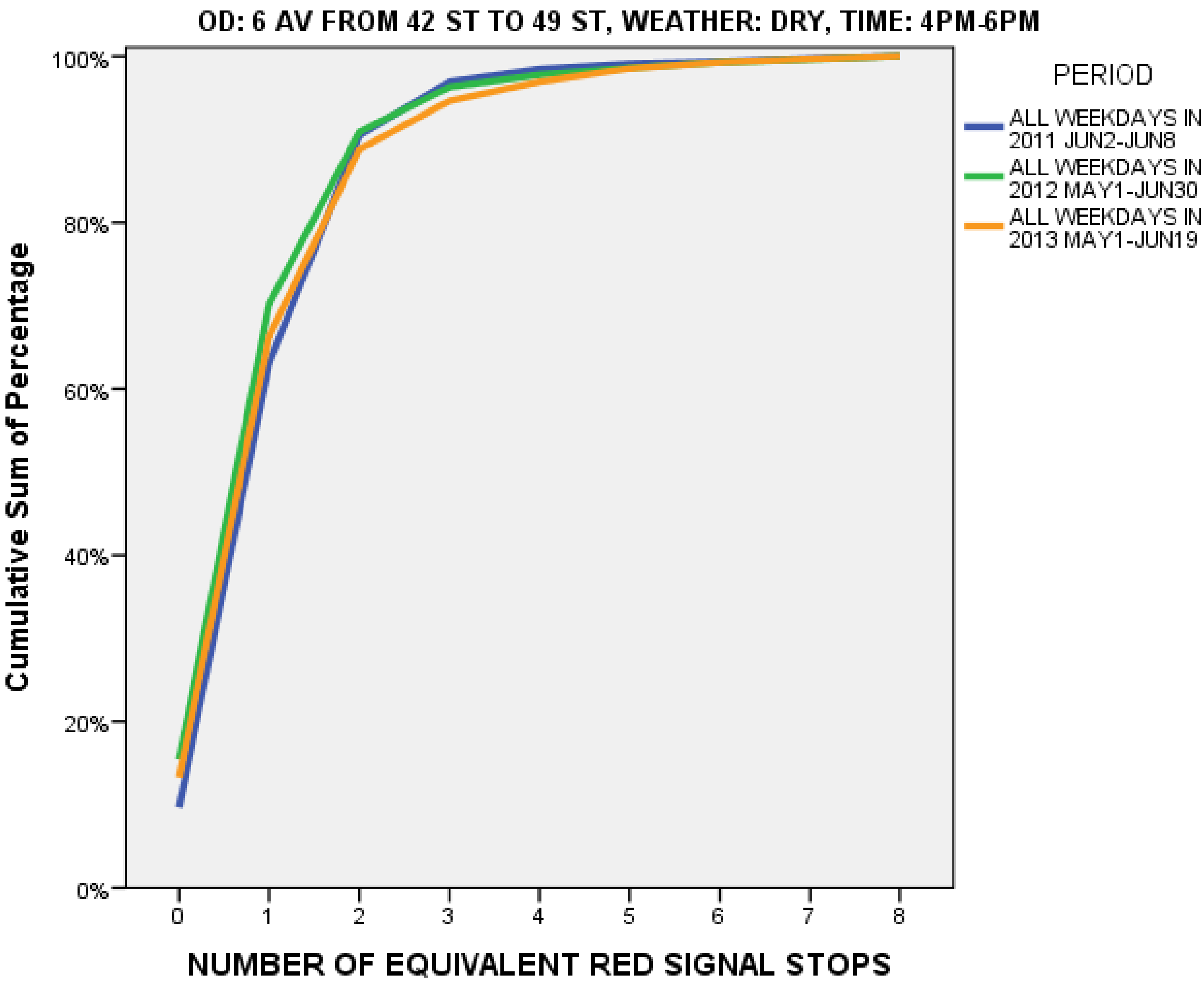
OD: 6 AV FROM 42 ST TO 49 ST, WEATHER: DRY, TIME: 4PM-6PM
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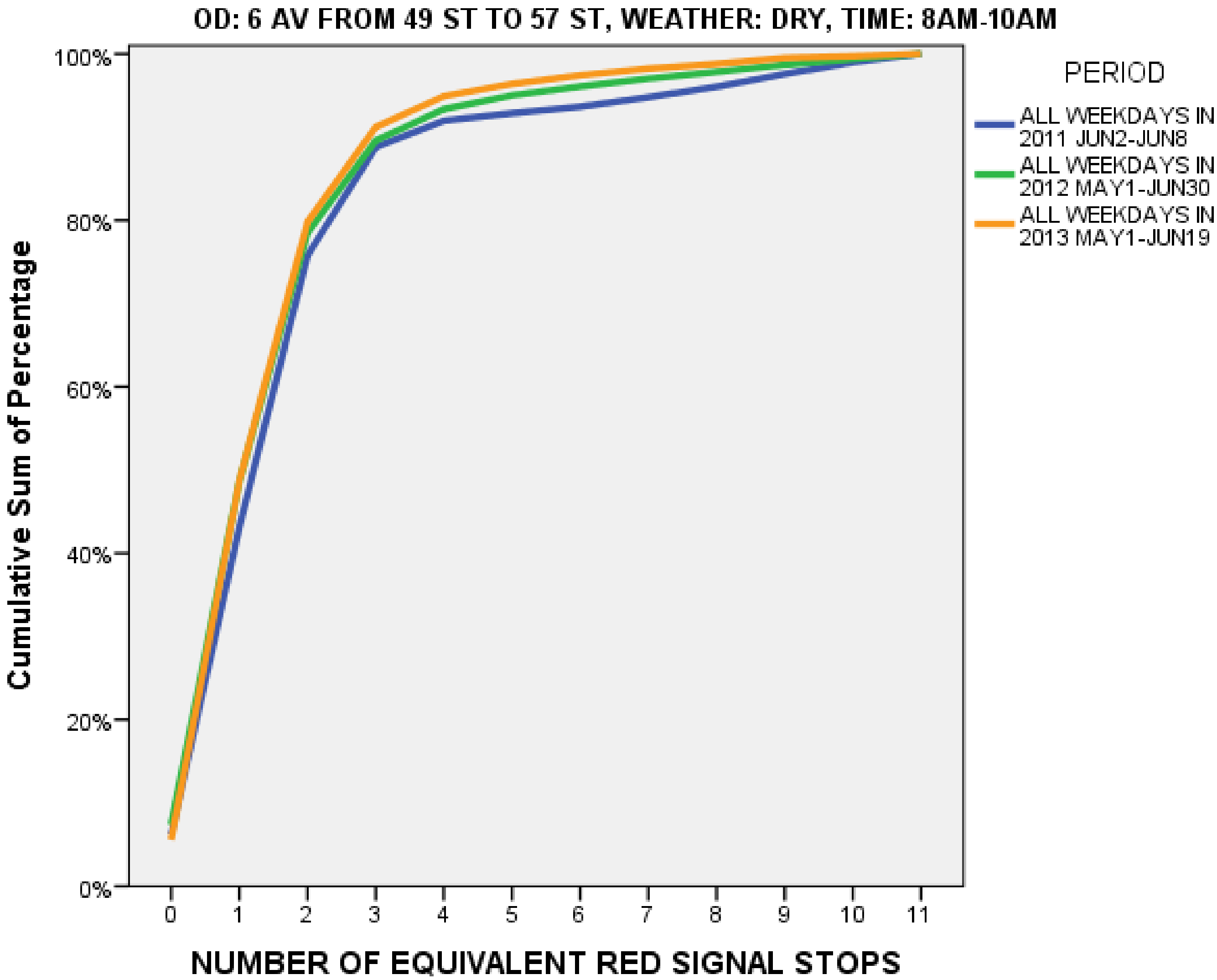
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Cumulative Sum of Percentage
100%
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NUMBER OF EQUIVALENT RED SIGNAL STOPS
PERIOD
ALL WEEKDAYS IN 2011 JUN2-JUN8
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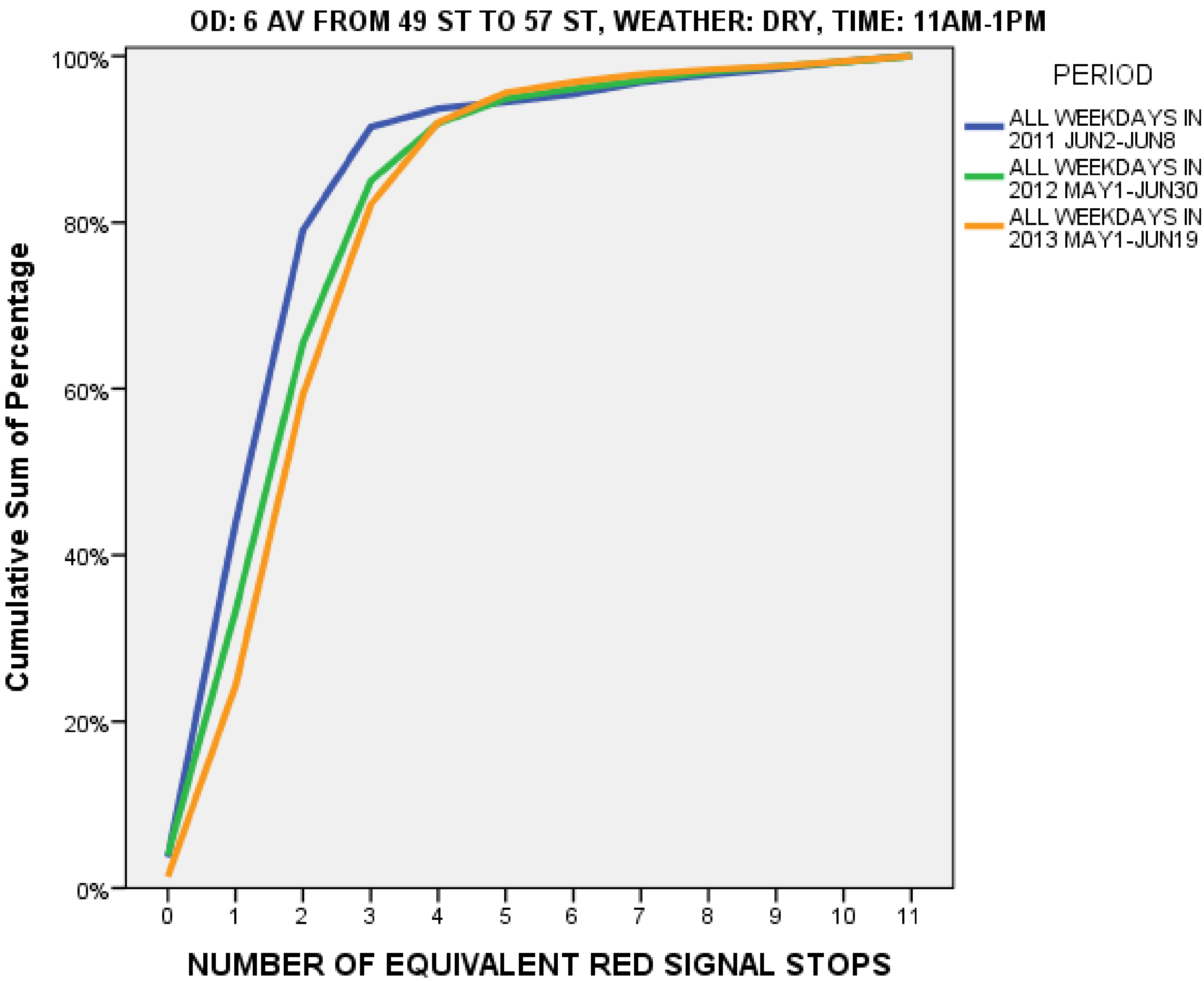
ALL WEEKDAYS IN 2013 MAY1-JUN19


OD: 6 AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 11AM-1PM
Cumulative Sum of Percentage
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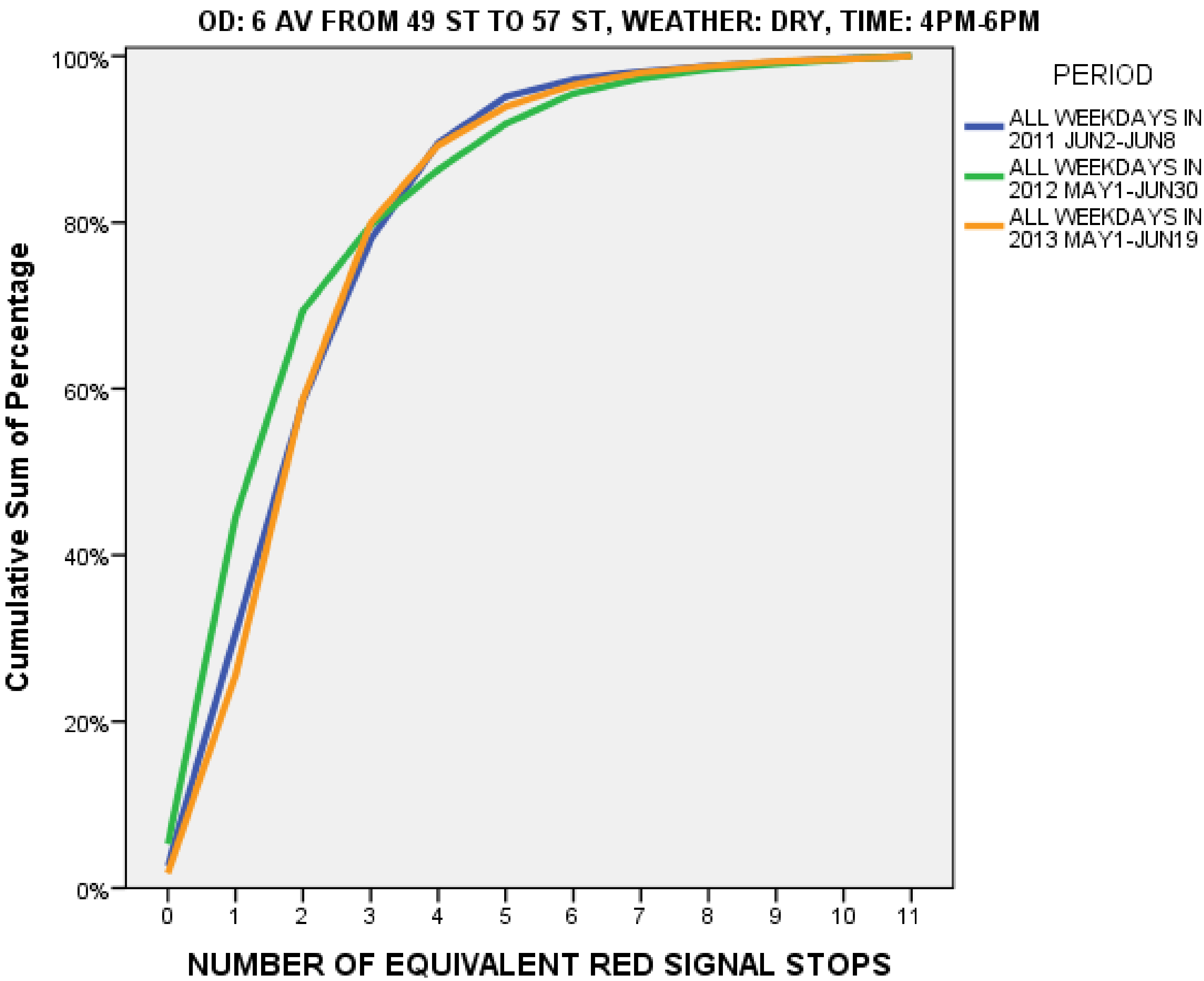
OD: 6 AV FROM 49 ST TO 57 ST, WEATHER: DRY, TIME: 4PM-6PM
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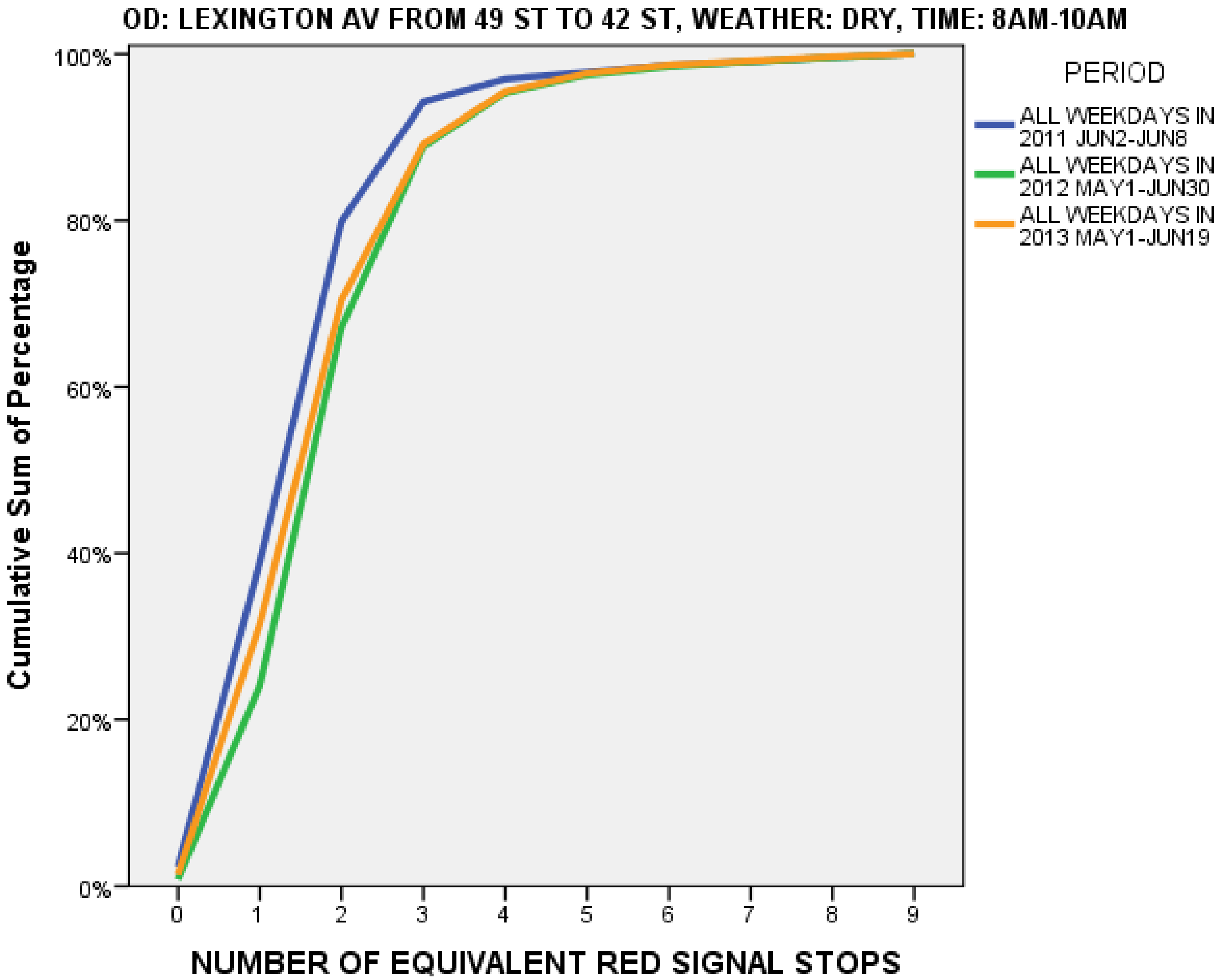
OD: LEXINGTON AV FROM 49 ST TO 42 ST, WEATHER: DRY, TIME: 8AM-10AM
Cumulative Sum of Percentage
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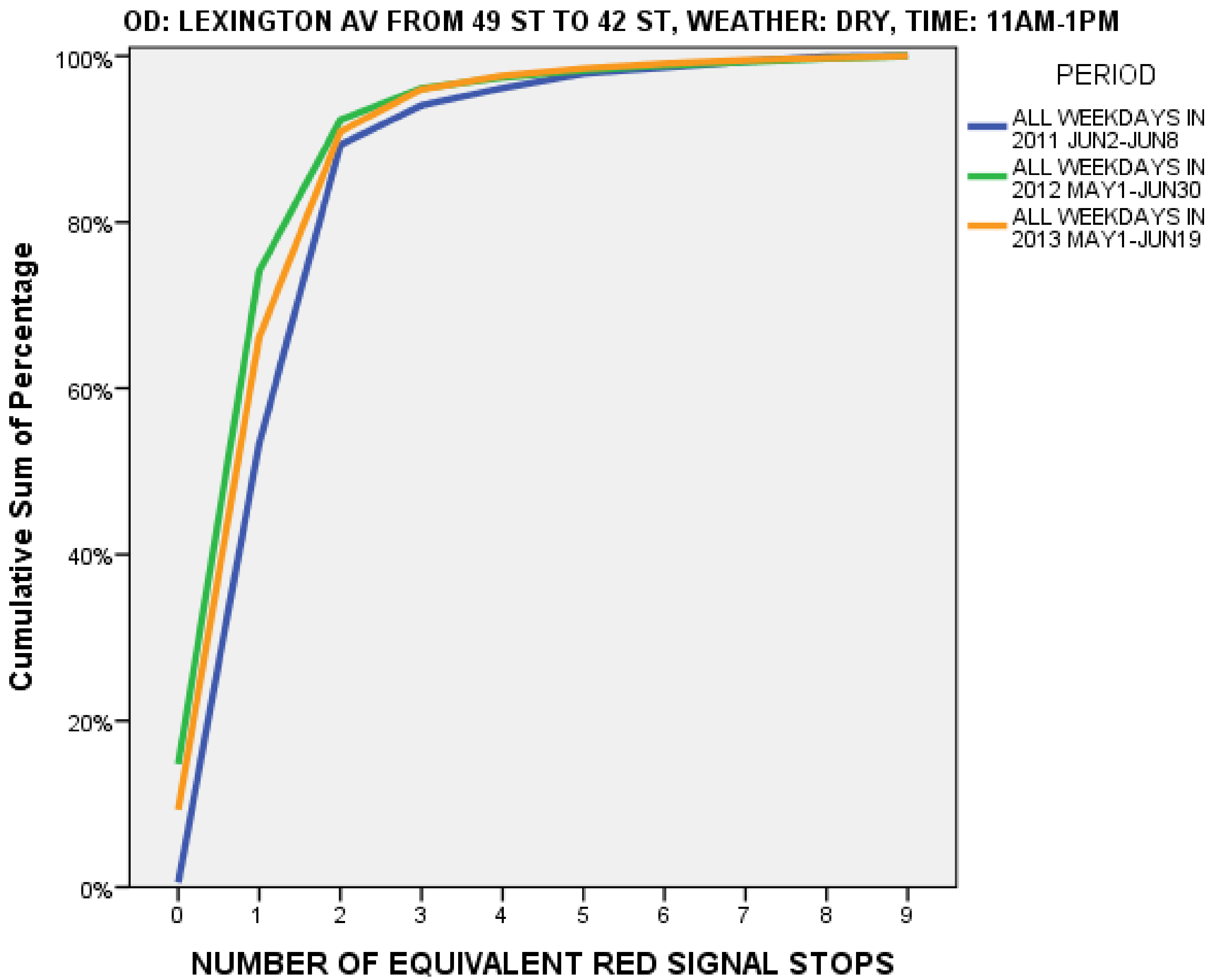

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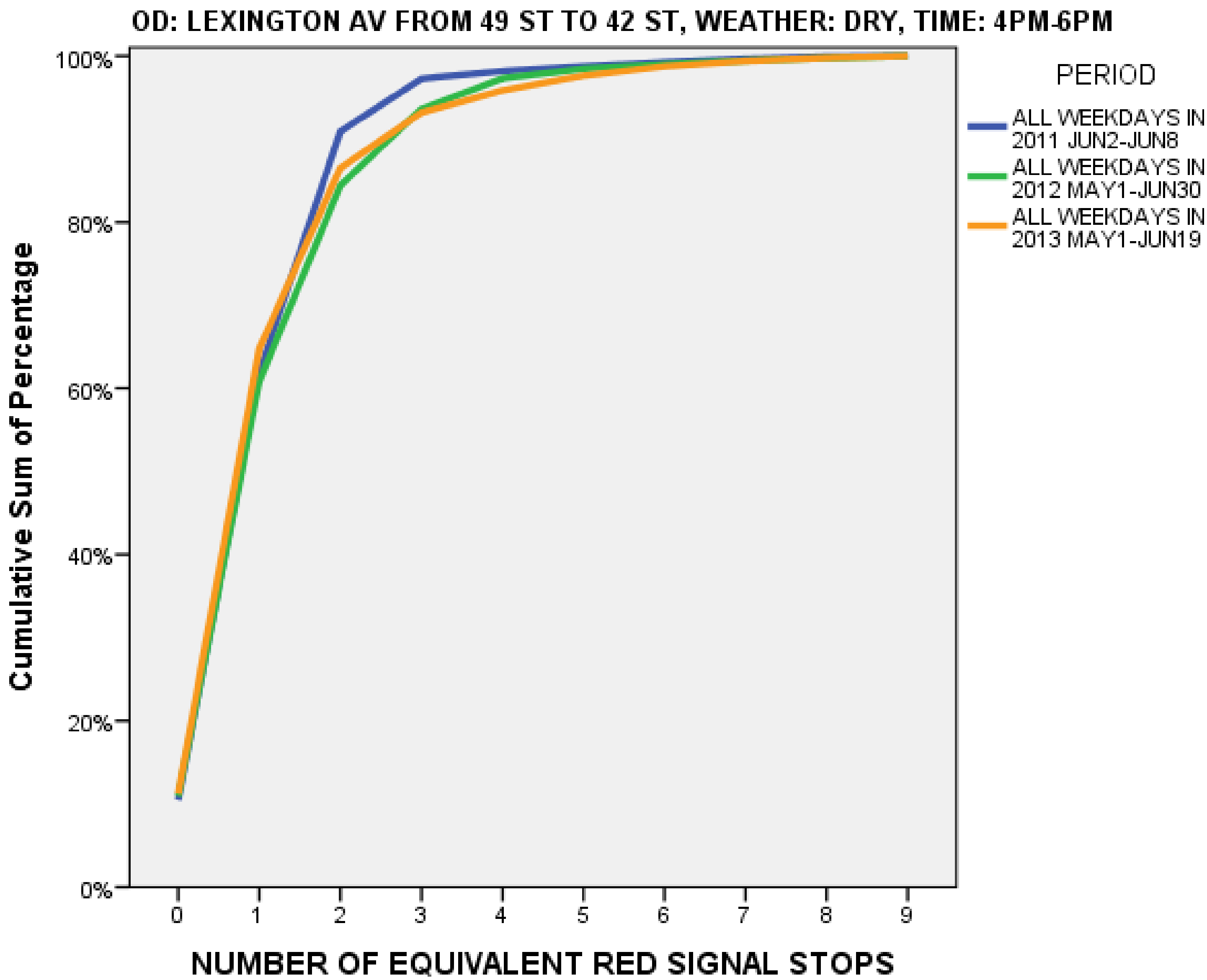
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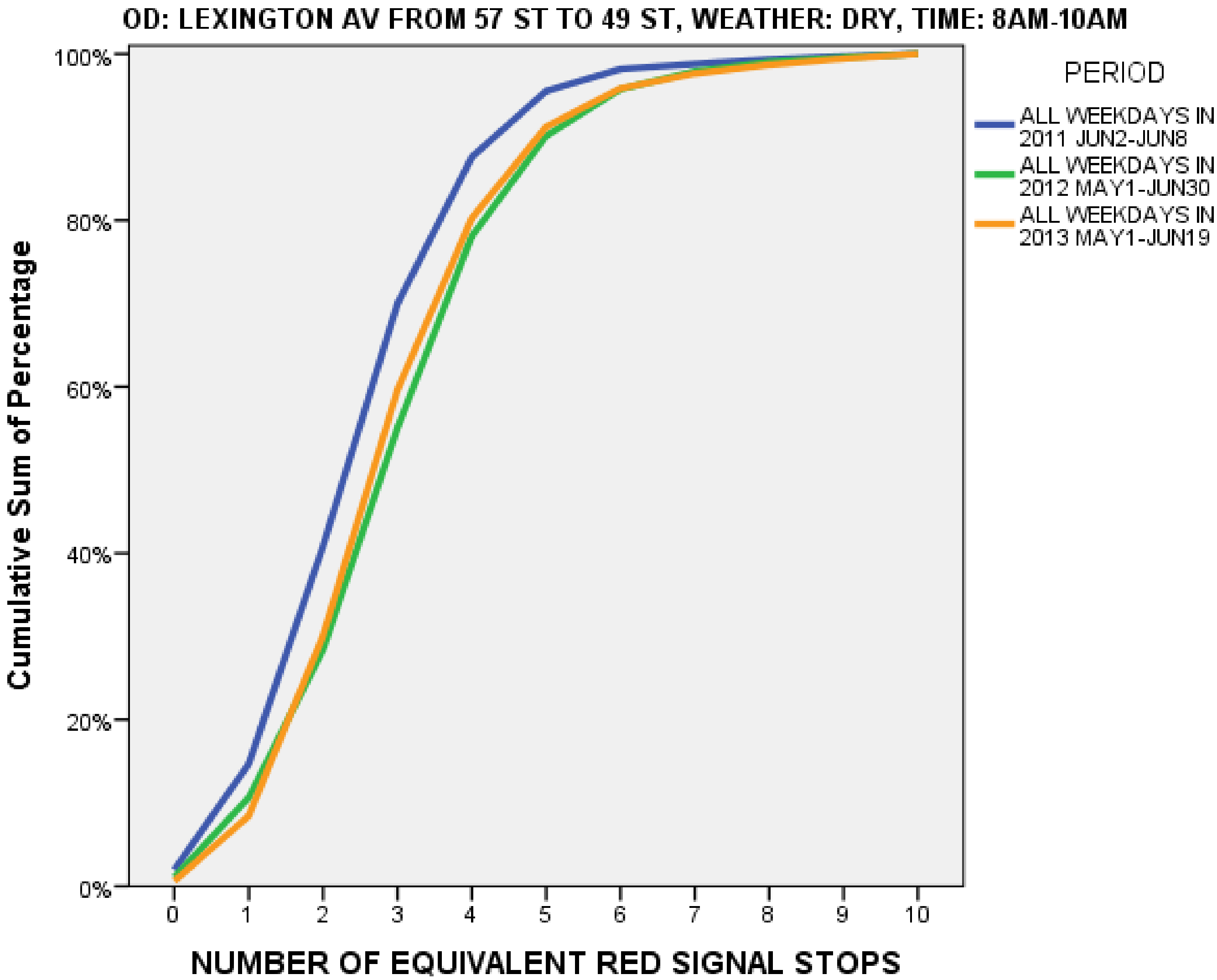
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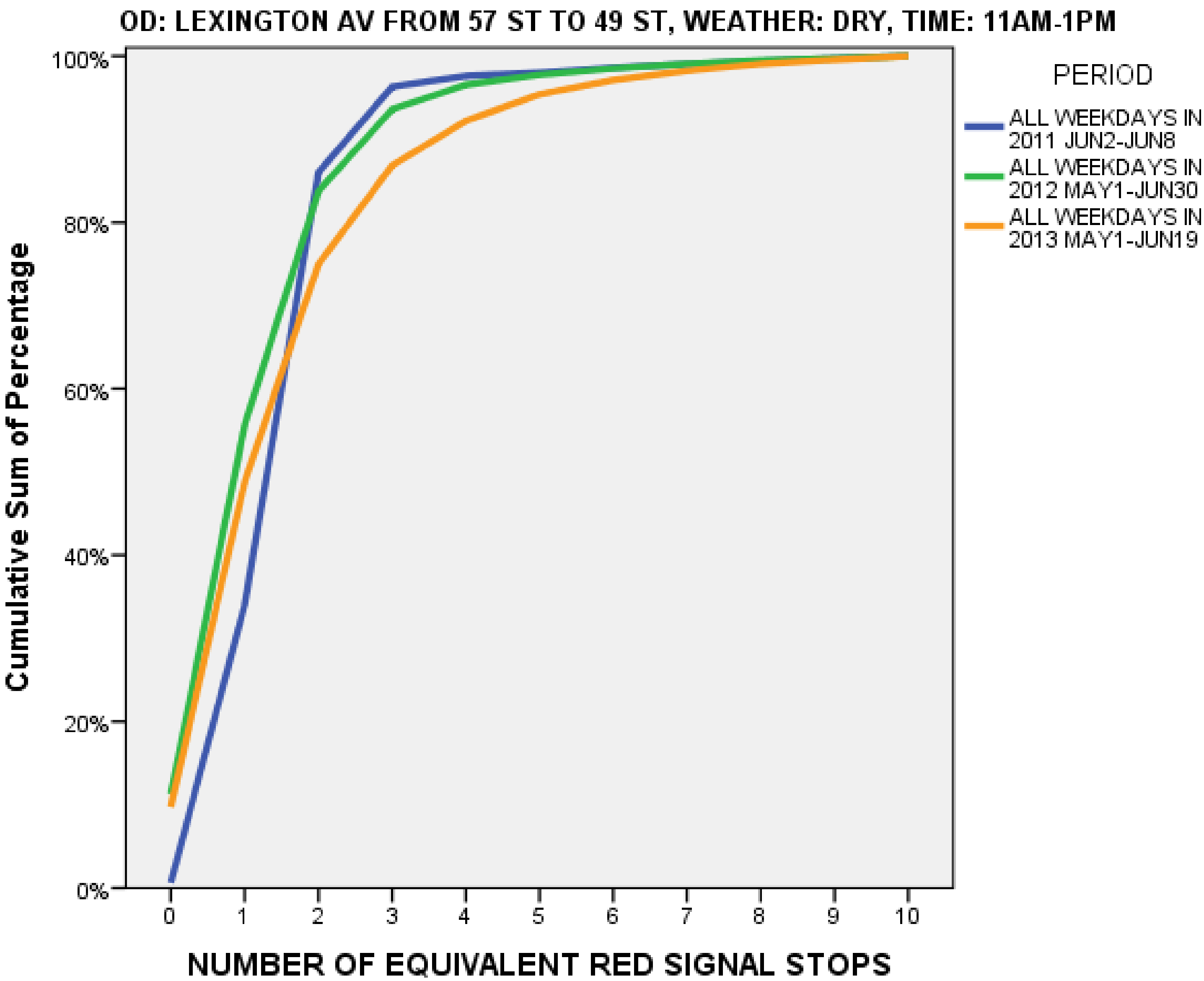
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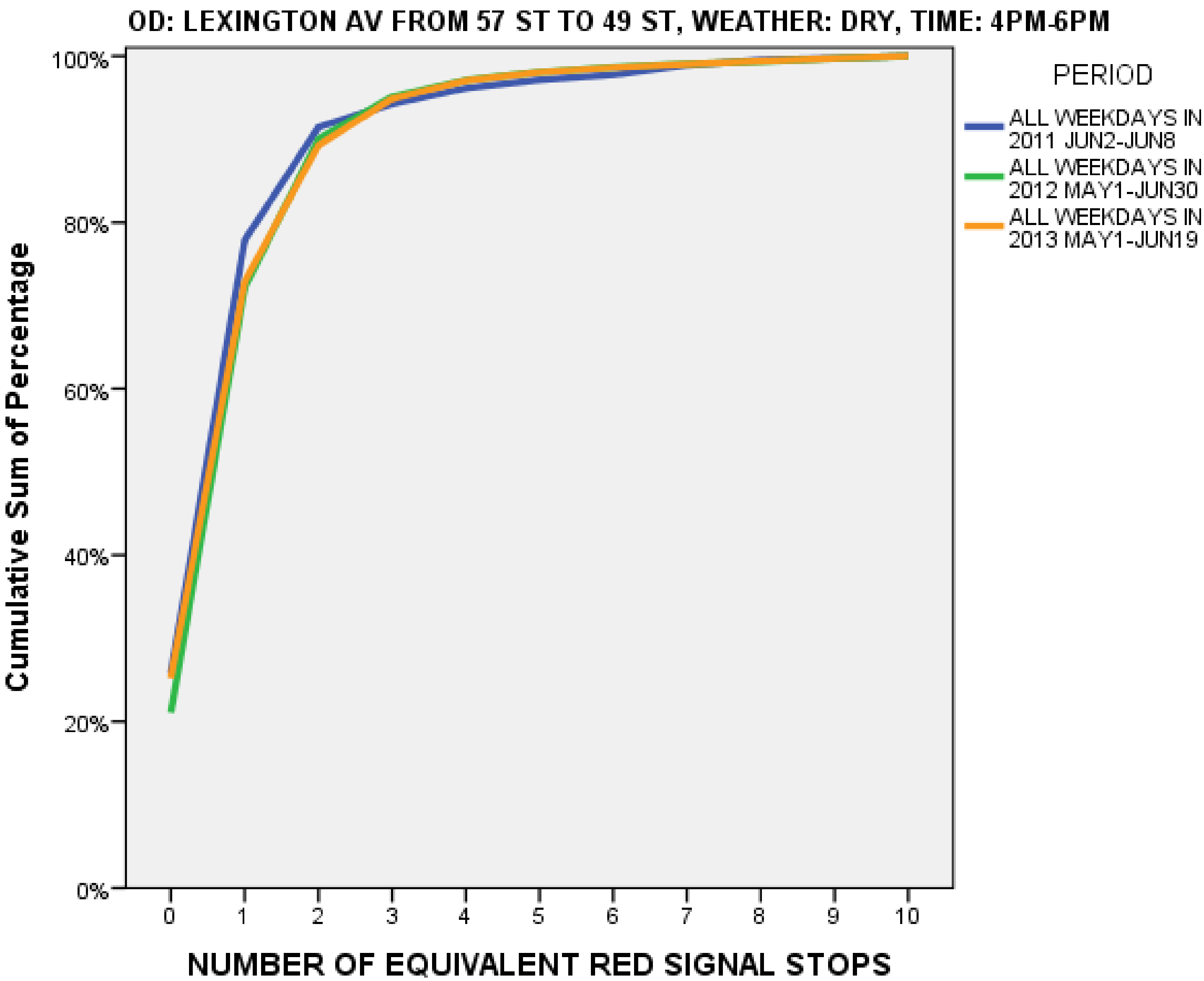
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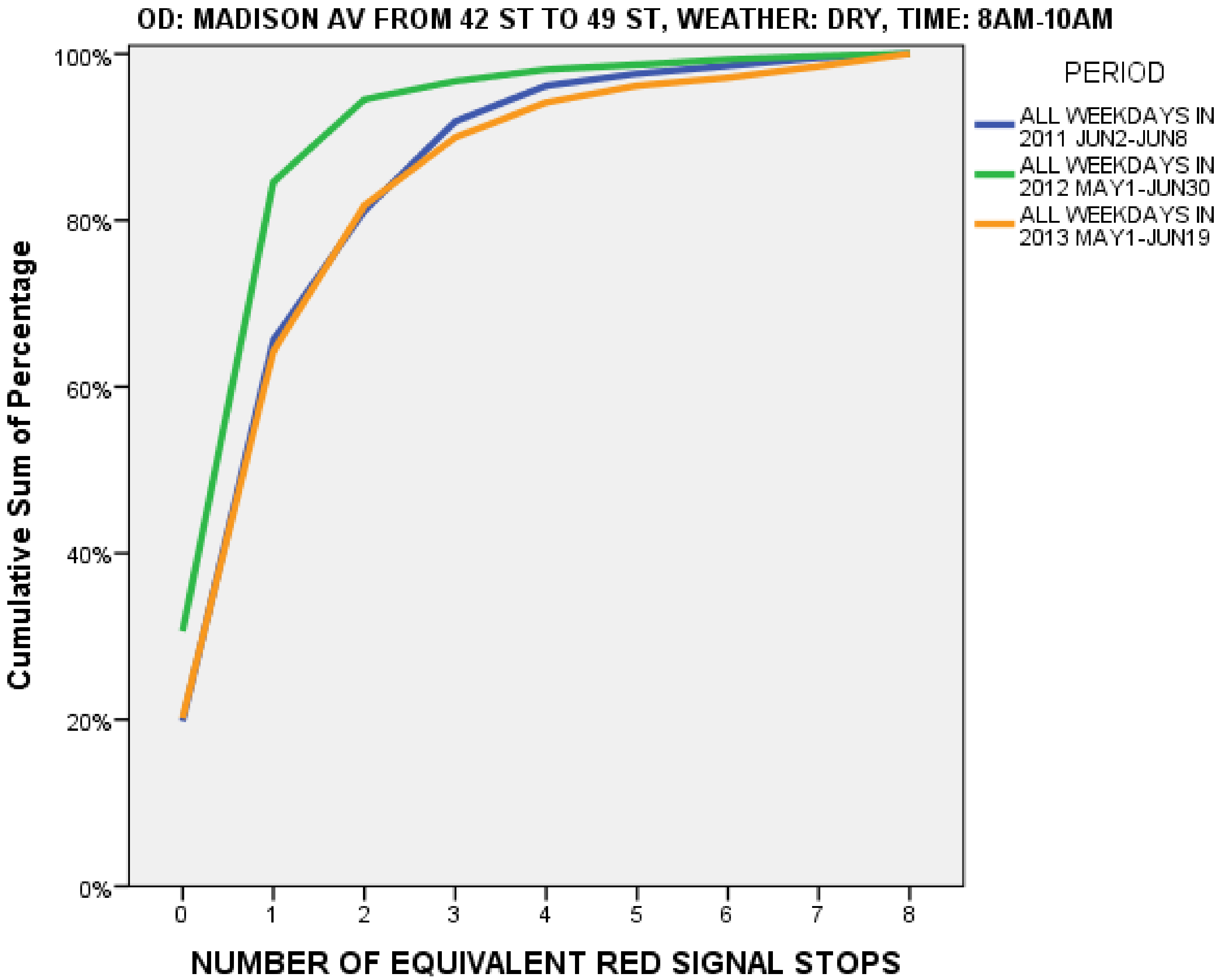
OD: MADISON AV FROM 42 ST TO 49 ST, WEATHER: DRY, TIME: 8AM-10AM
Cumulative Sum of Percentage
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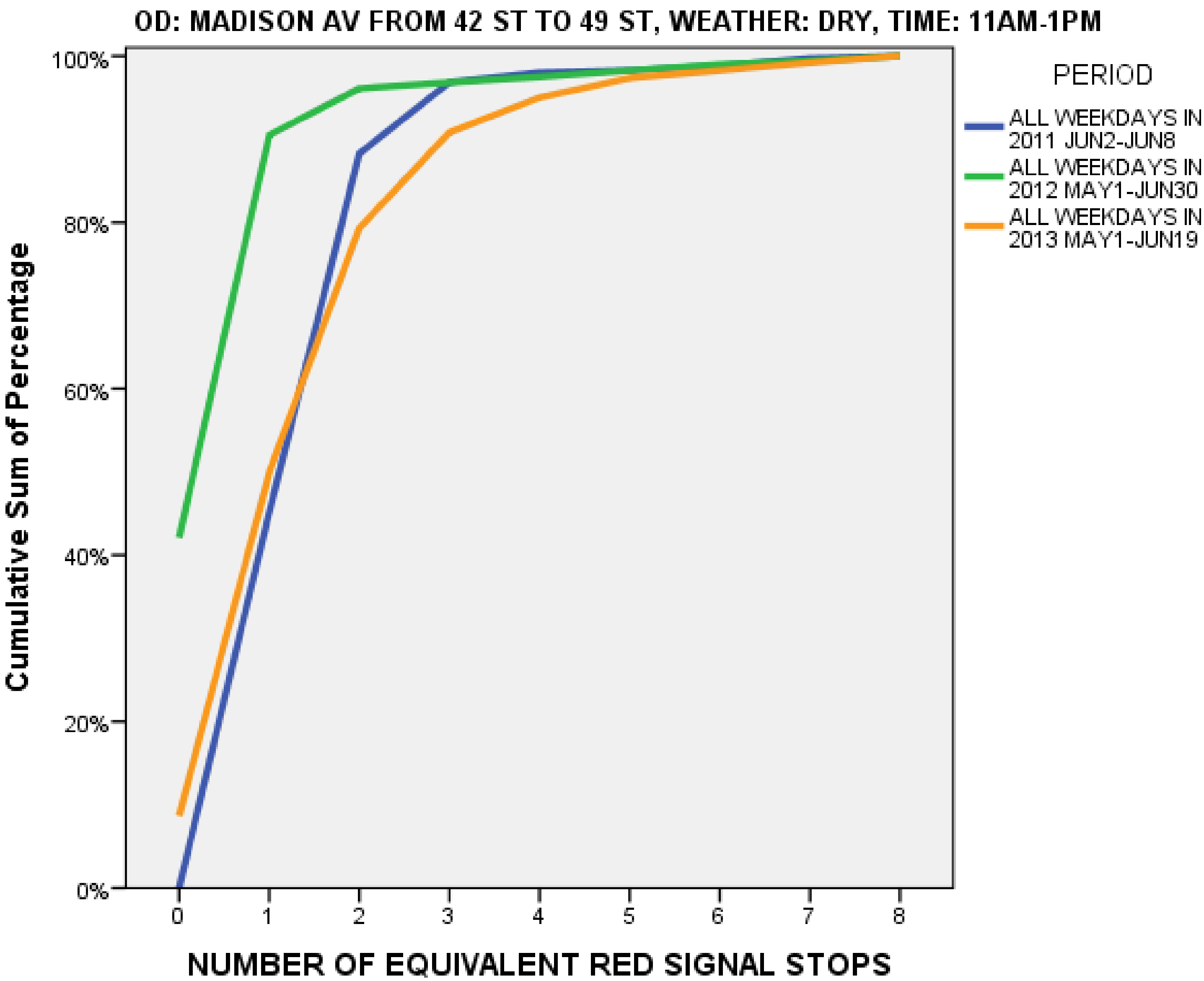
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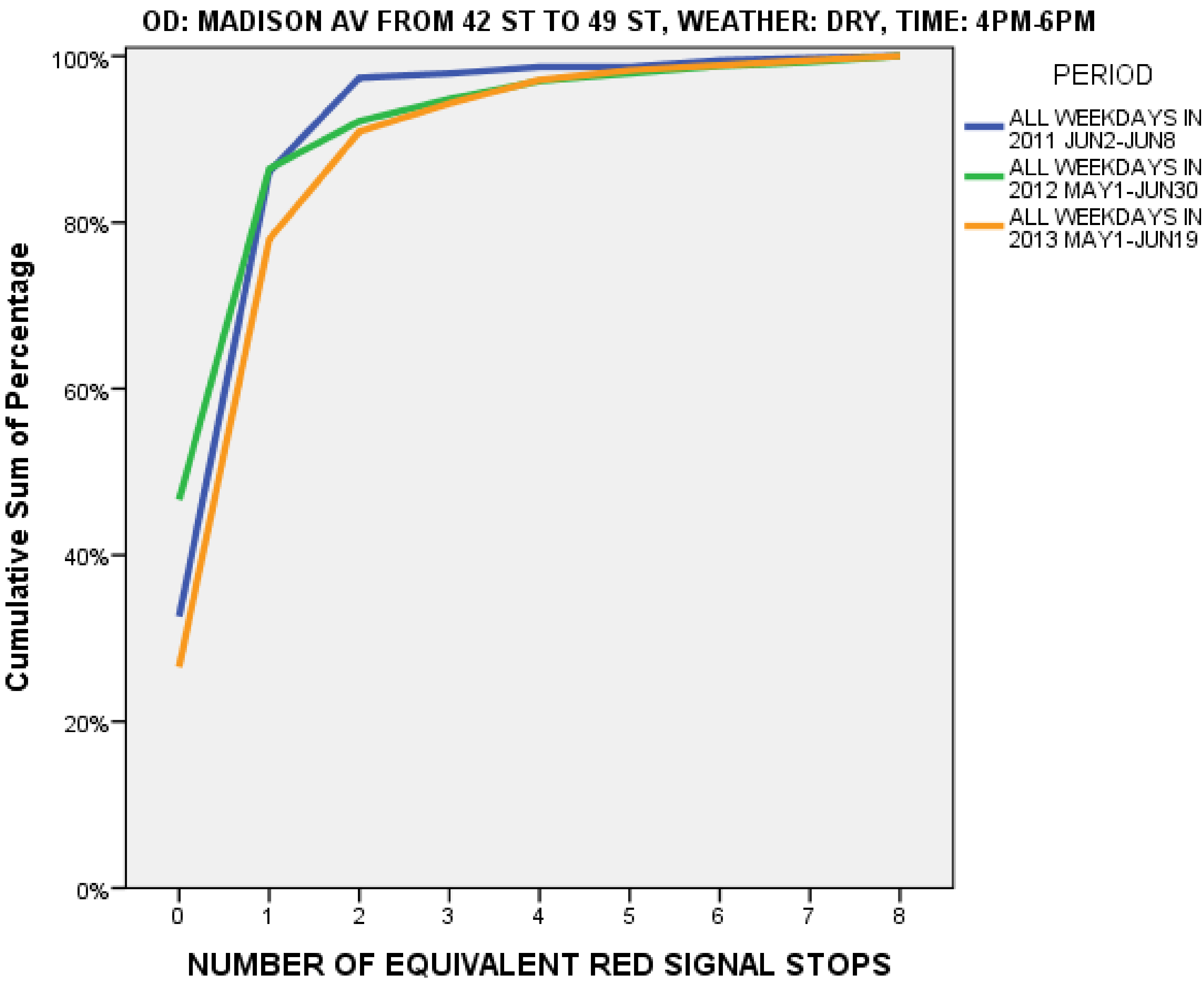

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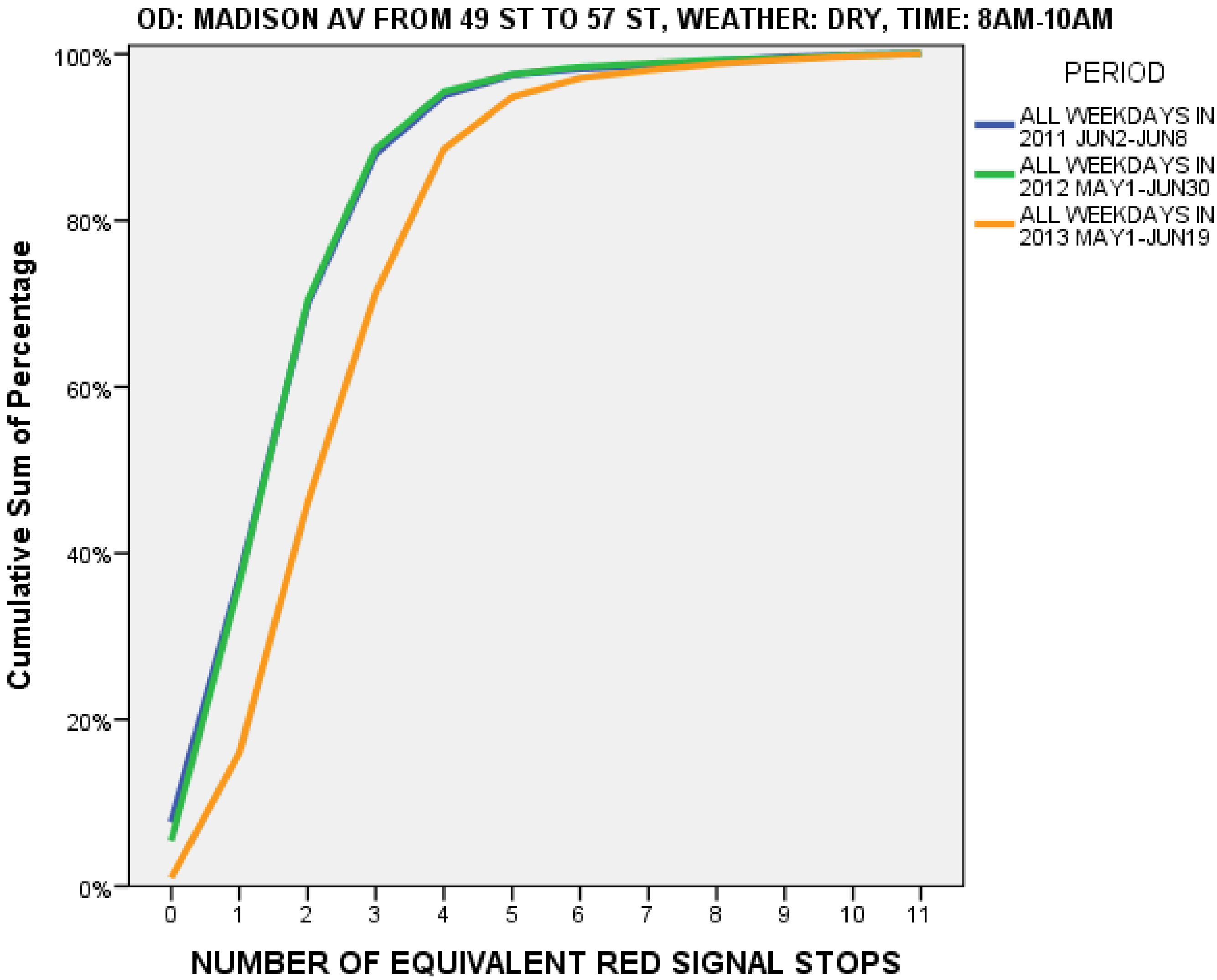

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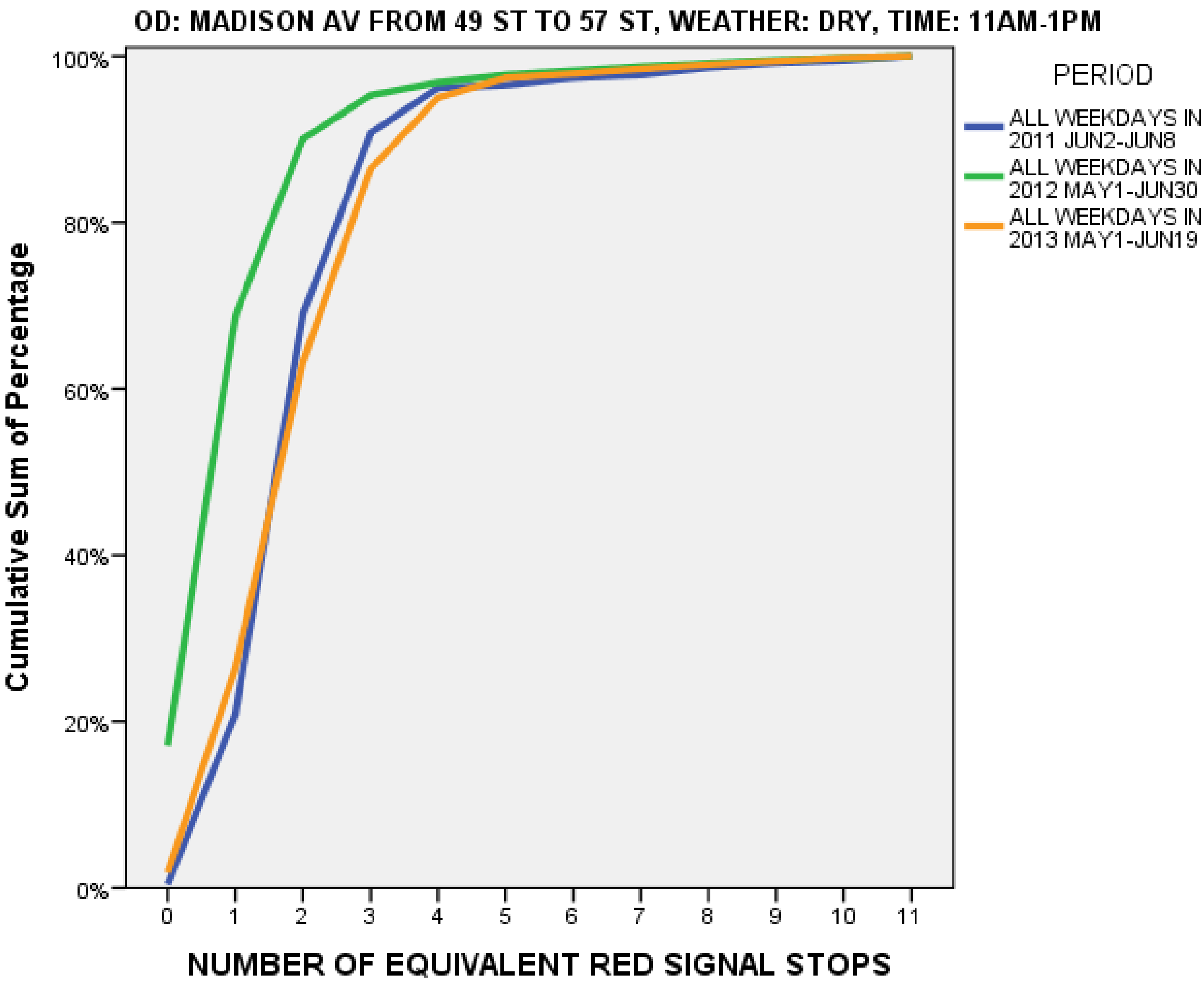
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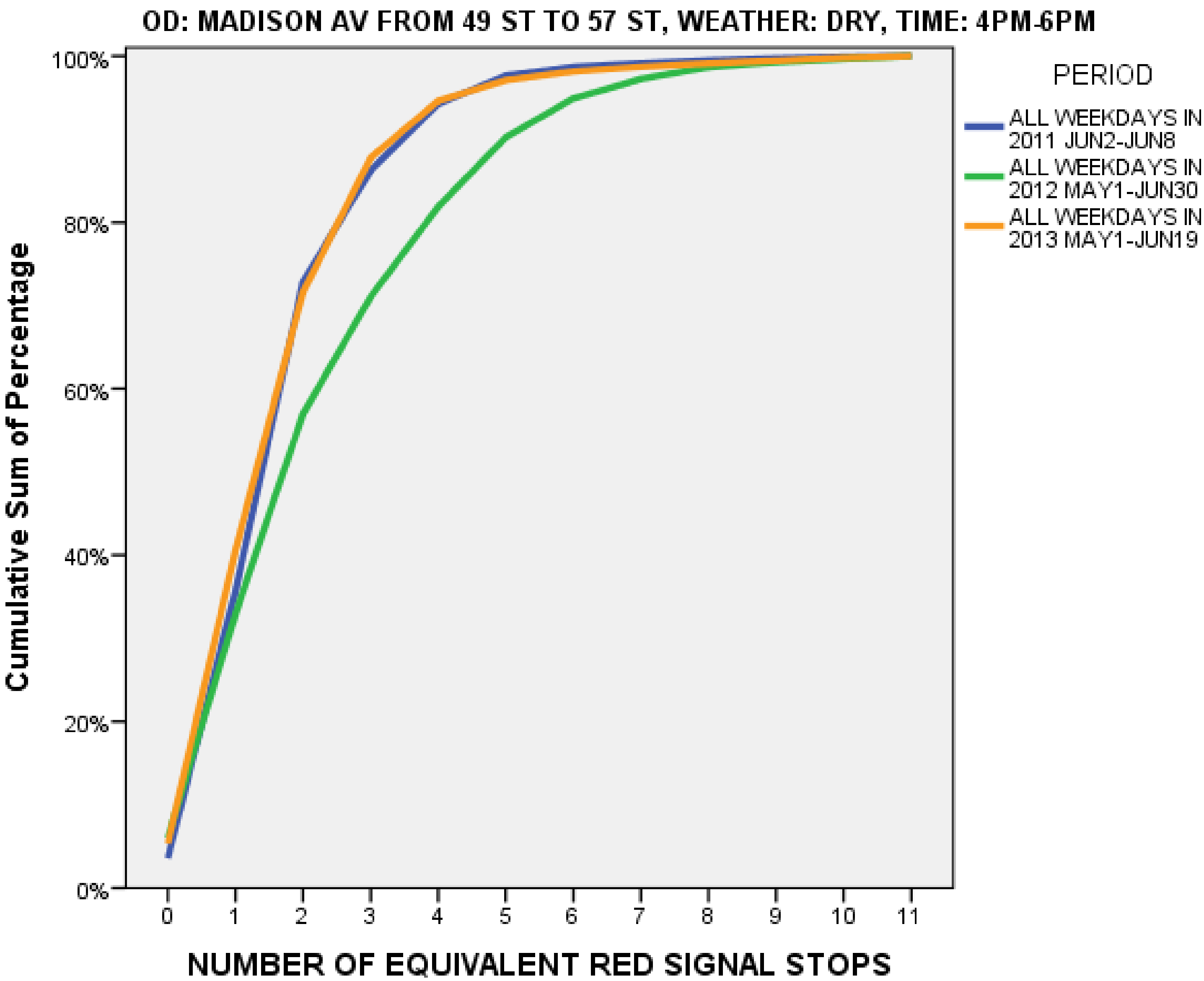
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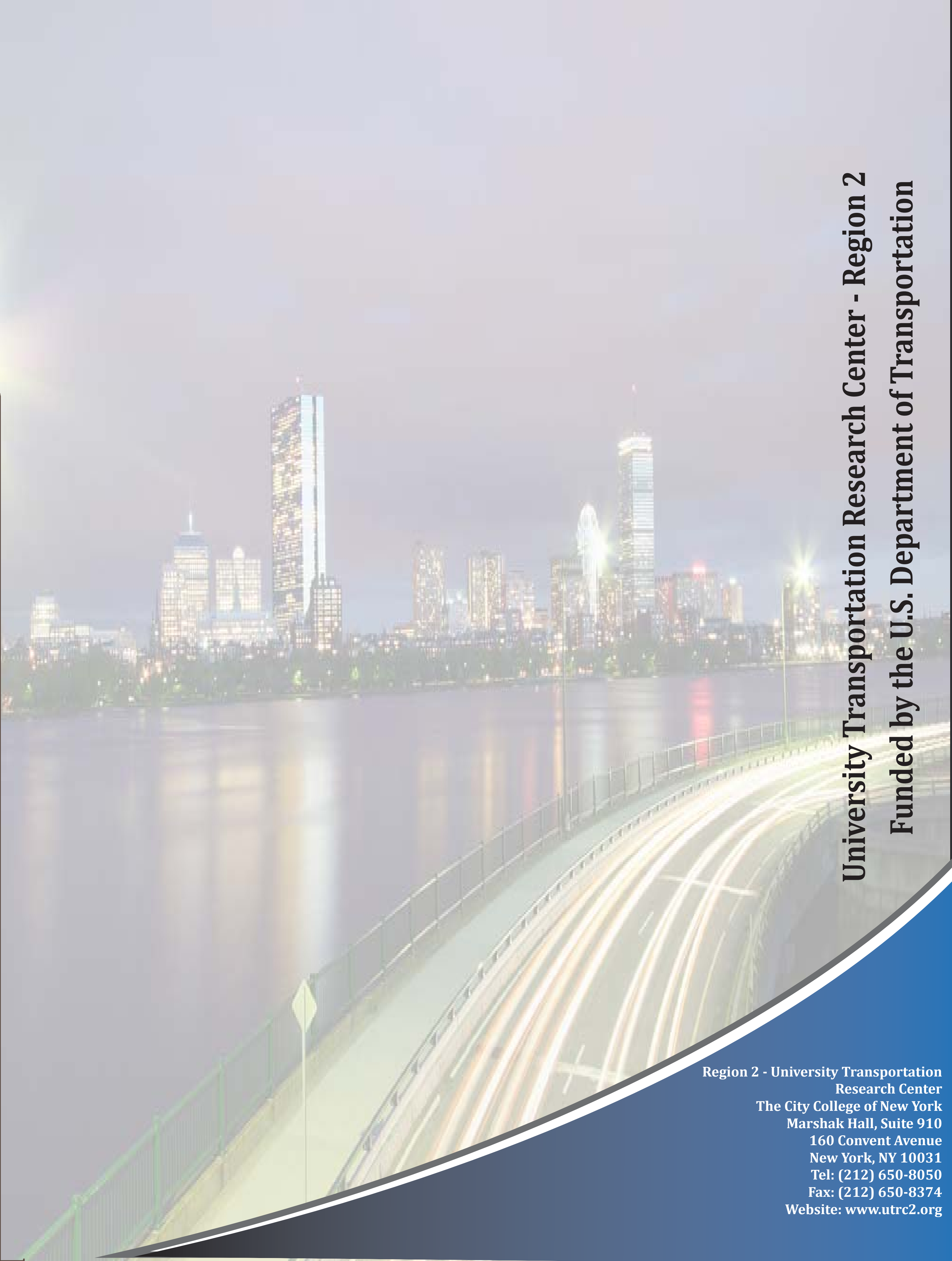

University Transportation Research Center - Region 2

Funded by the U.S. Department of Transportation

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New York, NY 10031
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Fax: (212) 650-8374
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