APPENDIX A

Technical Memorandum #1:

Existing Multimodal Traffic Conditions

1. Introduction

This technical memorandum establishes a baseline of existing multi-modal (pedestrian, bicycle, and motor vehicle) traffic conditions on Union Street in Old Town Alexandria, Virginia. In addition to the Union Street corridor, the study area (see Figure A) for this memorandum includes portions of Royal Street and the intersection of King Street and Fairfax Street, as shown in Figure B.

This memorandum includes documentation of data collection and analysis completed to (1) evaluate how multi-modal traffic flow characteristics vary throughout the day and week, (2) estimate existing operations at core study area intersections, (3) evaluate whether a traffic signal at the intersection of Union Street and King Street is warranted, and (4) gain a better understanding of users' behaviors at the intersection of King and Union Streets, as well as cyclists' experiences riding through Old Town.

The Data Collection portion of this memorandum summarizes the times, locations, and methods for collecting data while the analysis sections include Traffic Count Analysis, Level-of-Service Analysis, Signal Warrant Analysis, Video Behavioral Analysis, Bicycle Intercept Survey Results and a comparison of Union Street and Royal Street.

2. Data Collection

2.1 Field Assessments

The Union Street Corridor Study team performed field assessments to observe behavior and interactions along the corridor on one Friday and one mid-weekday between 10 AM and 12 PM and between 12 PM and 2 PM, respectively in May 2012. The team drove a car, bicycled and walked along Union Street, Royal Street, the Strand, and the unit and 100 blocks of King Street to evaluate the corridor as it functions presently and to identify or clarify issues. During one of the field visits, the team also met with City staff. These initial observations informed the approach for more specific field analysis, video behavioral analysis and existing traffic operations analysis.

2.2 Vehicle, Pedestrian, and Bicycle Counts at Intersections

Intersection counts (or turning-movement counts) are counts of each "through" movement and turning movement at an intersection for each mode, including cars, bicycles, and heavy

vehicles. Pedestrians are counted as the number of pedestrians crossing each crosswalk at the intersection. Table A below details the intersections and times of the May intersection counts by mode and Figure B illustrates the locations of these counts. The AM peak period in Table A is from 7:00 to 9:00 AM, the midday peak period is from 12:00 to 2:00 PM, and the PM peak period is from 5:00 to 7:00 PM. All other count periods are specified in the table.

Intersection	Tuesday	Wednesday	Thursday	Friday	Saturday
Union St & Pendleton St	AM, Midday, & PM Peak	AM, Midday, & PM Peak	AM, Midday, & PM Peak	AM & Midday Peak, 6-8 PM	10 AM – 2 PM, 7-9 PM
Union St & Cameron St	AM, Midday, & PM Peak	AM, Midday, & PM Peak	AM, Midday, & PM Peak	AM & Midday Peak, 6-8 PM	10 AM – 2 PM, 7-9 PM
Union St & King St	7 AM – 7 PM	7 AM – 7 PM	AM, Midday, & PM Peak	AM & Midday Peak, 6-8 PM	7 AM – 9 PM
Fairfax St & King St	7 AM – 7 PM	7 AM – 7 PM	-	-	7 AM – 7 PM
Union St & Duke St	AM, Midday, & PM Peak	AM, Midday, & PM Peak	AM, Midday, & PM Peak	AM & Midday Peak, 6-8 PM	10 AM – 2 PM, 7-9 PM
Union St & Gibbon St	AM, Midday, & PM Peak	AM, Midday, & PM Peak	AM, Midday, & PM Peak	AM & Midday Peak, 6-8 PM	10 AM – 2 PM, 7-9 PM
Union St & Franklin St	AM, Midday, & PM Peak	AM, Midday, & PM Peak	AM, Midday, & PM Peak	AM & Midday Peak, 6-8 PM	10 AM – 2 PM, 7-9 PM

Table A: Turning-Movement Count Intersections and Times

2.3 Daily Traffic Data

Automatic Traffic Recorders (ATRs or "tube counters") collected data on volume, speed, and vehicle class (e.g. passenger car, single-unit truck, or tractor trailer) at mid-block locations for 24 hours a day, seven days a week during one week in May 2012. Figure B illustrates the locations of the following mid-block traffic counts:

- Union Street between Wilkes and Wolfe Streets
- Union Street between Prince and King Streets
- Royal Street between Wilkes and Wolfe Streets
- Royal Street between Prince and King Streets

ATRs on Union Street

Additionally, bicycle, pedestrian, car, heavy vehicle, transit vehicle, and motorcoach counts were collected in May 2012 midblock for 12 hours on Saturday at the same locations. During this time, bicycle traffic entering and exiting the Wilkes Street Trail at Union Street was also counted.

Follow-up weeklong counts in July 2012 on Union Street between King and Prince Streets and between Wilkes and Gibbon Streets were conducted to determine how traffic volumes vary between the months of May and July. Some analysis was repeated using the July counts account for seasonal variation in traffic volumes. Additionally, follow-up 12-hour counts on Union Street between King and Prince Streets, with a breakdown by mode, demonstrates seasonal variation of bicycle and pedestrian volumes from spring (May 2012) to summer (July 2012). In the summer count, motorcycles were counted rather than transit vehicles to address concerns regarding high motorcycle volumes raised by the Waterfront Commission, the City's advisory group on matters relating to the Waterfront Small Area Plan implementation.

2.4 Bicycle Intercept Surveys

Bicyclists intercepted in July on the Mount Vernon Trail completed surveys concerning their on-street route through Old Town, opinions on that route, personal characteristics and trip purpose. Cyclist intercept locations were south of Old Town at the intersection of Washington Street and S. Alfred Street and north of Old Town where the Mt. Vernon Trail intersects Marina Drive, as shown in Figure C. The Mount Vernon Trail splits near both locations to connect trail users to either Union Street or to other north/south on-street routes west of Union Street, primarily Royal Street. Surveys were collected on Thursday, July 12, 2012 from 3:30 to 5:30 PM at the south location and from 6:00 to 8:00 PM at the north location and on Saturday, July 14, 2012 from 10:00 AM to 12:00 PM at the south location and from 1:00 PM to 3:00 PM at the north location.

Intercepting cyclists for surveys on the Mount Vernon Trail

2.5 Geometric Typical Cross-Sections

Roadway, lane, sidewalk, and buffer widths were measured at each block along the corridor to create geometric cross sections of Union Street from Pendleton Street to Potomac Street. Tree boxes, stairs, and parking locations were also measured and documented.

Figure D shows the locations of each of the unique typical cross-sections along the corridor, as shown in Figures E through G. Each typical cross-section shows the total curb-to-curb width, the use of each lane, and the width of each lane. The total curb-to-curb width of Union Street varies between 28 feet and 44 feet. At the northern end of Union Street, the curb-to-curb width is 44 feet with two 7-foot parking lanes, two 5-foot bike lanes and two 10-foot travel lanes. The majority of Union Street (between Queen Street and Wilkes Street) is 33-feet with two 13-foot travel lanes shared by motor vehicles and bicycles and one 7-foot parking lane. Parking along this section of Union Street is located on either the east or west side.

3. Intersection Traffic Count Analysis

As indicated, multi-modal daily traffic counts and intersection counts were collected for numerous days of the week to determine how multi-modal traffic (e.g. pedestrians, motor vehicles, bicyclists) varies by time-of-day and day-of-week. This section describes these variations for each of the seven study area intersections identified in Figure B. Additional mid-block traffic information is located in section 9 of this memorandum, "Union Street versus Royal Street".

3.1 Intersection Volumes by Mode

For each peak count period (see Table A for details on data collection intervals), the four highest consecutive 15-minute intervals constitute the "peak hour." The peak-hour intersection volumes at each intersection for the AM peak, midday peak, and PM peak are summarized on Figures H, I, and J, respectively. Each stacked bar chart illustrates the total volumes of all movements, broken down by mode, for each day of the week.

The peak hours vary by intersection and day of the week because the time with the highest volumes for each intersection are shown. It should be noted that pedestrians are counted once for each crosswalk they cross. Therefore, pedestrian volumes cannot be directly compared to bicycle or vehicle volumes in these charts because a single pedestrian may be double, or triple

counted if they cross more than one crosswalk. The pedestrian volume numbers can be used to compare the relative number of movements and the relative demand for each movement.

Overall Trends

The intersections of Union Street & Gibbon Street and Union Street & Franklin Street, located at the primarily residential southern end of the project area, have the lowest volumes compared to other intersections studied. At Pendleton Street, Union Street's northernmost intersection, vehicle volumes were similarly low, with higher bicycle and pedestrian volumes during the midday and PM peak hours.

The intersection of Union & King Streets consistently had the highest volumes for all modes due to the businesses on King Street which attract users of all modes to the intersection. Cameron and Duke Streets saw similar volumes of bicycles and vehicles. Furthermore, the intersection of Cameron Street and Union Street had higher pedestrian volumes, likely due to its close proximity to destinations on King Street, the Torpedo Factory, and the waterfront, which connects to Union Street via the alley at Cameron Street.

Trends by Time of Day

Morning (AM) Peak

During the morning peak, vehicle volumes remained consistent throughout the week, with higher volumes at the intersections of Union Street & King Street and Union Street & Duke Street. Bicycle volumes increased on Saturday north of King Street. Pedestrian volumes were relatively consistent at all intersections, except King Street, where they were significantly higher on Saturday. Figure H illustrates the morning peak-hour intersection volumes at each intersection.

Midday Peak

During the midday peak, vehicle volumes fluctuate more by day and location. Vehicle volumes were highest at the intersections of Union Street & Cameron, King, and Duke Streets. Additionally, vehicle volumes were highest on Friday at all intersections. Bicycle volumes are significantly higher on Saturdays throughout the entire corridor, which likely indicates increased recreational cyclists on the Mount Vernon Trail on the weekends. Pedestrian volumes are also higher on Saturday, most notably, at Union and King Streets. Figure I illustrates the midday peak hour intersection volumes at each intersection.

Evening (PM) Peak

During the evening peak, vehicle volumes fluctuated slightly throughout the week, with the highest volumes at the intersections of Union Street and Cameron, King, and Duke Streets. Bicycle volumes remained fairly consistent throughout the week, with slightly higher volumes Tuesday through Thursday. King Street pedestrian volumes were significantly higher than those at any other intersection. Pedestrian volumes were highest on Saturday, especially at Cameron and King Streets. Figure J illustrates the evening peak hour intersection volumes at each intersection.

Pedestrians, bicyclists, and motorists on Union Street

3.2 Intersection Movement Counts

Intersection movement counts represent the volume for each motor vehicle and bicycle movement (i.e. left, thru and right) for each approach and the volume of pedestrians using each crosswalk at an intersection. Figures K through O illustrate the turning-movement counts for the Saturday midday and PM peak hours and the Wednesday AM, midday, and PM peak hours. These peak hours vary by intersection, but fall within the given two-hour peak period. These counts will serve as the basis for the capacity analysis described in the Level-of-Service section numbered 4.2.

The highest volume of motor vehicle traffic on Union Street on weekdays comes from Pendleton and Franklin Streets. On the weekend, King and Duke Street contribute the most motor vehicle traffic to Union Street. Furthermore, motor vehicle traffic flows are heavier in the

northbound direction on weekday mornings and in the southbound direction on weekday evenings.

Bicyclists primarily access Union Street via Pendleton Street or Franklin Street during all weekday and weekend peak-hour periods, though some bicyclists also access Union Street via King Street during the Saturday midday peak period. Bicycle and pedestrian activity was counted at the Wilkes Street Trail during the Saturday midday peak, which shows heavy bicyclist activity to and from the west side of the trail.

South of King Street, pedestrians primarily walk along Union Street rather than across it. At King Street, more pedestrians walk along King, crossing Union Street, while at Cameron Street, crossing volumes are about equal on the east, west, and south crosswalks.

4. Level-of-Service Analysis

This section describes the methodology and results of the operations analysis for the intersections of Union Street & Cameron Street, King Street & Duke Street. This analysis can be used as a baseline for future analysis as re-development occurs along Union Street.

4.1 Level-of-Service Methodology

The study intersections' performance was evaluated through a qualitative measure of operating conditions called Levels of Service. The 2000 Highway Capacity Manual (2000 HCM) defines six Levels of Service (LOS) with letter designations from 'A' to 'F', ranging from LOS A, which represents the best operating conditions, to LOS F, which represents the worst. Levels of Service for intersections are based on average control delay, or the difference between the travel time experienced by motorists passing through the intersection and the reference travel time motorists would experience without traffic controls or conflicting traffic. At all-way stop-controlled intersections, delay is based on intersection geometry and movement demand volumes. The Level-of-Service thresholds for all-way stop-controlled intersections with volumes less than capacity are provided in Table B.

All-Way Stop Control Delay (s/veh)	Level of Service
0-10	A
>10-15	B
>15-25	C
>25-35	D
>35-50	E
>50	F

Table B: All-Way Stop Control Intersection Level-of-Service Thresholds

Traffic counts at the intersections of Union Street with Cameron Street, King Street and Duke Street were used to complete capacity analysis to determine the delay and LOS for motor vehicles for the Wednesday AM, midday, and PM peak hours and the Saturday midday and PM peak hours. Each of the intersections being evaluated are all-way stop-controlled intersections with stop signs on each approach to the intersection.

The 2010 Highway Capacity Manual has a methodology for determining the delay and LOS at all-way stop-controlled intersections. However, this methodology does not account for the impact that pedestrians crossing at the intersection have on motor-vehicle delay. As such, an alternate approach was developed and implemented as follows. The delay for these intersections was determined using Trafficware's SimTraffic, a traffic simulation software. The SimTraffic simulation was tested and calibrated to improve the accuracy of the results. The following outlines the methodology used for the SimTraffic Simulation.

1. Due to SimTraffic's limited ability to model pedestrians, the SimTraffic simulation was calibrated to more accurately represent actual operating conditions. Using the control delay methodology in the Manual of Transportation Engineering Studies and videos from the Union Street and King Street intersection, the control delay for the one approach was measured for a 15-minute period during each peak hour. Pedestrian volumes were adjusted such that the delays estimated using the control delay methodology mentioned above roughly matched the SimTraffic simulation results. Comparing these delays with the delays determined in SimTraffic roughly established the accuracy of the SimTraffic model at the intersections.
2. Each SimTraffic simulation lasted 60 minutes, with a 10-minute "seeding" period, or set-up period, in advance and the random simulations were each performed five times to determine the average intersection performance.

4.2 Level-of-Service Results

Table C below illustrates the LOS and Control Delay in seconds per vehicle by approach at each intersection for the peak hour on Wednesday morning, midday, and evening and Saturday midday and evening based on the SimTraffic simulations.

			Wednesday Morning		Wednesday Midday		Wednesday Evening		Saturday Midday		Saturday Evening	
Intersection		Approach	LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay
1	Union Street & Cameron Street	EB	A	3.2	A	4.0	A	3.5	A	8.4	A	5.0
		NB	A	6.9	A	7.8	A	7.9	A	9.8	A	8.0
		SB	A	4.8	A	5.6	A	6.7	A	7.3	A	7.7
		Overall	A	6.0	A	6.4	A	6.9	A	8.9	A	7.3
2	Union Street & King Street	EB	A	3.0	A	8.4	C	19.9	C	21.4	E	37.4
		WB	A	3.6	A	7.2	B	13.0	B	14.0	C	17.8
		NB	A	8.3	B	11.8	D	26.0	C	18.1	E	42.3
		SB	A	5.9	B	10.6	F	56.2	C	20.0	D	31.1
		Overall	A	6.7	A	9.9	E	35.6	C	19.4	D	34.9
3	Union Street & Duke Street	EB	A	3.6	A	4.2	A	4.0	A	4.5	A	4.4
		WB	A	2.9	A	4.1	A	4.7	A	5.1	A	4.8
		NB	A	5.2	A	4.7	A	4.8	A	5.1	A	5.4
		SB	A	3.5	A	5.7	A	7.5	A	5.7	A	5.1
		Overall	A	4.5	A	5.0	A	6.0	A	5.1	A	4.9

Table C: Level of Service and Vehicular Delay

Union and Cameron Streets

The intersection consistently operate with delays shorter than 10 seconds per vehicle (LOS A) during all periods studied.

Intersection of Union and Duke Streets

The intersection consistently operate with delays shorter than 10 seconds per vehicle (LOS A) during all periods studied.

Intersection of Union and King Streets

The intersection functions well with overall LOS A during the Wednesday morning and midday peak periods. During the periods with higher pedestrian volumes, LOS drops, but rarely illustrates failing conditions with delays over 50 seconds per vehicle. The westbound approach functions well, peaking at a 17.8 second delay (LOS C), likely due to the low traffic volumes on this approach. The intersection functioned worst, at an overall LOS E and D, during the Wednesday and Saturday Evening peak periods, respectively. The southbound approach had the highest delays with an LOS F on Wednesday evening, likely due to high traffic volumes and high volumes of conflicting pedestrians on that approach.

5. Crash Analysis

Figure P illustrates the location and types of crashes along Union Street from April 2007 to April 2012. The intersection of King and Union Streets had the most crashes, while the intersections of Union Street and Oronoco, Queen, and Wolfe Streets also each had more than one crash. In the five years analyzed, there were three crashes involving pedestrians and bicyclists:

- 200 block of N Union Street - A cyclist hit a pedestrian crossing outside the crosswalk. The cyclist was thrown from the bicycle and suffered minor injuries.
- King & Union Streets - A bicyclist failed to yield to and struck a pedestrian in the crosswalk due to malfunctioning hand breaks. The pedestrian suffered minor injuries.
- 300 block of N Union Street - A motorist signaled a right turn, then turned left, hitting a bicyclist who was attempting to pass on the left. The bicyclist suffered minor injuries.

Given the multimodal volumes on Union Street, reported crashes were low and do not sufficiently indicate specific problems along the corridor.

6. Video Behavioral Analysis

Video behavioral analysis can pinpoint conditions that threaten the safety and comfort of users at intersections better than crash data, which is often sparse and incomplete. Behavioral analysis of motorists, pedestrians, and bicyclists at the intersections of King & Union Streets and King & Fairfax Streets identified issues and provided context for the thoughts of residents, stakeholders, visitors, and the Waterfront Commission regarding conditions at the intersection. At the first Waterfront Commission Meeting on June 21, 2012, the Commission was asked to rank the concerns of different users at the intersection:

Video camera at King & Union

- Pedestrians were primarily concerned with being hit by a motorist or bicycle.
- Bicyclists were concerned with getting hit by a motorist and with having to stop.
- Motorists were concerned with hitting a pedestrian or bicycle and with waiting too long at the intersection.

As a result of this information, the behavioral analysis addressed motorist and bicyclist yielding, bicyclist compliance with the stop sign, and other related factors.

6.1 Approach

Video was recorded in May 2012 on Tuesday, Wednesday, and Saturday from 7:00 AM to 7:00 PM. Fifteen minutes of each Saturday and Wednesday midday and PM peak hour were analyzed to quantify motorist, bicyclist and pedestrian behavior. The following questions were answered by analyzing motorist, bicyclist, and pedestrian behavior:

- ***Are bicyclists complying with the stop signs? If not, are they exhibiting 'risky behavior'?*** Bicyclist compliance analysis considered whether bicyclists stopped at the stop sign and a concurrent risk assessment addressed whether vehicles were in or approaching the intersection and whether pedestrians were present in either of the conflicting crosswalks. For instance, bicyclists who did not stop at the stop sign when neither vehicles nor pedestrians were present in the crossing were considered non-compliant and non-risky.
- ***Are pedestrians being yielded to by bicyclists and motorists?*** Observations included whether a group of one or more pedestrians was yielded to or not yielded to by motorists or bicyclists when in the crosswalk. It should be noted that this is not a measure of whether motorists or bicyclists are yielding to pedestrians (i.e. motorist yield rate), but rather a measure of the pedestrian's experience and whether they are yielded to by bicyclists or motorists.
- ***What other behaviors are prevalent at the intersection?*** Other behaviors recorded included pedestrians crossing outside the crosswalk, motorists encroaching in the crosswalk, bicyclists traveling the wrong way, and bicyclists riding alongside a vehicle through the intersection.
- ***How does behavior differ at a nearby signalized intersection?*** Analysis of pedestrian compliance and pedestrian's experiencing yielding and at the intersection of King and Fairfax Streets helps illustrate how the intersection of King and Union Streets might function with a traffic signal.

6.2 Results

A) Intersection of King and Union Streets

Bicyclist Compliance

Over the four 15-minute periods studied, bicyclists at King and Union Streets were only 18% compliant with the stop sign. Chart A illustrates the results of the bicyclists' compliance and 'risky behavior' over the four 15-minute intervals studied. Across the four 15-minute study periods, bicycle compliance was highest (50% compliant) when both vehicles and pedestrians were present at the intersection. Six cyclists approached the intersection with neither vehicles nor pedestrians present and all of these cyclists did not stop at the stop sign. (Note: Many bicyclists appeared to be slowing at the intersection. Since it is difficult to discern if a bicyclist is slowing or maintaining speed throughout the intersection (i.e. disregarding the stop sign), only bicyclists that came to a complete stop were considered compliant).

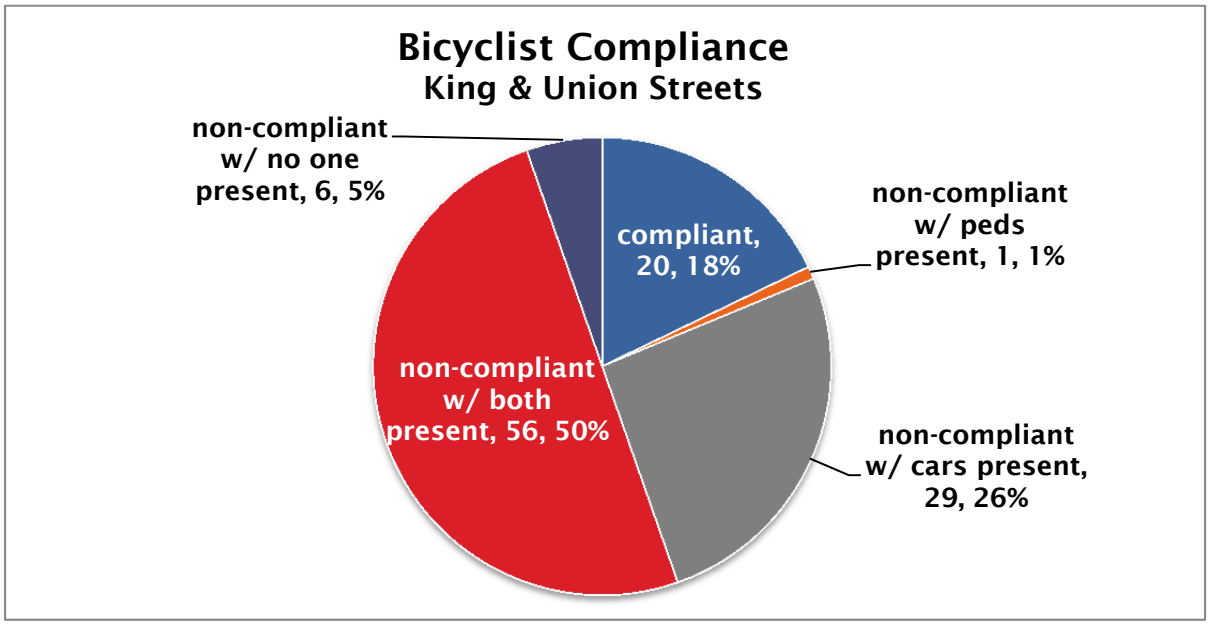

Chart A: Summary of behavior of 112 bicyclists observed

Yielding to Pedestrians

Table D illustrates the results of the analysis of both bicyclists' and motorists' yielding to pedestrians. Over all 15-minute intervals, 51% of the time pedestrians crossed at King & Union Streets when no motorists were present and 94% of the time when no bicyclists were present. A more detailed analysis of the results of the yielding-to-pedestrians analysis follows in Table D.

	All Time Periods, All Crosswalks		Weekday, All Crosswalks		Weekend, All Crosswalks	
	# of ped groups	% of ped groups	# of ped groups	% of ped groups	# of ped groups	% of ped groups
Pedestrians & Motorists - All Observations						
No Motorist Present	612	51%	270	70%	342	42%
Motorist Did Not Yield	140	12%	29	8%	111	14%
Motorist Yielded	442	37%	86	22%	356	44%
Total	1194	100%	385	100%	809	100%
Pedestrians & Motorists - With Motorists Present						
Motorist Did Not Yield	140	24%	29	25%	111	24%
Motorist Yielded	442	76%	86	75%	356	76%
Total	582	100%	115	100%	467	100%
Pedestrians & Bicyclists - All Observations						
No Bicyclist Present	1213	94%	362	97%	851	93%
Bicyclist Did Not Yield	51	4%	9	2%	42	5%
Bicyclist Yielded	23	2%	3	1%	20	2%
Total	1287	100%	374	97%	913	100%
Pedestrians & Bicyclists - With Bicyclists Present						
Bicyclist Did Not Yield	51	69%	9	75%	42	68%
Bicyclist Yielded	23	31%	3	25%	20	32%
Total	74	100%	12	100%	62	100%

Table D: Pedestrian groups' experience of being yielded to by bicyclists and motorists at the intersection of King and Union Streets

When observing each side of the crosswalk individually, pedestrians were more frequently yielded to (81% vs. 66%) by motorists on the approach to the intersection (right side of crosswalk from motorist perspective). This indicates that motorists are less likely to yield when exiting the intersection than when entering. Though the sample size is smaller for bicycles (84 vs. 582 for cars), the data indicates that bicycles are even more likely to yield on the approach than when exiting the intersection -- when bikes are present, 47% and 7% of pedestrians are yielded to on the right and left sides of the crosswalk, respectively.

Bicyclists Yielding to Pedestrians

Most pedestrian groups crossed at the intersection with no interaction with a bicyclist. For example, on Saturday 97% of pedestrian groups crossed without a bicyclist at the intersection. When pedestrians crossed with bicyclists present, they were yielded to by a bicyclist about one quarter to one third of the time. For example, on Saturday, 32% of pedestrian groups were yielded to by bicyclists when a bicyclist was present.

Motorists Yielding to Pedestrians

Of all 15-minute intervals observed, about half of pedestrian groups (51%) crossed when no motorist was present at the crossing. Of those pedestrian groups that experienced an interaction with a motorist, they were yielded to 76% of the time.

Weekday Results

Midday Wednesday when motorists were present, 64% of pedestrian groups were yielded to by motorists. On Wednesday evening when motorists were present, pedestrians were yielded to 80% of the time.

Saturday Results

The Saturday midday peak period had the highest volumes of pedestrians and bicyclists of the periods observed, so the results are the most telling. Half of pedestrians experienced a motorist present when crossing, and of those, 77% were yielded to by a motorist.

B) Intersection of King and Fairfax Streets

At the signalized intersection of King and Fairfax Streets, 63% of pedestrian groups crossing on the WALK or Flashing DON'T WALK indication did not experience conflicting motorists. Of those pedestrians who crossed with motorists present, 94% were yielded to, while only 6% were not yielded to by a motorist.

The percentage of pedestrian groups who crossed with the DON'T WALK indication varied from 10% on Wednesday afternoon to nearly 30% on Saturday afternoon. Note that these values do not necessarily represent the percentage of individual pedestrians crossing against the signal because pedestrian groups crossing with the DON'T WALK indication were typically smaller than those crossing with the WALK or Flashing DON'T WALK indication. Most pedestrians crossing against the signal observed no conflicting vehicles in the crosswalk before crossing, thus their behavior was not highly risky.

Other Behavioral Data

Across the four 15-minute periods studied, 105 pedestrians crossed outside the crosswalk; most of these pedestrians were forced out due to crosswalk crowding or motorists blocking the crosswalk. Motorists encroached in the crosswalk 126 times, either fully or partially blocking

the crosswalk. Six bicyclists rode on the wrong side of the street and 15 rode through the intersection alongside a vehicle rather than in line with the vehicle.

7. Signal Warrant Analysis

The intersection of Union Street and King Street was evaluated to determine if a traffic signal is warranted. The 2009 Manual on Uniform Traffic Control Devices (MUTCD) specifies nine cases that may warrant a full traffic signal at an intersection and one case that may warrant a Pedestrian Hybrid Beacon. Each of these warrants was evaluated at the intersection of Union Street and King Street. Warrants 1-4 and the special warrant for the pedestrian hybrid beacon are based on roadway volumes, so these warrants were evaluated for one Wednesday and one Saturday. Warrants 5-9 are based on overall conditions; thus, they are not evaluated by day of the week. Table E summarizes the results of these warrants.

Warrant		Wednesday	Saturday
1	8-Hour Vehicular Volume	NOT MET	NOT MET
2	4-Hour Vehicular Volume	NOT MET	NOT MET
3	Peak-Hour Vehicular Volume	NOT MET	NOT MET
4	Pedestrian Volume	MET	MET
5	School Crossing	NOT MET	
6	Coordinated Signal System	NOT MET	
7	Crash Experience	NOT MET	
8	Roadway Network	NOT MET	
9	Intersection Near a Grade Crossing	NOT MET	
Special	Pedestrian Hybrid Warrant	NOT MET	NOT MET

Table E: Signal Warrants

Of the nine warrants for a full signal and the special Pedestrian Hybrid Beacon warrant, the intersection of King and Union Streets only met Warrant 4 (Pedestrian Volume) on one weekday and one Saturday. This warrant has two criteria, one requiring pedestrian and vehicle volumes to meet higher thresholds for any one hour and a second with lower thresholds for any four hours on an average day. Table F illustrates the breakdown of the peak-hour and four-hour pedestrian volume warrants met at the intersection of King and Union Streets by hour.

Hour Beginning At:	Peak-Hour Warrant		Four-Hour Warrant	
	Wednesday	Saturday	Wednesday	Saturday
7:00 AM	NOT MET	NOT MET	NOT MET	NOT MET
8:00 AM	NOT MET	NOT MET	NOT MET	NOT MET
9:00 AM	NOT MET	NOT MET	NOT MET	NOT MET
10:00 AM	NOT MET	NOT MET	NOT MET	NOT MET
11:00 AM	NOT MET	**MET**	NOT MET	**MET**
12:00 PM	NOT MET	**MET**	NOT MET	**MET**
1:00 PM	NOT MET	**MET**	NOT MET	**MET**
2:00 PM	NOT MET	**MET**	**MET**	**MET**
3:00 PM	NOT MET	**MET**	NOT MET	**MET**
4:00 PM	NOT MET	NOT MET	**MET**	NOT MET
5:00 PM	NOT MET	NOT MET	**MET**	NOT MET
6:00 PM	**MET**	NOT MET	**MET**	NOT MET
7:00 PM	N/A	NOT MET	N/A	NOT MET
8:00 PM	N/A	NOT MET	N/A	NOT MET

Table F: Pedestrian Volume Warrants

The peak hour pedestrian warrant is satisfied from 6-7 PM on a Wednesday and for five hours on a Saturday, from 11 AM to 4 PM. The four hour pedestrian warrant is satisfied for four hours on a Wednesday, from 2-3 PM and 4-7 PM, and five hours on a Saturday, from 11 AM to 4 PM.

7.1 Traffic Signal Evaluation

The signal warrant criteria outlined in the MUCTD "define the minimum conditions under which installing traffic control signals might be justified." The following potential advantages and disadvantages of a traffic signal at the intersection of King and Union Streets should also be considered.

Advantages of a traffic signal:

- Designating phases for one or more movements of traffic better indicates the right-of-way for all users at the intersection and "provides for the orderly and efficient movement of people," according to the Federal Highway Administration's Traffic Signal Timing Manual.

- Traffic signals may improve yield rates for motor vehicles. When motorists are present, about 76% of pedestrian groups are yielded to at King and Union Streets, but at King and Fairfax Streets, 94% of pedestrian groups are yielded to by motorists.
- The MUTCD states that the pedestrian volume warrant is "intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street." At the intersection of King and Union Streets, the opposite occurs, in which motorists experience delay due to excessive pedestrian volumes. Thus, rather than reducing pedestrian delay, a traffic signal at this location could reduce motorist delay at peak pedestrian hours.
- Bicyclists may be more likely to stop at a signal.

Disadvantages of a traffic signal:

- Adding a traffic signal at King and Union Streets will increase pedestrian delay and will also increase bicycle and vehicle delay.
- As delay for pedestrians' increases, they become less likely to comply with traffic control devices. Approximately 19% of pedestrian groups observed at the intersection of King and Fairfax Streets crossed with the "don't walk" indication.
- A traffic signal may encourage higher speeds at the intersection compared to the present all-way stop control.

8. Bicyclist Intercept Survey Results

Nearly 350 trail users responded to the intercept survey on the Mount Vernon Trail. One third of respondents were male, the respondent's average age range was 40 to 49, and 86% of respondents owned a car. The survey collection team targeted cyclists, who comprise 88% of total respondents and had a 40% response rate.

As summarize in Chart B, the greatest concern for all routes through Old Town is that there is no separation from traffic, followed by cars passing too closely and the stop signs or traffic signals along the route.

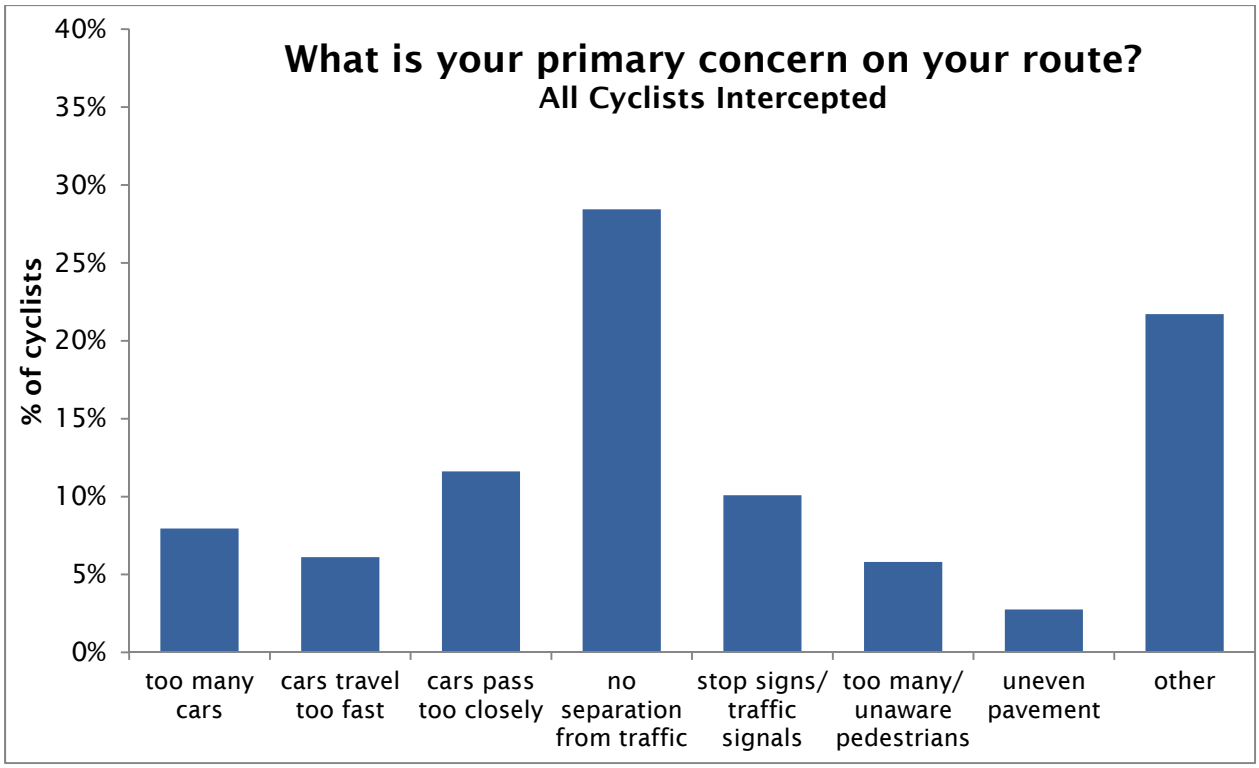

Chart B: Primary concerns of cyclists on their chosen on-street route through Old Town

Most cyclists (57%) took Union Street, while 18% took Royal Street. Three percent (3%) of cyclists alternate between Union and Royal Streets and 21% either take another route, such as Washington Street or Lee Street, or ride on a combination of streets through Old Town.

Chart C illustrates the routes cyclists use by trip purpose. As shown in this figure, the majority of cyclists riding through Old Town are riding for exercise. Of the 58% of cyclists traveling for exercise, 63% use Union Street, 18% use Royal Street, and 1% use both. The second most frequent trip purpose is commuting to/from work or school. Of the 18% of cyclists who were commuting to/from work or school, 35% use Union Street, 26% use Royal Street and 6% use both. Users commuting to/from work or school were also likely to be frequent trail users, with 61% riding daily and 38% two to three times a week.

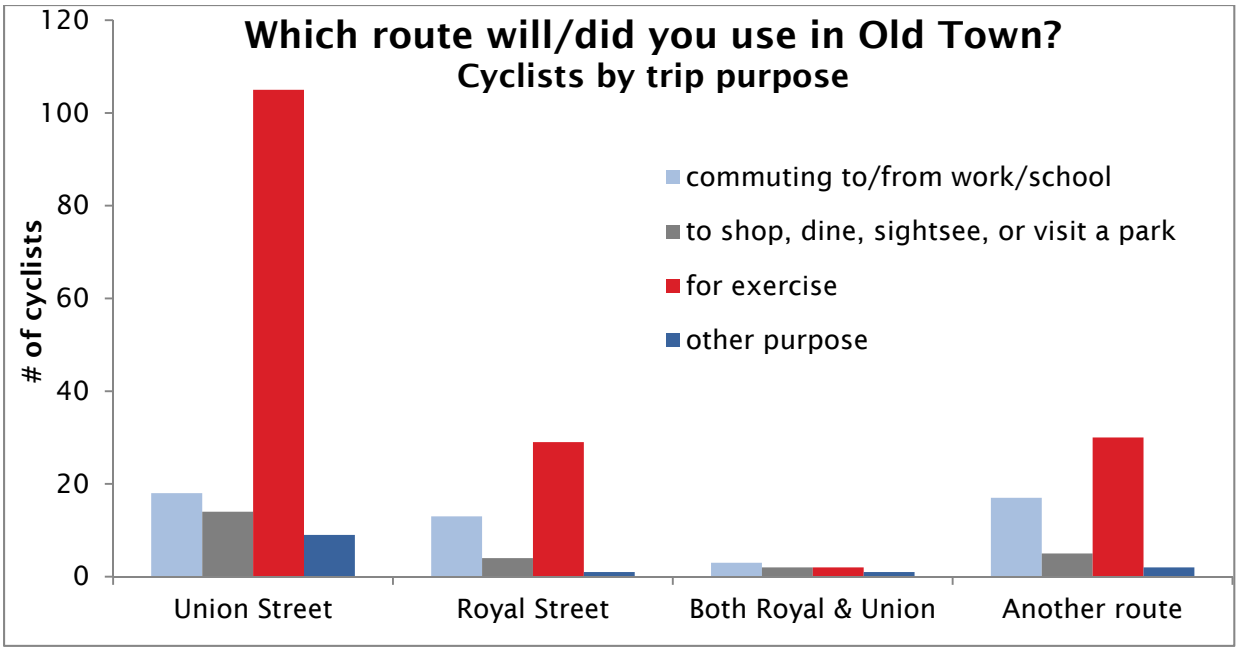

Chart C: Cyclist route choice by trip purpose.

Additional results of the bicycle intercept surveys can be found in the following section "Union Street Versus Royal Street Analysis".

9. Union Street Versus Royal Street Analysis

Union Street presently serves as the primary on-street connection for the Mount Vernon Trail through Old Town Alexandria; however, several parallel north-south connections in the Old Town grid also exist. The Waterfront Plan identifies Royal Street as a faster, more direct alternate to Union Street, the Pedestrian and Bicycle Mobility Plan cites Royal Street as a medium/long-term bicycle boulevard, and the Alexandria Bikeways map recognizes Royal Street as an on-road bikeway.

Royal Street parallels Union Street three blocks to the west. Royal Street connects to the Mount Vernon Trail in the north at Bashford Lane, about six blocks north of Pendleton Street, and in the south near Green Street, just west of Jones Point Park. Royal Street avoids the somewhat-circuitous Jones Point Park trail connection in the south and is three blocks closer to the north and south sections of the Mount Vernon Trail, making the route more direct. Additionally, there are fewer conflicts with pedestrians along Royal Street. However, the Royal Street route extends farther on street, with approximately nine more intersections than the Union Street route.

9.2 Bicyclist Intercept Survey Results Regarding Route Preference

Chart D summarized the responses by route to the question "Why do you ride on this route rather than another Mount Vernon Trail connection?" Most notably, 37% of cyclists who used Union Street said they prefer the atmosphere, while 34% of the cyclists who used Royal Street said this route is closer to their destination.

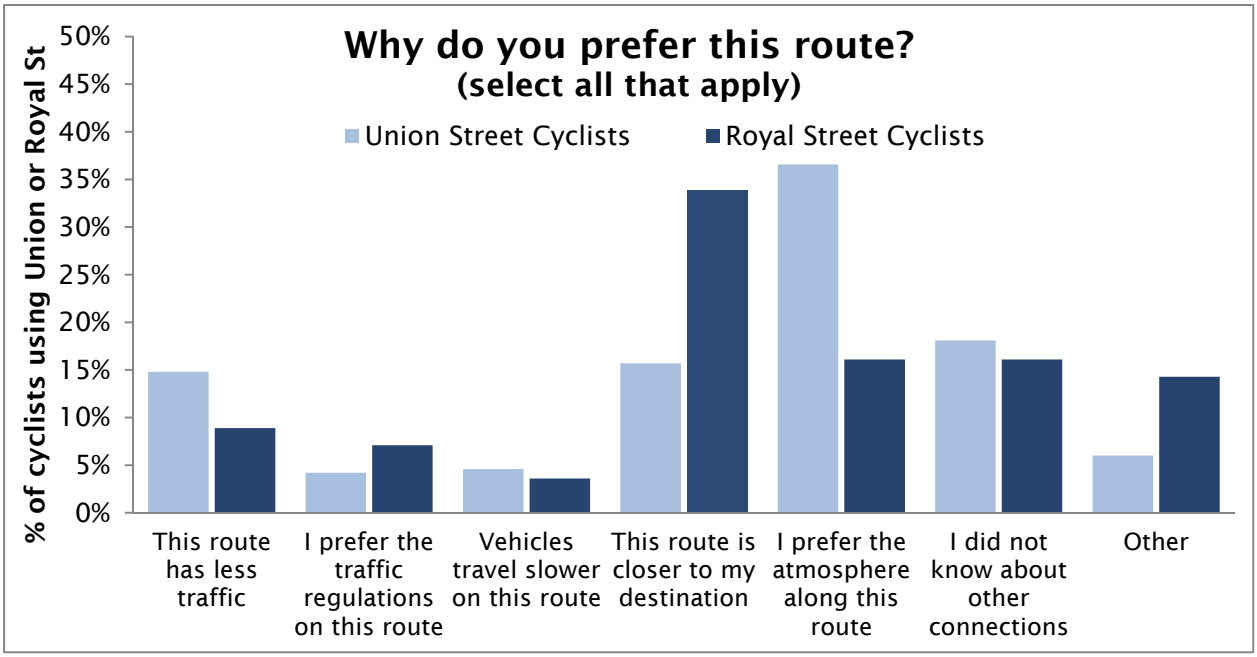

Chart D: Reasons why cyclists prefer Union Street or Royal Street.

When asked if they would change their route if conditions were improved (shorter travel time, better bike facilities, more pleasant environment, etc.) on the other route, 68% of cyclists on Union Street and 55% of cyclists on Royal Street said they would. The pie charts in Chart E summarize these responses by route. Additionally, 22 of the 42 cyclists (or 52%) on Union who prefer the atmosphere and 6 of the 11 cyclists (or 55%) who ride on Royal to be closer to their destinations would be willing to change their route given improved conditions on another route. Of the 150 users biking for exercise, 100 (or 67%) would be willing to change routes. Reasons riders would not change routes include that they do not have a problem with their current route, that Union Street is more scenic, or that they prefer alternate routes.

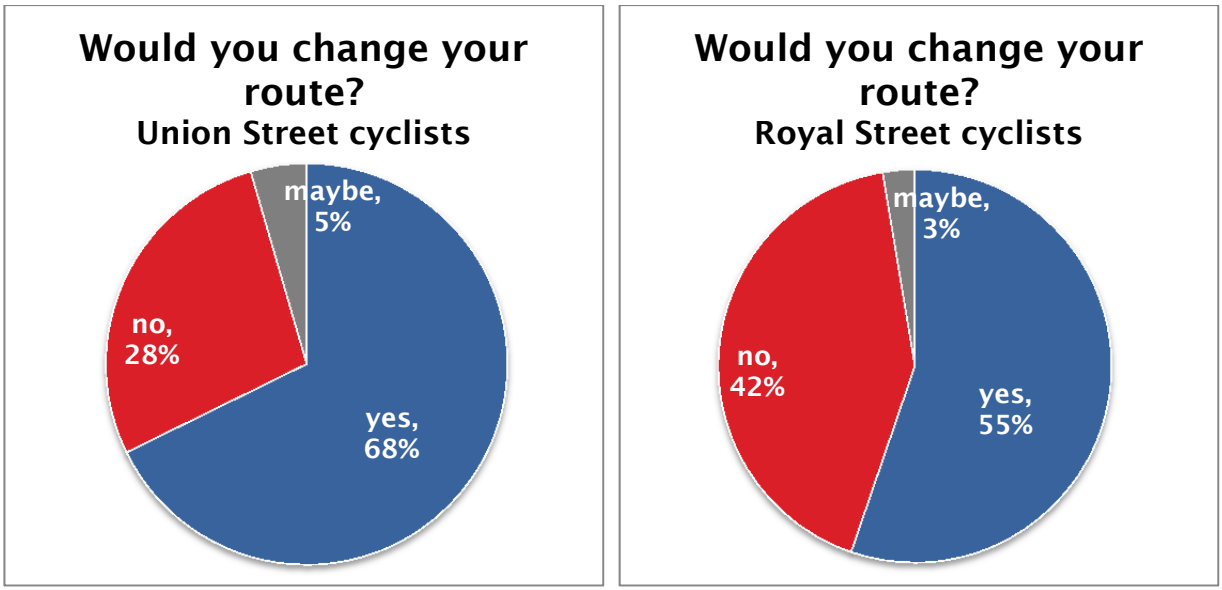

Chart E: Union Street and Royal Street cyclists' willingness to change routes.

Bicyclist intercept surveys were collected approximately one week after the "soft opening" of Jones Point Park and the trail connection to Union Street at Jefferson Street.

9.1 Mid-Block Multi-modal Volumes on Union Street and Royal Street

Union Street and Royal Street have unique atmospheres and traffic conditions. These traffic conditions are critical to evaluating the potential conflicts bicyclists might experience with motorists and pedestrians. On all-way stop-controlled Union Street, pedestrian volumes are higher and vehicle volumes are more concentrated near King Street. Royal has both all-way stop-controlled and signal-controlled intersections and vehicle volumes experience greater peaking throughout the day.

Peak-Hour Multi-modal Volumes and Speeds

Figure Q illustrates the mid-block peak-hour volumes at two locations along Union Street and Royal Street on Tuesday and Saturday. The vehicle volumes on both days are broken down by speed and Saturdays also include pedestrian and bicycle volumes.

Tuesday vehicle volumes are slightly higher on Royal Street than Union Street. Saturday vehicle volumes are about equal between Wilkes and Gibbon Streets and higher on Union Street between King and Prince Streets. Speeds on Union Street are lower than on Royal Street between King and Prince Streets, but higher between Wilkes and Gibbon Streets. The greater

distance between stop signs and sense of openness along this stretch of Union Street next to Windmill Hill Park may cause motorists to travel faster.

All the locations counted had similar bicycle volumes, with slightly more bicycles on Union Street than Royal Street between King and Prince Streets. Both Royal and Union Streets have higher pedestrian volumes between King Street and Prince Street.

Weeklong Multi-modal Volumes and Speeds and Saturday Mode Breakdown

Figures R through U illustrate the May 2012 weeklong vehicle volumes by speed and multimodal 12-hour volumes for each of the four locations summarized in Figure Q, while Figures R.1 and S.1 illustrate the coordinating volumes and speeds from the July 2012 counts. On these figures, the top chart illustrates vehicle volumes with a breakdown of the vehicular speeds for an entire week. The lower chart shows the mode breakdown from 7 AM to 7 PM at the mid-block location, with heavy vehicles stacked atop passenger vehicles and pedestrian and bicycle volumes represented over time with lines.

At all locations, AM and PM peaks in vehicle volumes are apparent Monday through Friday, while Saturday and Sunday volumes steadily rise and fall over the day. Peaks are more significant on Royal Street than Union Street.

On Union Street between King and Prince Streets, vehicular speeds were very low and pedestrian volumes rose greatly throughout the day. Bicycle volumes were noticeable, nearly exceeding vehicle volumes on Saturday at 11:00 AM. Between Wilkes and Gibbon Streets, speeds on Union Street were higher, with the weekday peak periods seeing a disproportionate increase in speeds. Saturday and Sunday volumes were greater overall; however, speeds were also much lower. Bicycle volumes on Royal Street are fairly consistent, with some Saturday peaking in the late morning.

Lower pedestrian and bicycle volumes at the southern end of Union Street may be a result of the construction at Jones Point Park, which established a detour along Franklin and Royal Streets to connect to the Mount Vernon Trail. Pedestrians and bicyclists may have chosen to connect to Royal via the Wilkes Street Trail, which bypasses the intersections of Fairfax Street and Lee Street rather than the on-street route via Franklin Street. With the opening of Jones Point Park in July 2012, some bicyclists and pedestrians may shift their route to the new trail connection via the southern end Union Street, but some Union Street riders may still choose the more direct route via Royal Street and the Wilkes Street Trail.

9.3 Analysis

Union Street's proximity to the waterfront and lower weekday traffic volumes generally attract more infrequent riders and riders traveling for recreational purposes, such as sightseeing and exercising. Many of these riders would be willing to change their route to Royal Street, given significant improvement in the bicycle facilities on Royal Street.

Though Union Street has significantly more pedestrians than Royal Street, particularly on the weekends, a slightly larger proportion of Royal Street riders (9% versus 5% of Union Street riders) listed pedestrians as their primary concern on their route. This indicates that cyclists are not largely concerned with on-street conflicts with pedestrians.

10. Summary of Findings

The Union Street corridor serves motorists, bicyclists, and pedestrians in varying capacities throughout the week. On the weekdays, motorist and bicyclist commuter traffic is matched by high pedestrian volumes only in the evenings, while on the weekends, pedestrian volumes exceed those of the other modes overall, particularly at the complex all-way stop-controlled intersection of Union and King Streets. Even though this intersection meets the pedestrian warrant for a traffic signal, which could improve vehicular flow, a traffic signal may have adverse effects on delay and crash severity. Presently, the quantity of crashes is low, with the greatest quantity at King and Union Streets, and crashes rarely involve bicyclists and/or pedestrians. Royal and Union Streets both provide on-street connection to the Mount Vernon Trail, with Union Street offering a more scenic route while Royal Street is more direct.

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Figure A:
Project Location Map

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Figure B: Observations and Data Collection Location Map

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Figure C: Intercept Survey Collection Locations

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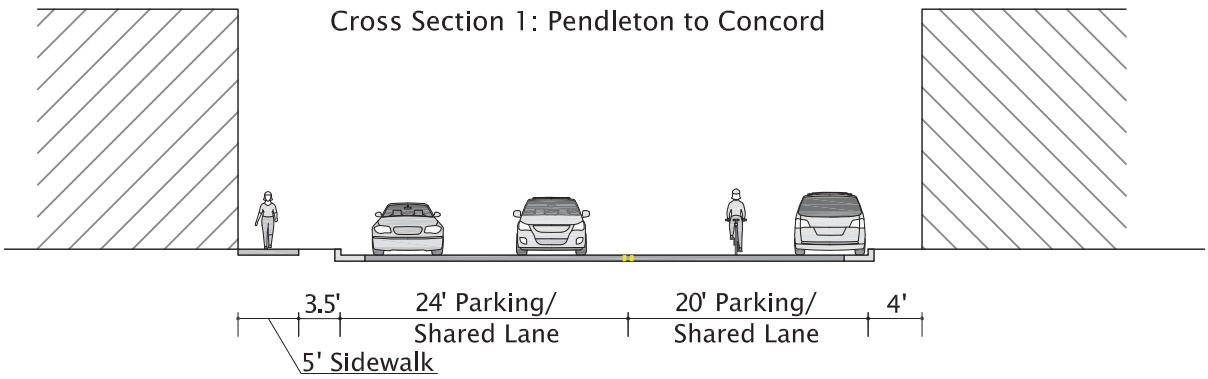
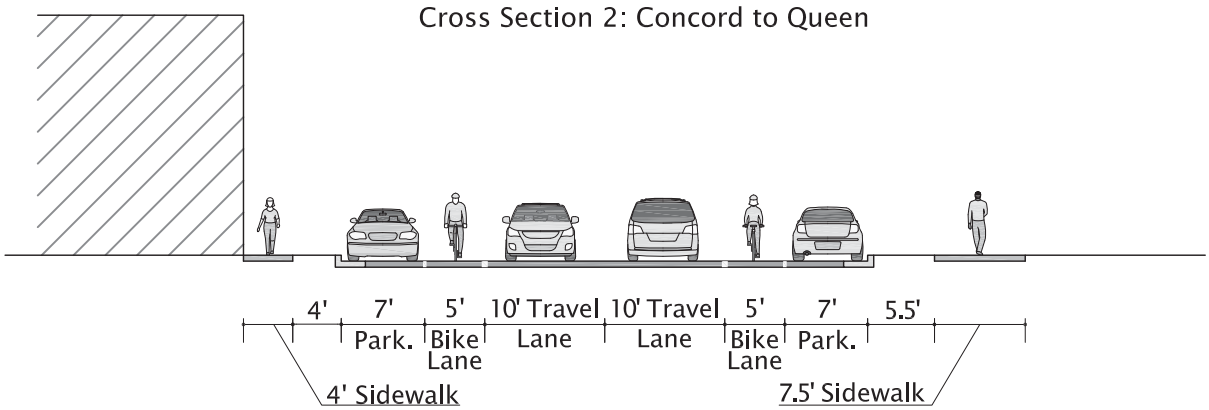
Figure D:
Existing Cross Section Location Map





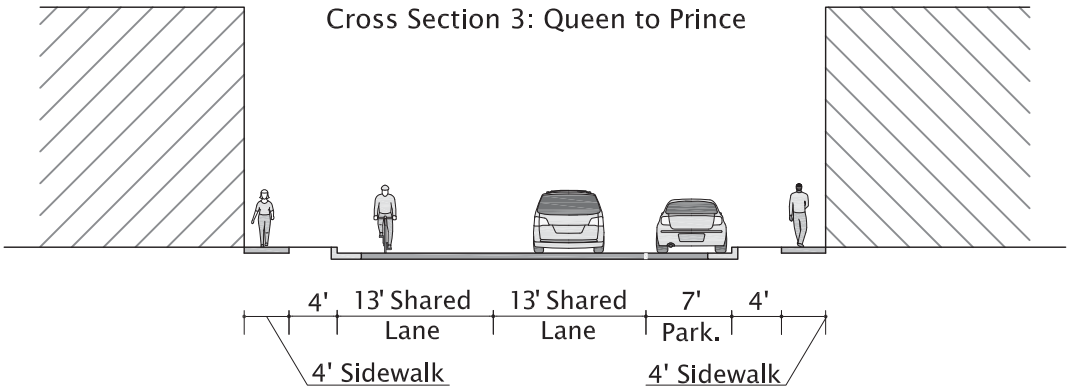


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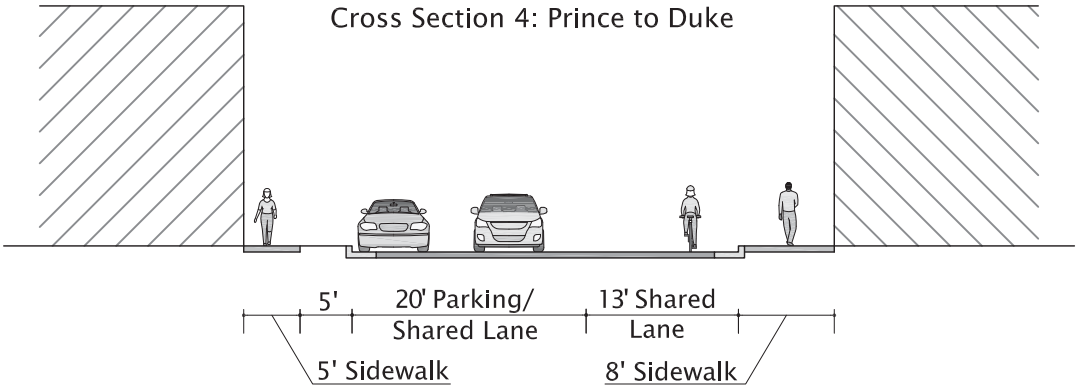
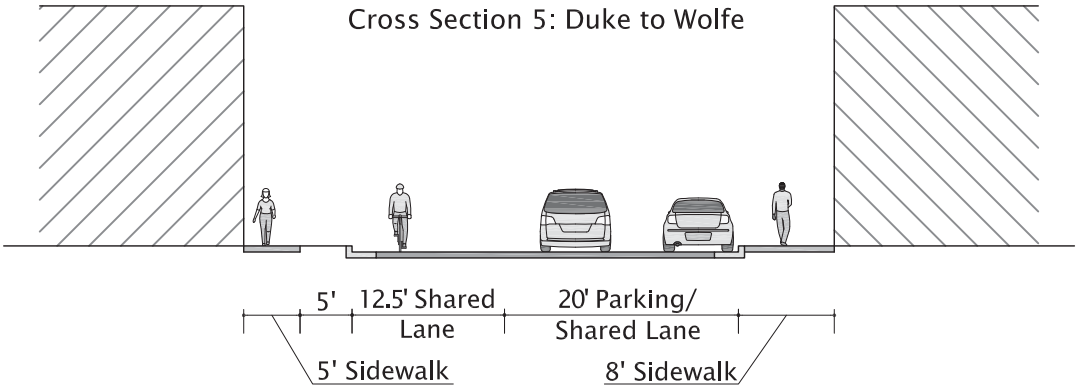
Figure E: Union Street Existing Cross Sections 1-3





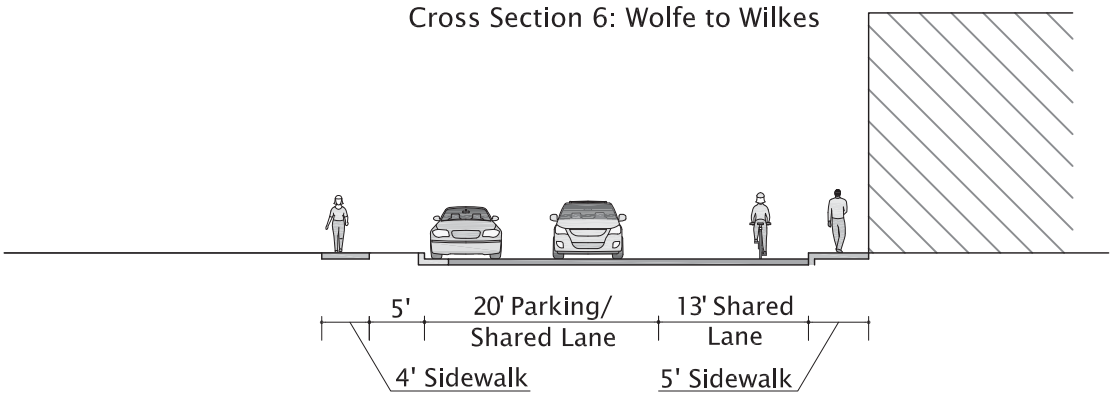


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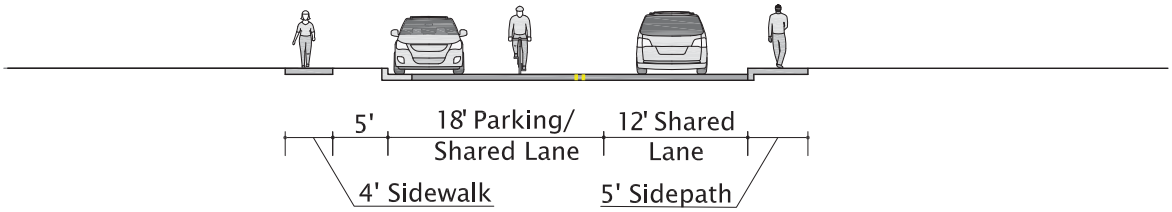
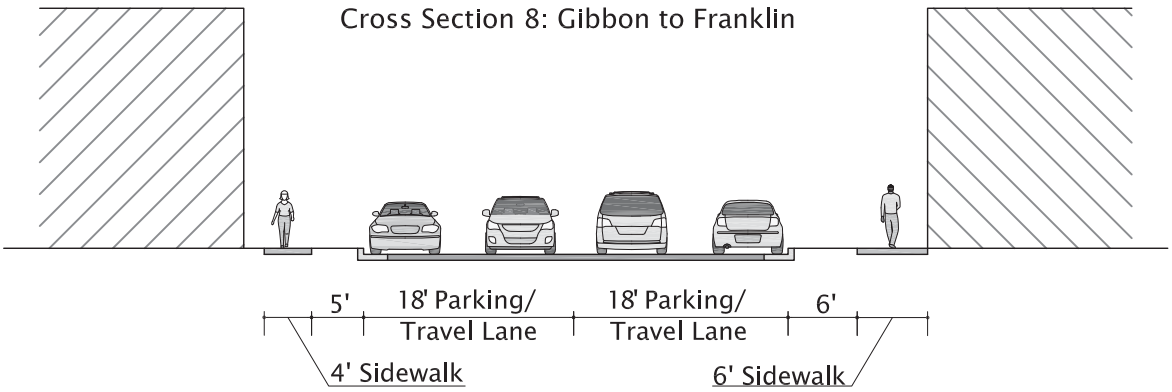
Figure F: Union Street Existing Cross Sections 4-6

Cross Section 7: Wilkes to Gibbon



Cross Section 8: Gibbon to Franklin



Cross Section 9: Franklin to Jefferson

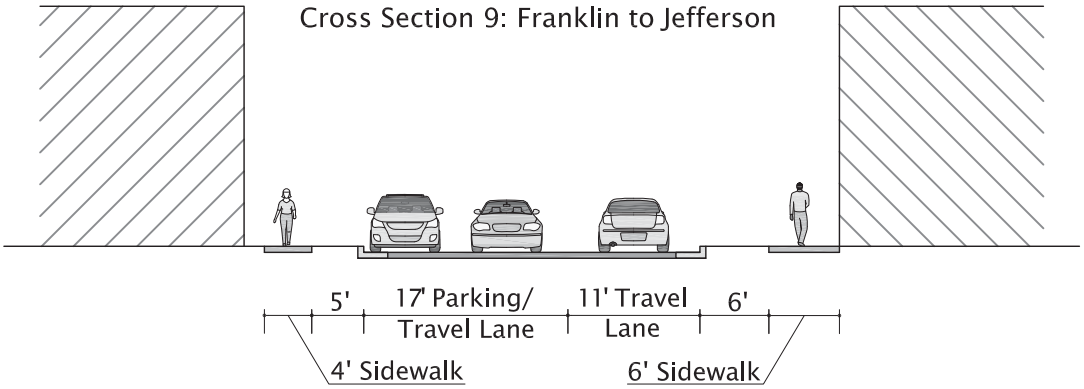


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Figure G: Union Street Existing Cross Sections 7-9

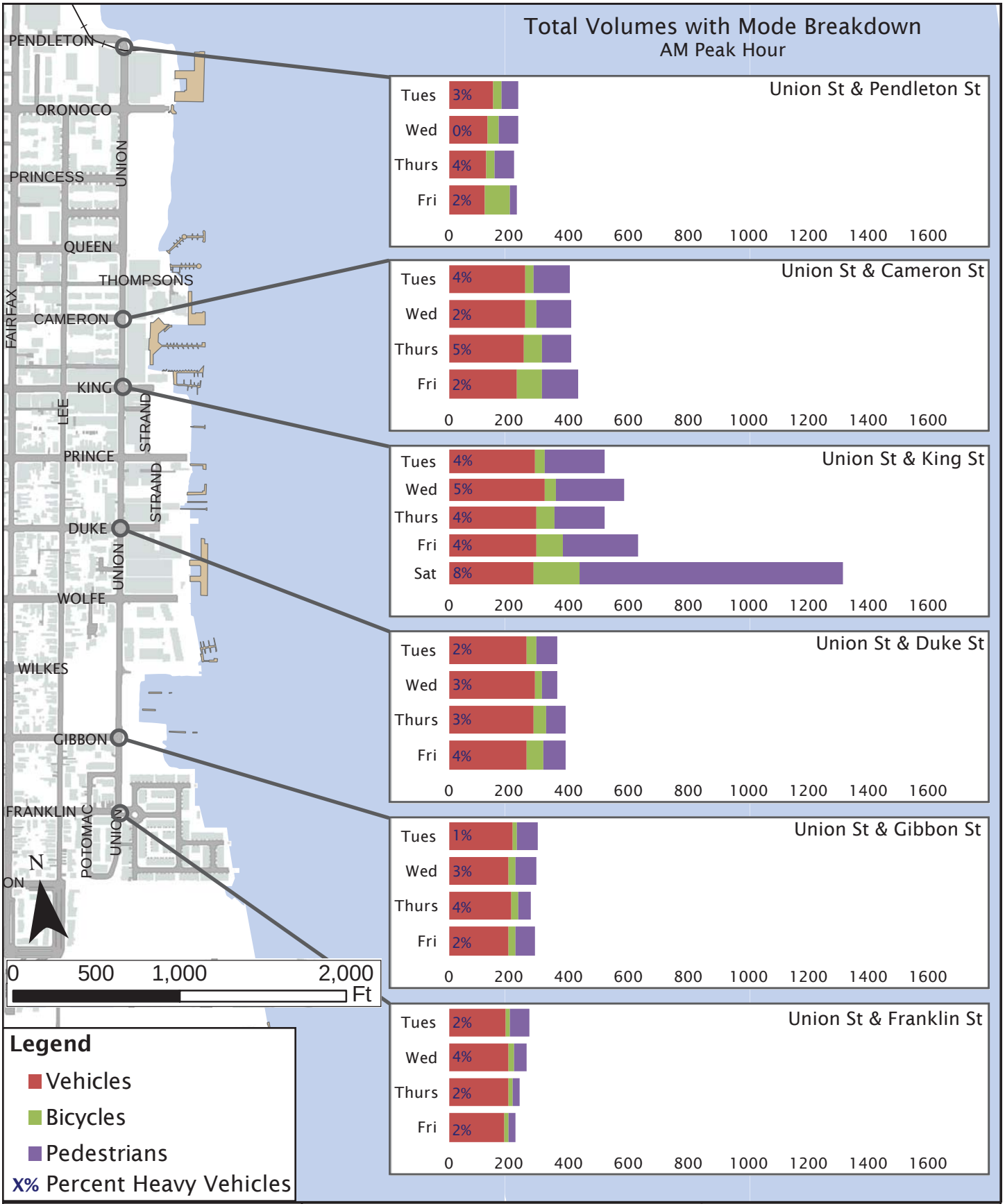

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Figure H: Total AM Peak-Hour Volumes

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Figure I: Total Midday Peak-Hour Volumes

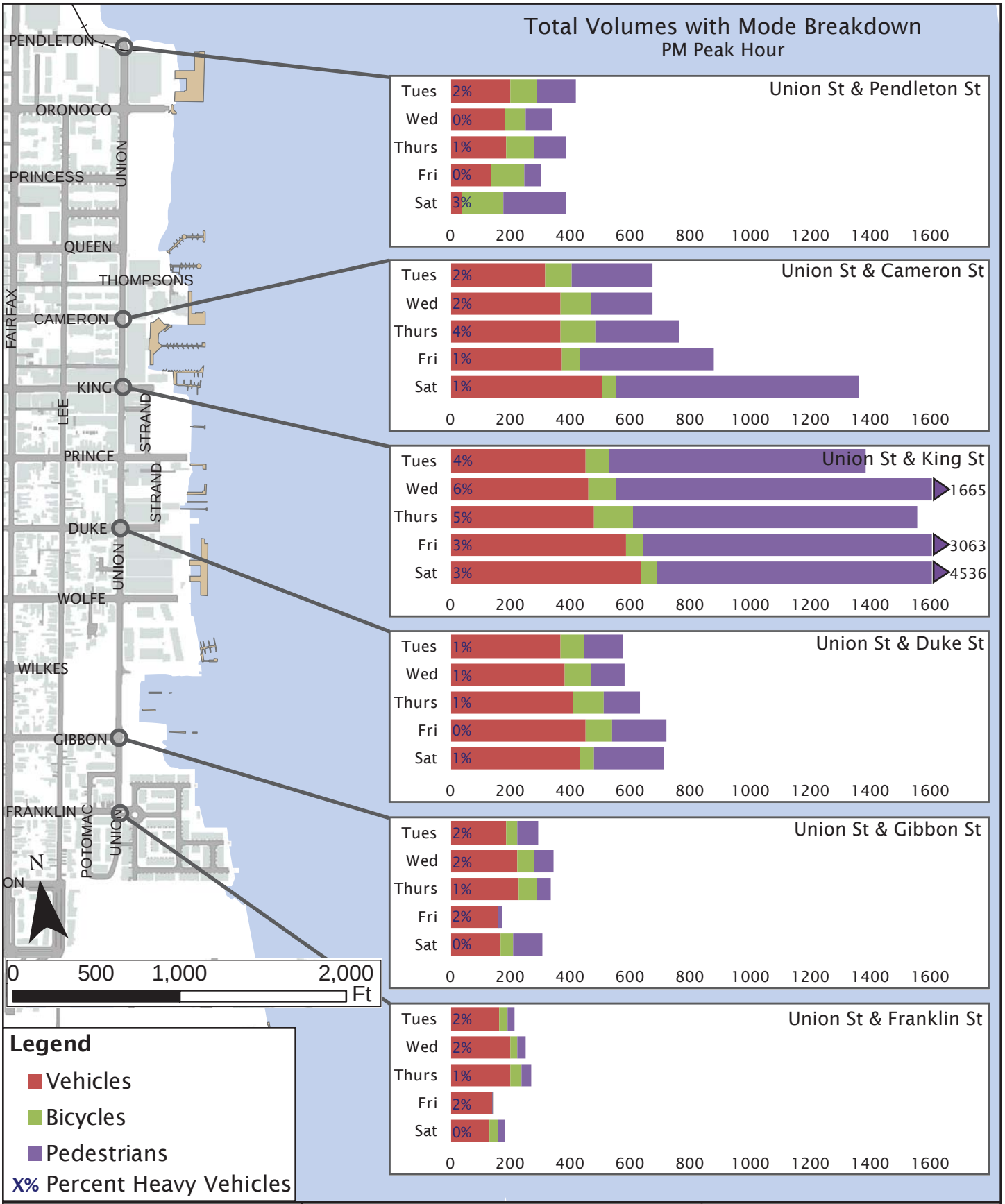

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Figure J: Total PM Peak-Hour Volumes

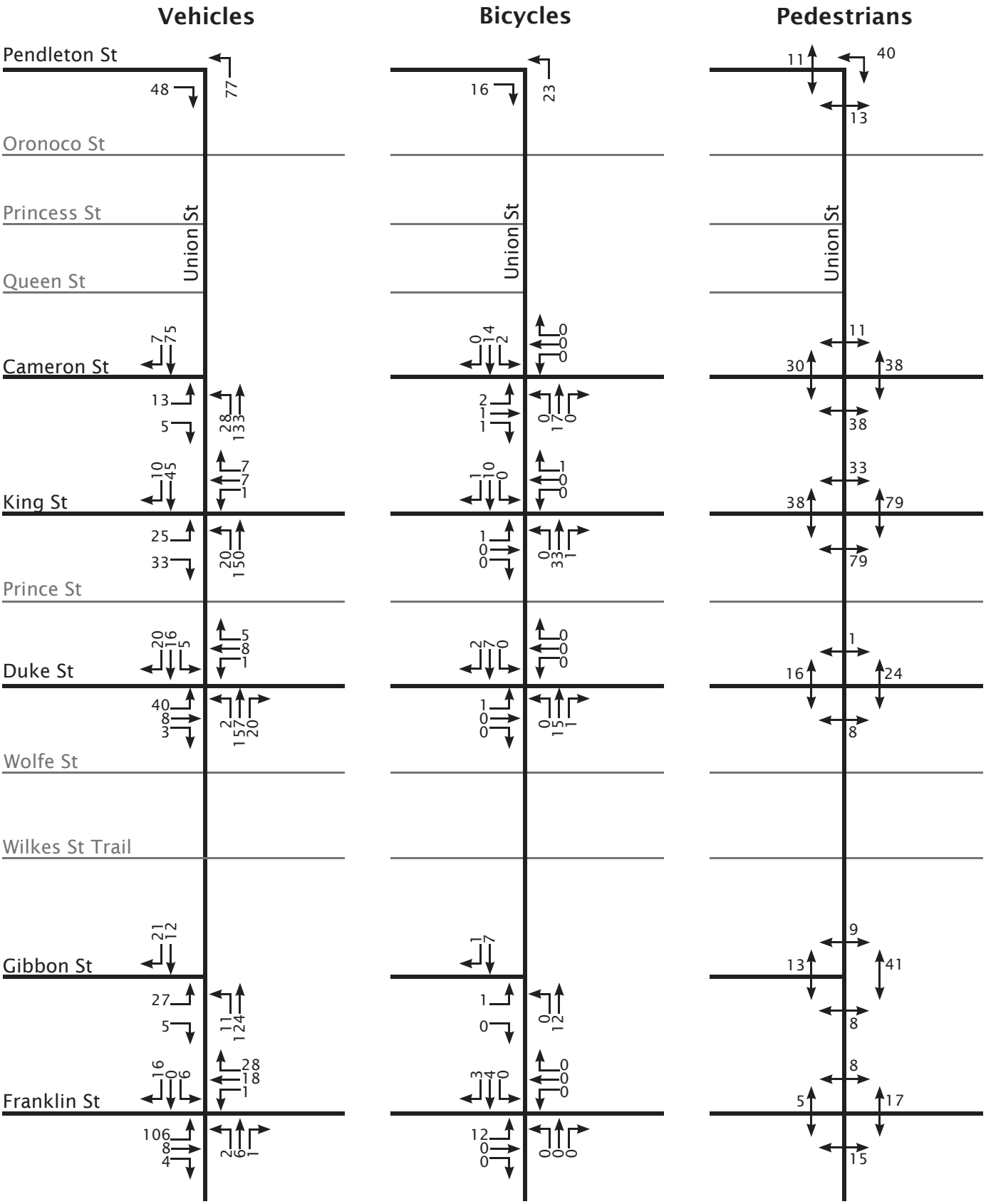

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Figure K: Weekday AM-Peak Turning-Movement Counts

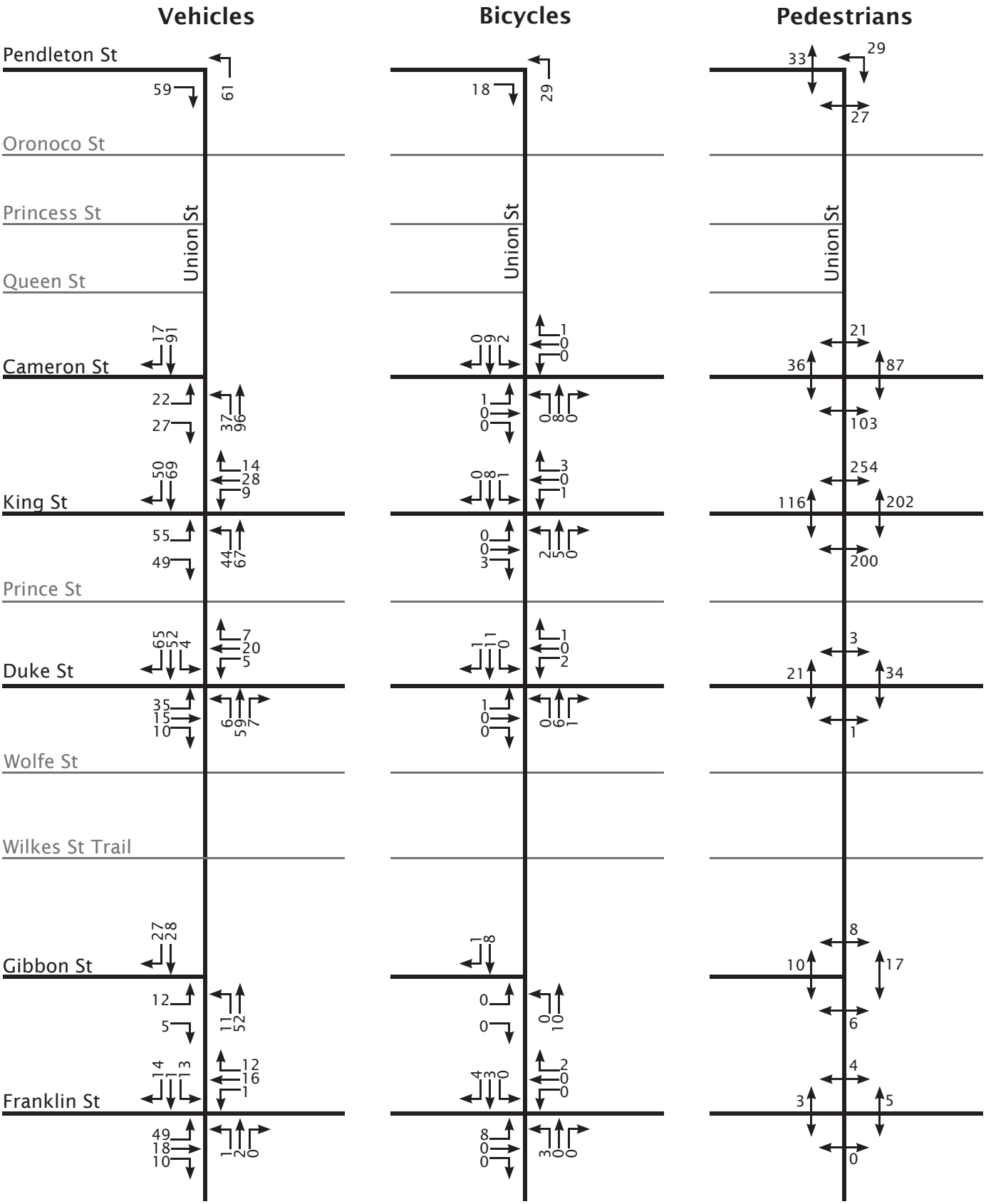

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Figure L: Weekday Midday-Peak Turning-Movement Counts

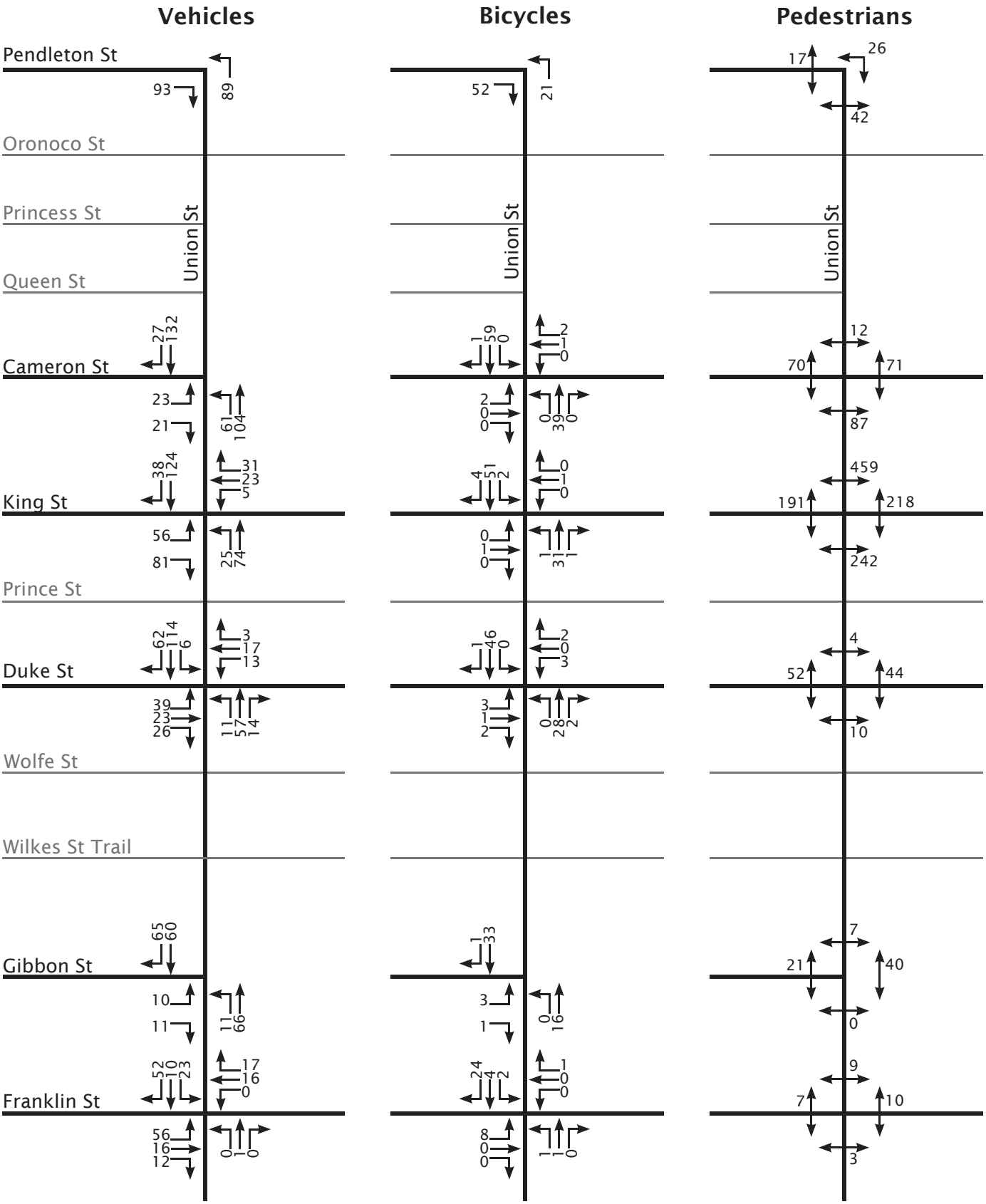

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Figure M: Weekday PM-Peak Turning-Movement Counts

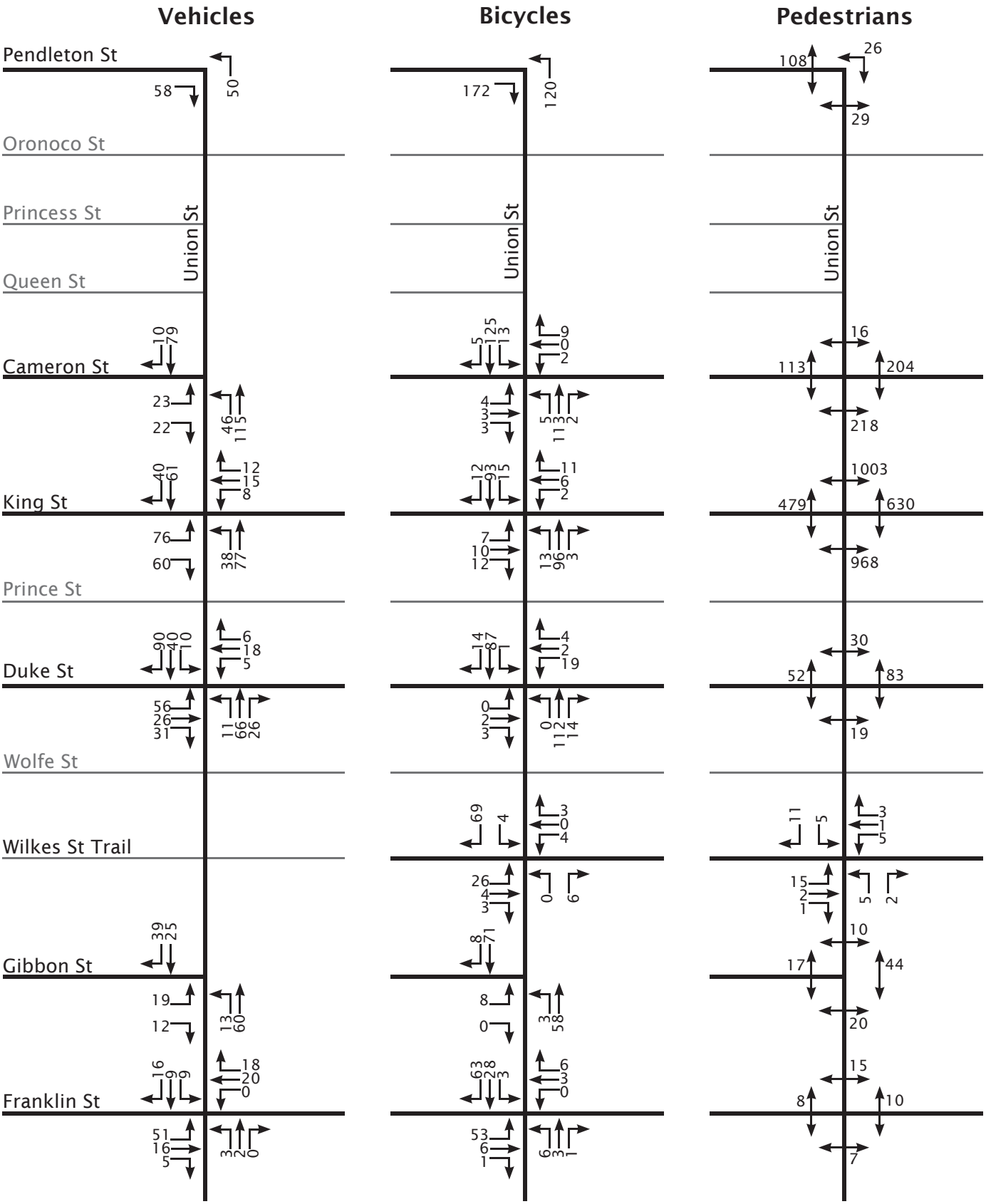

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Figure N: Saturday Midday-Peak Turning-Movement Counts

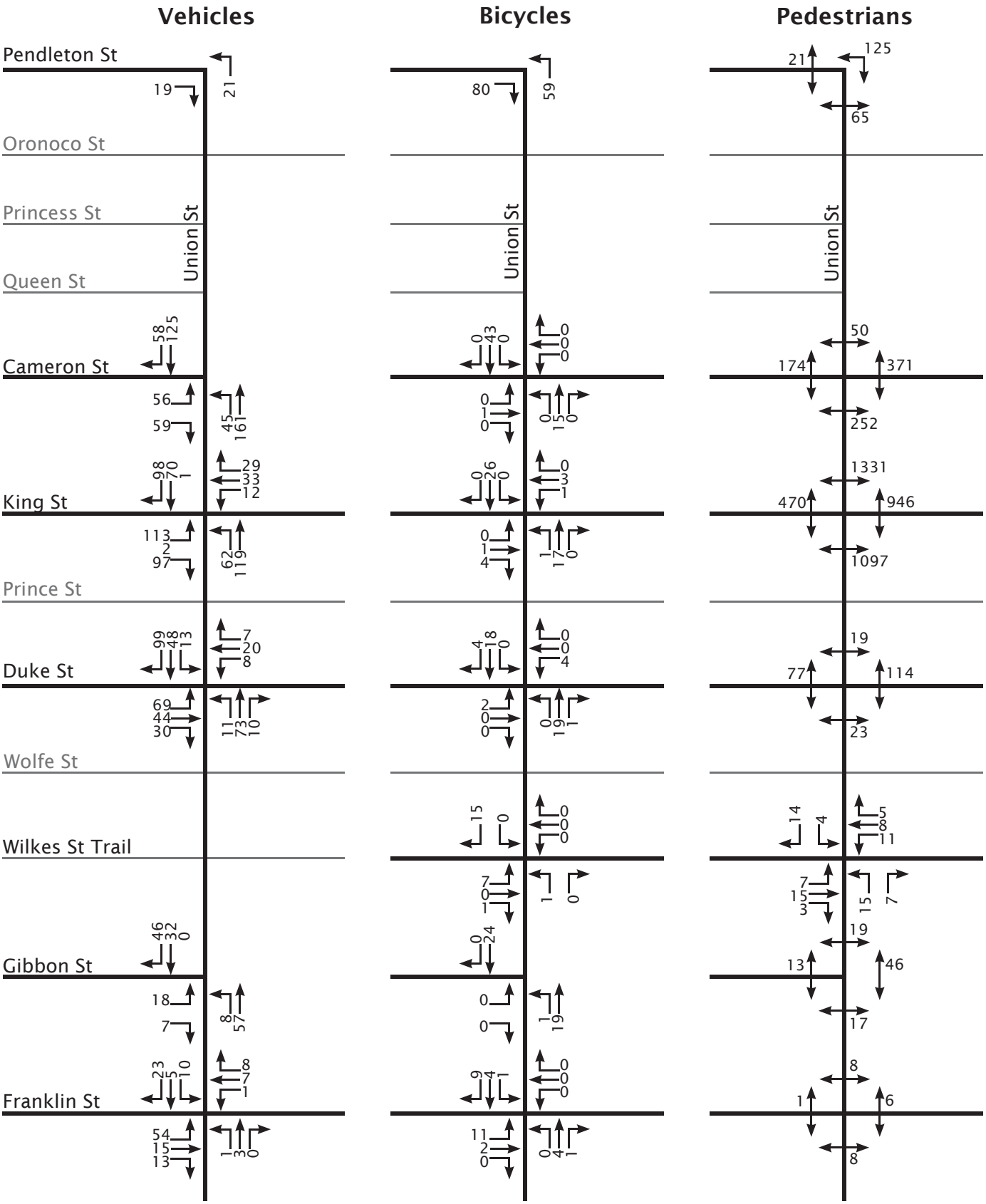

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Figure O: Saturday PM-Peak Turning-Movement Counts

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Figure P: Crash Data Summary Map

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Figure Q: Royal St & Union St Midblock Peak-Hour Volumes

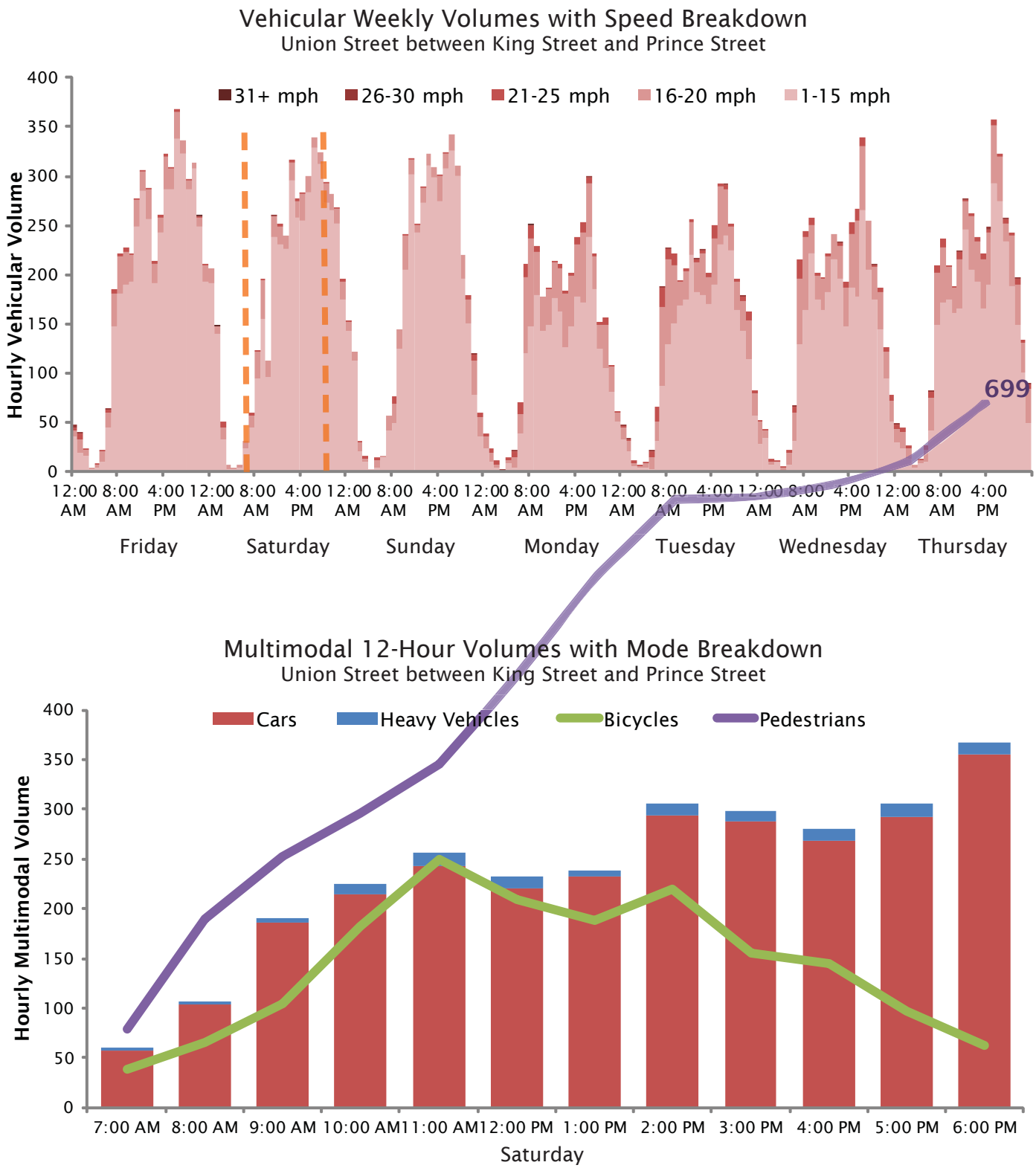

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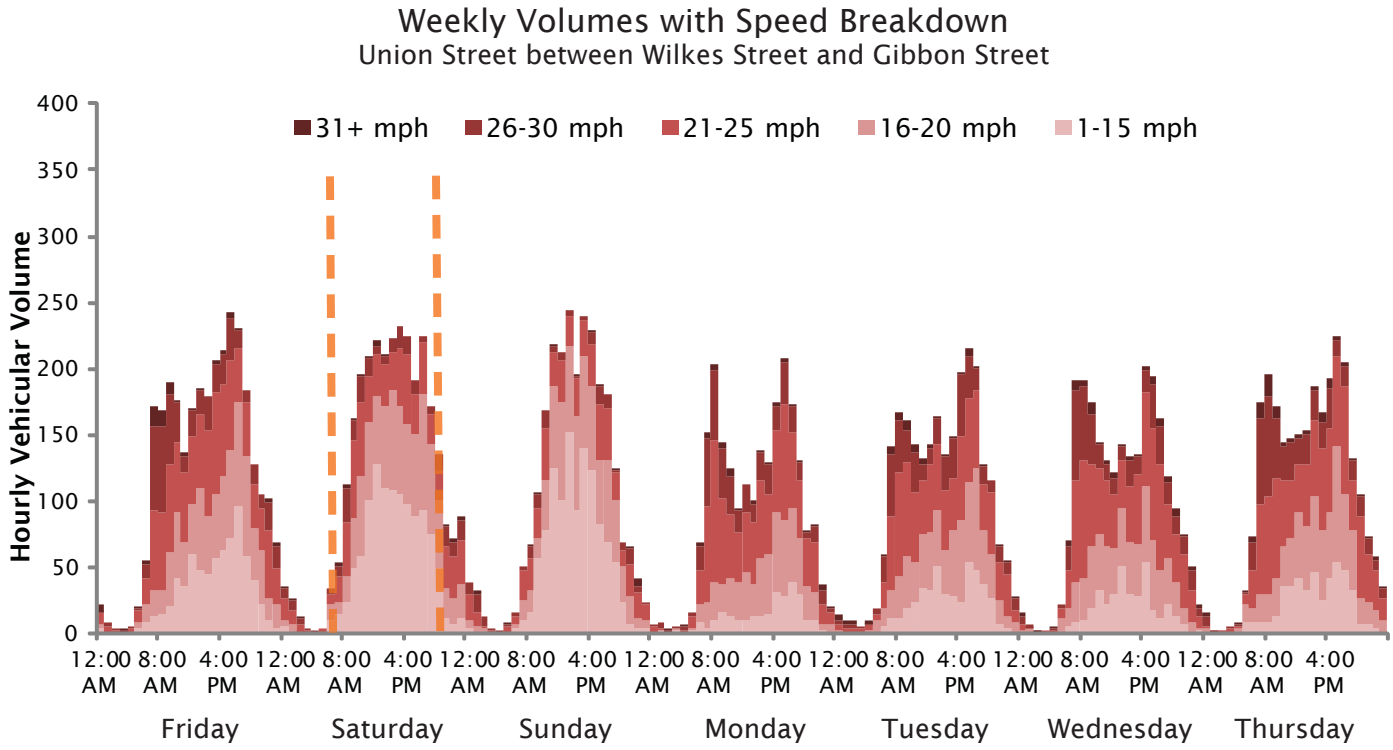
Figure R: Volumes by Speed and Mode on Union from King to Prince



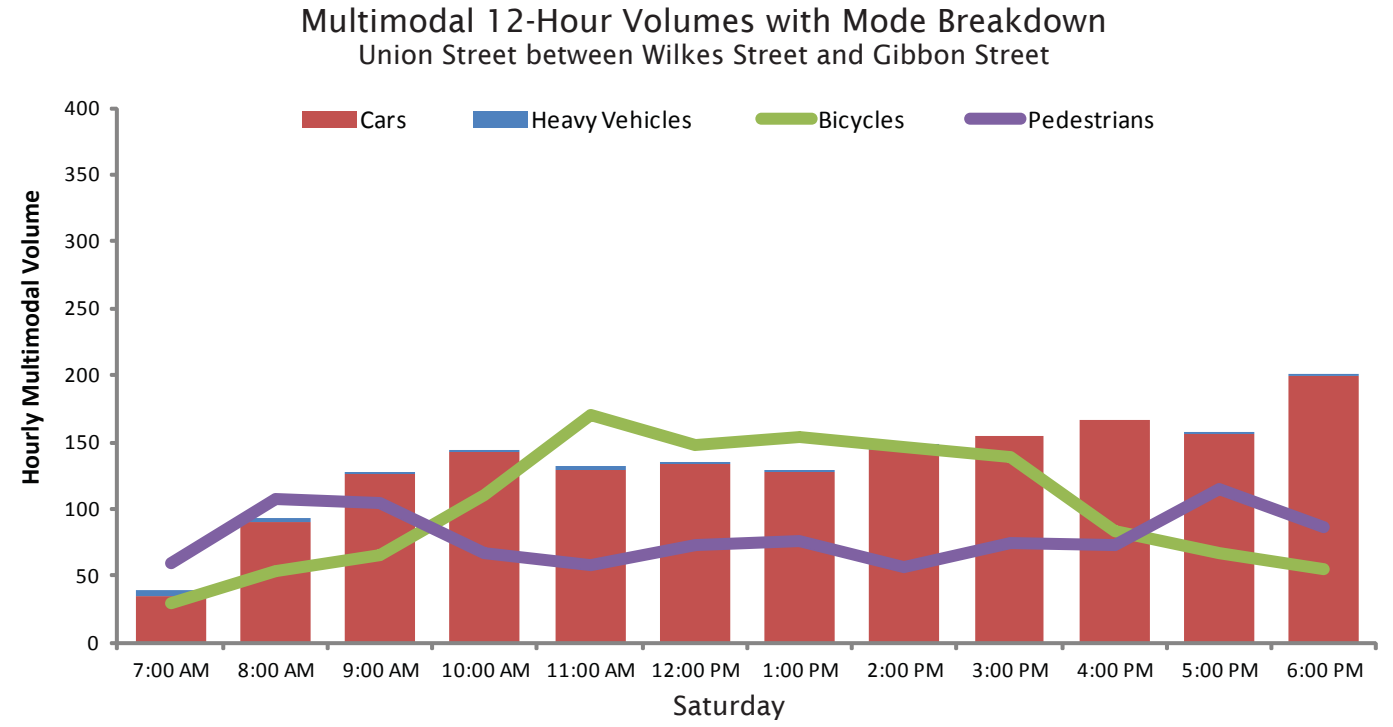


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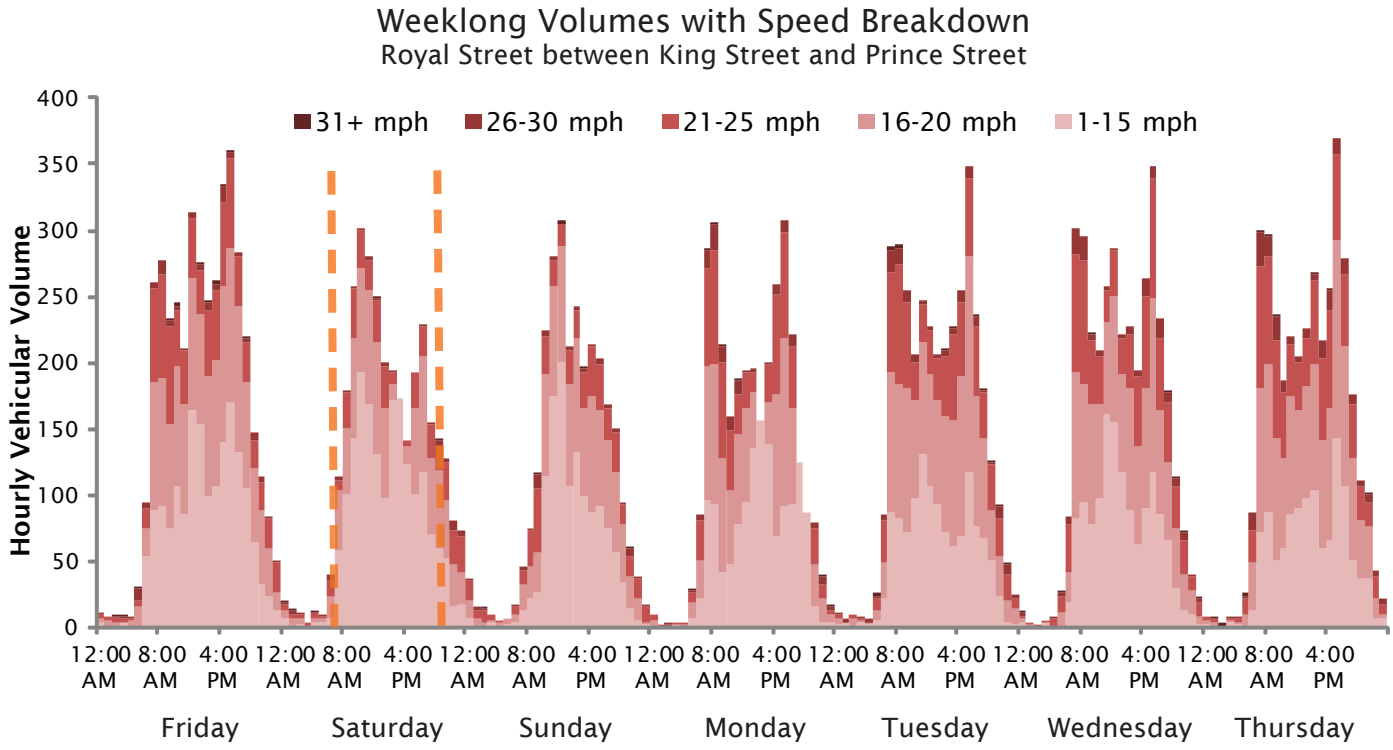
Figure S: Volumes by Speed and Mode on Union from Wilkes to Gibbon



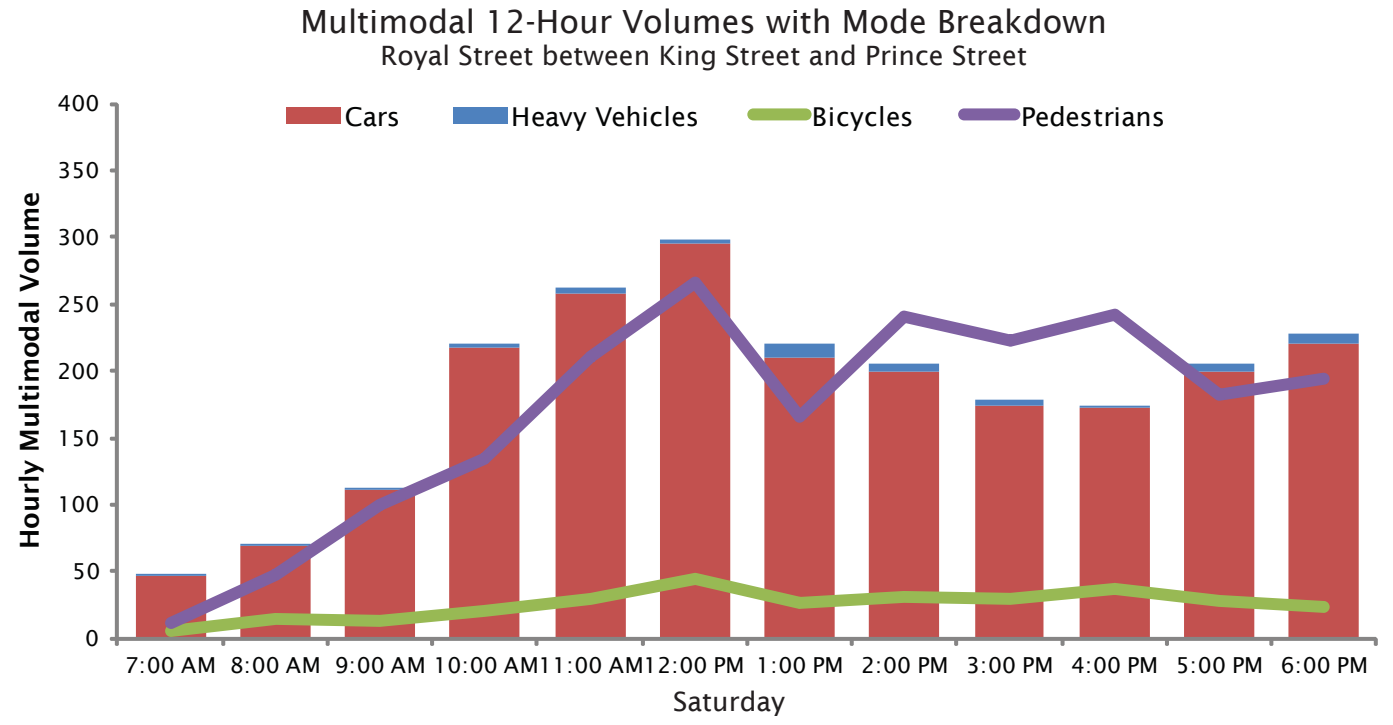


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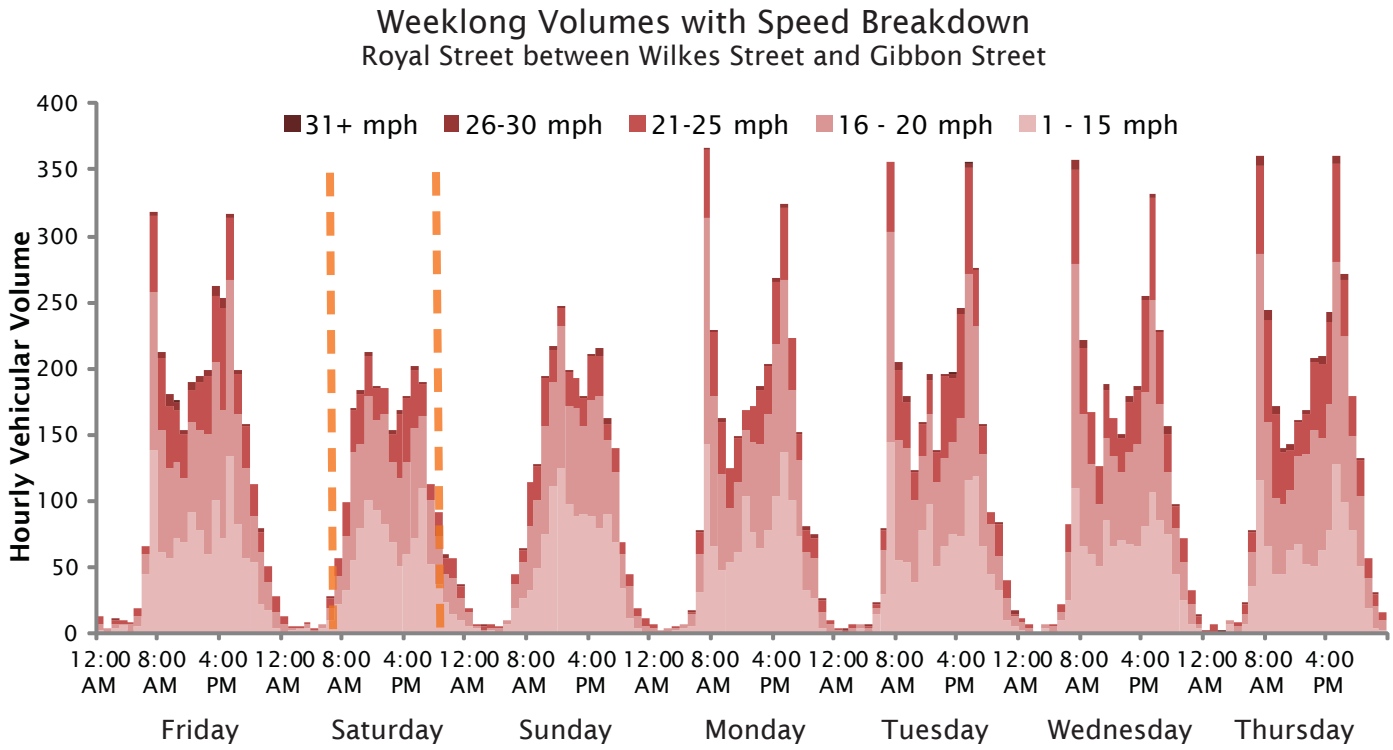
Figure T: Volumes by Speed and Mode on Royal from King to Prince



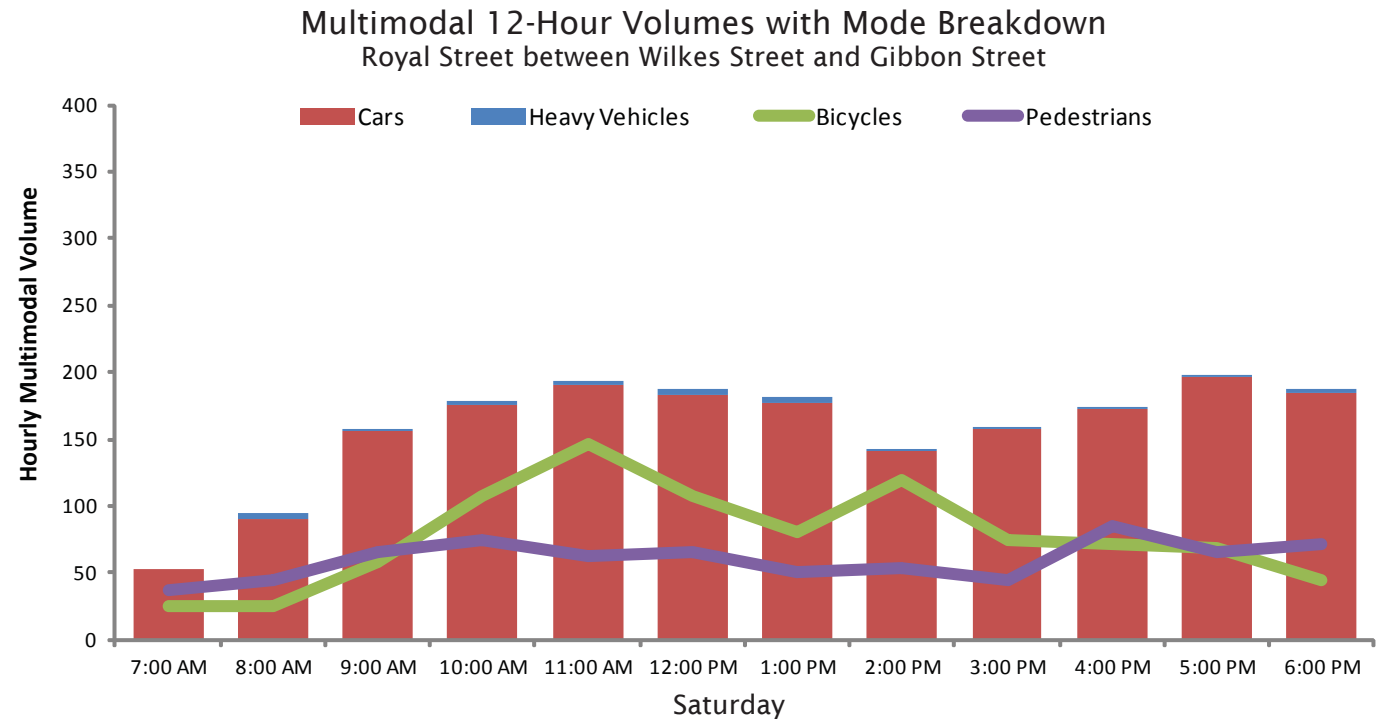


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Figure W: Volumes by Speed and Mode on Royal from Wilkes to Gibbon

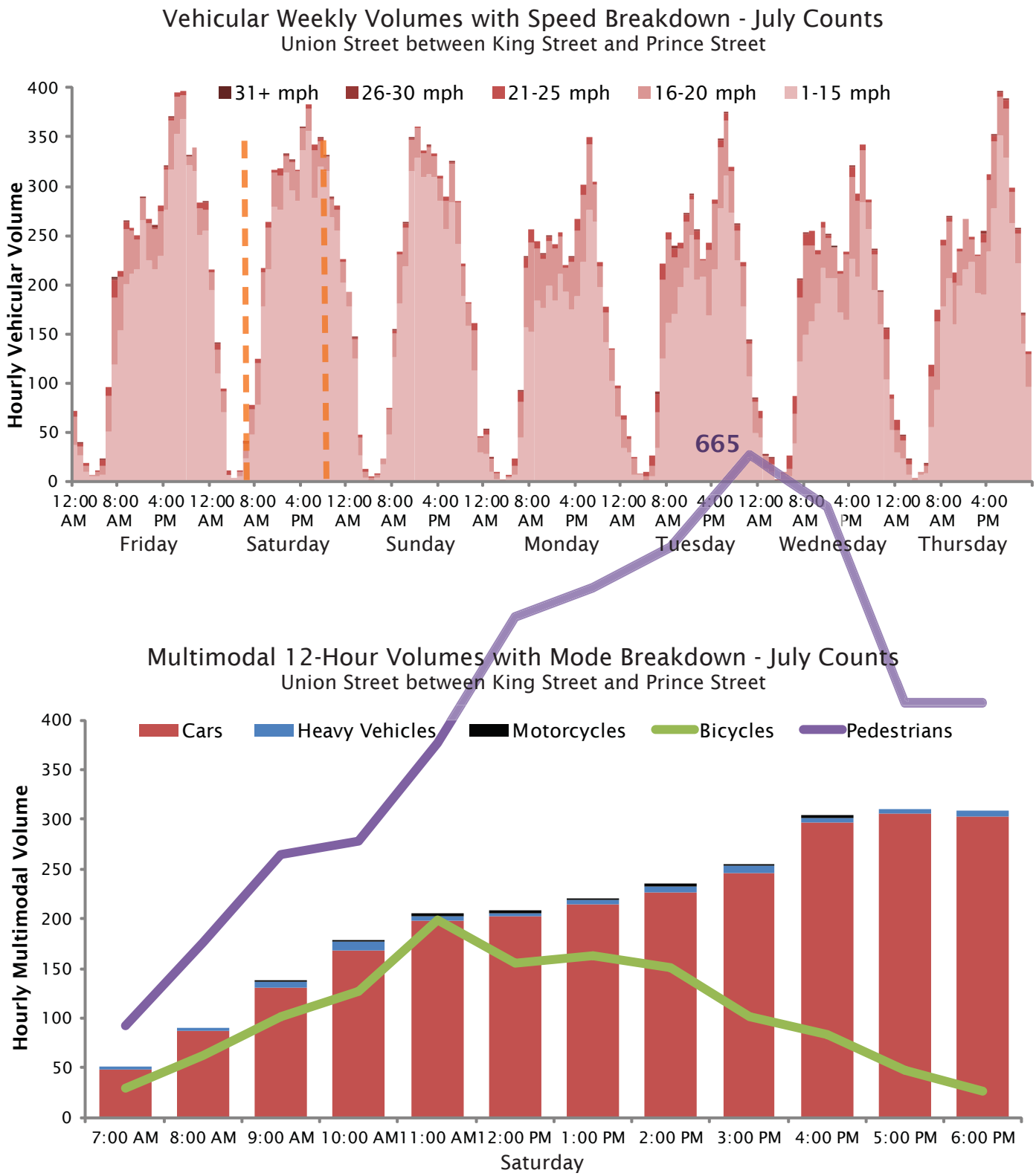

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Fig. R.1: July Volumes by Speed and Mode on Union from King to Prince

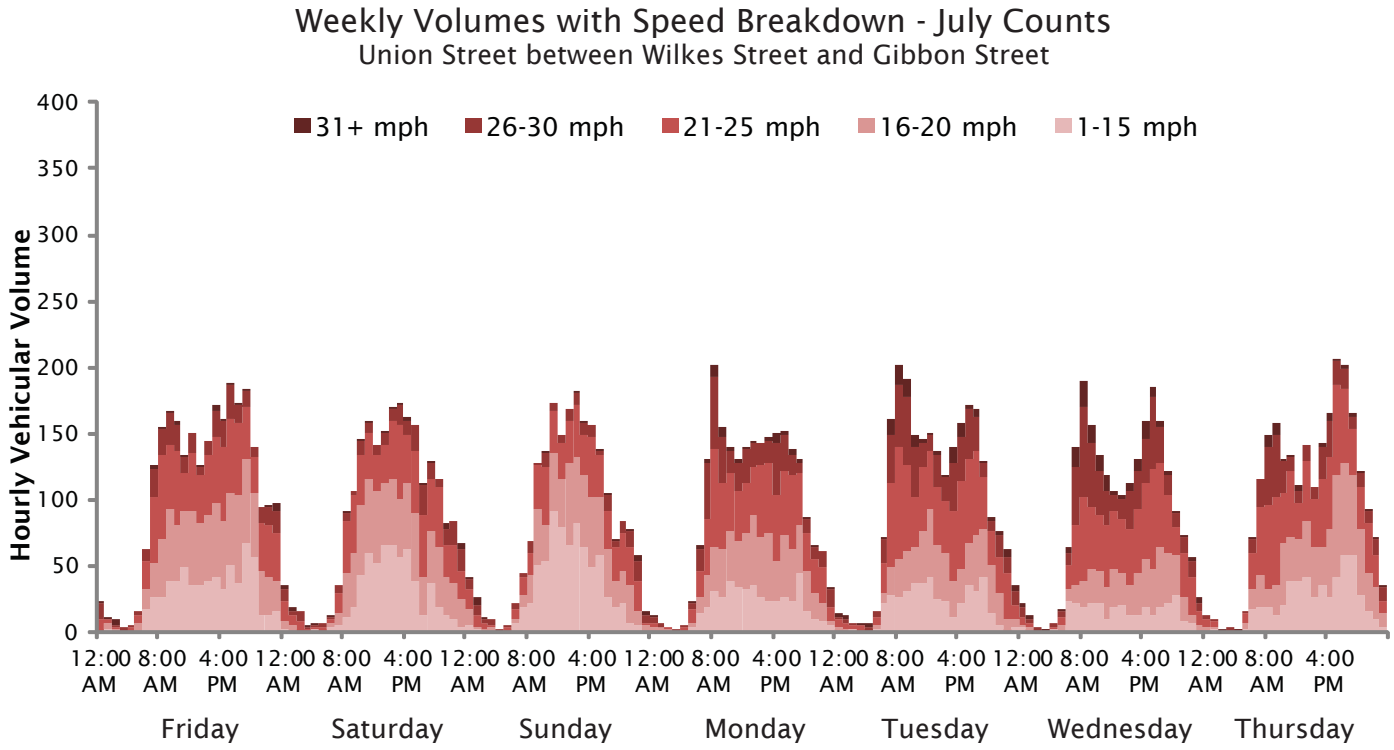

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Fig. S.1: July Volumes by Speed and Mode on Union from Wilkes to Gibbon