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Evidence from Urban Roads without Bicycle Lanes on the Impact of Bicycle Traffic on Passenger Car Travel Speeds

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1 **Evidence from Urban Roads without Bicycle Lanes on the Impact of Bicycle Traffic on**
2 **Passenger Car Travel Speeds**

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30

1 **ABSTRACT**

2 A concern raised by some motorists regarding the presence of bicycles on urban roads without bicycle
3 lanes, discussed in part of the traffic literature, is that cyclists will slow down motorized vehicles and
4 therefore create congestion. This research answers this question: do bicycles reduce passenger car travel
5 speeds on urban roads without bicycle lanes? To answer this question, a detailed comparative analysis of
6 passenger car (class two vehicles) travel speeds on lower volume urban roads without bicycles lanes is
7 presented. Speed distributions, the mean, and the 50th and 85th percentile speeds for two scenarios were
8 examined: (i) a passenger car that was preceded by a bicycle and (ii) a passenger car that was preceded by
9 another passenger car. Peak hour traffic and 24-hour traffic speeds were analyzed using *t*-tests and
10 confidence intervals. Although a few statistically significant differences between scenarios (i) and (ii)
11 were found, the actual speed differences were generally on the order of one mile per hour or less. Hence,
12 differences in class two (motorized passenger) vehicle speeds with and without cyclists were found to be
13 negligible from a practical perspective.

14
15 **Keywords:** Shared, local, arterial roads, vehicle-bicycle interaction, speed, distributions.

1 **INTRODUCTION**

2 Bicycling is a vastly underutilized mode throughout most of the US, comprising just half of a
3 percent of commuters throughout the nation.[1] Given its potential for greater flexibility in route choice
4 and lower costs for infrastructure and operation compared to transit, there is a substantial opportunity for
5 cities to expand bicycling as a primary transportation mode. Congestion mitigation and environmental
6 concerns from rising urban populations have been significant factors cited by communities as they push
7 for greener transportation policies and travel modes.

8 According to the Portland Bureau of Transportation, in 2017, 6.3% of commuters traveled by
9 bicycle.[2] The Portland Bike Plan has established a goal to increase that mode share to 25% by the year
10 2030.[3] With this mode shift toward bicycling, it is necessary to study the impacts these changes may
11 have on the existing transportation network and motorized vehicles. In support of the Portland Bike
12 Plan’s goal to reach a 25% bicycle mode share, the City expects to add nearly 100 miles (161 km) of
13 bikeways to the existing 385 miles (620 km), approximately 36% of which are currently shared-use
14 roadways.[2]

15 Although it is generally favored to segregate bicyclists and motor vehicles, it is infeasible and
16 often unnecessary to create such infrastructure on every road. For example, Danish bicycle design
17 guidelines suggest that mixed traffic conditions are acceptable for roadways with speed limits less than
18 approximately 35 km/h (22 mph) and ADT less than approximately 2500 vehicles.[4]

19 Shared-use roads can be an economical solution to a growing demand for bicycle facilities.
20 However, this sharing of space presents its own challenges in the contexts of safety and mobility. Several
21 research studies have been conducted on vehicle-bicycle interactions, many of them focused on lateral
22 positioning and passing behavior. Of particular interest, however, is the effect of bicycle traffic on
23 motorized traffic speed, capacity, and flow.

24 A general concern of motorists regarding the presence of bicycles on roads without bicycle lanes
25 is that they will impede motor vehicles due to their differing performance characteristics, which may
26 serve to increase congestion and vehicle emissions – two consequences of urbanization that a larger
27 bicycle mode share seeks to mitigate. Recent discussions based on a simulated traffic study have warned
28 that traffic congestion and travel time delay will worsen as the bicycle mode share increases unless
29 bicycle lanes are installed.[5-6] To the authors’ knowledge, there have not been any studies to date using
30 empirical data of passenger cars on shared roads or roads without bicycle lanes that explore the validity of
31 this claim. This paper seeks to expand the knowledge on vehicle-bicycle interactions by studying the
32 impact of bicycles on the travel speed of passenger cars on roadways without bicycle lanes.

33
34 **LITERATURE REVIEW**

35 Shared roads or roads without explicit bicycle lanes can constitute a considerable portion of an
36 urban bicycle network. Danish bikeway design guidelines suggest that mixed traffic conditions are
37 acceptable for roadways with low speed limits (less than 35 km/h [22 mph]) and low traffic volumes (less
38 than 2500 ADT).[4] The FHWA lays out similar guidelines, advising shared roadways are suitable in
39 urban areas on streets with speeds of 25 mph (40 km/h) or less and a maximum of 3,000 ADT.[7-8] The
40 National Association of City Transportation Officials (NACTO) also recommends a target speed of 20-25
41 mph (32-40 km/h) and traffic volumes below 1,500 vehicles per day for shared streets to be appropriate
42 for all ages and abilities.[9]

43 In light of the growing trend of bicycling as a transportation mode, there is a considerable need
44 for additional research into how bicycles affect traffic operations, particularly in these mixed traffic
45 contexts. Relatively few studies have attempted to model vehicle-bicycle interactions as they relate to
46 travel speed or delay.

47 Bicycles may interact with motor vehicles in a number of ways, including their position relative
48 to each other and their lateral movements. Conflicts can arise when bicycles and motor vehicles attempt
49 to occupy the same space due to lane changes and merging, turning movements, or shared roadways. The
50 differential in performance characteristics between bicycles and motor vehicles, particularly on roadways

1 with significant positive grades, contributes to the potential for these conflicts as motor vehicles
2 frequently operate at higher speeds and desire to overtake slower moving bicycles.

3 Jia et al. [10] describe two types of influence bicycles may impose upon motor vehicles, namely
4 friction interference and block interference. Even when a bicyclist is riding within a dedicated bicycle
5 lane, a motor vehicle may slow down when passing on account of safety. This is referred to as friction
6 interference. Block interference occurs when a bicyclist occupies a portion of the motor lane, causing a
7 trailing motor vehicle to reduce its speed. On shared roadways, it has been demonstrated that shared lane
8 markings encourage bicyclists to ride farther from the curb in a more central position within the lane [11-
9 13] which may increase instances of block interference on shared roads.

10 In the absence of empirical data, simulations have been used to study vehicle-bicycle interactions.
11 Oketch [14] designed a model using a deterministic car following rule to simulate heterogeneous traffic
12 behavior in which multiple types of non-motorized vehicles were present along with conventional motor
13 vehicles. Speed-flow relationships were developed, and trends in capacity and saturation flows were
14 analyzed for a two-lane road with three meters (10 ft.) lane widths. The average desired speed was set to
15 80 km/h (50 mph) with a flow of 1000 vehicles per hour to model a typical urban arterial road. Results of
16 a simulation comprised of 25% bicycles and 75% private cars showed a 36% decrease in capacity versus
17 a homogenous traffic stream of private cars. This decrease in capacity was attributed to a reduction in the
18 mean free flow speed. However, it is important to note the desired motor vehicle speed and traffic flow
19 values utilized in these simulations far exceed the bicycle design recommendations for mixed traffic
20 roadways.

21 Bicycle lane provisions and bicycle volume have been found to affect the average velocities of
22 cars in China. Researchers in Beijing collected and analyzed field data for three sections of road with
23 designated bicycle lanes of varying width and 3.7 m (12 ft.) motor vehicle lanes using photography to
24 quantify the impact bicycles exert on vehicles in mixed urban traffic. The researchers observed that as the
25 number of bicycles increased or the width of the bicycle lane decreased, motor vehicles were increasingly
26 affected by block interference as opposed to friction interference due to the overflow of bicycles into the
27 motor vehicle lane, which offered insufficient space to pass. The average velocities of cars on the three
28 road sections when no interference occurred ranged from 35.15 km/h to 41.56 km/h (21.84 mph to 25.82
29 mph). Compared to conditions where no interference occurred, a 17-21% decrease in average velocity
30 was observed when friction interference was present. Under block interference conditions, a 29-37%
31 decrease in average velocity was seen as compared to no interference.[10]

32 Bicycle lane width, motor vehicle lane width, and traffic volume – both motor vehicle and bicycle
33 – influence lateral movements and passing behavior, which may, in turn, affect speed and travel time.
34 Using a simulation of a two-lane urban roadway and based on a motor vehicle speed of 37.4 mph (60
35 km/h), Gosse & Clarens [6] found that a 10% bicycle mode share incurred travel time delay costs when
36 shared travel lanes were not sufficiently wide to allow heavy vehicles to pass safely. This effect was
37 magnified on sections with a positive 4% grade. In their simulations, the researchers concluded a curb-to-
38 curb road width of 8.6 m (28.2 ft.) or greater provided adequate space for larger vehicles to pass and
39 resulted in reduced travel time delay costs with a 10% bicycle mode share.

40 Unlike previous (cited) studies that utilize simulations to analyze motorized traffic delays due to
41 the presence of cyclists, this research utilizes empirical traffic speed and vehicle classification data that
42 was collected at six different locations with different roadway geometric design and topography in
43 Portland, Oregon.

44 **DATA COLLECTION**

45 The City of Portland, Oregon is well known throughout the US for its bicycling culture. There are
46 currently 385 miles (620 km) of bikeways in Portland with an additional 95 miles (153 km) being
47 installed in the next five years. Over 100 miles (161 km) of the existing bikeways are shared roadways.[2]
48 In order to investigate the effect bicycles may have on passenger car travel speeds on shared-use
49 roadways or roads without bicycle lanes, traffic speed survey data was sourced from the Portland Bureau
50 of Transportation (PBOT). PBOT uses pneumatic tubes configured to record vehicle speed and classify
51

1 the vehicle according to the number of axles and the axle spacing detected. PBOT uses a modified FHWA
2 Scheme F [15] to classify vehicles with bicycles included as class one and passenger cars as class two.
3 Pneumatic tubes are commonly used for short-term traffic counts. Although pneumatic tubes have a
4 general tendency to undercount bicycles, Nordback et al.[16] found that the JAMAR tubes performed
5 better than two other brands of classification counters tested and that manually computed bicycle speeds
6 were in agreeance with those reported by the JAMAR model. The Portland Bureau of Transportation has
7 been using JAMAR brand tube counters for many years and the crews are experienced regarding
8 appropriate placement of the tubes to gather counts and speeds for both motorized vehicles and bicycles.

9 The data, collected at six different sites, was sourced from available PBOT speed data collection
10 efforts and selected based on the availability of data within the context of roadways without bicycle lanes.
11 Bidirectional data was available for five of the six sites, producing a total of eleven datasets. The posted
12 speed limit at the time of collection for all sites was 25 mph (40 km/h). Grades ranged from flat to greater
13 than 4%, all positive in the eastbound direction. Table 1 describes the basic geometric and traffic
14 characteristics of each site including the percentage of class one vehicles and estimated ADT.

15 SE Harrison St and SE Lincoln St are classified by the City as local streets. Additionally, they are
16 designated as neighborhood greenways – streets with low speed limits and low volumes where bicyclists
17 are encouraged to travel. The speed limit and traffic volume on these streets can be considered within the
18 design recommendations for mixed traffic roadways. These streets are two-way, two lanes, and parallel
19 parking is permitted on both sides of the street, although it is minimally utilized along Harrison and
20 moderately utilized along Lincoln. Formerly a double yellow center lane was present along SE Harrison
21 St. However, it has been allowed to fade to a nearly imperceptible state except within roughly 40 feet (12
22 m) of a traffic control device. Lane markings along SE Lincoln St are only present near traffic control
23 devices. Sharrows (shared lane markings) are present along both SE Harrison St and SE Lincoln St.
24 Bicycle lanes are absent at all locations presented in Table 1.

25
26 **Insert Table 1 HERE**
27

28 SE Hawthorne Blvd is classified as a district collector. It is a two-way road with one lane in each
29 direction and a center turn lane. Parallel parking is also permitted on both sides of the road and is
30 frequently occupied. No sharrows are present at this location.

31 A few of the data collection sites have additional, noteworthy characteristics. All-way stop signs
32 are present at the intersection of SE Harrison and 30th and the intersection of SE Harrison and 26th. The
33 Lincoln site is situated midway between two speed humps, approximately 460 feet (140 m) apart. Figures
34 1 through 3 provide street level views of a representative site along SE Harrison, the SE Lincoln site, and
35 the SE Hawthorne site, respectively.[17-19]

36
37 **Insert Figures 1, 2, and 3 HERE**
38

39 Speed distributions of class one vehicles were inspected as part of the data cleaning process.
40 Vehicle speeds appeared to be normally distributed for all datasets. Figure 4 provides a representative
41 example of class one speed distributions, showing those from the SE Harrison west of 30th location. Mean
42 class one speeds at this location were 11.2 mph (18 km/h) and 11.9 mph (19 km/h) for the eastbound and
43 westbound directions, respectively.

44
45 **Insert Figure 4 HERE**
46

47 ANALYSIS

48 Motorized vehicles may be forced to reduce their speed before or during overtaking maneuvers
49 when approaching a slower-moving bicycle from behind. Data was selected for the following two
50 scenarios. (i) Observations of a class two vehicle (passenger car) that was preceded by a class one vehicle
51 (bicycle) and (ii) observations of a class two vehicle (passenger car) preceded by another class two

1 vehicle (passenger car) were selected for analysis from the datasets supplied. The data were selected as
2 such to test the hypothesis that bicycles provoke reduced passenger car travel speeds on roads without
3 bicycle lanes, either by friction or block interference.

4 The timestamp associated with each observation in the datasets allowed the gap time between the
5 vehicle of interest and the preceding vehicle to be calculated. An analysis of gap time versus speed was
6 performed to determine whether a correlation between them was present. A vehicle with a smaller gap
7 time may be influenced by the preceding vehicle to a greater degree than one with a larger gap time. A
8 series of plots were constructed, and linear correlation coefficients were calculated to inspect for a
9 relationship between gap time and speed. Should one such relationship exist, we might expect to see some
10 degree of positive correlation, particularly for vehicles following a bicycle. In traffic engineering and
11 speed studies a gap of four to six seconds is usually used as a threshold to determine if the leading vehicle
12 is affecting the behavior of the follower.

13 Comparisons of speed between the two vehicle configurations were made in several ways. First,
14 mean speed was calculated for each configuration of class two vehicles in each dataset, and a two-sample
15 *t*-test was performed. To further evaluate the practical implication of any difference in speed for the two
16 configurations, 50th and 85th percentile speeds with 95% confidence intervals were calculated and
17 compared.

18 Each dataset was first analyzed for a whole day (24-hour period) and was then analyzed for peak
19 hour traffic separately. A potential limitation of this study is the inability of the traffic monitoring
20 equipment (pneumatic tubes) to differentiate between motorized and non-motorized class one vehicles.
21 This limitation was regarded as irrelevant to this study due to the negligible percentage of traffic that
22 motorcycles typically comprise [20] and observed to be the case, too in Portland urban area roads.

24 RESULTS

25 24-Hour Period

26 Figure 5 presents the speed-gap plots generated for the SE Harrison west of 23rd westbound
27 dataset and their associated *r*-values noted as a typical example for all sites. With *r*-values close to zero, it
28 can clearly be seen that the disaggregated data are highly scattered, and no apparent relationship exists
29 between gap time and vehicle speed for either vehicle configuration. This finding was consistent
30 throughout all of the datasets analyzed where linear correlation coefficients were low and not significant.
31 A subsequent analysis limited to observations with a gap time of 10s or less presented comparable results.
32 Figure 6 displays the speed-gap plots of the westbound SE Harrison west of 23rd dataset when limited to a
33 10s gap time.

34
35 **Insert Figures 5 and 6 HERE**
36
37

38 The results of the *t*-tests can be seen in Table 2, along with the mean class one speeds for
39 reference. The null hypothesis is defined as scenarios (i) and (ii) having equal mean speeds. The null is
40 rejected when there is a statistically significant difference between the mean speeds. If the difference is
41 not statistically significant, we fail to reject the null. Five of the eleven datasets show a statistically
42 significant difference at the $p = 0.05$ level, rejecting the null hypothesis.

43 Figure 7 displays the empirical speed distributions and mean speeds for the westbound SE
44 Harrison east of 27th dataset and the eastbound SE Harrison west of 23rd dataset. These empirical
45 distributions also provide a visual of the level of compliance to the posted speed limit. At the westbound
46 SE Harrison east of 27th location, the proportion of observations exceeding the posted speed limit was
47 24.9% and 31.48% for scenarios (i) and (ii), respectively. At the eastbound SE Harrison west of 23rd
48 location, 24.0% and 17.45% of observations exceeded the speed limit for scenarios (i) and (ii),
49 respectively.

1 **Insert Table 2 HERE**

2
3
4 **Insert Figure 7 HERE**

5
6
7 Table 3 presents the results of the calculated 95% confidence intervals for the 50th percentile
8 speeds. Only one dataset, the westbound direction at SE Harrison east of 27th, shows non-overlapping
9 confidence intervals for the 50th percentile speeds. Apart from this dataset, a high degree of overlap is
10 observed. It can be observed that the intervals may differ by approximately one mile per hour (1.6 km/h)
11 or less for all locations where sharrows are present. A broader confidence interval is given for scenario (i)
12 at the SE Hawthorne location, yet the confidence interval for scenario (ii) remains within these bounds.

13
14 **Insert Table 3 HERE**

15
16
17 Table 4 gives the results for the 85th percentile speed confidence intervals. As with those of the
18 50th percentile speeds, the confidence intervals for the two vehicle configurations here correspond well
19 with each other, reinforcing the previous findings of this analysis. The SE Hawthorne east of 44th dataset
20 displays the greatest amount of discrepancy between the two vehicle configurations for the 85th percentile
21 speed confidence intervals while the westbound SE Harrison west of 30th dataset are nearly identical. The
22 empirical distributions and 85th percentile speeds for these datasets are plotted in Figure 8. Notice the high
23 percentage of observations in excess of the posted speed limit for both scenarios (i) and (ii) at the SE
24 Hawthorne location (50.0% and 68.88%, respectively) compared to the westbound SE Harrison west of
25 30th location of 19.0% for scenario (i) and 19.8% for scenario (ii).

26
27 **Insert Table 4 HERE**

28
29 **Insert Figure 8 HERE**

30
31
32
33 **Peak-Hour Period**

34 To address concerns that changes in passenger car speeds due to bicycles may only occur during
35 peak traffic hours when the volume is highest, a separate analysis was performed. The traffic volume
36 distribution by the time of day indicated the morning peak hours to be 7:30 am to 9:30 am and the
37 evening peak hours to be 4:30 pm to 6:30 pm. Due to an insufficient number of data points, the SE
38 Hawthorne east of 44th location was not evaluated for peak hours.

39 The speed-gap time analysis was performed again for peak hours. The resulting range of linear
40 correlation coefficients was similar to that of the 24-hour period traffic with low and insignificant
41 coefficients of correlation. This outcome seems to verify the absence of a relationship between gap time
42 and vehicle speed in the data presented here.

43 The *t*-tests between mean speeds for peak hour traffic (Table 5) revealed only one dataset,
44 westbound SE Harrison west of 30th, that rejected the null hypothesis with a statistically significant result
45 ($p = 0.034$). The difference in mean speeds was calculated to be less than one mile per hour (1.6 km/h).
46 Interestingly, this dataset was also one of the five in which the null hypothesis was rejected when the 24-
47 hour period was analyzed.

48
49 **Insert Table 5 HERE**

1
2 The evaluation of the 95% confidence intervals for the 50th and 85th percentile speeds continued
3 to be consistent with the previous analyses. No non-overlapping intervals were observed for either
4 percentile. Table 6 and Table 7 display the confidence intervals of 50th and 85th percentile speeds,
5 respectively. From these tables it can be seen that the confidence intervals for the westbound SE Harrison
6 west of 30th dataset are quite similar when comparing the two vehicle configurations. The 50th percentile
7 confidence intervals in mph were (22.09, 23.55) and (22.96, 23.93); the 85th percentile confidence
8 intervals were (25.30, 26.70) and (25.51, 27.13). The largest discrepancy between confidence intervals for
9 the 50th percentile speeds was found with the eastbound SE Harrison west of 23rd dataset. For the 85th
10 percentile speeds, the westbound SE Lincoln east of 48th dataset produced the biggest difference. In both
11 cases, the confidence intervals had a high degree of accord and differences in bounds were less than
12 two miles per hour (3.2 km/h).

13
14 **Insert Table 6 HERE**

15
16
17
18 **Insert Table 7 HERE**

19
20
21 **DISCUSSION**

22 When considered in whole, the results of the *t*-tests and 95% confidence intervals indicate that
23 bicycles are not likely to lead to reduced passenger car travel speed, despite their differences in
24 performance capabilities and the absence of bicycle lanes. In most cases, the differences in speed were not
25 significant from a practical standpoint. However, this study did find a few instances where differences
26 were seen.

27 For the analysis including all 24 hours, the most apparent exception occurred with the SE
28 Harrison east of 27th westbound dataset where the mean speeds between the two class two vehicle
29 configurations were highly statistically different, i.e. the null hypothesis was rejected, with $p = 6.0 \text{ E-}05$,
30 and the 95% confidence intervals for the 50th percentile speeds were non-overlapping. At this location,
31 traffic travels downhill at a grade greater than 4% in the westbound direction which might encourage
32 bicycles to travel at a higher speed, thereby lowering the desire of a motor vehicle to overtake
33 immediately and instead be satisfied traveling temporarily at a slightly reduced speed. Additionally, it is
34 possible that the presence of the all-way stop at 26th influences passing behavior with motor vehicles
35 preferring to delay overtaking a bicycle until after they clear the traffic control device. While the results
36 of the analysis did find a statistically significant difference in speed at this location, the difference is
37 relatively small – a 5.3% and 6.6% reduction, or 1.27 mph (2.04 km/h) and 1.58 mph (2.54 km/h) – for
38 mean and 50th percentile speeds, respectively. Moreover, the 95% confidence intervals for the 85th
39 percentile speeds do not illustrate a distinguishable difference. The peak hour analysis provided additional
40 evidence that bicycles do not cause lower passenger car speeds at this location, as confirmed by the *t*-test
41 results, which failed to reject the null hypothesis ($p = 0.407$).

42 The null hypothesis was rejected for both the eastbound and westbound directions at SE Harrison
43 west of 30th and the westbound direction at SE Lincoln east of 48th, showing statistically significant
44 differences when the *t*-test was applied in the 24-hour analysis ($p = 0.0026$, $p = 0.047$, and $p = 0.027$,
45 respectively). Nevertheless, the 95% confidence intervals calculated for the 50th and 85th percentile speeds
46 at these locations did not indicate a relevant difference in speed. The difference in mean speed at these
47 sites was limited to roughly 0.5 mph (0.8 km/h). For peak hours, only the westbound SE Harrison west of
48 30th dataset produced a rejection of the null hypothesis, displaying a statistically significant difference in
49 mean speeds equating to less than one mile per hour (1.6 km/h). The all-way stop at 30th and the double
50 yellow line just west of it may discourage the passing behavior of eastbound traffic on Harrison in a
51 similar manner as described above, leading to the nominal speed difference when all hours are

1 considered. Westbound traffic at this location may also be influenced by the double yellow line, inhibiting
2 passing behavior. The minor difference observed at the SE Lincoln location could be attributed to the
3 higher occupancy rate of street parking, effectively decreasing the space available for motor vehicles to
4 safely pass bicycles. It bears reiterating that apart from one dataset, we fail to reject the null hypothesis as
5 no significant differences in speeds were found for peak hour traffic.

6 The *t*-test for the SE Hawthorne east of 44th dataset did reject the null hypothesis ($p = 0.015$), and
7 a difference in mean speeds of approximately 3 mph (4.8 km/h) was observed between scenarios (i) and
8 (ii). Similar differences were seen for the 50th and 85th percentile speeds at this location, although the
9 confidence intervals were found to overlap. SE Hawthorne carries a district collector classification
10 whereas all other locations are lower classed local streets. Traffic volume along SE Hawthorne is well in
11 excess of even the most generous design guidelines for shared roads and motor vehicle operating speeds
12 are above the recommended target of 20-25 mph (32-40 km/h). Combined with the high occupancy of
13 street parking which removes effective width for passing, these characteristics likely contributed to the
14 small differences observed between scenarios (i) and (ii).

15 On Harrison and Lincoln, the road width, low to moderate parking occupancy, and lack of a
16 center lane delineator likely all contribute to the ability of passenger cars to maintain their speed. The low
17 traffic volume provides adequate opportunity for passing, and the speed limit of 25 mph (40 km/h) helps
18 to mitigate the amount a motor vehicle needs to slow down when approaching or overtaking a bicycle.
19 Although minor differences in speeds were found at a few locations where sharrows were present, the
20 magnitude of the difference was smaller than at the SE Hawthorne location where sharrows are absent. It
21 is likely that the higher speed difference and higher levels of motorized traffic (see Table 1) make SE
22 Hawthorne a more stressful roadway for cyclists [21] and this in turn contributes to explain the lower
23 bicycle volumes on SE Hawthorne.

24 Finally, although concerns have been voiced that increased bicycle volume on shared roads could
25 lead to significantly reduced motor vehicle speeds, the results of this study failed to show a positive
26 correlation between the magnitude of difference in mean speeds between the two scenarios and the
27 percent of traffic comprised of class one vehicles.

28 **CONCLUSIONS**

29 Speed distributions, the mean, and the 50th and 85th percentile speeds for two scenarios were
30 examined: (i) a passenger car that was preceded by a bicycle and (ii) a passenger car that was preceded by
31 another passenger car. Peak hour traffic and 24-hour traffic speeds were analyzed.

32 This paper has presented evidence from urban roads without bicycle lanes in Portland, indicating
33 that bicycles do not reduce passenger car speeds by more than one mile per hour (1.6 km/h) at most
34 locations. This finding was reinforced by the results of the 95% confidence intervals for the 50th and 85th
35 percentile speeds and the separate analysis performed for peak hours. While the results of the analysis did
36 find five of the eleven datasets to have statistically significant differences in mean speed, rejecting the
37 null hypothesis when all hours were analyzed, this result is in part due to a large number of observations
38 since the actual speed differences are trivial in a practical sense. Higher speed differences, in the order of
39 two to three miles per hour (3.2-4.8 km/h), were found only at locations that do not meet the guidelines
40 for a shared road.

41 Due to the limited variability in roadway characteristics of the sites analyzed, the conclusions
42 drawn may not be directly transferable to all roadways without bicycle lanes. Nonetheless, the results
43 presented here deliver encouragement for incorporating shared roads into urban bicycle networks to
44 support an increasing bicycle mode share without negatively impacting travel speed or creating
45 congestion, provided that cities ensure these shared roads follow recommended bikeway guidelines.

46 Future work should include roadways with a wider variety of vehicle classifications and roadway
47 characteristics such as ADT, grade, and pavement markings to evaluate the consistency of the findings
48 presented here and to further investigate the effects the roadway environment and traffic composition may
49 have on vehicle-bicycle interactions and resulting travel speed.

1 **ACKNOWLEDGMENTS**

2 The authors would like to acknowledge Tom Jensen and Scott Batson of PBOT for providing the data
3 used in this analysis.

4

5 **AUTHOR CONTRIBUTIONS**

6 The authors confirm contribution to the paper as follows: study conception and design: MAF, AU; data
7 collection: PBOT; analysis and interpretation of results: JSS, MAF, AU; draft manuscript preparation:
8 JSS, MAF, AU. All authors reviewed the results and approved the final version of the manuscript.

9

1 **TABLE 1 Characteristics of the Data Collection Sites**

Location	Road Markings	Grade %	Road Width (ft.)	ADT		% Class 1	
				EB	WB	EB	WB
SE Harrison W of 23 rd	Sharrow	4.1	35.5	663	1084	67	46
SE Harrison W of 26 th	Sharrow*	4.0	35.5	553	923	22	34
SE Harrison E of 27 th	Sharrow	4.3	35.5	1249	1462	17	24
SE Harrison W of 30 th	Sharrow*	1.6	35.5	1594	1450	31	34
SE Lincoln E of 48 th	Sharrow	1.4	34	642	719	6	13
SE Hawthorne E of 44 th	Center left-hand turn lane	0	51 with 12 ft. center lane	na	6568	na	2

2 Note: EB = eastbound, WB = westbound, na = not applicable.
 3 *Double yellow lines at these sites are only placed within 40 ft. of a traffic control device.
 4

5 **TABLE 2 t-Test between Mean Speeds**

Location		N		Mean (mph)			t-Statistic	p-Value
		Following Class 1	Following Class 2	Class 1	Following Class 1	Following Class 2		
Harrison W of 23 rd	EB	146	149	9.91	21.77	21.95	-0.34	0.731
	WB	462	379	22.10	24.54	24.88	-1.16	0.246
Harrison W of 26 th	EB	220	471	14.30	21.22	21.39	-0.46	0.648
	WB	350	767	20.30	21.95	21.86	0.32	0.753
Harrison E of 27 th	EB	148	591	9.67	22.95	23.32	-0.95	0.341
	WB	181	629	16.30	22.66	23.93	-4.07	6.0 E-05*
Harrison W of 30 th	EB	496	1108	11.20	22.45	23.06	-3.02	2.6 E-03*
	WB	479	980	11.90	22.58	22.99	-1.99	0.047*
Lincoln E of 48 th	EB	323	2720	22.0	22.24	22.05	0.68	0.495
	WB	286	2895	18.70	21.93	22.50	-2.21	0.027*
Hawthorne E of 44 th	WB	28	9041	10.70	24.21	27.48	-2.59	0.015*

6 Note: N = number of observations.
 7 * >95% significance.
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1 **TABLE 3 50th Percentile Speeds and 95% Confidence Intervals (in mph)**

Location		Following Class 1		Following Class2	
		50 th Percentile	CI	50 th Percentile	CI
SE Harrison W of 23 rd	EB	21.72	(20.79, 22.61)	21.53	(21.08, 22.49)
	WB	24.56	(23.91, 25.09)	24.93	(24.55, 25.57)
SE Harrison W of 26 th	EB	21.79	(21.05, 22.46)	21.85	(21.26, 22.26)
	WB	22.68	(21.96, 23.08)	22.36	(22.10, 22.63)
SE Harrison E of 27 th	EB	23.10	(22.10, 24.07)	23.50	(22.90, 23.78)
	WB	22.44	(22.17, 23.07)*	24.02	(23.80, 24.33)*
SE Harrison W of 30 th	EB	22.90	(22.53, 23.38)	23.27	(23.08, 23.57)
	WB	22.76	(22.49, 23.21)	23.24	(22.99, 23.46)
SE Lincoln E of 48 th	EB	22.50	(21.93, 23.43)	22.30	(22.10, 22.50)
	WB	21.88	(21.21, 22.66)	22.71	(22.57, 22.90)
SE Hawthorne E of 44 th	WB	24.84	(21.98, 28.45)	28.06	(27.93, 28.16)

2 Note: CI = confidence interval.
 3 * Non-overlapping confidence intervals.
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5 **TABLE 4 85th Percentile Speeds and 95% Confidence Intervals (in mph)**

Location		Following Class 1		Following Class2	
		85 th Percentile	CI	85 th Percentile	CI
SE Harrison W of 23 rd	EB	27.25	(26.05, 28.72)	25.96	(25.25, 27.94)
	WB	29.03	(28.48, 29.41)	29.07	(28.62, 29.82)
SE Harrison W of 26 th	EB	25.98	(25.32, 26.68)	25.60	(25.07, 26.09)
	WB	26.39	(25.99, 27.10)	26.13	(25.54, 26.49)
SE Harrison E of 27 th	EB	27.44	(26.60, 28.14)	27.43	(27.00, 28.07)
	WB	26.41	(25.95, 27.94)	27.27	(26.88, 27.74)
SE Harrison W of 30 th	EB	26.00	(25.59, 26.50)	26.26	(26.03, 26.63)
	WB	26.07	(25.58, 26.43)	26.04	(25.78, 26.44)
SE Lincoln E of 48 th	EB	26.93	(26.28, 27.57)	26.27	(26.11, 26.50)
	WB	26.24	(25.36, 27.15)	26.46	(26.29, 26.61)
SE Hawthorne E of 44 th	WB	30.60	(29.34, 35.50)	32.69	(32.53, 32.82)

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8 **TABLE 5 *t*-Test between Mean Speeds for Peak Hours**

Location		N		Mean (mph)		<i>t</i> -Statistic	<i>p</i> -Value
		Following Class 1	Following Class 2	Following Class 1	Following Class 2		
Harrison W of 23rd	EB	48	28	20.69	21.36	-0.64	0.525
	WB	179	73	24.46	25.01	-1.01	0.316
	EB	91	118	21.20	21.45	-0.41	0.686

Harrison W of 26th	WB	131	195	22.06	22.17	-0.21	0.835
Harrison E of 27th	EB	79	181	23.01	23.49	-0.89	0.377
	WB	92	199	23.16	23.56	-0.83	0.407
Harrison W of 30th	EB	203	262	22.15	22.88	-1.95	0.051
	WB	169	229	22.42	23.21	-2.13	0.034*
Lincoln E of 48th	EB	102	897	21.90	22.10	-0.40	0.687
	WB	77	937	21.49	22.18	-1.40	0.164

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3 **TABLE 6 50th Percentile Speeds and 95% Confidence Intervals for Peak Hours (in mph)**

Location		Following Class 1		Following Class2	
		50 th Percentile	CI	50 th Percentile	CI
SE Harrison W of 23 rd	EB	20.63	(19.93, 22.16)	20.59	(19.73, 24.10)
	WB	24.40	(23.56, 25.36)	25.00	(24.26, 26.25)
SE Harrison W of 26 th	EB	22.05	(20.28, 22.77)	22.10	(20.98, 22.76)
	WB	22.96	(21.63, 23.92)	23.17	(22.16, 23.72)
SE Harrison E of 27 th	EB	23.18	(22.12, 24.40)	23.40	(22.93, 24.23)
	WB	23.41	(22.05, 24.27)	23.84	(23.40, 24.21)
SE Harrison W of 30 th	EB	22.78	(22.18, 23.46)	23.31	(22.67, 23.78)
	WB	22.62	(22.09, 23.55)	23.47	(22.96, 23.93)
SE Lincoln E of 48 th	EB	22.47	(21.61, 23.67)	22.37	(22.10, 22.71)
	WB	21.11	(20.04, 22.63)	22.35	(22.01, 22.69)

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6 **TABLE 7 85th Percentile Speeds and 95% Confidence Intervals for Peak Hours (in mph)**

Location		Following Class 1		Following Class2	
		85 th Percentile	CI	85 th Percentile	CI
SE Harrison W of 23 rd	EB	25.58	(23.31, 27.89)	26.47	(24.29, 28.30)
	WB	29.21	(28.50, 30.00)	28.88	(28.18, 30.23)
SE Harrison W of 26 th	EB	25.64	(24.45, 26.83)	25.68	(25.01, 26.92)
	WB	26.88	(25.97, 28.09)	26.87	(26.32, 27.26)
SE Harrison E of 27 th	EB	26.82	(26.17, 28.98)	27.91	(26.74, 28.74)
	WB	27.31	(26.30, 28.32)	26.54	(26.07, 27.39)
SE Harrison W of 30 th	EB	25.86	(25.19, 26.52)	26.30	(25.92, 27.09)
	WB	25.97	(25.30, 26.70)	26.25	(25.51, 27.13)
SE Lincoln E of 48 th	EB	26.53	(25.61, 27.93)	26.32	(26.00, 26.89)
	WB	25.95	(24.45, 27.62)	26.32	(25.87, 26.67)

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Figure 1 SE Harrison west of 30th, looking east (left) and west (right).[17]

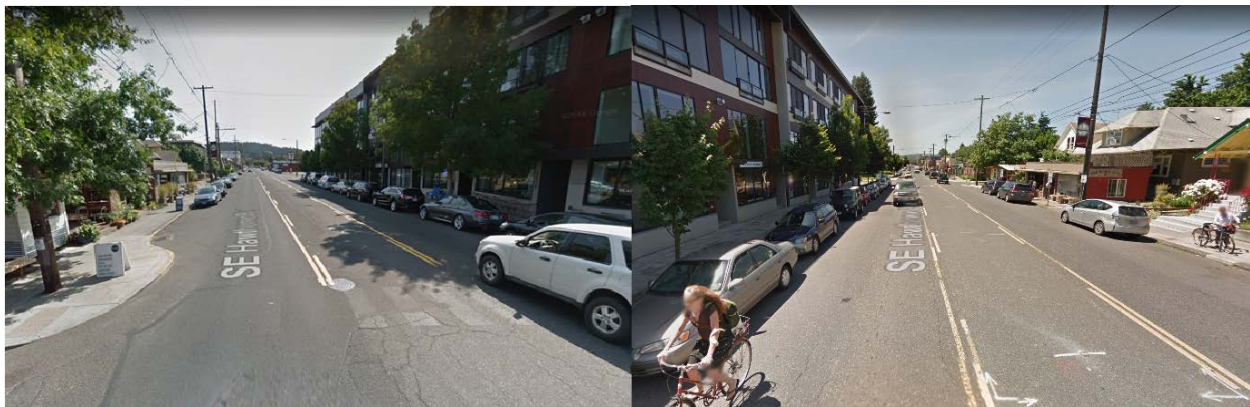
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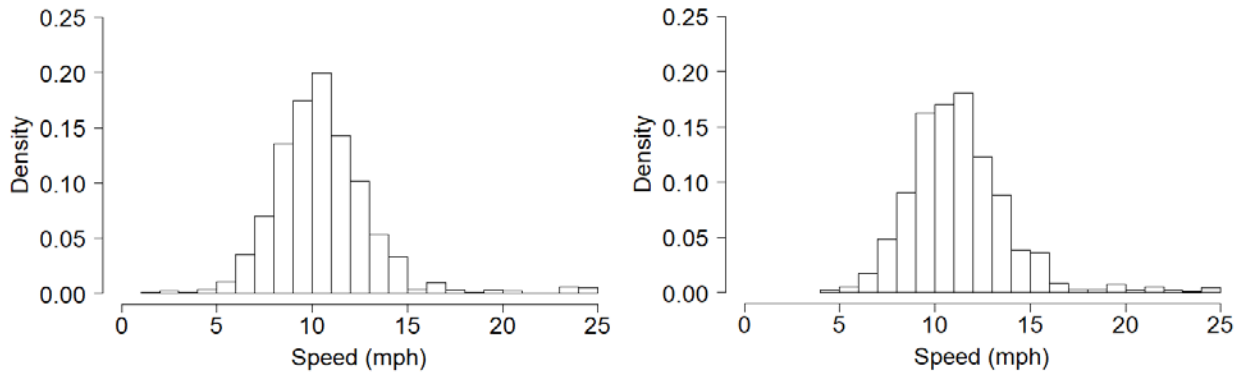
Figure 2 SE Lincoln east of 48th, looking east (left) and west (right).[18]

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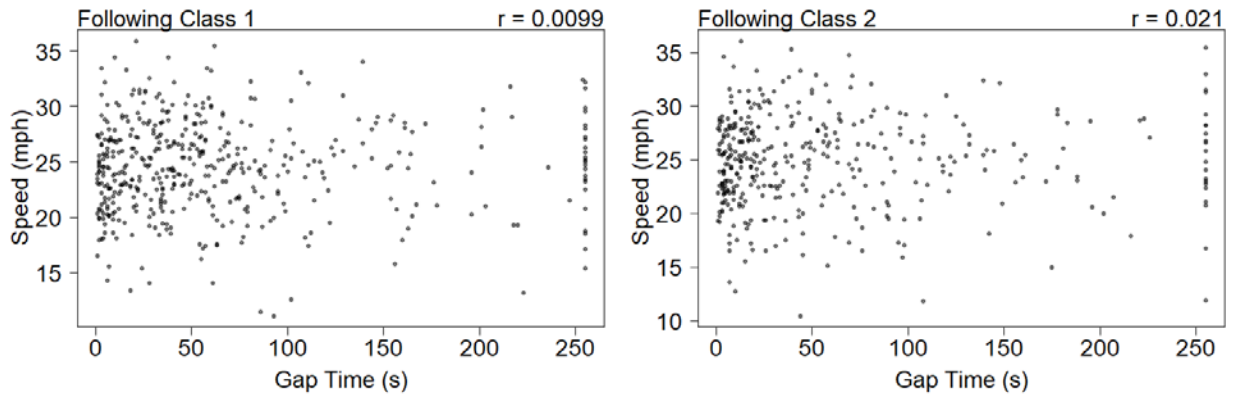
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Figure 3 SE Hawthorne east of 44th, looking east (left) and west (right).[19]



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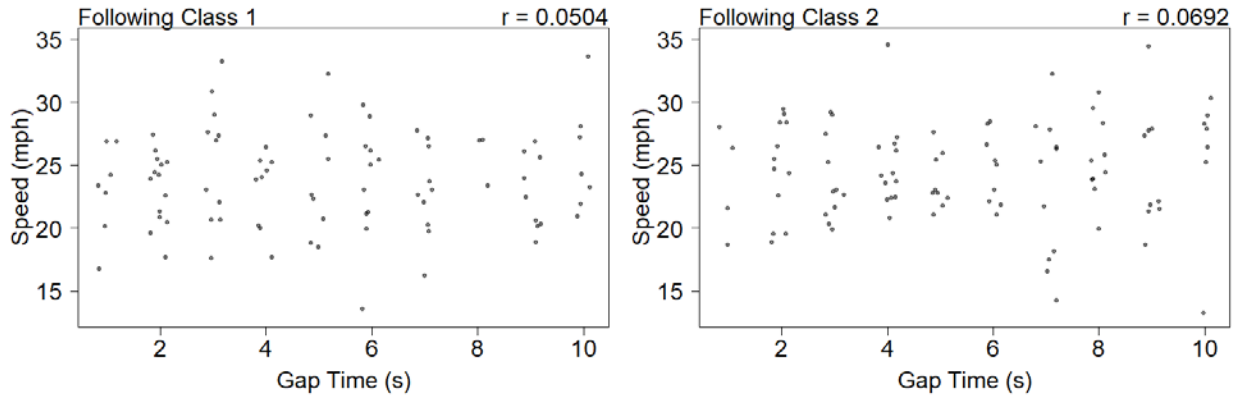
Figure 4 Class one speed distributions for the SE Harrison west of 30th location eastbound (right) and westbound (left).



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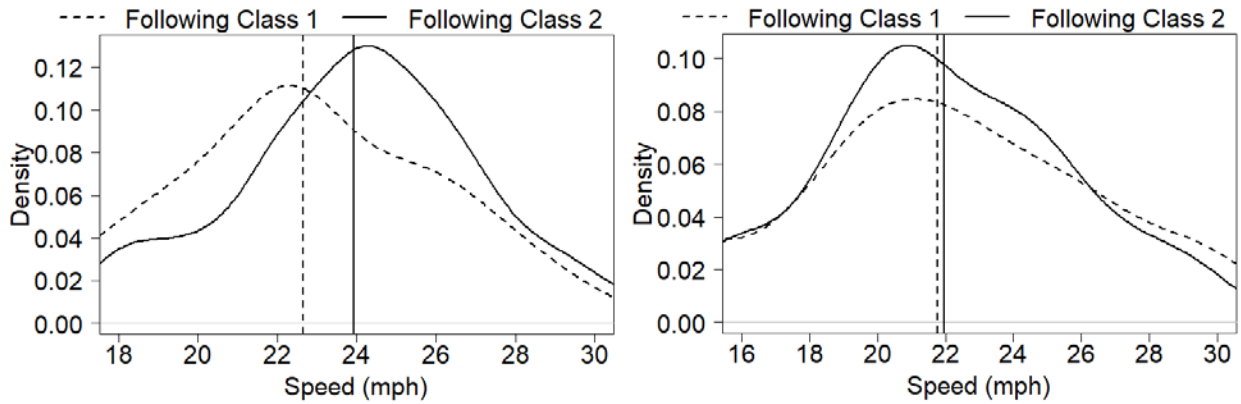
Figure 5 Gap analysis plots for SE Harrison west of 23rd, westbound. Class two following class one configuration (left) and class two following class two configuration (right).

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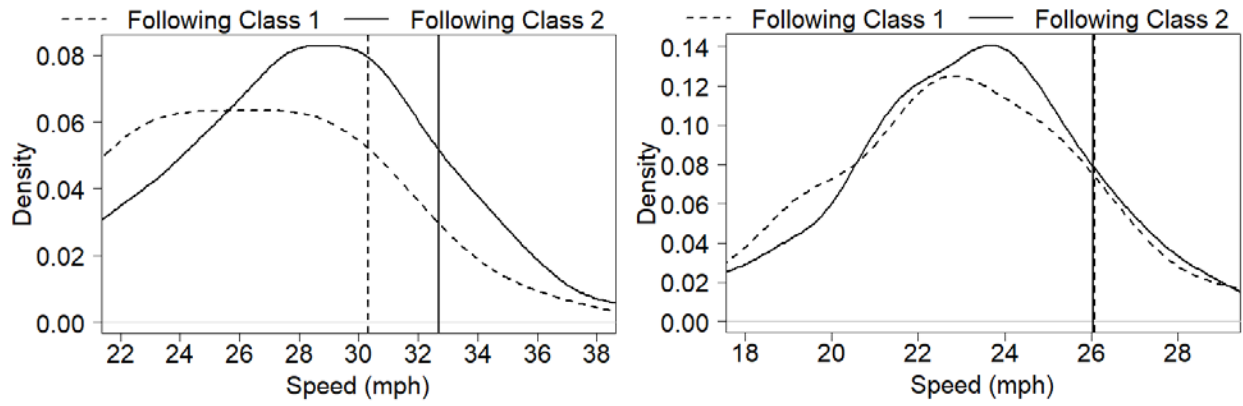
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Figure 6 Gap analysis plots for SE Harrison west of 23rd, westbound limited to observations of a 10s gap time. Class two following class one configuration (left) and class two following class two configuration (right). Notice the similar data trend as when all observations are retained.



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Figure 7 Empirical distributions with mean speeds for westbound SE Harrison east of 27th (left) and eastbound SE Harrison west of 23rd (right).



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Figure 8 Empirical distributions with the 85th percentile speeds for westbound SE Hawthorne east of 44th (left) and westbound SE Harrison west of 30th (right).

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