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# Effect of Narrower Lane Width on Traffic Operations for Urban Midblock Segments

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# Effect of Narrower Lane Width on Traffic Operations for Urban Midblock Segments

## **Abstract**

The narrower lane width would reduce travel speed on high speed roadways, but for urban streets, the past studies have been inconclusive in establishing consistent relationship between lane width and vehicle speed. This paper presents an analysis of the effects of narrower lane width on travel speed and vehicle lane violation for urban midblock segments between signalized intersections. Data collected from 14 midblock segments in Nebraska were used for analysis. General regression techniques were used for modeling. The study found that 10 ft lane width is associated with higher travel speed on midblock segments with a speed limit of 25 mph or 35 mph. For speed limits of 40 mph and 45 mph, the 10 ft lane width appeared to reduce the travel speeds, which might be used for traffic calming. The midblock segments with 11 ft lane width would have higher travel speed compared to those with 12 ft lane width, but the differences in reducing lane violation in terms of encroachments on adjacent lanes are not significant. The 9 ft and 10 ft lanes were associated with a high rate of lane violation on midblock segments with speed limits of 25 mph and 35 mph. The effects of narrower lane width on travel speeds and vehicle lane violation have a wide viability across study data sets.

## **Keywords**

lane width, narrower lane, speed, midblock segment, lane violation

## **Disciplines**

Civil Engineering | Transportation Engineering

## **Comments**

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1 **Title: Effect of Narrower Lane Width on Traffic Operations for Urban Midblock Segments**

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39

40

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42

1 **ABSTRACT**

2 The narrower lane width would reduce travel speed on high speed roadways, but for urban  
3 streets, the past studies have been inconclusive in establishing consistent relationship between  
4 lane width and vehicle speed. This paper presents an analysis of the effects of narrower lane  
5 width on travel speed and vehicle lane violation for urban midblock segments between signalized  
6 intersections. Data collected from 14 midblock segments in Nebraska were used for analysis.  
7 General regression techniques were used for modeling. The study found that 10 ft lane width is  
8 associated with higher travel speed on midblock segments with a speed limit of 25 mph or 35  
9 mph. For speed limits of 40 mph and 45 mph, the 10 ft lane width appeared to reduce the travel  
10 speeds, which might be used for traffic calming. The midblock segments with 11 ft lane width  
11 would have higher travel speed compared to those with 12 ft lane width, but the differences in  
12 reducing lane violation in terms of encroachments on adjacent lanes are not significant. The 9 ft  
13 and 10 ft lanes were associated with a high rate of lane violation on midblock segments with  
14 speed limits of 25 mph and 35 mph. The effects of narrower lane width on travel speeds and  
15 vehicle lane violation have a wide viability across study data sets.

16

17 *Keywords:* lane width, narrower lane, speed, midblock segment, lane violation.

18

19

20

21 07/19/2017: complement

22

23 1) Use the linear mixed effects model for travel speed. More discussions on the results. How  
24 many travel time would be saved or wasted under the narrow lane width?

25

26 2) Use the Beta regression model for violation rates by hour

27

28 3) Add a new part discussing the relationship between travel speed and violations rate. May add  
29 the travel speeds as a covariate of violation rate analysis.

30

31

32 4) Bivariate analysis???? Not sure what is a good model.

33

34

35 5) More discussions or figures on some special segments. Finally, increase the total words to  
36 around 7000 not including figures or tables.

## 1 INTRODUCTION

2 Complete Streets is a transportation policy that requires streets to be safe, convenient, and  
 3 comfortable for all street users, regardless of transportation mode. With the recent trend in  
 4 designing according to Complete Streets, the demand for using narrower lane widths instead of  
 5 the 12 ft standard lane has increased significantly. Standard lane widths often accommodate  
 6 parking, bike lanes, sidewalks, drainage, and utilities on the existing right of way. The using of  
 7 reduced lane widths is more evident in urban areas where the right of way constraints often limit  
 8 the desired roadway design. In 2013, a survey to five states (Wyoming, Missouri, California,  
 9 Kansas, and Iowa) regarding the lane width policy for urban areas found that the right of way  
 10 constraints are the key reason for the implementation of narrower lane widths in the agencies'  
 11 roadway design (1). An early study in 1990 found the most common reasons of using narrower  
 12 lanes are provision of additional through lanes and addition of a two-way left turn lane during a  
 13 survey to 50 state highway agencies and 150 local agencies (2). However, narrower lane widths  
 14 possibly increase the risk of crash and may also have adverse traffic operational impact. The  
 15 nationwide guide to the implementation of narrower lane widths is limited due to inconsistent  
 16 evidences on the safety and operational effects. The AASHTO's *A Policy on the Geometric*  
 17 *Design of Highways and Streets* (6th Edition), commonly known as the Green Book,  
 18 recommends lanes 10–12 ft wide for urban and suburban arterials (3). It states that 10 ft lanes  
 19 should generally be used on roadways that have little or no truck traffic, and recommends 11 ft  
 20 lanes for urban Arterials and 12 ft lanes for higher speed, free-flowing principal arterials.  
 21 Additionally, lanes 10–12 ft wide are recommended for urban collectors. The *Mitigation*  
 22 *Strategies for Design Exceptions* by FHWA (4) suggests that narrowing lane widths may be used  
 23 as a method to reduce speed while also shortening crossing distances for pedestrians and  
 24 incorporating other cross-sectional elements, such as medians for access control, bike lanes, on-  
 25 street parking, transit stops, low-speed environments, etc. The National Association of City  
 26 Transportation Officials (NACTO) recommends that the normal lane width for urban street  
 27 should be 10 ft with 11 ft possibly used in curb lanes on streets with heavy bus traffic (5).

28  
 29 According to the Highway Capacity Manual (6), the lane widths of less than 12 ft can reduce  
 30 travel speeds on high-speed roadways and these negative effects increased with the decrease of  
 31 shoulder width. The effects of lane width on traffic operation for high speed roadway (55 mph or  
 32 higher) have been well studied in literature, however, the relationships between lane width and  
 33 operational performance measures that hold for high speed roadways (especially rural highways)  
 34 may not hold for urban and suburban arterials with speeds 45 mph or less. There are many  
 35 factors influencing driver's speed choice in urban areas, including lane width, roadside  
 36 environment, traffic control devices and many others. These influencing factors may have  
 37 interactive impacts, which makes it difficult to identify the effect of lane width independently of  
 38 other factors.

39  
 40 In past studies, the relationships between lane width and changes in safety operational are often  
 41 quantified using before-after study and/or analysis of multiple road segments of varying lane  
 42 widths. An early study in 1983 found narrower lane widths decreased travel speed on four-lane  
 43 undivided urban roadways. One foot decrease in lane width would reduce travel speed by 0.6  
 44 mph (7). The National Cooperative Highway Research Program (NCHRP) Report 330,  
 45 "*Effective Utilization of Street Width on Urban Arterials*," studied the operational and safety  
 46 effects of lane widths from 9 ft to 14 ft in urban areas and found more than 67% highway

1 agencies that implemented narrower lane widths did not report any adverse effect on traffic  
2 operation at the study time of 1990 (2). This report states the narrower lane widths of less than  
3 11 ft “can be used effectively in urban arterial street improvement projects where the additional  
4 space provided can be used to relieve traffic congestion or address specific accident patterns.” A  
5 literature review on the effects of roadway design on driving speed conducted in 1997 found the  
6 narrower lane widths improved lane keeping and reduce travel speed (8). Fitzpatrick et al. (9)  
7 found lane width is a significant variable to explain the speed variability for straight road  
8 sections on suburban arterials when the analyses were performed without using posted speed  
9 limit. When lane widths are 1 m (3.3 ft) greater, speeds are predicted to be 15 km/h (9.4 mph)  
10 faster. In NCHRP Report 504, “*Design Speed, Operating Speed, and Posted Speed Practices*”  
11 (10), the review of research literature found the relationship between lane width and operating  
12 speed is weak in some cases and there is a wide variability between studies site. The field study  
13 using data from 78 sites in urban, suburban and rural areas in seven cities of six states found no  
14 apparent relationship between lane width and speed. It is difficult to draw a definitive conclusion  
15 regarding the operational effect of narrower lane width from existing studies. A comprehensive  
16 literature review found no consistent conclusion on the relationship between lane width and  
17 travel speed for urban arterials. Narrower lane width might also cause erratic driving maneuvers.  
18 In a simulator based study, Green et al. found the standard deviation of vehicle lateral position  
19 significantly increase as the increase of road lane width on roads ranging from 15 ft to 24 ft (11).  
20 The past studies generally show the lane widths less than 12 ft increase the possibility of large  
21 vehicles off-tracking into adjacent lane or shoulder.  
22

23 Most of existing studies on traffic operational effects of narrower lane width in urban areas focus  
24 on the capacity and delay at signalized intersections. This paper aims to examine the effects of  
25 narrower lane width on traffic operation in terms of vehicles speed and lane violation for  
26 midblock segments between signalized intersections in urban areas. Using data collected from 14  
27 midblock segments in Nebraska, this paper investigates how the narrower lane widths affect  
28 speed variability and the impact of other influencing factors such as the presence of shoulder and  
29 median. The 12 ft lane width is used as a baseline to evaluate the effort of narrower lane widths.  
30 The lane violations in terms of encroachments on adjacent lanes on midblock segments with  
31 different lane widths is also analyzed.  
32

### 33 **DATA COLLECTION**

34 Traffic operation related data including traffic volume, speed, vehicle classification and lane  
35 violation data were collected from 14 midblock segments in Lincoln, Nebraska. These 14  
36 midblock segments were randomly selected from a list of segments prepared by a research  
37 project for Nebraska Department of Roads that investigated the effects of lane width on urban  
38 roadway safety. From the view of road functional classification, these midblock segments are  
39 located on urban principal (4 sites), minor (5 sites) and collector (5 sites) arterials. The posted  
40 speed limits of these midblock segments are 25 mph (4 sites), 35 mph (4 sites), 40 mph (3 sites)  
41 and 45 mph (3 sites), while the lane widths range from 9 ft to 12 ft. All the 25 mph midblock  
42 segments are located in downtown area. Each midblock segment represents a combination of  
43 posted speed limit and lane width. In this paper, a midblock segment refers to the roadway  
44 section bounded by two consecutive signalized intersections. To minimize the effect caused by  
45 signalized intersections, the midblock segment does not include the portions within 200 ft from  
46 the stop bars of downstream/upstream intersections. Only the lane groups in the interested traffic

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1 direction is included in the study. Each midblock segment is homogenous with respect to traffic  
 2 volume, number of through lanes, median type, left-turn treatment, and presence of on-street  
 3 parking. The shoulder width and median type for the 14 midblock segments were also recorded.  
 4 Shoulder was measured by the distance between the painted edge of outside travel lane and the  
 5 curb line. For the segments with shoulder, the shoulder width is either 1.3 ft or 2 ft. No on-street  
 6 parking was available at the 14 midblock segments.

7  
 8 The vehicle speeds and lane violation data were collected on each midblock segment during a  
 9 two-hour nonpeak traffic period (1:00 pm to 3:00 pm) and a two-hour peak traffic period (3:30  
 10 pm to 5:30 pm) during mild weather. A Wavetronix HD Sensor (12) was used to record vehicle  
 11 speeds and vehicle counts. A Contour HD camera was used to record videos for observing  
 12 vehicle lane violations. Figure 1 shows the equipment setup for data collection. A total of 34,294  
 13 speed observations were recorded. In this paper, the lane violation is defined as an instance that  
 14 any tire of a straight moving vehicle touches the lane marking on the midblock segment. An  
 15 example of vehicle lane violation is shown in Figure 2, where the left front tire of the vehicle is  
 16 off-tracking into adjacent lane. Any encroachments on adjacent lanes are considered lane  
 17 violation. A total of 287 vehicle lane violations were observed on the 14 midblock segments  
 18 during the study period, nearly 7% of all vehicles recorded.  
 19



20  
 21 **FIGURE 1 Data collection setup.**



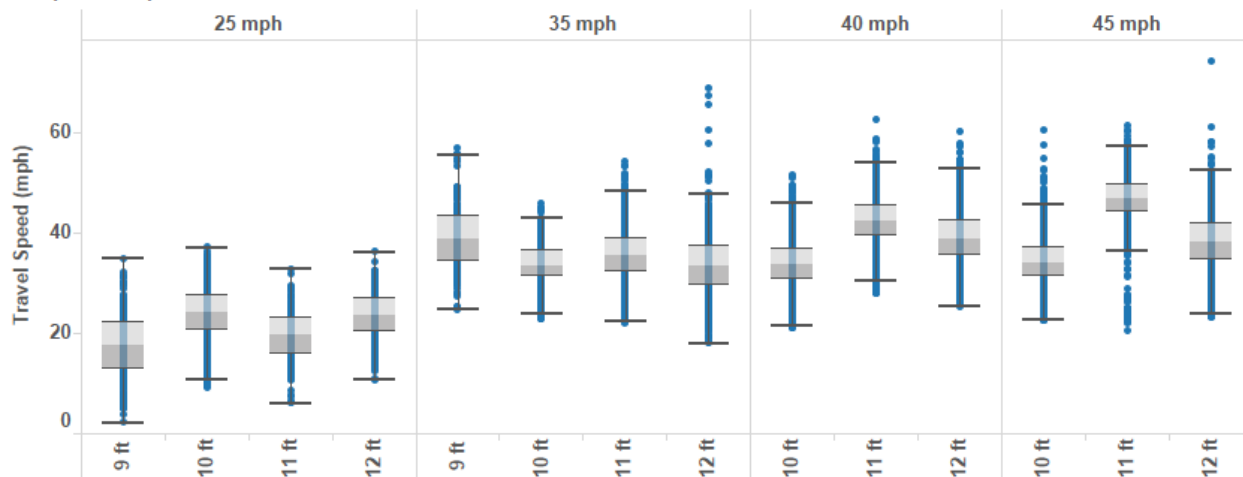
22  
 23 **FIGURE 2 Example of a lane violation.**

1 **METHOD**

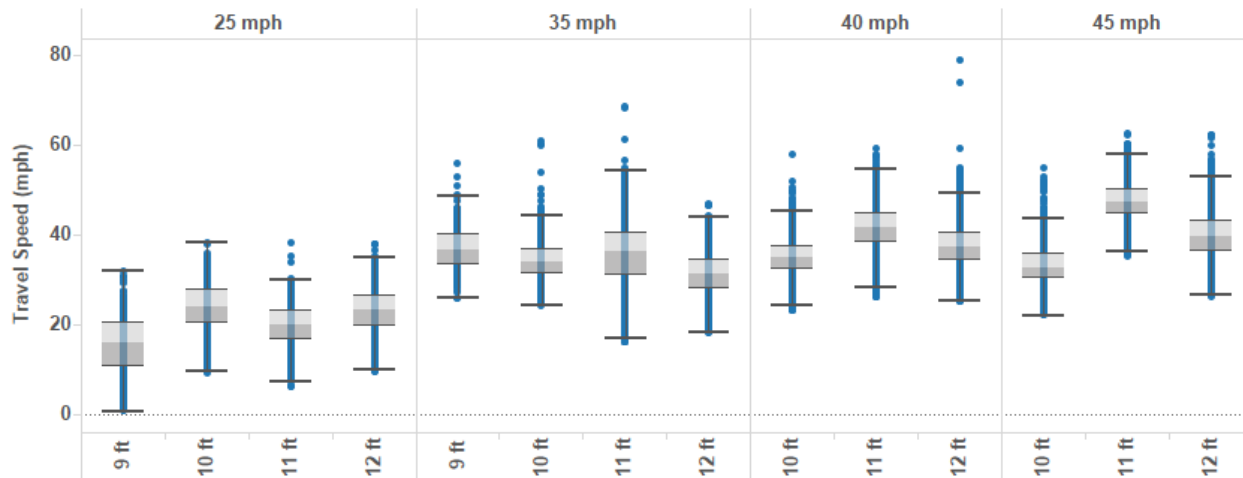
2 Before statistical modeling, boxplots were created to understand the distribution of vehicle speed  
3 data. The box plots of vehicle speeds by speed limit and lane width are shown in Figures 3 for  
4 both peak and nonpeak traffic periods. The boxplots indicate that traffic speeds did not tend to  
5 monotonically increase with the increase of lane width. The effects of narrower lane widths vary  
6 by speed zone, and within each speed zone, the trends for peak and nonpeak hours were similar.  
7 As shown in Figure 3, the 9 ft lane was not implemented in speed zones of 40 mph or higher.  
8 Since 35 mph is the most common posted speed limit in urban Nebraska and many other states,  
9 the speed limit of 35 mph and 12ft lane width was used as a baseline for comparison. Two data  
10 sets were generated to analyze the effects of narrower lane widths on travel speed:

- 11 • Group 1: midblock segments with speed limit of 35 mph or lower & lane width 9-12 ft
- 12 • Group 2: midblock segments with speed limit of 35 mph or higher & lane width 10 -12 ft

13 1:00 pm - 3:00 pm



3:30 pm - 5:30 pm



14  
15

16 **FIGURE 3 Traffic Speed Distributions by speed limit and lane width.**



1 There were 11,669 speed observations on eight midblock segments in Group 1, and Group 2  
 2 included 30, 210 speed observations on nine midblock segments. The variables used in the initial  
 3 analysis of travel speed for midblock segments are listed in Table 1.

4  
 5 General regression techniques were used to investigate how narrower lane width affects travel  
 6 speeds. Several combinations of variables were attempted. The shoulder width was replaced by a  
 7 shoulder presence indicator. This modification was based on the following facts:

- 8 • The majorities of midblock segments have no shoulder and all shoulders are 2 ft or less.
- 9 • In the *Highway Capacity Manual*, the operational effects of lane width for two-lane  
 10 highways are given by lane width and shoulder width ranges; shoulders 2ft or less are  
 11 considered having consistent effects for a given lane width (6).

12  
 13 **TABLE 1 Variables used in Analysis**

|  |  |
|--|--|
| Traffic volume<br>(vehicles per lane per hour) | Group 1: min. =90, max.= 723, Std. Dev = 223<br>Group 2: min. =118, max.= 1,263, Std. Dev = 274                                  |
| Shoulder width                                 | Group 1: 0 ft (7 sites), 2 ft (1 site)<br>Group 2: 0 ft (7 sites), 1.3 ft (1 site), 2ft (1 site)                                 |
| Median presence                                | Group 1: median presence (4 sites), no median (4 sites)<br>Group 2: median presence (8 sites), no median (1 sites)               |
| Number of through lanes                        | Group 1: 1 lane (2 sites), 2 lanes (5 sites), 3 lanes (1 site)<br>Group 2: 1 lane (1 site), 2 lanes (6 sites), 3 lanes (2 sites) |
| Posted speed limit                             | Group 1: 25 mph (4 sites), 35 mph (4 sites)<br>Group 2: 35 mph (3 sites), 40 mph (3 sites), 45 mph (3 sites)                     |

15  
 16 The indicators of posted speed limit were used in modeling and shown to be a significant  
 17 variable. Generally, the posted speed limit are set based on the 85th percentile speeds, In this  
 18 context, it may be not appropriate to use posted speed limit as a variable to analyze travel speed.  
 19 However, Fitzpatrick et al. (9) found that the findings in literature are inconclusive in  
 20 determining the causal relationship between the posted speed limit and the operating speed. Also,  
 21 their analysis using data for suburban streets in Texas shows posted speed limit is a significant  
 22 variable for explaining the speed variation on horizontal curves. In the current study, models  
 23 with and without posted speed limit indicators were both constructed and the results show adding  
 24 posted speed limit indicators did not change the statistical significances of other variables but the  
 25 adjusted  $R^2$  value increased. This indicates the significance of speed limit.

26  
 27 As many factors can influence the travel speeds on urban midblock segments, within each of the  
 28 two data sets, one possibility is that the effect of narrower lane width on travel speed is different  
 29 at different speed limit. To account for this interaction, interaction terms were added to  
 30 regression models. For Group 1, three interaction items were used: 9 ft lane width×25 mph, 10 ft  
 31 lane width×25 mph, 11 ft lane width×25 mph. Similarly, four interaction terms were added to  
 32 model for Group 2, including 10 ft lane width×40 mph speed limit, 11 ft lane width×40 mph  
 33 speed limit, 10 ft lane width×45 mph speed limit, and 11 ft lane width×45 mph speed limit.  
 34 None of these interaction terms are found to be significant. Therefore, interaction terms were not

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used in further analysis. Correlation between independent variables were checked to ensure no significant correlation would violate the model assumptions.

## RESULTS

### Travel Speed (Random effects model)

The estimated coefficients of models for the two data sets are shown in Table 2. All the variables in this table are significant at 95% confidence level.

**TABLE 2 Estimated coefficients of the model for segments**

| Variables   | Estimate | Std. Error | <i>p</i> -value |
|---|----------|------------|-----------------|
| <i>Group 1: Speed limit 25-35 mph &amp; lane width 9 – 12 ft</i>  |          |            |                 |
| 9 ft lane width<br>(1, lane width is 9 ft; 0, not)                | -5.6588  | 0.4718     | <0.0001         |
| 10 ft lane width<br>(1, lane width is 10 ft; 0, not)              | 0.8272   | 0.2247     | 0.0002          |
| 11 ft lane width<br>(1, lane width is 11 ft; 0, not)              | -3.6079  | 0.275      | <0.0001         |
| 25 mph posted speed limit<br>(1, speed limit is 25 mph; 0, not)   | -21.2446 | 0.4017     | <0.0001         |
| Shoulder indicator<br>(1, shoulder exists; 0, no shoulder)        | 7.8845   | 0.3485     | <0.0001         |
| Median indicator<br>(1, median exists; 0, no median)              | -12.1499 | 0.5495     | <0.0001         |
| Number of through lanes   | -11.1873 | 0.4435     | <0.0001         |
| Volume (vehicles per lane per hour)                               | -0.0021  | 0.0009     | 0.02            |
| Constant  | 41.4680  | 0.9566     | <0.0001         |
| <i>Group 2: Speed limit 35-45 mph &amp; lane width 10 – 12 ft</i> |          |            |                 |
| 10 ft lane width<br>(1, lane width is 10 ft; 0, not)              | -5.2409  | 0.2264     | <0.0001         |
| 11 ft lane width<br>(1, lane width is 11 ft; 0, not)              | 5.6177   | 0.1229     | <0.0001         |
| 40 mph posted speed limit<br>(1, speed limit is 40 mph; 0, not)   | 4.2821   | 0.0981     | <0.0001         |
| 45 mph posted speed limit<br>(1, speed limit is 45 mph; 0, not)   | 9.4513   | 0.1545     | <0.0001         |
| Shoulder indicator<br>(1, shoulder exists; 0, no shoulder)        | -3.8572  | 0.1064     | <0.0001         |
| Median indicator<br>(1, median exists; 0, no median)              | -1.5599  | 0.1539     | <0.0001         |
| Number of through lanes   | 7.2407   | 0.2521     | <0.0001         |
| Volume (vehicles per lane per hour)                               | 0.0059   | 0.0003     | 0.02            |
| Constant  | 16.7425  | 0.6194     | <0.0001         |

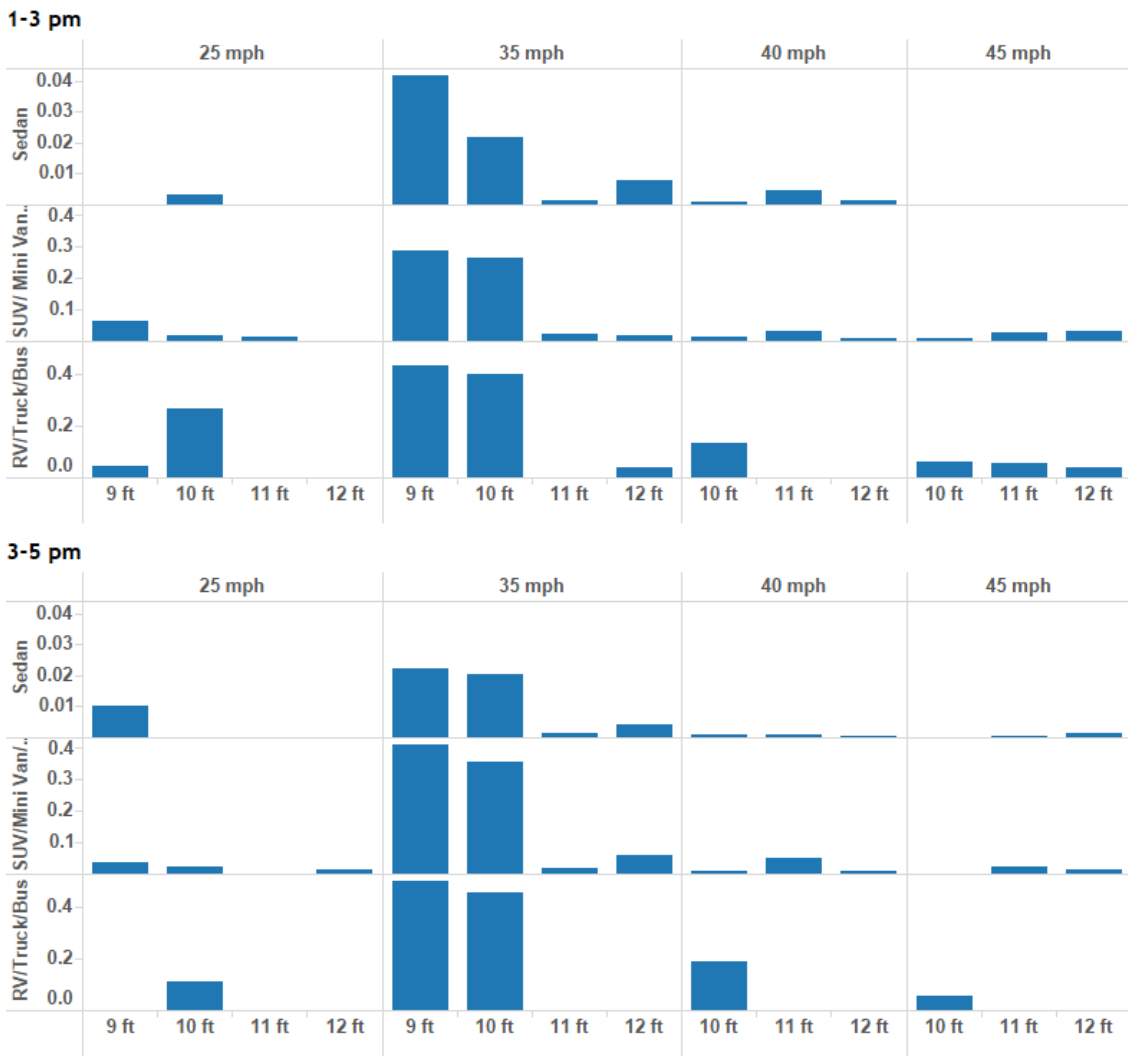
1 The results show posted speed limits affect travel speeds on midblock segments. The presence of  
2 median is negatively associated with travel speeds, which is opposite to the findings in many  
3 research that speeds on divided highway are higher. Caution should be used to interpret the  
4 findings beyond the limits of the data collected for this study. In lower speed zone ( $\leq 35$ mph),  
5 the use of 10 ft lane would increase travel speed compared to 12 ft lane, and the 9 ft and 11 ft  
6 lanes would reduce travel speeds. This is reflected by the trends illustrated in Figure 3. It should  
7 be noted that all the midblock segments with speed limit of 25 mph are located in downtown  
8 areas. The complicated driving environment in this area might affect driver's speed choice. Some  
9 other factors, e.g. type of left turn, distance to upstream and downstream intersections, and  
10 access point density, may have influenced the travel speeds. Due to the limitation of data, those  
11 factors were not studied in this paper.

12  
13 For midblock segments with speed limit ranging from 35 mph to 45 mph, the 10 ft lane width is  
14 related to lower travel speed compared to 11 ft and 12 ft lanes, and the travel speed of 11ft lane  
15 appeared to be higher than the 12 ft lane. In this case, the 10 ft might be used for traffic calming  
16 to reduce speeds. Different effects were found for the presence of shoulder, number of through  
17 lanes and traffic volume in the two data sets.

#### 18 19 **Vehicle Lane Violation (Beta regression by hour????)**

20 The number of lane violations per vehicle was used as a metric for evaluation the effects of  
21 narrower lane widths on lane keeping. The observed vehicles were divided into three categories:  
22 sedan; sport utility vehicle (SUV), pickup, and van; and large vehicles including truck, bus, and  
23 recreational vehicle (RV). Figure 4 depicts the number of lane violations per vehicle class by  
24 speed limit and lane width. In low speed zone of 35 mph or less, the violation rate was higher on  
25 9 ft and 10 ft lanes for all vehicle classes compared to 11ft and 12 ft lanes. The lane violations  
26 were mostly frequently occurs on 9 ft and 10 ft lanes at speed limit of 35 mph. It is  
27 straightforward that large vehicles have a higher probability of committing lane violations, as  
28 shown in Figure 4. At speed limit of 40 mph and 45 mph, the lane violation rate for 10 ft lane  
29 tended to reduce with the increase of speed limit, which might be because drivers are more  
30 cautious when travelling at higher speeds on narrow roads. Study also found narrower lane  
31 widths require more mental effort for the drivers to maintain the lane position (13).

32



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**FIGURE 4 Vehicle lane violation rate by speed limit and lane width.**

**CONCLUSION**

The narrower lane widths can reduce travel speed and highway capacity on high speed roadways. But for the effects of narrower lane width on vehicle speed on urban arterials and local streets, existing studies draw a mixed conclusion including no apparent effect, weak effect, and significant negative effects. The magnitude of identified negative effects also vary across studies. This paper focuses on the traffic operational effects of narrower lane width for urban midblock segments. Through regression analysis, the paper found:

- On midblock segments with a speed limit of 35 mph or 25 mph, the 10 ft lane width is associated with higher travel speed; the 9 ft and 10 ft lane widths are associated with a high rate of lane violation for all types of vehicles.
- For midblock segments with speed limit of 40 mph or 45 mph, the 11 ft lane width results in higher travel speeds than the 12 ft lane width, but the 11 ft lane width does not shown significant advantage in reducing lane violations. The narrower lane of 10ft would cause drivers to be cautious and slow down to avoid potential traffic conflicts, but it results in a

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1 higher rate of lane violation for large vehicles including truck, bus, and recreational  
2 vehicle.

3 As the effects of narrower lane width on travel speed and lane violation for midblock segments  
4 vary between studied data sets, and the lane width is not the sole factor influencing travel speed,  
5 further research with large sample size is needed to provide better guidance for implementing  
6 narrower lane widths for urban streets.

7

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