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### Title

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### Permalink

<https://escholarship.org/uc/item/1gg418bj>

### Journal

NA

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### Publication Date

2026

Peer reviewed

1 **REROUTING IMPACTS OF AUXILIARY LANES**

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21 Word Count: 6475 words + 4 table(s) × 250 = 7475 words

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28 Submission Date: August 1, 2025

**1 ABSTRACT**

2 This paper investigates the network-wide impacts of auxiliary lane removal on the I-210 free-  
3 way corridor using microsimulation analysis. While previous studies have focused primarily on  
4 localized safety and operational effects of auxiliary lanes, this research addresses a critical gap  
5 by examining how auxiliary lane modifications affect both freeway mainline and adjacent arterial  
6 street performance. Using an Aimsun Next model calibrated to 2019 traffic conditions in northern  
7 Los Angeles County, we analyzed three auxiliary lane removal scenarios during peak periods. Re-  
8 sults reveal that auxiliary lane impacts vary significantly with traffic conditions: during free-flow  
9 conditions, auxiliary lanes increase mainline flows by facilitating smoother merging movements,  
10 while during congested conditions, they paradoxically reduce mainline flows due to increased fric-  
11 tion from merging vehicles. Across all scenarios, mainline speeds and travel times showed minimal  
12 changes (less than 5%), but significant flow redistribution occurred. Local on-ramp flows decreased  
13 by 100-200 veh/hr without auxiliary lanes, while arterial streets absorbed the diverted traffic with  
14 only modest impacts on speeds (0.5-1.5 mph reduction). The study suggests that auxiliary lanes  
15 primarily function as operational features that modify route choice and access patterns rather than  
16 substantially changing corridor capacity. These findings also suggest that the flow changes due to  
17 rerouting were larger in magnitude than those that would be expected from induced demand.

18

19 *Keywords:* Auxiliary lanes, VMT, induced demand, microsimulation, freeway operations

## 1 ABBREVIATIONS

ADT:	Average Daily Traffic
AASHTO:	American Association of State Highway and Transportation Officials
CMF:	Crash Modification Factor
CEQA:	California Environmental Quality Act
EIR:	Environmental Impact Report
FDoT:	Florida Department of Transportation
FONSI:	Finding of No Significant Impact
HCM:	Highway Capacity Manual
HCS:	Highway Capacity Software
LOS:	Level of Service
MEV:	Million Entering Vehicles
ODOT:	Oregon Department of Transportation
ORJ:	On-ramp Junction
VMT:	Vehicle Miles Traveled
TxDOT:	Texas Department of Transportation
SPF:	Safety Performance Function
TCMF:	Traffic Conflict Modification Factor

## 2 INTRODUCTION

3 State departments of transportation (DOTs) are increasingly tasked with balancing the dual ob-  
4 jectives of improving roadway safety and operations while minimizing the environmental impacts  
5 associated with added roadway capacity. Auxiliary lanes, commonly used to address merging,  
6 diverging, or weaving issues, are often proposed as targeted improvements that avoid general-  
7 purpose lane expansions. However, the effects of auxiliary lanes on vehicle miles traveled (VMT)  
8 and induced demand remain the subject of considerable debate, with limited empirical evidence  
9 available to guide planning and policy decisions.

10 This study was undertaken to understand how auxiliary lanes function within congested  
11 freeway networks, especially in terms of their operational benefits and potential rerouting conse-  
12 quences. Specifically, this paper seeks to quantify and directly compare the magnitude of traffic  
13 flow changes caused by rerouting with those caused by induced demand, focusing on auxiliary lane  
14 projects shorter than approximately one mile. The project aimed: (1) to evaluate the localized and  
15 network-level impacts of auxiliary lane modifications using microsimulation, and (2) to compare  
16 the magnitude of short-term rerouting effects against longer-term induced demand. To our knowl-  
17 edge, this is the first study to employ a calibrated regional microsimulation model to directly and  
18 quantitatively compare the magnitude of network-level flow changes due to rerouting and induced  
19 demand. Furthermore, it is the first to apply this approach specifically to auxiliary lane projects,  
20 providing a unique perspective on their broader network impacts.

21 A series of traffic simulations were conducted using a calibrated Aimsun model of the I-210  
22 freeway corridor in northern Los Angeles County Dion et al. (1). Simulation results showed that  
23 auxiliary lanes have significant localized effects, particularly at ramps, but that their influence on  
24 mainline freeway flow varies depending on whether the freeway is in free-flow or congested con-  
25 ditions. Importantly, the results demonstrated that auxiliary lanes can lead to substantial rerouting  
26 of traffic during a peak period (on the order of hundreds of vehicles per hour) between ramps and

1 across the arterial network. When these effects were compared with estimates of induced demand  
2 using an external VMT calculator Volker and Handy (2), the simulation-based rerouting effects for  
3 auxiliary lanes of approximately one mile or less in length were found to be somewhat greater than  
4 the induced demand effects.

5 In practical terms, the findings of this study support the idea of a length threshold to screen  
6 auxiliary lane projects. More research is needed to assess under which circumstances a longer or  
7 shorter threshold is appropriate. However, auxiliary lanes shorter than about one mile are likely to  
8 cause rerouting effects that are larger than the induced demand effects.

9 The next section provides a review of the literature. This is followed by a description of  
10 the simulation methodology used to compare freeway and arterial operations with and without an  
11 auxiliary lane between adjacent ramps. Results are then presented with detailed explanations at  
12 three locations where existing auxiliary lanes were removed. Finally, key points are discussed in  
13 the conclusion.

## 14 **Document Organization**

15 The remainder of this paper is organized as follows. First, background information and key defi-  
16 nitions related to lane designations and capacity are provided. This is followed by a review of the  
17 relevant literature, including a comparison of empirical and simulation studies. Next, the simula-  
18 tion methodology is described, detailing how freeway and arterial operations were analyzed with  
19 and without auxiliary lanes. The results section presents the findings from simulations conducted at  
20 three key locations. Subsequently, a discussion compares observed flow changes with estimates of  
21 induced demand. Finally, the paper concludes with a summary of the key points and implications.

## 22 **BACKGROUND**

23 This section provides a framework for considering questions about auxiliary lanes and their rela-  
24 tionship with flow capacity. This framework is crucial as the term “auxiliary lane” is not consis-  
25 tently used in the literature. This lack of consistency causes confusion, especially when attempting  
26 to synthesize results across multiple studies to form robust conclusions.

### 27 **Definitions for Lane Designations**

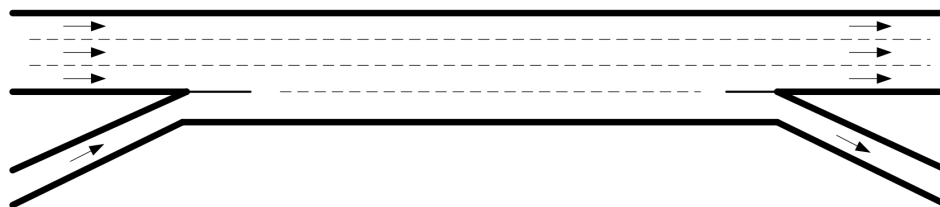
28 Clear definitions of acceleration, deceleration, and auxiliary lanes are crucial because the term  
29 “auxiliary lane” is often used interchangeably with other lane types, leading to confusion in both  
30 research and practice.

#### 31 *Auxiliary Lane*

32 As shown in Figure 1, an auxiliary lane is an outer lane on the right side of a freeway that begins  
33 at an on-ramp and ends at the following off-ramp. It can be conceptualized as an acceleration lane  
34 connected to a deceleration lane, and it functions as a transition zone for weaving movements.  
35 These lanes are typically 500 feet to one mile in length, connecting entrance or exit ramps to the  
36 main travel lanes, facilitating maneuvers to merge onto or exit from the freeway.

37 Although the auxiliary lane shown in Figure 1 will typically connect an upstream junction  
38 to a downstream junction, the number of freeway mainline lanes remains constant. Ideally, the flow  
39 from the on-ramp directly to the off-ramp should be zero. In cases where the on-ramp is metered,  
40 the incentive to use the auxiliary lane as a shunt from one junction to the next can be reduced.

41 It is important that the auxiliary lane be shorter than some threshold to operate as intended.



**FIGURE 1 Auxiliary lane Qi et al. (3)**

1 The threshold is arbitrary, but several references select a threshold on the order of 1 mile Oregon  
2 Department of Transportation (4) California Department of Transportation (5). A threshold of  
3 10 miles would be too long, as a lane of such length would function as the right-most lane of  
4 a homogeneous freeway for most of that distance. It is not the purpose of this study to select a  
5 specific threshold, but rather to assert that a threshold should be selected with the intent that the  
6 auxiliary lane behaves primarily as a transition zone for weaving movements.

## 7 LITERATURE REVIEW

8 In assessing the effectiveness of auxiliary lane projects, aside from safety analysis, the level of  
9 service (LOS) is the typical metric used for operational performance. Skabardonis and Kim (6)  
10 outline the different methods of evaluating LOS for weaving sections by analyzing geometric and  
11 operational conditions, such as lane configuration and traffic volume. Qi et al. (3) conclude that  
12 density, speed, and capacity are appropriate performance measures. However, recent regulatory  
13 shifts have introduced VMT as a key metric for evaluating environmental impacts, reflecting a  
14 broader focus on sustainability and long-term traffic patterns. Despite this, there appears to be  
15 limited guidance on analyzing the VMT impacts of auxiliary lane projects, with certain thresholds  
16 being adhered to, but not necessarily grounded in empirical analysis.

17 For example, a recent Caltrans document California Department of Transportation (7) out-  
18 lines the environmental impact analysis for an auxiliary lane project on State Route 1 in Santa  
19 Cruz. The report details the process for determining a Finding of No Significant Impact (FONSI)  
20 to comply with CEQA, explaining how the project will reduce congestion and increase speeds  
21 without increasing VMT, as it is under one mile in length and therefore exempt from further VMT  
22 analysis under CEQA.

23 Several studies have examined the operational performance of auxiliary lanes by analyzing  
24 other key metrics such as speed, capacity, and density over the existing freeway section. Research  
25 has demonstrated that auxiliary lanes alleviate congestion by reducing conflicts caused by weaving  
26 and merging Qi et al., Washburn et al. (3, 8). However, some studies appear to conflate the benefits  
27 of an auxiliary lane with those of adding an extra general-purpose lane. The study conducted  
28 in Chapter 4 of Qi et al. (3) shows that an auxiliary lane that is extended to become an extra  
29 lane improves operational efficiency by increasing capacity (up to 56%), reducing density, and  
30 enhancing speed.

31 Their methodology for calculating capacity relies on VISSIM simulations rather than what  
32 is defined in the HCM Transportation Research Board (9), which does not account for auxiliary  
33 lanes in its capacity estimates. While this approach allows for a more detailed analysis of traffic  
34 flow, it does not differentiate between the functional role of an auxiliary lane and a full general-

1 purpose lane. The geometry of the added lane in that scenario is not consistent with the definition  
2 of an auxiliary lane in the present study. As a result, a large capacity increase of 56% is mea-  
3 sured where an additional lane continues beyond the off-ramp. This also reflects a fundamental  
4 discrepancy in how capacity is defined. While our analysis considers auxiliary lanes primarily for  
5 their role in facilitating merging and diverging, their study evaluates them as capacity-enhancing  
6 features by evaluating point capacity improvements.

7 Additionally, despite the title of Chapter 5 of Qi et al. (3) on “corridor-level” impacts, the  
8 study primarily examines extended freeway segments only. It does not consider the dynamics of a  
9 freeway and nearby arterials together.

10 Interestingly, Washburn et al. (8) emphasized the importance of the number of mainline  
11 lanes rather than auxiliary lane length in determining their impact on freeway capacity and traffic  
12 flow. Through CORSIM simulation analysis, the study measured point capacity at the segment,  
13 including the auxiliary lane, similar to Qi et al. (3). They found that auxiliary lanes increase  
14 throughput point capacity by 48.9% for two-lane freeways, 32.0% for three-lane freeways, 23.8%  
15 for four-lane freeways, and 18.7% for five-lane freeways. Notably, factors previously thought to be  
16 significant, such as weaving volume ratios and interchange spacing, were reported to have minimal  
17 impact on auxiliary lane performance.

18 Finding definitive answers about induced demand in the context of auxiliary lanes is a  
19 major gap in the literature. Because auxiliary lanes can improve traffic flow, it is hypothesized  
20 that they also risk encouraging increased vehicle use by making driving more convenient. Induced  
21 travel contributes to an increase in VMT, which raises concerns about the environmental impacts  
22 of such projects, particularly in regions where VMT reduction is a central goal of transportation  
23 policy. The Transportation Analysis under CEQA report California Department of Transportation  
24 (5) suggests that adding capacity through auxiliary lanes, especially those longer than one mile, can  
25 induce additional travel, leading to longer trips or an increase in the frequency of trips. However,  
26 the rationale for selecting an arbitrary threshold of one mile in length is unclear. More quantitative  
27 analysis of the effects of auxiliary lanes is helpful to provide support for a reasonable threshold.

28 While there exist simulation studies and technical reports, these often focus on short-term  
29 or localized effects, such as improvements in speed or density, without considering long-term shifts  
30 in travel behavior or broader impacts on adjacent arterials. The simulation models that have been  
31 used to predict the effects of auxiliary lanes on freeway operations generally focus on the freeway  
32 itself and do not take into account the broader network effects. This is a key gap in the existing  
33 research, as the introduction of auxiliary lanes may lead to rerouted traffic or changes in travel  
34 patterns that impact local roads. The lack of real-world, empirical data on the long-term impacts  
35 of auxiliary lanes, particularly regarding their effects on local networks and VMT, is a limitation  
36 that future research must address.

37 The definitions of exactly what constitutes an “auxiliary lane” as well as notions of capacity  
38 or capacity increases are not standardized across the literature. These terms can be used differently  
39 and create confusion. For this reason, it becomes difficult to compare results across multiple studies  
40 and to synthesize holistic guidance.

41 Existing operational studies appear to define capacity using point capacity that does not  
42 represent the long-haul throughput capacity of a freeway segment extending upstream and down-  
43 stream of a weaving section, as is needed in the current context. By focusing on localized capacity  
44 changes at a single point, these studies may overstate the impact of auxiliary lanes on overall  
45 freeway performance, failing to capture their primary role in improving merging and diverging

1 operations rather than increasing sustained freeway throughput.

2       There are well-established guidelines for acceleration and deceleration lanes and the length  
3 required for them to achieve their safety and operational benefits American Association of State  
4 Highway and Transportation Officials, American Association of State Highway and Transportation  
5 Officials (10, 11). In addition, there are established evaluation methods to estimate the expected  
6 benefits of auxiliary lanes installed at weaving segments Le and Porter, Wang and Cheu (12, 13).  
7 These benefits primarily consist of reducing the number of conflicts, reducing crashes, and main-  
8 taining the intended capacity. However, there are research gaps, primarily concerning the operation  
9 of auxiliary lanes in the context of a complete road network, including arterial streets. This study  
10 aims to shed some light on vehicular rerouting and how demand might shift across a network  
11 depending on how auxiliary lanes are deployed.

12       Despite the extensive research examining auxiliary lanes in terms of safety and localized  
13 operational benefits, significant gaps remain regarding their broader network impacts, particularly  
14 how they influence rerouting behavior and vehicle miles traveled (VMT) within both freeway and  
15 adjacent arterial systems. Given these persistent research gaps in understanding how auxiliary  
16 lanes impact both freeways and adjacent arterials, this study adopts a novel approach by leveraging  
17 a regionally-calibrated microsimulation model. The following section describes in detail how this  
18 integrated simulation framework was constructed and used to quantitatively assess both rerouting  
19 and induced demand effects stemming from auxiliary lane modifications.

## 20 **SIMULATION METHODOLOGY**

### 21 **Basic Description**

22 To address the research gaps identified in the literature, the simulations presented in this study were  
23 run using an Aimsun Next microsimulation model of the I-210 freeway corridor and environs. A  
24 diagram of the modeled network, is shown in Figure 2. The modeled corridor includes main  
25 portions of the cities of Pasadena, Arcadia, Monrovia, and Duarte, between the SR-134 and I-  
26 605 freeways in northern Los Angeles County. It further includes about 1000 miles of roads, 485  
27 centroids from which traffic originates from and travels to, and a comprehensive modeling of all  
28 the traffic signals operated within the area.



**FIGURE 2 Traffic simulation network**

29       For this project, various sections along the I-210 freeway were selected for auxiliary lane re-  
30 moval. For each alteration considered, two configurations were compared: (1) a baseline scenario,

1 and (2) an alternate scenario with a modified auxiliary lane. To account for model stochasticity,  
2 five simulations were run for each configuration, and analyses were subsequently performed by  
3 comparing the average results associated with each configuration.

4 To investigate the impacts associated with the geometrical changes considered, the traffic  
5 demand entering the network was kept constant across all scenarios. However, routing patterns  
6 were updated to account for the increase or decrease in local capacity resulting from the imple-  
7 mented changes. This was performed by generating new static assignments for each analysis  
8 period. Within Aimsun, these static assignments provide an initial set of paths for each origin-  
9 destination pair based on estimated travel costs across the network when factoring expected traffic  
10 volumes. While approximately 85% of vehicles enter the network with the intent to follow one of  
11 the defined paths, vehicles may alter their planned route during a dynamic simulation if specific  
12 situations are encountered, such as unusual congestion, blockages, etc. The remainder 15% of  
13 vehicles typically determine their paths based on traffic conditions that exist at their time of entry.

14 The I-210 Aimsun model was built and calibrated specifically to simulate non-recurrent  
15 congestion resulting from traffic incidents. Details about the model and its calibration are described  
16 in Dion et al. (1). At the heart of the model is a set of density-based triggers along the freeways,  
17 ramps, and arterials used to assess local traffic conditions. These triggers are intended to detect  
18 when certain links become congested and to push vehicles to recalculate their paths accordingly,  
19 in a manner that aims to replicate how drivers tend to react to congestion.

20 Traffic demand and network elements were calibrated to replicate behavior observed in the  
21 network in 2019, before the COVID pandemic. Simulation results compare well with data charac-  
22 terizing average weekday traffic conditions, as well as historical traffic incidents, thus confirming  
23 that the model faithfully reproduces traffic behavior in the corridor. Therefore, we expect that the  
24 model is also useful for estimating likely traffic responses to infrastructure alterations where an  
25 auxiliary lane may be added or removed.

26 The evolution of traffic during the morning (6 AM to 9 AM) and afternoon (4 PM to 7  
27 PM) peak periods was of primary interest. For the morning period, a static assignment plan com-  
28 bining specific static assignments developed to represent traffic conditions within the 6-7 AM and  
29 7-9 AM intervals was used. For the afternoon, the static assignment plan considers individual  
30 static assignments generated to capture traffic conditions within the 2-4 PM, 4-6 PM, and 6-8 PM  
31 intervals.

32 For each of the AM/ PM periods, a few key weaving sections in the model were selected  
33 where modifications in the form of removing a lane were made. The auxiliary lane deletions are  
34 listed in Table 1.

35 For simulations covering the 6-9 AM period, a 20-minute warmup was used as the network  
36 generally starts in free-flow conditions. This helped address issues related to the replacement of  
37 simulation links by new ones to implement the desired changes in auxiliary lanes. For simulations  
38 covering the 4-7 PM period, an initial state was developed using Aimsun tools to ensure proper  
39 replication of the congestion that exists at the start of the evaluation period. This initial state was  
40 developed by starting a simulation at 3 PM and instructing Aimsun to save vehicles where they  
41 stand at 4 PM. This initial state was then used at the beginning of the simulation of the afternoon  
42 peak.

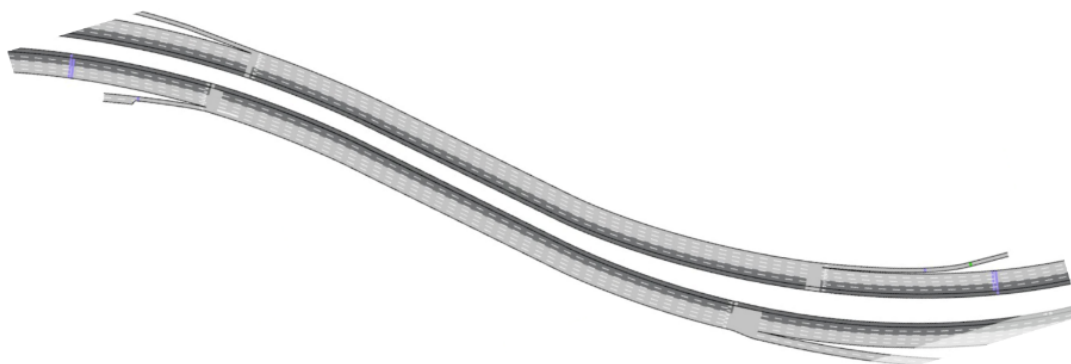
**TABLE 1 Characteristics of Study Sites for Auxiliary Lane Removals**

Location	Length (ft)	Lanes	Peak	Mainline (veh/hr)	On Ramp (veh/hr)	Off Ramp (veh/hr)
I-210 W – Madre / San Gabriel	1750	6	AM	7519	443	322
			PM	7616	527	688
I-210 E – San Gabriel / Madre	1700	6	AM	7296	382	580
			PM	7910	398	894
I-210 W – Hill / Lake	900	6	AM	8115	617	889
			PM	9009	946	1088

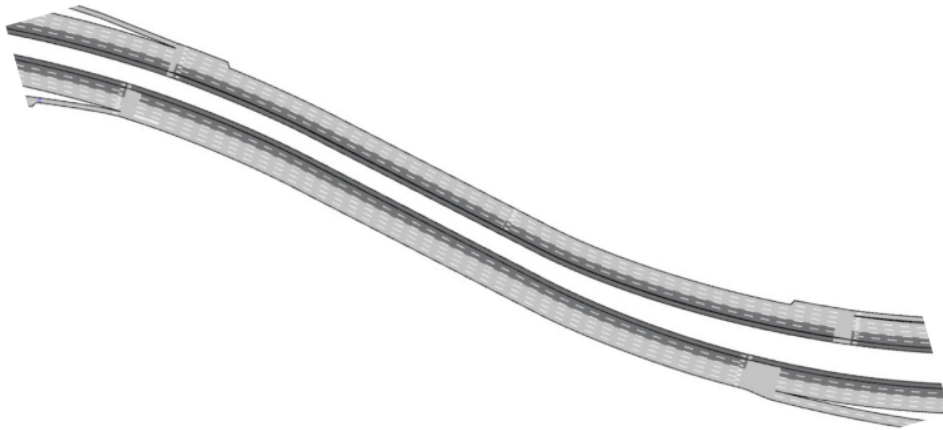
**1 Auxiliary Lane Removal between Sierra Madre Villa and San Gabriel**

2 The I-210 West freeway between Sierra Madre Villa and San Gabriel is a critical part of the network  
 3 due to its idiosyncratic geometry. The auxiliary lane is located at the eastern edge of Pasadena,  
 4 along a horizontal curve. Just upstream of the curve, in the city of Arcadia, the freeway runs  
 5 between Foothill, to the north, and Colorado Blvd., to the south. The freeway curves to the north  
 6 and passes over Foothill then curves back again to straighten out between Maple, to the north, and  
 7 Corson, to the south. Just downstream of the curve, two high-volume on-ramps enter the freeway  
 8 from Maple.

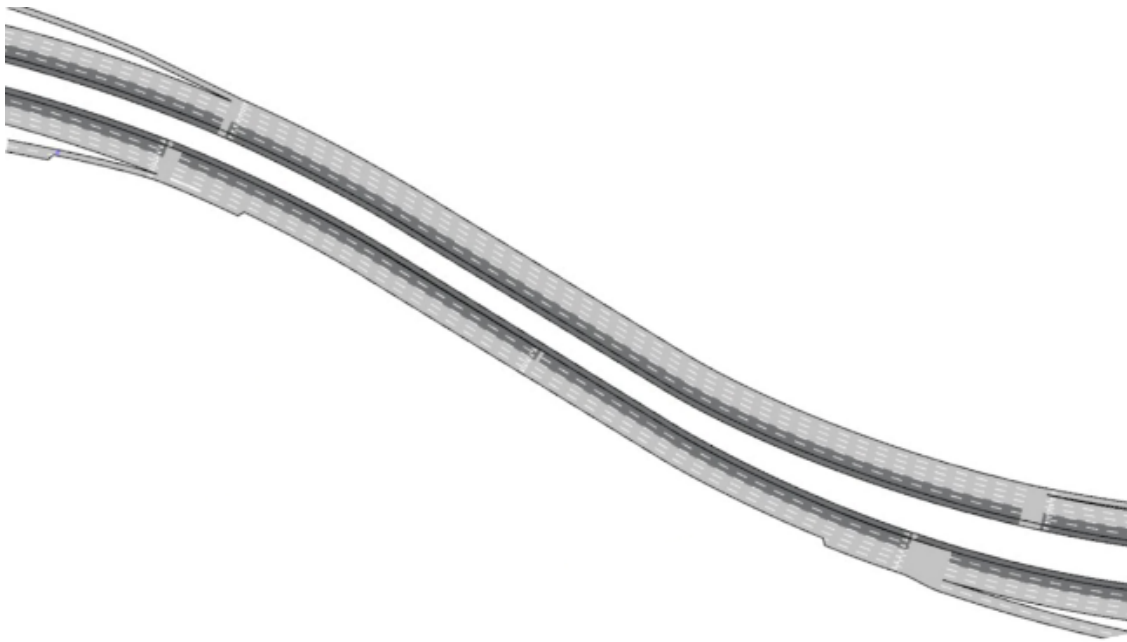
9 The existing configuration is shown in Figure 3. In addition to 1760 ft of auxiliary lane,  
 10 this section has an HOV lane and five general purpose lanes. In Figure 4, the auxiliary lane was  
 11 removed along the westbound section to make an on-ramp of 113.85 ft. and an off-ramp of 122.70  
 12 ft. In Figure 5 the eastbound direction of the auxiliary lane was removed to make an on-ramp of  
 13 155.18 ft. and an off-ramp of 161.42 ft.



**FIGURE 3 I-210 with Existing Auxiliary Lanes between Sierra Madre Villa and San Gabriel**



**FIGURE 4 I-210 without Westbound Auxiliary Lanes between Sierra Madre Villa and San Gabriel**



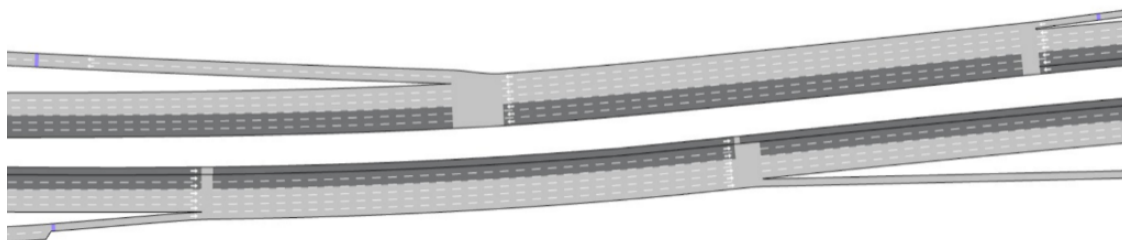
**FIGURE 5 I-210 without Eastbound Auxiliary Lanes between Sierra Madre Villa and San Gabriel**

**1 Auxiliary Lane Removal between Lake and Hill**

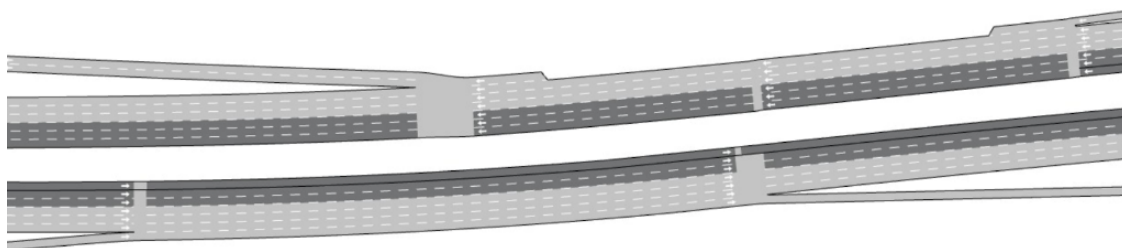
2 Figure 6 illustrates the existing configuration along I-210 West between the Hill on-ramp and Lake  
 3 off-ramp in Pasadena, where the two ramps are connected by a short auxiliary lane running parallel  
 4 to Maple Street. There is an additional on-ramp downstream of Lake, allowing traffic from Fair  
 5 Oaks Avenue to enter the SR-134 freeway downstream of the I-210/SR-134 split. All three of these  
 6 ramps (on, off, and on again) exhibit flows of 1000+ veh/hour during peak periods.

7 As shown in Figure 6, this freeway includes one HOV lane, 6 general-purpose lanes, and

1 an auxiliary lane approximately 900 feet in length. In Figure 7 the auxiliary lane is removed in the  
 2 westbound direction and replaced with acceleration and deceleration lanes measuring 103.67 feet  
 3 in length.



**FIGURE 6 I-210 with Existing Westbound Auxiliary Lane between Lake and Hill**



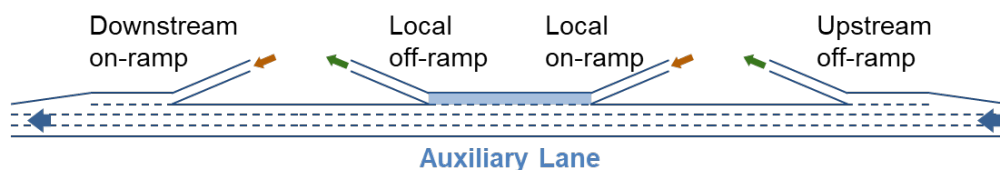
**FIGURE 7 I-210 without Westbound Auxiliary Lanes between Lake and Hill**

4 **RESULTS**

5 Common traffic-related features observed during simulations are summarized in this section. De-  
 6 tailed results are presented for the main scenarios below. Results depend on whether the modified  
 7 auxiliary lane is operating in congested or free-flow conditions. Without an auxiliary lane, the  
 8 following local effects are observed:

- 9 • Local on-ramp flow decreases
- 10 • During the free flow regime, local mainline flow decreases
- 11 • During the congested regime, local mainline flow increases

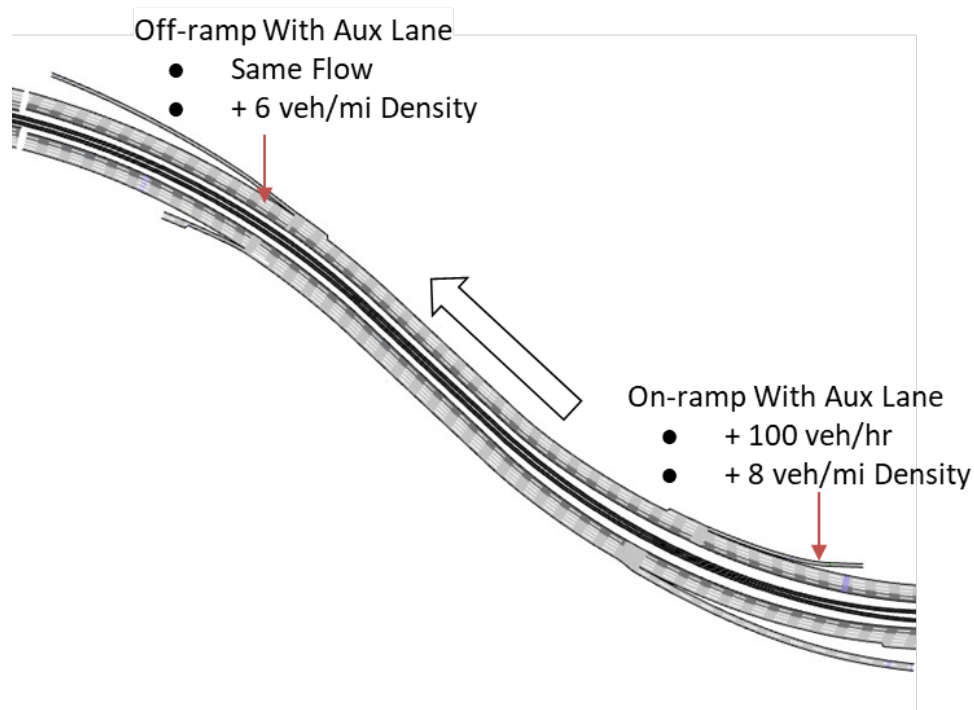
12 The above effects are evidenced by changes in flows at upstream and downstream ramps  
 13 due to rerouting behavior. Both the nearby off-ramp and downstream on-ramp flows are observed  
 14 to increase with the removal of an auxiliary lane. Depending on local features, off-ramp flow  
 15 increases may occur at the upstream off-ramp or the local off-ramp, as illustrated in Figure 8.



**FIGURE 8 Schematic view of freeway auxiliary lane with labels**

### 1 I-210 West Sierra Madre / San Gabriel

2 This section presents simulation results associated with the simulated removal of the existing aux-  
 3 iliary lane between the Sierra Madre on-ramp and San Gabriel off-ramp along I-210 West. Results  
 4 are first presented for simulations covering the morning peak period, extending from 6 am to 9  
 5 am. Figure 9 summarizes the local effects for this configuration. With an auxiliary lane, local  
 6 on-ramp flows are about 100 veh/hr higher than without, with a corresponding slight increase in  
 7 traffic density. Local off-ramp flows are not significantly affected.



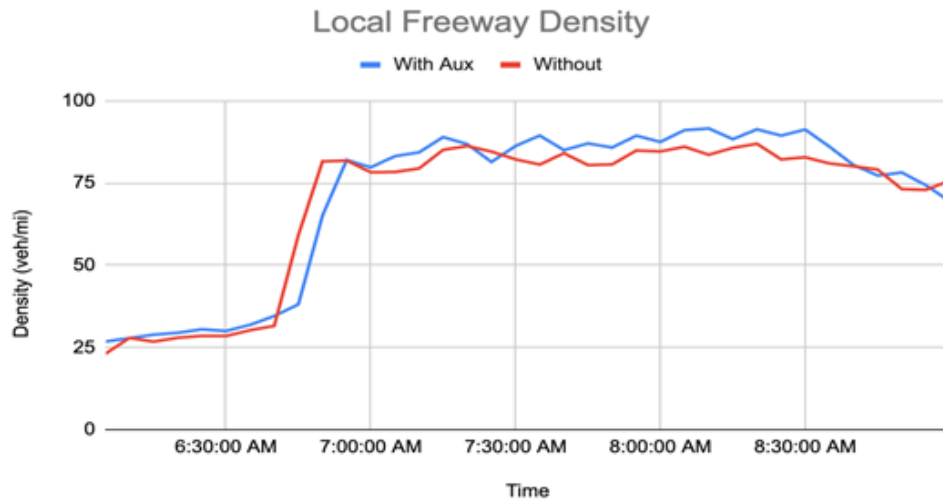
**FIGURE 9 Local effects on I-210 West at Sierra Madre during the morning peak period**

8 Figure 10 plots the local mainline freeway density during the morning peak at Sierra Madre.  
 9 Time series are shown in blue (red) for the scenario with (without) an auxiliary lane. As evidenced  
 10 by relatively low densities, the period before 6:45 am is in free flow. The period after 6:45 am is  
 11 congested as evidenced by sustained densities above 75 veh/mile.

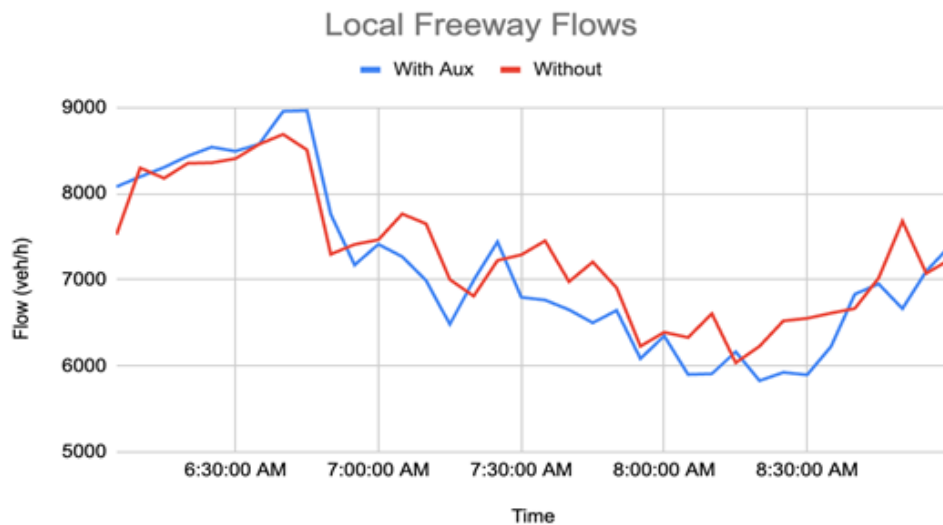
12 Figure 11 plots the mainline freeway flow during the morning peak at Sierra Madre. Time  
 13 series are shown in blue (red) for the scenario with (without) an auxiliary lane. During free flow  
 14 conditions, before 6:45 am, the flows are greater with an auxiliary lane. During congestion after  
 15 6:45 am the flows are typically lower with an auxiliary lane.

16 Figure 12 shows that the local on-ramp flow at Sierra Madre, increases with the addition  
 17 of the auxiliary lane when the freeway is congested. This is due to the increased facility provided  
 18 to motorists to enter the freeway with the auxiliary lane. Without the lane, traffic has a very short  
 19 distance to merge onto the mainline. Because of this constraint, the entering flow is reduced,  
 20 causing traffic to queue on the on-ramp. Adding the auxiliary lane removes this constraint, thus  
 21 improving ramp operations.

22 A key observation from the simulation results is that different impacts associated with the

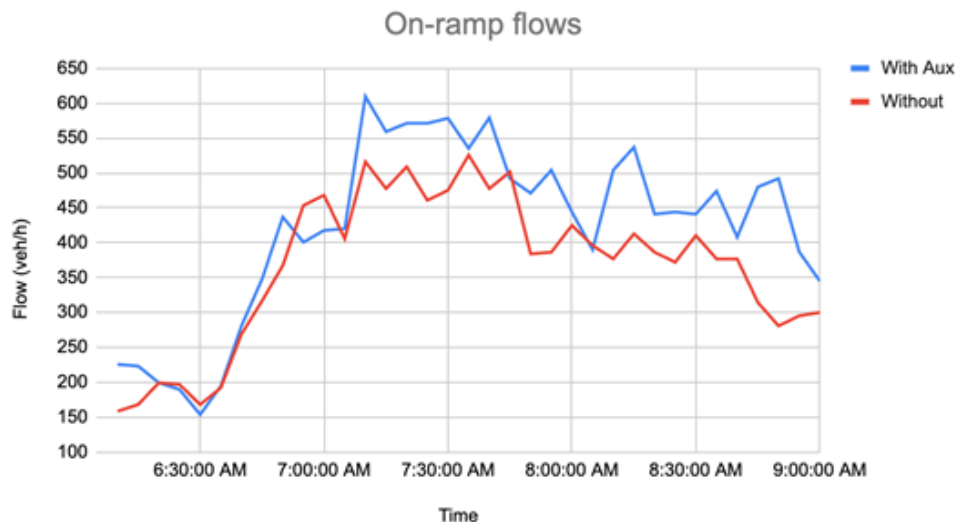


**FIGURE 10 Local I-210 West mainline freeway density during morning peak at Sierra Madre**



**FIGURE 11 Local I-210 West mainline flow during morning peak at Sierra Madre**

- 1 removal of the auxiliary lanes are obtained depending on the traffic flow regime on the freeway
- 2 mainline:
  - 3 • Before 6:45 am, when the freeway traffic is in free flow, higher mainline flows are ob-
  - 4 served with the auxiliary lane.
  - 5 • After 6:45 am, when the freeway is congested, lower mainline flows are observed with
  - 6 the auxiliary lane.
- 7 In both cases, however, there are only minor effects on mainline traffic speeds and travel
- 8 times.
- 9 The above effects could be linked to the friction caused by vehicles entering the freeway.



**FIGURE 12 Local on-ramp flow during the morning peak at Sierra Madre**

1 In the absence of congestion, the presence of an auxiliary lane gives entering vehicles more space  
 2 to seek a suitable gap and insert themselves into the traffic without forcing other vehicles to slow  
 3 down. In the presence of congestion, entering vehicles are more likely to create ripples on the  
 4 mainline. In this case, the auxiliary lane allows more vehicles to enter, and thus, more vehicles to  
 5 cause disruptions and impact freeway flow.

#### 6 **I-210 West Lake/ Hill**

7 While the Sierra Madre / San Gabriel analysis illustrates the balance of free-flow and congested  
 8 conditions, the next scenario at Lake/Hill offers insights into auxiliary lane impacts in a location  
 9 that experiences more sustained congestion. The following results reveal how these differing traffic  
 10 regimes influence the operational effects of an auxiliary lane.

11 Figure 13 plots local mainline freeway density during the morning peak period at Lake,  
 12 while Figure 14 plots the freeway flow. As shown in Figure 13, the highest traffic density at this  
 13 location, and thus the highest congestion, occurs between 7:30 am and 8:30 am. This coincides  
 14 with the period of lowest flow in Figure 14. During this period, the flow within the scenario  
 15 with the auxiliary lane remains lower than in the scenario without the lane, as evidenced by the  
 16 blue line remaining below the red line. This suggests that removing the auxiliary lane results in  
 17 higher simulated flows along the freeway mainline and is consistent with the trend described in the  
 18 previous scenario, where mainline flows were lower in congestion with an auxiliary lane. However,  
 19 due to an increase in flow after 8:30 am, the overall average mainline flow over the entire simulated  
 20 morning period is the same with or without the auxiliary lane.

21 Figure 15 shows that local on-ramp flows are about 200 veh/hr higher with an auxiliary  
 22 lane than without. Again, this is due to the added facility provided to entering traffic to merge into  
 23 the mainline traffic. The added friction from the entering vehicles causes in turn the upstream flow  
 24 rate on the mainline to drop by 200 veh/hr. Overall, however, the changes in mainline, on-ramp,  
 25 and off-ramp flows result in a net downstream increase of about 100 veh/hr in flow rate.

26 Figure 15 suggests that the presence of the auxiliary lane has a significant effect on local

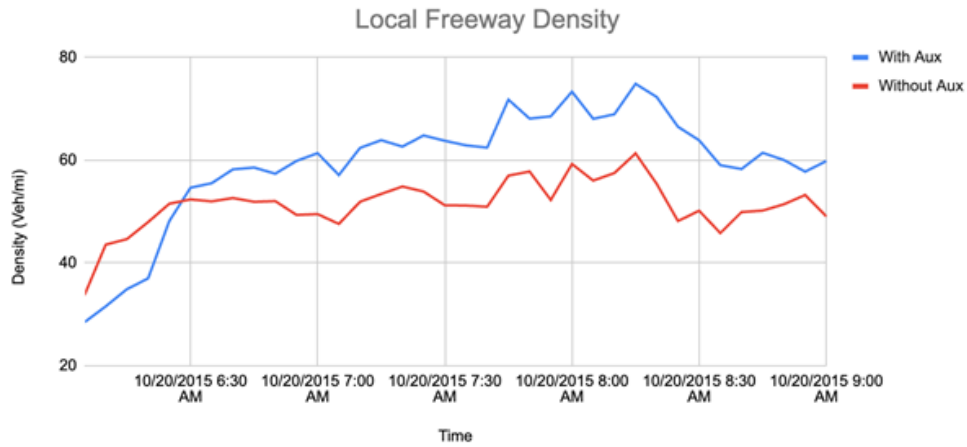


FIGURE 13 Local mainline freeway density during the morning peak period at Lake

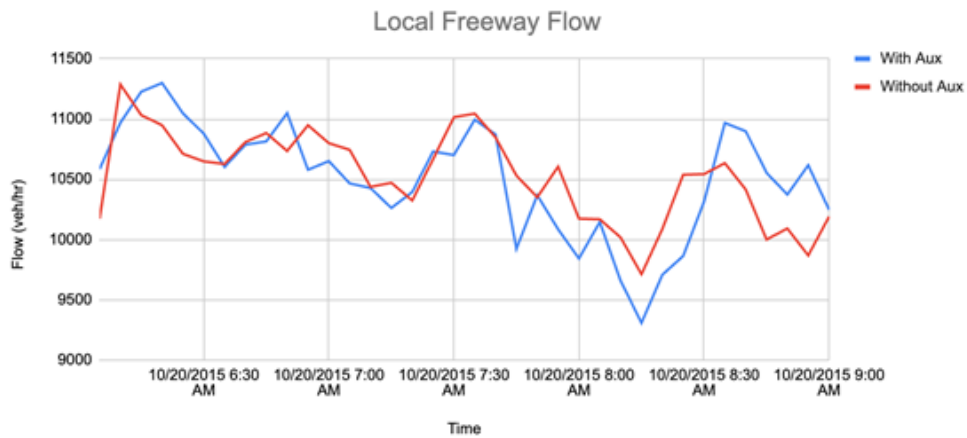


FIGURE 14 Local mainline freeway flow during the morning peak period at Lake

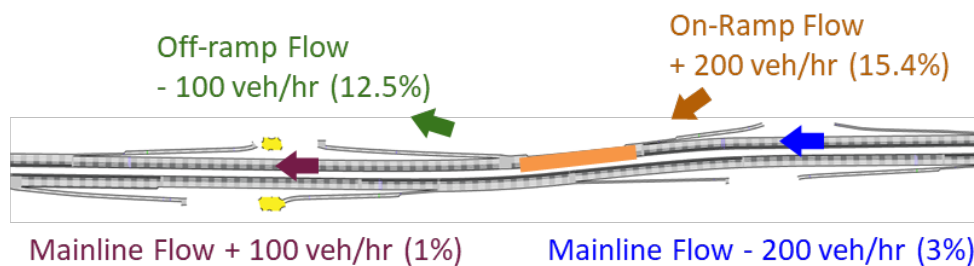


FIGURE 15 Effects of an auxiliary lane on I-210 W at Lake during the morning peak period

- 1 on-ramp and off-ramp flows. The biggest effect is seen on the on-ramp. As explained earlier, the
- 2 auxiliary lane provides additional space for entering vehicles to muscle into the freeway. In the
- 3 simulations, this results in the auxiliary lane becoming dominated by entering vehicles, and becom-

1 ing less available for vehicles to exit at the local off-ramp. Because exiting traffic has increasing  
 2 difficulty using the auxiliary lane, this explains the reduced off-ramp flows.

3 Another effect noted in the dynamic simulations is that without the auxiliary lane, the  
 4 local on-ramp is more likely to become completely queued. When this happens, it triggers the  
 5 queue flush mechanism in the ramp meter controller, thus increasing the meter rate and allowing  
 6 additional vehicles to enter the freeway. However, the limited available space to merge tends to  
 7 limit the on-ramp flow. With the auxiliary lane, the flow limiting factor is more often caused by  
 8 the ramp meter, not the geometry of the merge.

9 **I-210 East San Gabriel / Sierra Madre**

10 Unlike the previous scenarios, the I-210 East freeway at San Gabriel / Sierra Madre is mostly un-  
 11 congested during both the morning and afternoon peak periods. As shown in Figure 16, traffic  
 12 densities mostly stay below 25 veh/mile. The main commuting peak happens in the afternoon for  
 13 this eastbound segment. Since the freeway mainly operates in free flow, the presence of the auxil-  
 14 iary lane results in higher mainline flows, as evidenced in Figure 17 by the blue line, representing  
 15 mainline flow with the auxiliary lane, tracking significantly higher than the red line, representing  
 16 flow without the auxiliary lane. The difference in flow is noticeable, reaching around 500 vehi-  
 17 cles/hour between 4 pm and 5 pm. This is consistent with previous observations, which suggested  
 18 that the effect may be due to the increased ease the auxiliary lane provides to the entering traffic  
 19 for merging into the mainline stream.

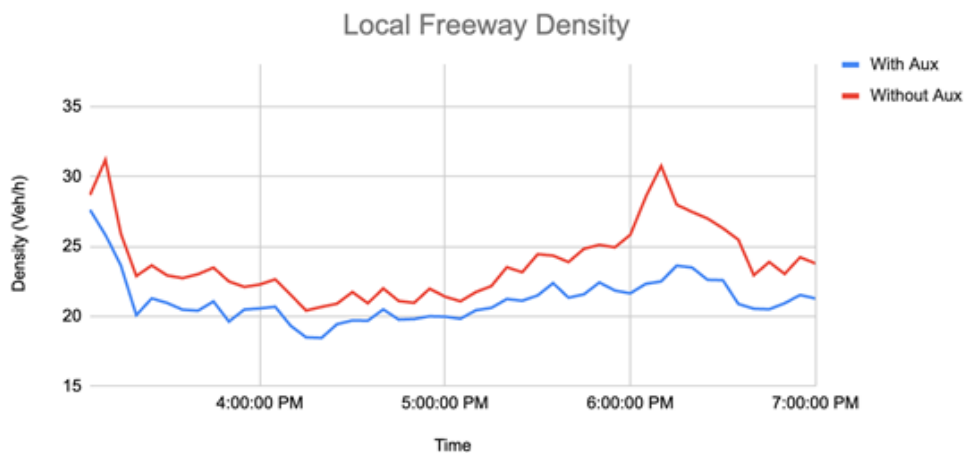
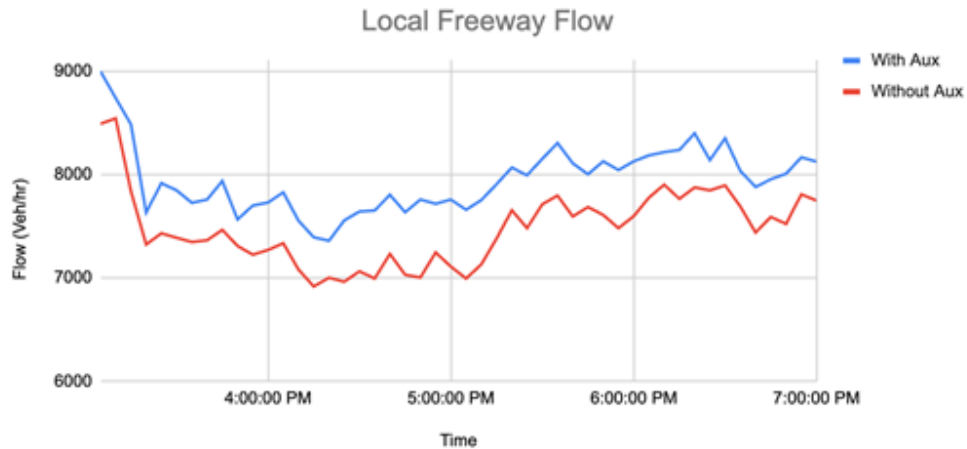


FIGURE 16 Local mainline freeway density during afternoon peak at Sierra Madre

20 Figure 18 summarizes local effects on I-210 East at Sierra Madre during the afternoon  
 21 peak. For the on-ramp and off-ramps, the outcomes are slightly different than those of previous  
 22 scenarios:

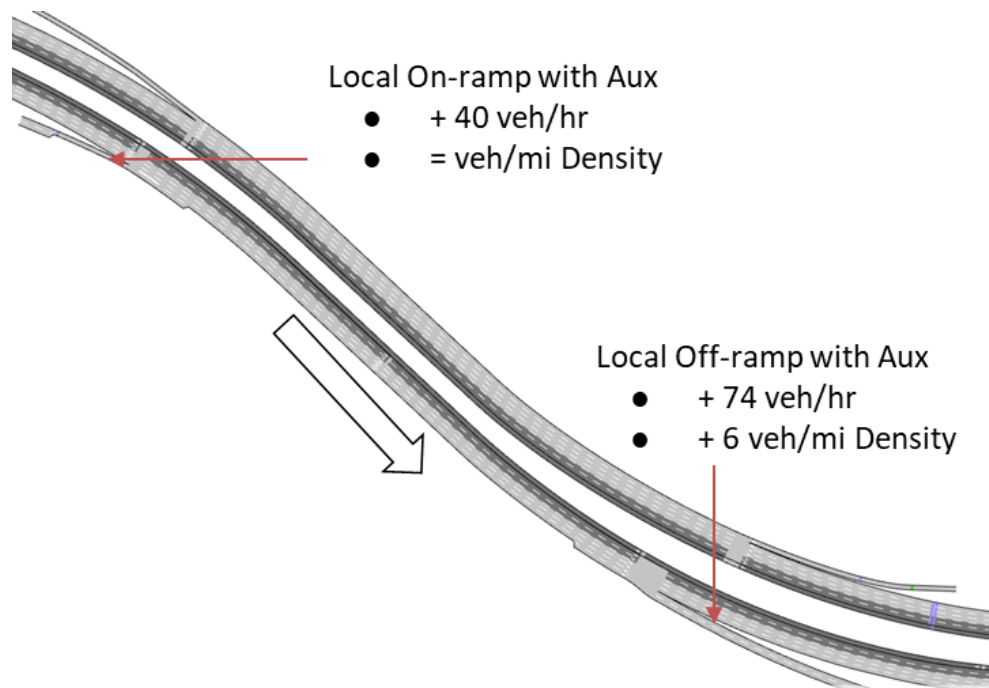
- 23 • Similar to previous examples, local on-ramp flows increase with the auxiliary lane present.  
 24 In this case, the increase is about 40 veh/hr.
- 25 • Contrary to previous examples, local off-ramp flows also increase with the auxiliary  
 26 present.

27 In this case, the lack of heavy congestion on the mainline reduces the maneuvering diffi-  
 28 culty for vehicles entering and exiting the freeway. With the auxiliary lane providing extra space to



**FIGURE 17 Local mainline freeway flow during the afternoon peak at Sierra Madre**

- 1 facilitate these maneuvers, the freeway could thus easily accommodate higher entry and exit flows.
- 2 It should be noted, however, that the observed changes remain moderate.



**FIGURE 18 Local effects on I-210 East at Sierra Madre during the afternoon peak**

**3 Summary of Performance Metrics**

4 Table 2 compares basic traffic metrics for the three studied mainline freeway segments. Throughout  
 5 the peak periods, average speeds and total travel times for the two auxiliary lane configurations are  
 6 almost the same. There is little evidence that the auxiliary lane causes large changes in speeds and  
 7 travel times along the mainline freeway. Instead, the lane modifies the ease of access and egress

1 from the freeway, thus impacting route choice.

**TABLE 2 Mainline Freeway Performance Comparison for Three Study Segments**

Scenario	Length (mi)	VMT		VHT		Speed	
		With (veh·mi)	Without (veh·mi)	With (veh·hr)	Without (veh·hr)	With (mph)	Without (mph)
Sierra Madre/San Gabriel (AM)	1.66	37,162	36,478	1,892	1,846	19.6	19.8
Lake/Hill (AM)	2.55	67,361	68,195	2,620	2,535	25.7	26.9
San Gabriel/Sierra Madre (PM)	2.14	63,689	61,379	1,073	1,023	59.4	60.0

2 Table 3 further compares traffic performance on adjacent arterial streets for the three con-  
 3 figurations. The results show that while the presence of the freeway auxiliary lane is associated  
 4 with lower flow and lower VMT on nearby arterial roads, the effect is small. The addition or sub-  
 5 traction of an auxiliary lane had a small, but measurable, effect on arterial speeds and travel times.  
 6 This indicates that any additional flow was gracefully absorbed by the local arterials.

**TABLE 3 Arterial Street Performance Comparison for Three Study Segments**

Location	Arterial	Length (mi)	VMT		VHT		Speed	
			With (veh·mi)	Without (veh·mi)	With (veh·hr)	Without (veh·hr)	With (mph)	Without (mph)
Sierra Madre	Foothill/Maple	1.20	1,908	2,124	88.2	102	21.6	20.9
Lake/Hill	Wilson Ave (SB)	1.23	253	281	14.5	17.4	17.4	16.2
Lake/Hill	Walnut St (WB)	1.79	2,436	2,724	105	120.2	23.2	22.7

7 **DISCUSSION**

8 This study makes possible a preliminary comparison of order-of-magnitude effects for two con-  
 9 founding factors that can result from a modification of the traffic network. The first effect is  
 10 rerouting, while the second is induced demand. Rerouting effects, and related changes in VMT,  
 11 VHT, and traffic flows, are described in the previous section. Induced demand is estimated by  
 12 using an online calculator from Volker and Handy (2). It should be stressed that this is something  
 13 of an apples-and-oranges comparison. On one hand, the simulated results are generated from a  
 14 microscopic traffic model, with the metric to be compared measured from observed flows in the  
 15 simulation. On the other hand, the induced demand calculator results depend on elasticities from  
 16 statistical regression models and are intended to estimate overall VMT changes across an entire  
 17 network, not specific flow changes along a particular facility. No precise conversion is possible  
 18 between these two methodologies, but it is possible to compare order-of-magnitude expectations.

19 The lane-mile modifications in the simulations ranged from 850 ft to 4000 ft. As an exam-  
 20 ple, the Sierra Madre auxiliary lane modification was 1700 ft (about 0.32 miles). For this example,  
 21 the third row of Table 4 provides estimates for the additional yearly VMT corresponding to the  
 22 increase in lane miles in the first row produced by the online estimator. The fourth row provides

1 a daily estimate for VMT. The fifth row provides two assumptions for the average length of trips  
 2 in miles. This average trip length is used to approximate the corresponding number of additional  
 3 trips (or flow rate) that might be measured along a road affected by the VMT increase. According  
 4 to these assumptions, a lane-mile modification corresponding to the Sierra Madre configuration  
 5 may result in an increased observation of about 77 vehicles/hour during the peak period. As shown  
 6 in the last two columns, a longer auxiliary lane of about one mile might be expected to induce  
 7 additional flow between 119 and 238 vehicles/hour, depending on the assumptions.

**TABLE 4 Approximation of Traffic Induced by an Auxiliary Lane**

Metric	Scenario 1	Scenario 2	Scenario 3
Increase in lane miles for auxiliary lane	0.32	1.00	1.00
LA-LongBeach-Anaheim MSA Total VMT per year	31,000,000,000	31,000,000,000	31,000,000,000
Additional VMT per year	2,800,000	8,700,000	8,700,000
Additional VMT per day	7,671	23,836	23,836
Average trip length (mi)	10	10	20
Additional trips per day	767	2,384	1,192
Additional trips per peak period	256	795	397
Additional trips per hour during peak period	77	238	119

8 Depending on the scenario, the changes in freeway flow rates due to rerouting could be  
 9 sustained at about 500 vehicles/hour. In addition, changes in ramp flow rates were commonly in  
 10 the range of 100 vehicles/hour or more. To minimize stochastic effects in the model, the results  
 11 presented in the previous section were averages based on five simulation runs. Therefore, we  
 12 expect the simulated results to reflect structural changes in the vehicle routing decisions and not  
 13 just random noise.

14 Given this empirical finding, we conclude that for an auxiliary lane addition of about one  
 15 mile or less, the effects of rerouting are likely to be larger than the effects of induced demand.  
 16 In terms of recommendations, the findings of this study support the idea of a length threshold to  
 17 screen auxiliary lane projects. More research is needed to assess under which circumstances a  
 18 longer or shorter threshold is appropriate.

19 A new conceptual approach might be helpful to describe freeway mainline capacity in  
 20 a non-ambiguous and geometrical way. This might be accomplished by defining a maximum  
 21 distance between capacity control points on the mainline of each stretch of freeway. This would  
 22 require two numbers to parameterize the freeway capacity:

- 23 • N, the maximum number of throughput mainline lanes
- 24 • D, the maximum distance between capacity control points

25 Along each stretch, one would define a threshold, D, on the maximum distance between  
 26 points on the freeway where the number of lanes, N, must not exceed the maximum. In between  
 27 these capacity control points, it may be appropriate to add auxiliary lanes to facilitate merging  
 28 maneuvers or increase queue storage capacity. However, an auxiliary lane would never be allowed  
 29 to grow beyond the length of D. The purpose of defining a value for D is to prevent the situation  
 30 where multiple auxiliary lanes built over time would eventually connect, becoming a de facto  
 31 additional mainline lane. It would be preferable for stakeholders and the local community to agree  
 32 transparently if or when to increase the capacity of a freeway stretch from (N, D) to (N+1, D+Δ).

33 It should be noted that the study also revealed several nuances in the effects of an auxiliary  
 34 lane, and local factors that should be considered. In places with high on-ramp demand:

- 1 • An auxiliary lane may exacerbate a merge bottleneck
- 2 • In areas with high on-ramp demand, auxiliary lanes provide additional space for entering
- 3 vehicles to muscle onto the freeway
- 4 • Ramp meter effectiveness may be limited by the queue flush mechanism
- 5 • An acceleration lane of extended length may have a similar effect as an auxiliary lane
- 6 It might further be advantageous to limit the length of a merge area. In a dense urban
- 7 network, it might be desirable to spread out the demand of entering vehicles across multiple on-
- 8 ramps and enforce strict ramp metering to discourage short freeway trips.
- 9 In places with high off-ramp demand:
- 10 • An auxiliary lane may mitigate a diverge bottleneck
- 11 • In areas with high off-ramp demand, auxiliary lanes provide additional space for exiting
- 12 vehicles to queue along the freeway if the off-ramp is congested
- 13 • An extended deceleration lane or multiple-lane off-ramp may also help

## 14 CONCLUSION

15 This study investigated the impacts of auxiliary lanes on freeway operations through a detailed  
16 and large-scale microsimulation of the I-210 corridor in Los Angeles County. The research was  
17 motivated by the need to evaluate whether auxiliary lane projects improve safety and operations  
18 without triggering substantial increases in vehicle miles traveled (VMT) that would conflict with  
19 environmental goals.

20 The literature review revealed that auxiliary lanes are commonly justified for safety and  
21 operational benefits, particularly in weaving sections. However, it also exposed persistent ambi-  
22 guity around definitions, inconsistent modeling practices, and a lack of clarity on when auxiliary  
23 lanes constitute added capacity versus operational enhancements. Notably, guidelines from state  
24 departments of transportation (e.g., Oregon DOT and Caltrans) identify thresholds for auxiliary  
25 lane lengths, suggesting that lanes shorter than one mile should not be considered as capacity in-  
26 creasing, while longer installations risk functioning as general-purpose lanes that could induce  
27 demand. However, before this study, empirical support for the one-mile threshold was limited.

28 To fill this gap, the study conducted a series of simulations using a calibrated Aimsun model  
29 of the I-210 freeway. Several scenarios were tested, evaluating traffic effects with and without  
30 auxiliary lanes under both free-flow and congested conditions. Results consistently showed that  
31 auxiliary lanes alter local traffic patterns through rerouting effects that shift demand across ramps  
32 and arterials. The simulations also revealed an important asymmetry in flow effects depending  
33 on the level of congestion. When freeways operated under free-flow conditions, auxiliary lanes  
34 appeared to increase mainline freeway flow. Under congested conditions, however, they allowed  
35 more opportunities for entering vehicles to encroach on the mainline freeway, increasing friction  
36 and sometimes reducing mainline flow. In both cases, on-ramp and off-ramp flow patterns were  
37 significantly affected. Yet changes to speeds and travel times on local arterials remained modest,  
38 suggesting that rerouted traffic could generally be absorbed by the surrounding network.

39 In comparing rerouting and induced demand, the study combined simulated flow changes  
40 with external estimates of induced VMT using the induced demand calculator from Volker and  
41 Handy (2). This comparison, while approximate due to differing methodologies, demonstrated  
42 that rerouting effects resulting from auxiliary lane modifications, especially those under one mile  
43 in length, can be larger than the expected induced demand. For example, rerouting effects could  
44 change freeway mainline flow by 500 veh/hr and ramp flows by 100-200 veh/hr during a peak

1 period. Induced demand for a lane-mile modification was estimated to add less than that amount  
2 in comparable flow terms.

3         Based on these findings, the present work offers practical guidance for state departments of  
4 transportation. The findings support the idea of a length threshold to screen auxiliary lanes projects.  
5 However more research is needed to provide additional empirical evidence to refine what threshold  
6 lengths are most appropriate for the situation. Second, local demand patterns are important in  
7 predicting the rerouting effects of a proposed auxiliary lane. An auxiliary lane may favor entering  
8 vehicles at the expense of freeway mainline vehicles. Finally, this study suggests a method to  
9 communicate the throughput mainline freeway capacity in a non-ambiguous and geometrical way  
10 using two numbers to parameterize the freeway capacity by specifying both the number of lanes  
11 and the maximum extent of allowable deviations.

## 12 **ACKNOWLEDGMENTS**

13 The authors thank the California Department of Transportation (Caltrans) for initiating and funding  
14 this research project.

15         Portions of the LaTeX manuscript formatting and the abstract drafting were assisted by  
16 AI-based tools (including generative language models). All AI-generated materials were reviewed  
17 and verified by the authors for accuracy and compliance with TRB policy.

## 18 **AUTHOR CONTRIBUTION STATEMENT**

19 The authors confirm contribution to the paper as follows: study conception and design: A. Patire, F.  
20 Dion; simulation: L. Abuelsamen; simulation analysis and data interpretation: L. Abuelsamen, A.  
21 Patire, F. Dion; draft manuscript preparation: A. Patire, L. Abuelsamen; technical review and val-  
22 idation: F. Dion; critical revision for intellectual content: A. Patire, F. Dion. All authors reviewed  
23 the results and approved the final version of the manuscript.

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