I-70 Reversible Lane

Georgetown to Floyd Hill

Phase 1 Feasibility Study

Existing Traffic Data Evaluation

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1) Introduction

The Colorado Department of Transportation (CDOT) is considering a reversible (Zipper) lane west of Denver to alleviate congestion. The current strategy under consideration calls for an eastbound reversible lane to begin at approximately milepost 230.5 (west of Empire Junction) and for the lane to terminate at the base of Floyd Hill (milepost 244.0). The lane would provide additional capacity for eastbound peak traffic periods by converting one westbound lane to eastbound flow through the use of a movable barrier.

In support of this effort, several analyses have been undertaken to evaluate the initial feasibility of this strategy. One of the initial evaluations is a study of the existing traffic patterns along I-70. This technical memorandum examines traffic count data available from CDOT for the 2009 calendar year on I-70 west of Denver.

The segment of I-70 between the Eisenhower Johnson Memorial Tunnel (EJMT) and Denver (Figure 1) typically experiences recurring peak period congestion. The majority of the congestion occurs in a segment between Floyd Hill and the Georgetown area for several reasons:

- The Twin Tunnels between Idaho Springs and Floyd Hill are constrained due to their narrow width
- The roadway geometry through Idaho Springs is constrained, with narrow shoulders and tight curves
- Considerable volumes enter and exit I-70 at Empire Junction (US 40 interchange) just east of Georgetown
- The I-70 corridor is a major transport route that carries up to 10% trucks.
- Roadway users have to contend with some of the steepest interstate grades in the nation.

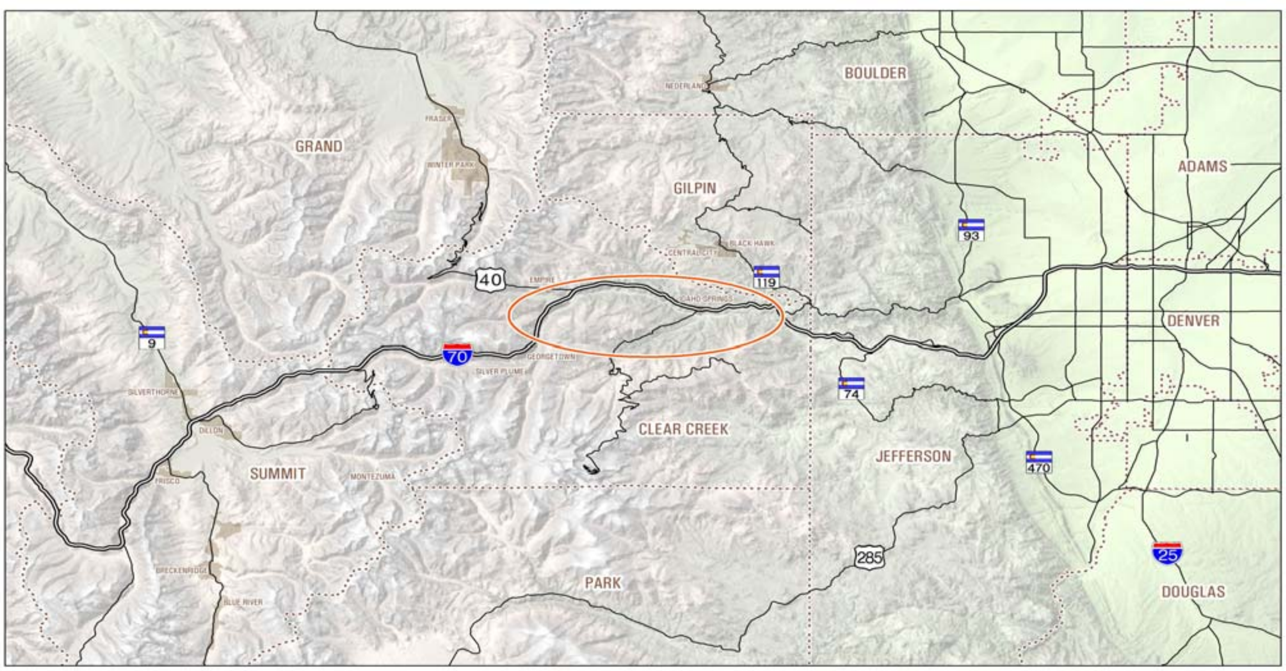

Figure 1. I-70 Reversible Lane Study Project Area

2) Tunnel Capacity

The capacity of I-70 in the study area is generally controlled by the Twin Tunnels. Therefore it was necessary to gain an understanding of the actual amount of traffic I-70 can accommodate in this area. Three approaches were considered. One analysis was based on previous research into tunnel capacities, and two analyses were based on the Highway Capacity Manual (HCM). These are described below.

a) Tunnel Capacity Research

Research on tunnel capacities is limited. Levinson et al. estimated the capacity of the Callahan Tunnel in Boston to be between 1600 and 1650 vehicles per hour per lane (vphpl) after installing traffic management improvements[1]. Levinson et al. also cite a New York Port Authority estimate of 1660 vphpl as the maximum theoretical capacity of a tunnel lane[2]. However, observed maximum volumes in New York and New Jersey tunnels suggest a maximum practical capacity of 1350 to1450 vphpl. Lin et al. estimated the capacity of a tunnel in Taiwan after improvements to be 1300 vphpl in the southbound direction, but only 1150 vphpl in the northbound direction[3]. Koshi et al. observed the capacities of tunnels in Japan under congested conditions to be in the range of 1100 to 1400 vphpl, with the average being about 1325 vphpl[4].

After reviewing these references, capacities of the Twin Tunnels during regular operations are estimated to be similar to the capacity of the improved Callahan Tunnel of about 1600 vphpl. The capacities of the westbound lanes in the Twin Tunnels with the zipper lane barrier installed were estimated to be 1350 vphpl, which is at the high end of the capacities observed in Japan.

b) Highway Capacity Manual

The HCM postulates that facilities will operate between LOS A and LOS E. LOS F conditions generally represent over-capacity or breakdown conditions, where only some traffic flows and remaining demand is unserved and forms a queue. For a vehicle to be counted at a count station, it must pass through the count station, implying operation between LOS A and LOS E. On congested facilities, the highest counted volume will often represent capacity, or the boundary between LOS E and LOS F.

An analysis was performed using the basic freeway module in the HCM. Given that existing counts are available at the east side of the Twin Tunnels, an effort was made to see how well the HCS replicates operations at the tunnels. The following background conditions were coded into the Basic Freeway Segment module of the Highway Capacity Software (HCS), which replicates the procedures outlined in the HCM:

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[1] Levinson, H.S., M. Golenberg, and J. Howard. Callahan Tunnel Capacity Management. In *Transportation Research Record 1005,* TRB, National Research Council, Washington, D.C., 1985, pp. 1–10.
[2] Levinson, 1985.
[3] Lin F-B, C-W Chang, P-Y Tseng, and C-W Su. Capacity and Other Traffic Characteristics in Taiwan's 12.9-km-Long Shea-San Tunnel. In *Transportation Research Record 2130,* TRB, National Research Council, Washington, D.C., 2009, pp. 101-108.
[4] Koshi, M., M. Kuwarara, and M. Acahane. Capacity of Sags and Tunnels on Japanese Motorways. *ITE Journal*, Vol. 62, No. 5, 1992, pp. 17–22.

- Two lanes per direction
- PHF = 0.90
- Terrain = rolling
- Driver population factor =1.00
- Measured FFS = 60 mph
- 10% heavy vehicles; 2% RVs

The ten highest counts at the tunnels (based on data from the permanent count station) were entered, and the results were reviewed. None of the high volume scenarios resulted in LOS F operations, indicating that the HCM overestimated the capacity of the tunnel. As a calibration tool, the driver population factor was reduced to 0.98, and the top ten volumes were then reanalyzed. The results indicated that three highest volumes resulted in LOS F operations. The next five highest volumes were essentially constant between 3327 vehicles per hour (vph) and 3384 vph, and resulted in LOS E operations. Given that these data were relatively constant, and that the top eight volumes are within a band around the LOS E / LOS F boundary, it was assumed that a reasonable calibration had been achieved.

With the surrogate calibration factor in place, a series of runs with artificial volumes ranging from 3,000 vph to 3,600 vph in 50-vehicle increments were performed. This analysis indicated that the LOS E/ LOS F boundary occurs at approximately 3,450 vph or 1725 vphpl. However, the use of the surrogate calibration factor calls these results into question.

The Highway Capacity Manual does not evaluate one-lane freeways, which would exist if the reversible lane were in place. However, a second surrogate analysis was performed assuming that the reversible lane scenario would function as a rural two-lane highway. Using the HCS two-lane road analysis module, the team specified the following:

- 10% trucks and buses, 0% RVs
- 100% no-passing zones
- 60 mph base free-flow speed
- 50/50 directional split
- Rolling terrain
- 0 access points per mile

With those conditions, 1500 vphpl (3000 for both directions) is the break point between LOS E and LOS F. The LOS is based on Percent Time Spent Following (PTSF), which does not vary with changes in lane width, right shoulder width, or segment length. The HCM analysis also assumes a center stripe (not a concrete barrier). Lane and shoulder width (but not segment length) slightly affect the average travel speed (ATS). The team set the lane and shoulder widths to their highest possible values, and obtained an ATS of 34.6 mph. Setting them to their lowest possible values results in an ATS of 29.3 mph.

c) Conclusion

Given the three approaches to tunnel analysis documented above, (research, HCM Freeways, and HCM two-lane rural road), three results were obtained. Research indicated between 1325 vphpl and 1650 vphpl in tunnels. The HCM Freeways results indicated approximately 1725 vphpl, based on field conditions with a questionable calibration factor. Actual field volumes were approximately 1675 vphpl. The HCM two-lane rural road results indicate 1500 vphpl. Given these values, it was assumed that capacity for the westbound Twin Tunnel is **1600** vphpl. If the reversible lane is in operation, a lower value of **1350** vphpl was assumed, which is 10% to 15% less than the assumed existing capacity, and reflects the low end of the capacity data reviewed.

It should be noted that while capacity is being used to determine the level at which a reversible lanes may be beneficial, volumes approaching capacity will not necessarily be free flowing. As volumes increase and approach capacity, speeds decrease.

3) Analysis Approach

The I-70 recurring congestion typically occurs during four peak periods. They are:

- Weekday AM (commuters to Denver)
- Weekday PM (commuters from Denver)
- Saturday AM (recreational / tourist traffic to the mountains)
- Sunday PM (recreational / tourist traffic from the mountains)

There are also notable differences in traffic levels (and hence congestion) in various seasons. This is related to skier traffic in the winter, hiking and mountain biking in the summer, and lower recreational uses in spring and fall. These variations are discussed in detail below.

a) Weekdays

Weekday traffic volume patterns are relatively similar Monday through Thursday. However, Friday patterns are affected by recreational traffic, and are therefore included in the weekend analysis. Refer to Figures 2 and 3 below for a summary of weekday traffic volumes at the Twin Tunnels (mile marker 241.1) for the 2009 calendar year.

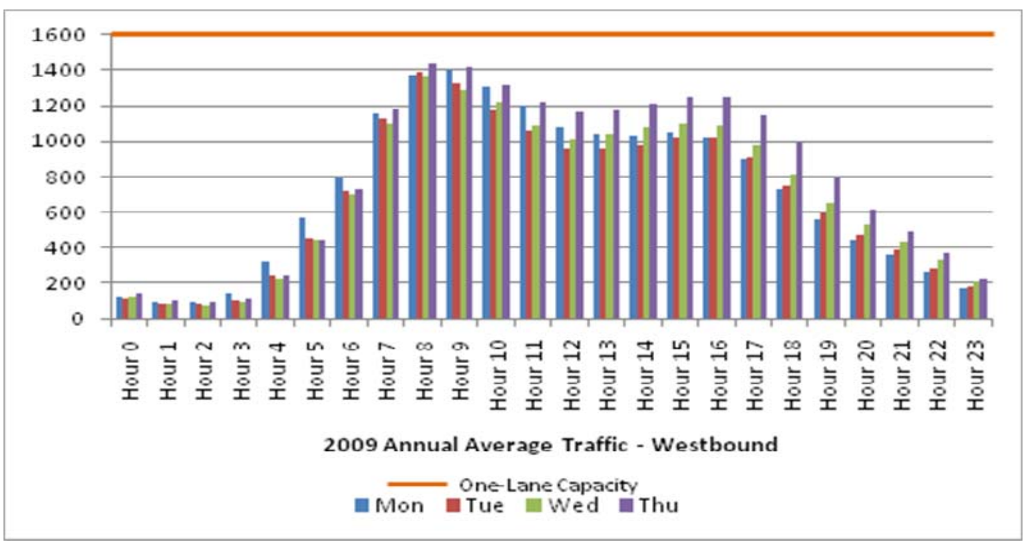

Figure 2. 2009 Annual Average Traffic—Westbound

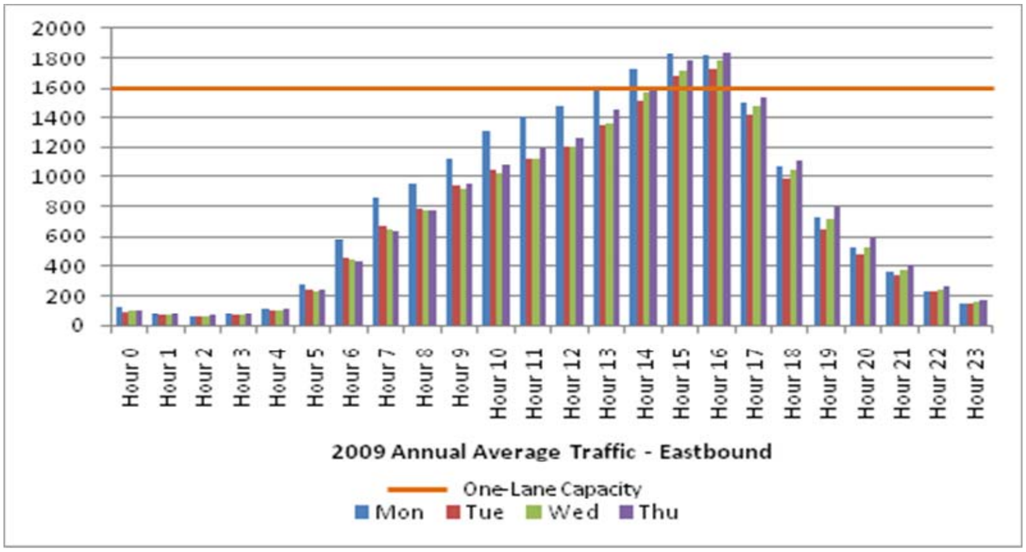

Figure 3. 2009 Average Daily Traffic—Eastbound

As Figures 2 and 3 show, the average 2009 weekday volumes at the Twin Tunnels never exceed 2000 vph. This value is well below the capacity of the Twin Tunnels (3200 vph). Therefore, a reversible lane would provide little benefit on an average weekday.

One of the key concerns, however, is seasonal variations in traffic. The graphs above have been redone for only the summer months (June, July, and August) as Figures 4 and 5.

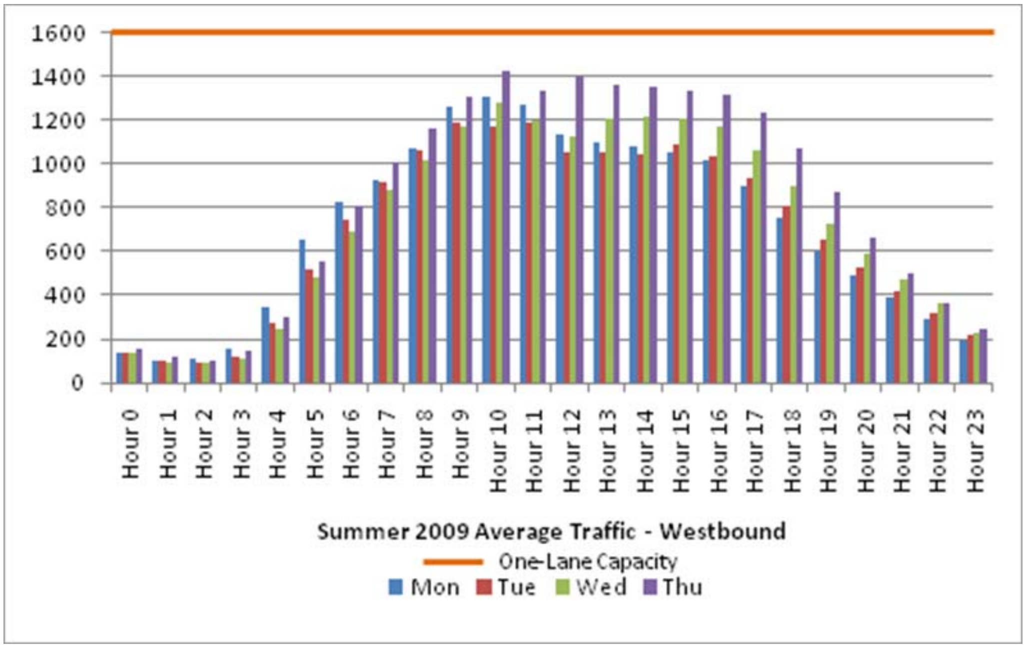

Figure 4. 2009 Summer Average Traffic—Westbound

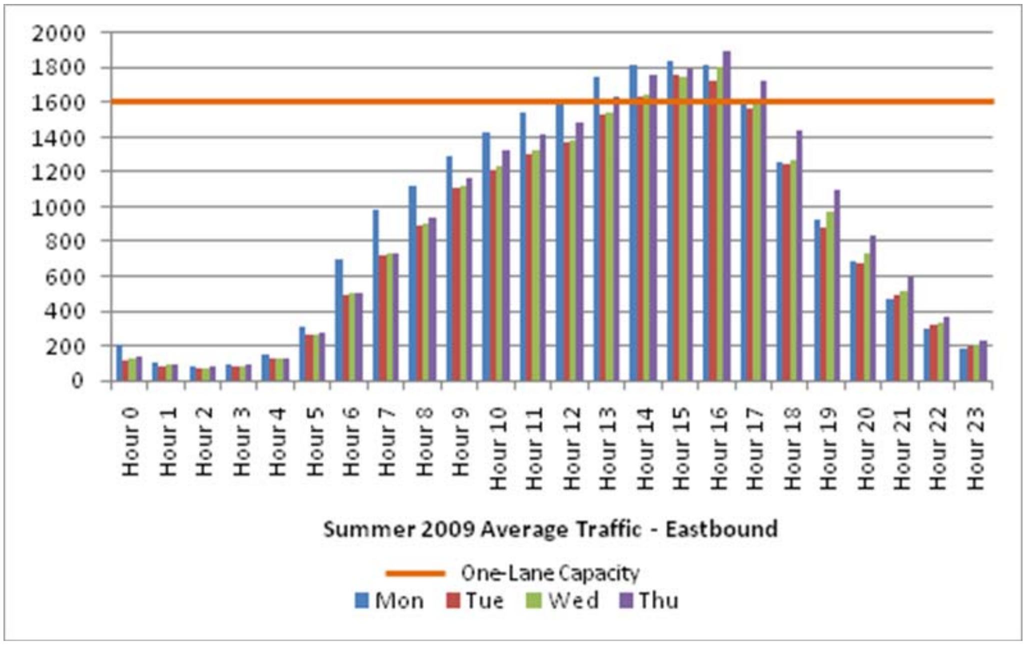

Figure 5. 2009 Summer Average Traffic—Eastbound

Very little difference between the annual and the summer data are evident. Therefore, a reversible lane would provide little benefit on a summer weekday. The graphs above have been redone for only the winter months (December, January, February, and March) as Figures 6 and 7.

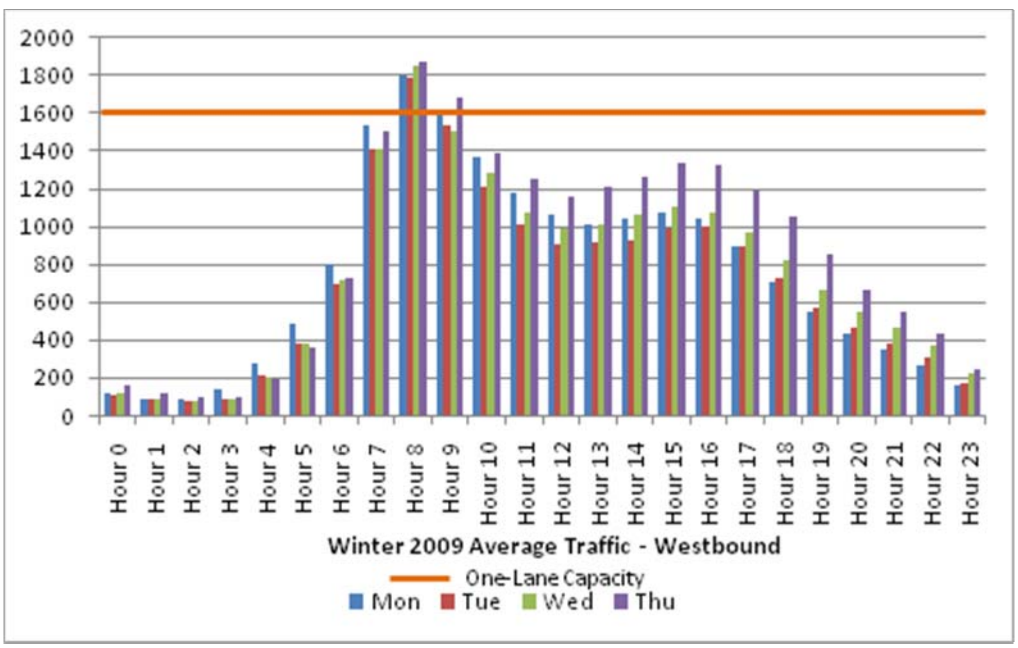

Figure 6. 2009 Winter Average Traffic—Westbound

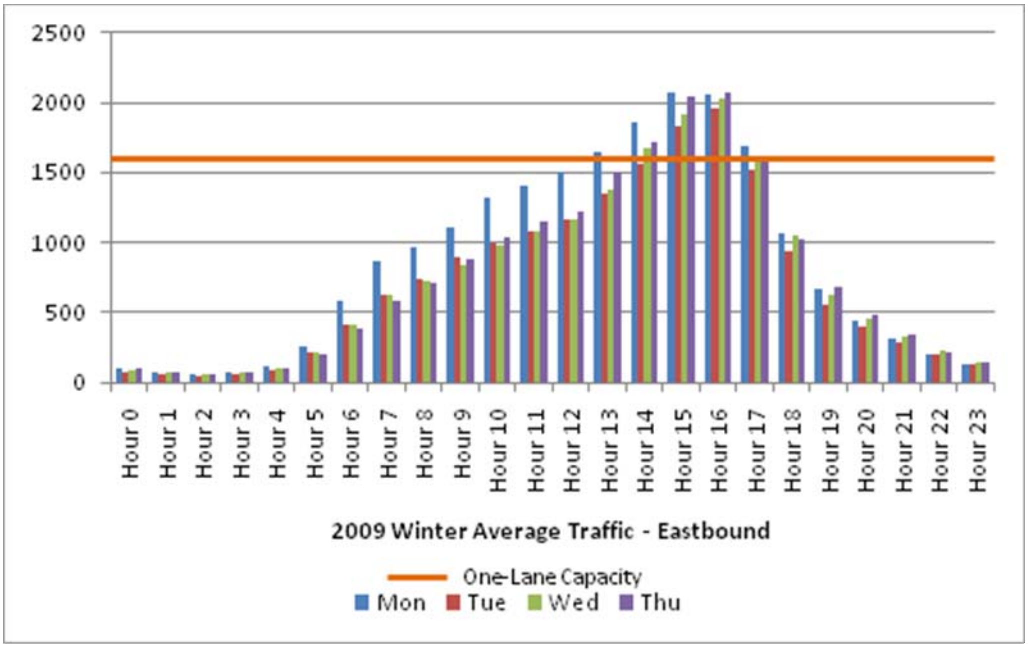

Figure 7. 2009 Winter Average Traffic—Eastbound

The winter data are somewhat higher than the average annual data for both directions. However, the winter traffic volumes do not exceed 2100 vph in either direction. Therefore, a reversible lane would provide little benefit on a winter weekday.

b) Weekends

Weekend traffic volume patterns vary widely between Friday, Saturday, and Sunday. Friday and Saturday tend to emphasize travel to the mountains, while Sunday travel emphasizes a return to the Denver area. Refer to Figures 8 and 9 below for a summary of weekend traffic volumes.

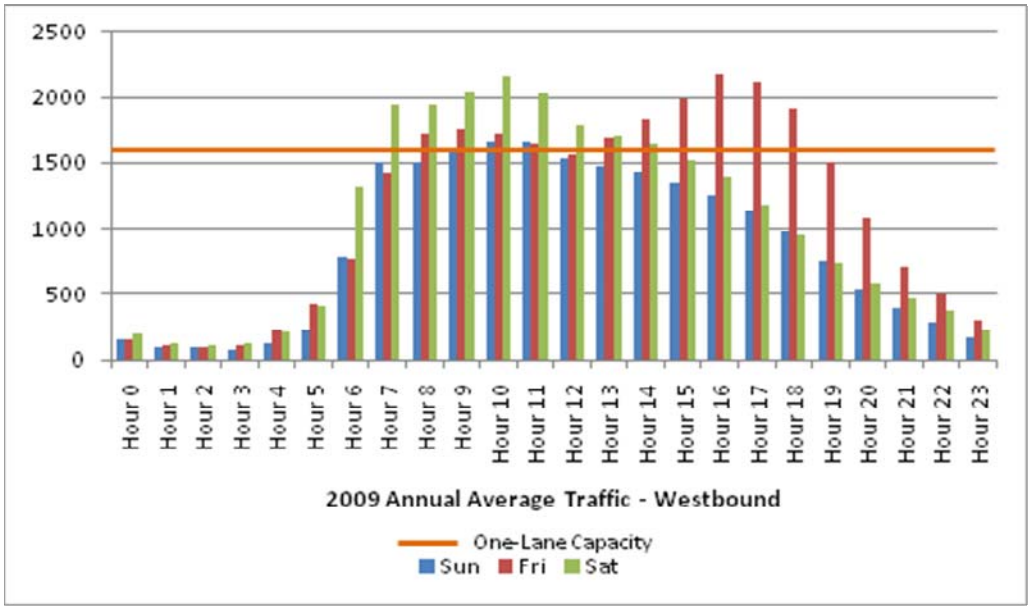

Figure 8. 2009 Annual Average Traffic—Westbound

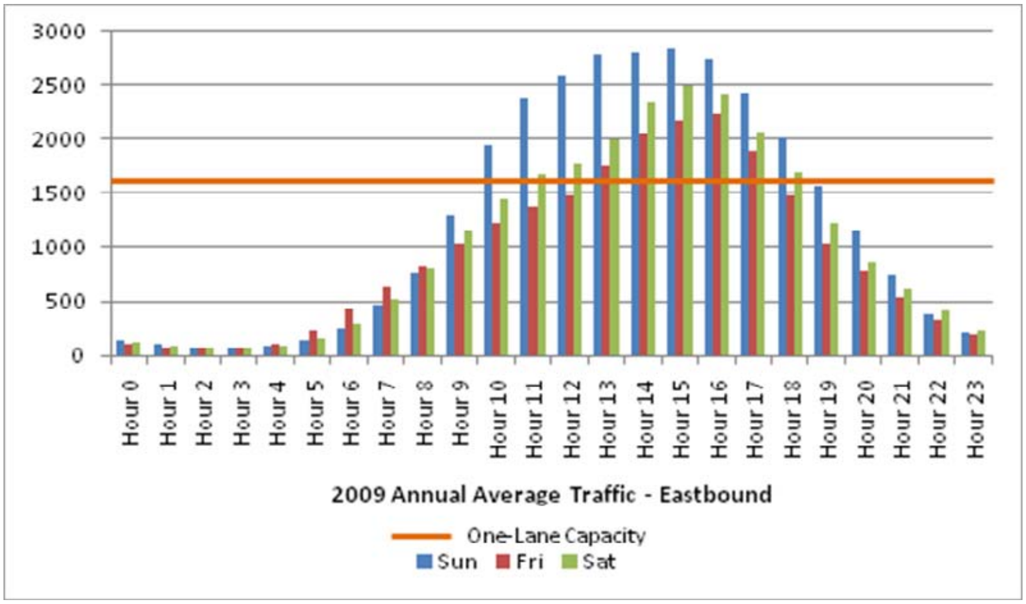

Figure 9. 2009 Annual Average Traffic—Eastbound

As Figures 8 and 9 show, the average 2009 weekday volumes at the Twin Tunnels exceed 2000 vph on Friday and Saturday, and eastbound volumes exceed 2000 vph all three weekend days in the eastbound direction. The eastbound 2009 average weekend volumes approach capacity at 2850 vph on Sunday afternoons, nearing the capacity of the Twin Tunnels (3200 vph). As field experience shows, westbound congestion occurs on some Friday evenings and some Saturday mornings, and eastbound congestion occurs regularly on Sunday afternoons. Therefore, a reversible lane could provide benefits on weekends.

Again, these data have been limited to summer weekends and are shown in Figures 10 and 11.

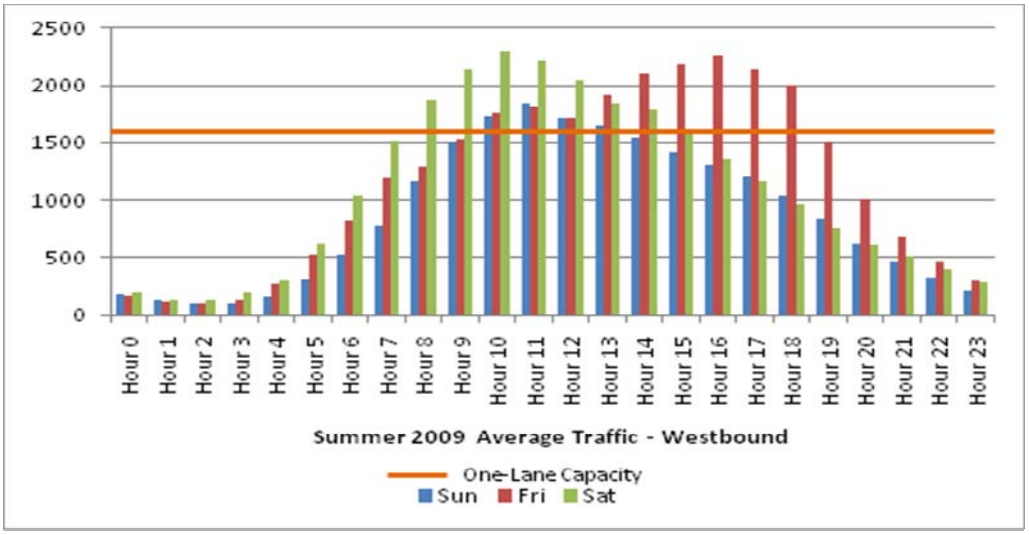

Figure 10. 2009 Summer Average Traffic—Westbound

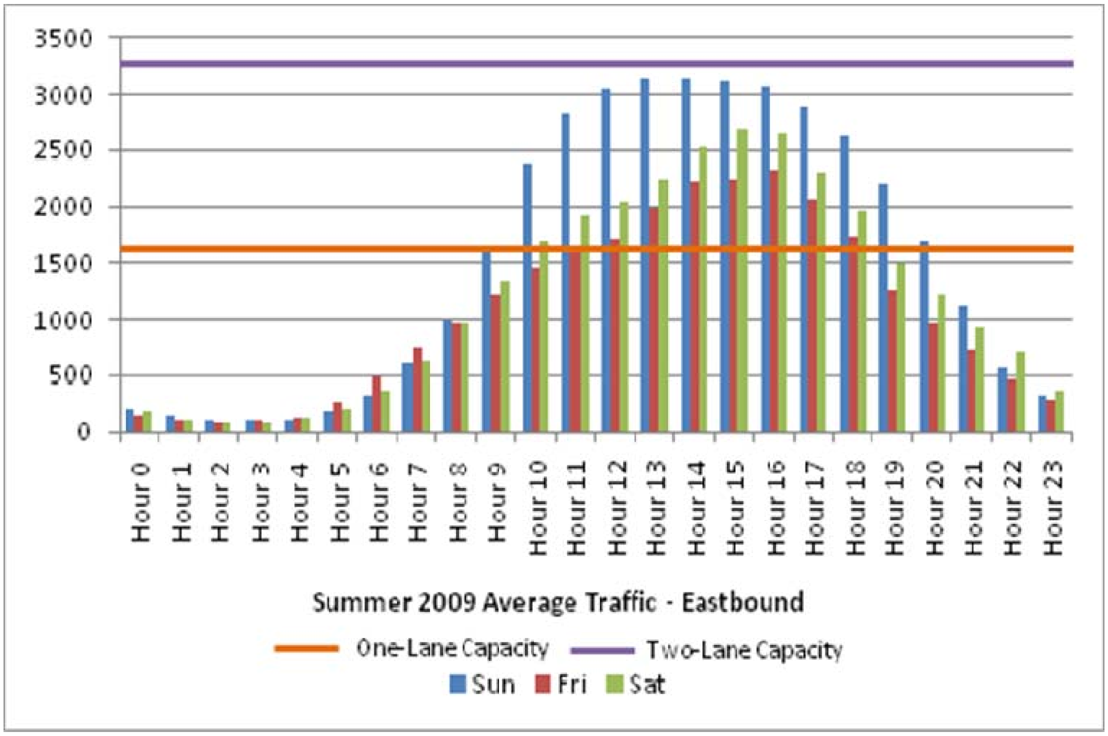

Figure 11. 2009 Summer Average Traffic—Eastbound

As can be seen, the westbound peak traffic (Figure 10) on Friday afternoon is approximately 2250 vph, and the Saturday morning peak traffic flow is approximately 2300 vph. Both of these values exceed the one-lane capacity (1600 vph), but are not high enough to result in congestion in the westbound direction (3200 vph) on an average summer weekend.

The eastbound graph (Figure 11) shows that the eastbound lanes are operating at or near capacity (3200 vph) for several hours on Sunday afternoon. Friday and Saturday volumes are between 2350 vph and 2700 vph, exceeding the one-lane capacity, but not high enough to result in severe congestion in the eastbound direction.

A similar evaluation was performed for winter weekend volumes. Refer to Figures 12 and 13.

As can be seen, the westbound peak traffic (Figure 12) on Friday afternoon is approximately 2400 vph, and the Saturday morning peak traffic flow is approximately 3200 vph. The Saturday morning value is at capacity, while the Friday afternoon value is below the two-lane capacity (but well above the one lane capacity).

The eastbound graph (Figure 13) shows that the eastbound lanes are operating at or near capacity (3200 vph) for several peak hours on Sunday afternoon. The Saturday data also reflect one peak hour approaching capacity (3000 vph). The Friday peak volumes are between 2400 and 2500, exceeding the one-lane capacity, but not high enough to result in severe congestion in the eastbound direction.

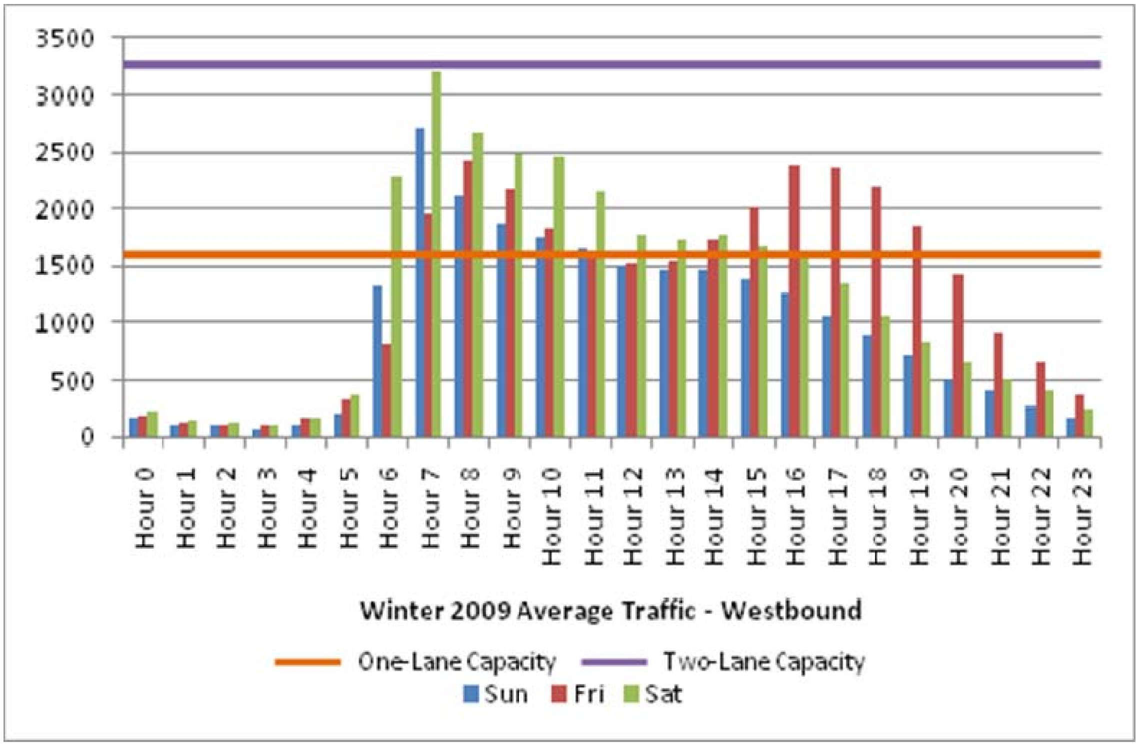

Figure 12. 2009 Winter Average Traffic—Westbound

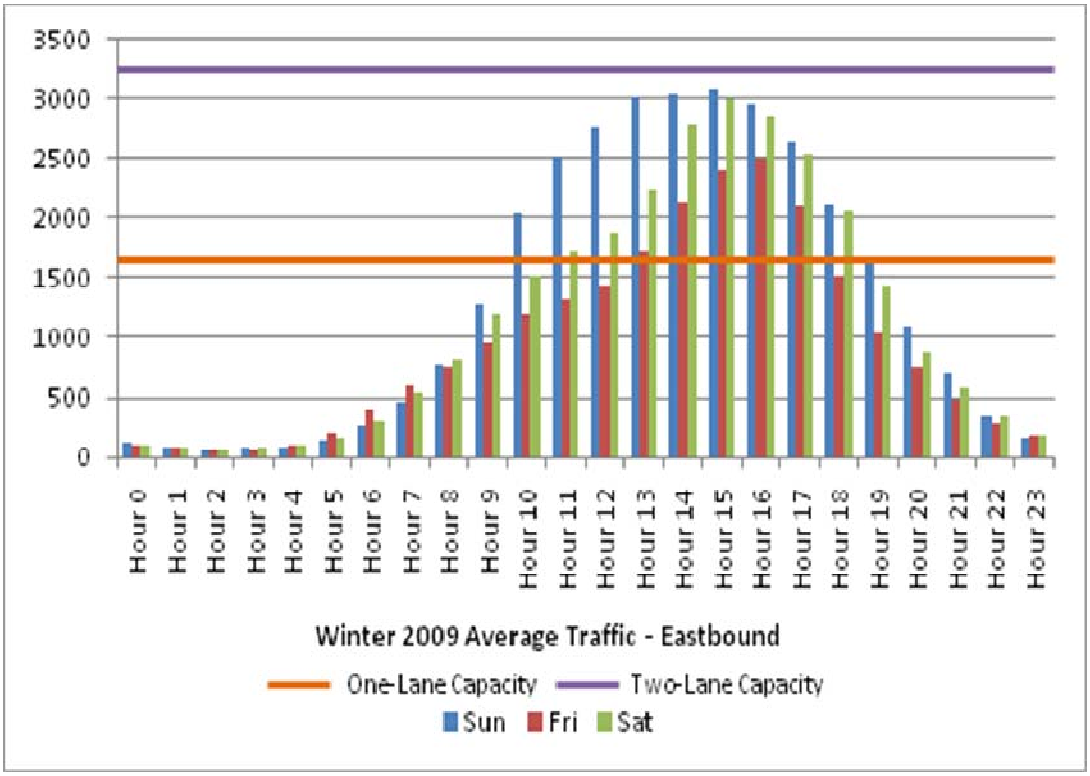

Figure 13. 2009 Winter Average Traffic—Eastbound

4) Conclusions

CDOT considered the feasibility of reversible operation on summer Sunday afternoons to alleviate the eastbound congestion shown in Figure 11. In order for this to work efficiently, the westbound traffic during this time period must be at or below the single lane capacity (1350 vph). A review of the data in Figure 10 shows several hours over 1350 vph, including one hour over 1800 vph. Therefore, it was concluded that summer weekend reversible lane operations would not be feasible.

CDOT also considered the feasibility of reversible lane operation for several winter periods to alleviate the congestion shown in Figures 12 and 13. Again, in order for this to work efficiently, the off-peak direction of traffic during the reversible lane time period must be at or below the single lane capacity.

- Westbound Saturday morning—the westbound volume is at or near capacity for one AM peak hour, and the eastbound volumes during this time period are well below the 1350 vph threshold for one lane operation. Reversible lane operations during this time period could be feasible, although the benefit would be limited since westbound traffic is only at or near capacity for one hour.
- Eastbound Saturday afternoon - the eastbound volume is near capacity for one PM peak hour. Westbound volumes during this hour are about 1400 vph; however, the volumes in the two hours before this hour (when the reversible lane would be set up) exceed the 1350 vph one lane operation threshold. Reversible lane operations during this time period would not be feasible.
- Eastbound Sunday afternoon - The eastbound volume is at or near capacity for four PM hours and the predominant direction of travel is eastbound late into the evening. Westbound volumes are at or near 1,350 vph for approximately 3 hours during initially proposed hours of reversible lane operation. Because of the pronounced directional split, winter Sunday PM provides the highest potential benefit to reversible lane operation

Based on the evaluations above, developing an eastbound reversible lane on winter Sunday afternoons was found to have the potential for greatest benefit, based on traffic patterns in the I-70 corridor.