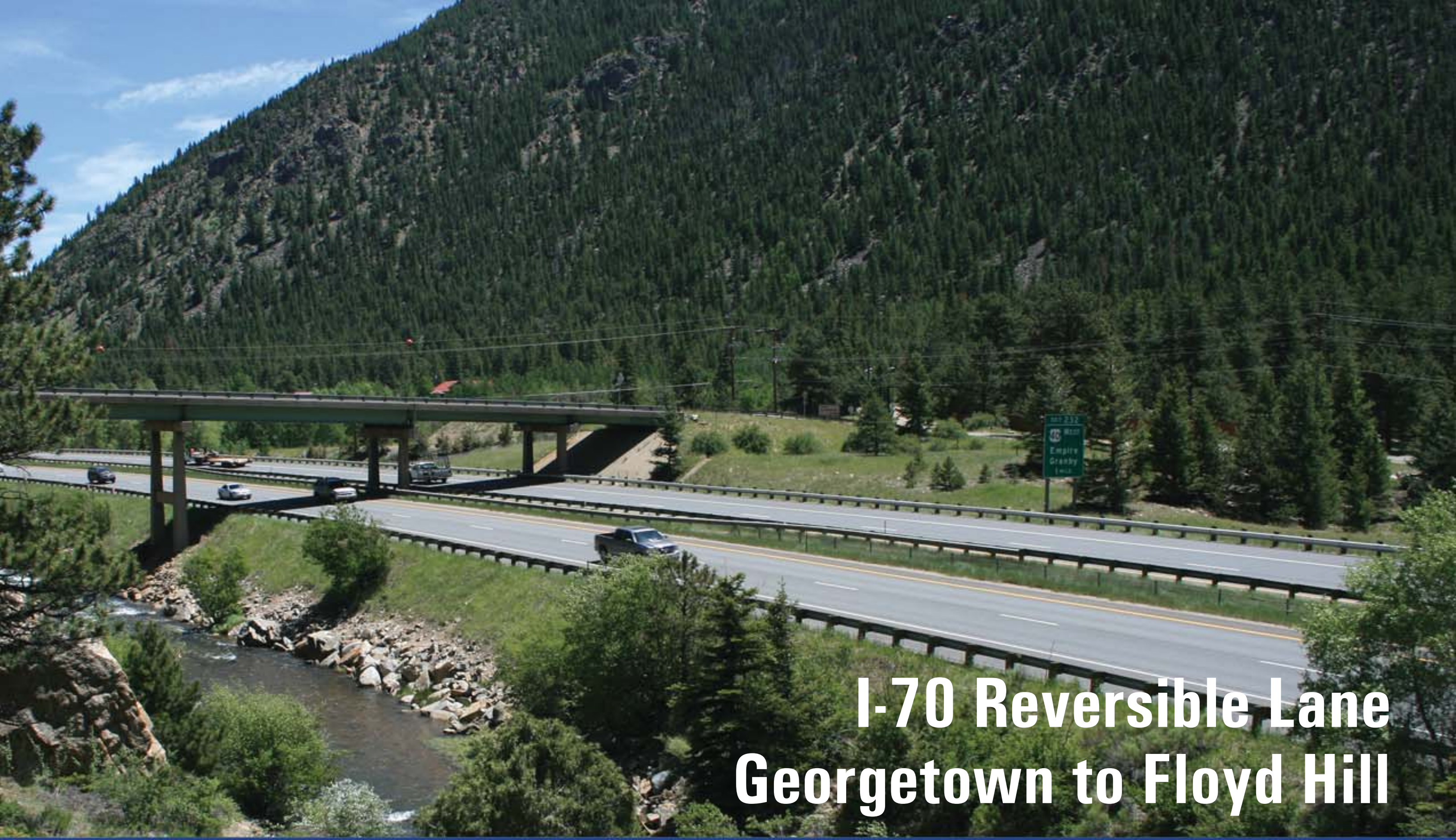

I-70 Reversible Lane
Georgetown to Floyd Hill

Phase I Feasibility Study
Executive Summary Report

August 10, 2010

DEPARTMENT OF TRANSPORTATION

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1. Executive Overview

The Colorado Department of Transportation (CDOT) is considering a reversible (zipper) lane on I-70 west of Denver to manage congestion during peak times on winter Sundays. The current strategy under consideration calls for an eastbound reversible lane to begin west of Empire Junction (approximately Milepost 230.5) 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 using a movable barrier for approximately 13.5 proposed miles. Traffic would enter the reversible lane in the Georgetown area and would exit near the base of Floyd Hill, with no intermediate access points.

Several analyses were undertaken to evaluate the initial feasibility of this reversible lane. The goal of the Phase I Feasibility Study was to answer the following fundamental questions:

- Do roadway geometry and topography allow construction of transition crossovers that can operate safely? Are there other geometric constraints that would prohibit using the movable barrier technology to create an eastbound reversible lane?
- Is implementing a reversible lane in the eastbound direction on winter Sunday afternoons feasible considering traffic volumes? Specifically, what would be the impact to westbound traffic?

Key elements and findings of these analyses are contained in this Phase I Feasibility Study Executive Summary Report. The overall conclusions are as follows:

- Traffic modeling indicates that implementation of the reversible lanes would decrease travel time for the eastbound traffic on average from 79 minutes to 41 minutes with trucks, or 40 minutes without trucks.
- Traffic modeling indicates that implementation of the reversible lanes would increase travel time for the westbound traffic on average from 34 minutes to 69 minutes with trucks, or 60 minutes without trucks.
- Traffic analysis indicates that for Sunday afternoons during the ski season, the reversible lane provides an overall 13 percent travel time benefit to the traveling public in the I-70 corridor.

Critical issues that should be considered during the next phase of study (Phase II) include safety and emergency response, maintenance and snow removal, public relations, environmental impacts, modes of operation and project delivery, concept of operations and operational enhancements, and geometric design issues.

2. Problem Statement

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

- Heavy traffic volumes enter and exit I-70 at Empire Junction (US 40 interchange) just east of Georgetown.
- The roadway geometry through Idaho Springs is constrained, with narrow shoulders and tight curves.
- The Twin Tunnels (between Idaho Springs and Floyd Hill) are operationally constrained because of the narrow width of shoulders.
- The I-70 corridor carries an average of about 10 percent truck traffic.
- Roadway users also have to contend with three percent to four percent grades (refer to **Figure 2**). Slow-moving vehicles contribute to congestion.

These operational and geometric issues lead to several consequences:

- The traveling public experiences substantial delays during congested periods. Travel times can double when compared to uncongested conditions.
- Motorists divert to alternate routes and cause congestion on those routes, affecting areas beyond the interstate itself (refer to **Figure 3**).
- Emergency services and transportation-dependent commerce are delayed.

Figure 1. I-70 Reversible Lane Study Project Area

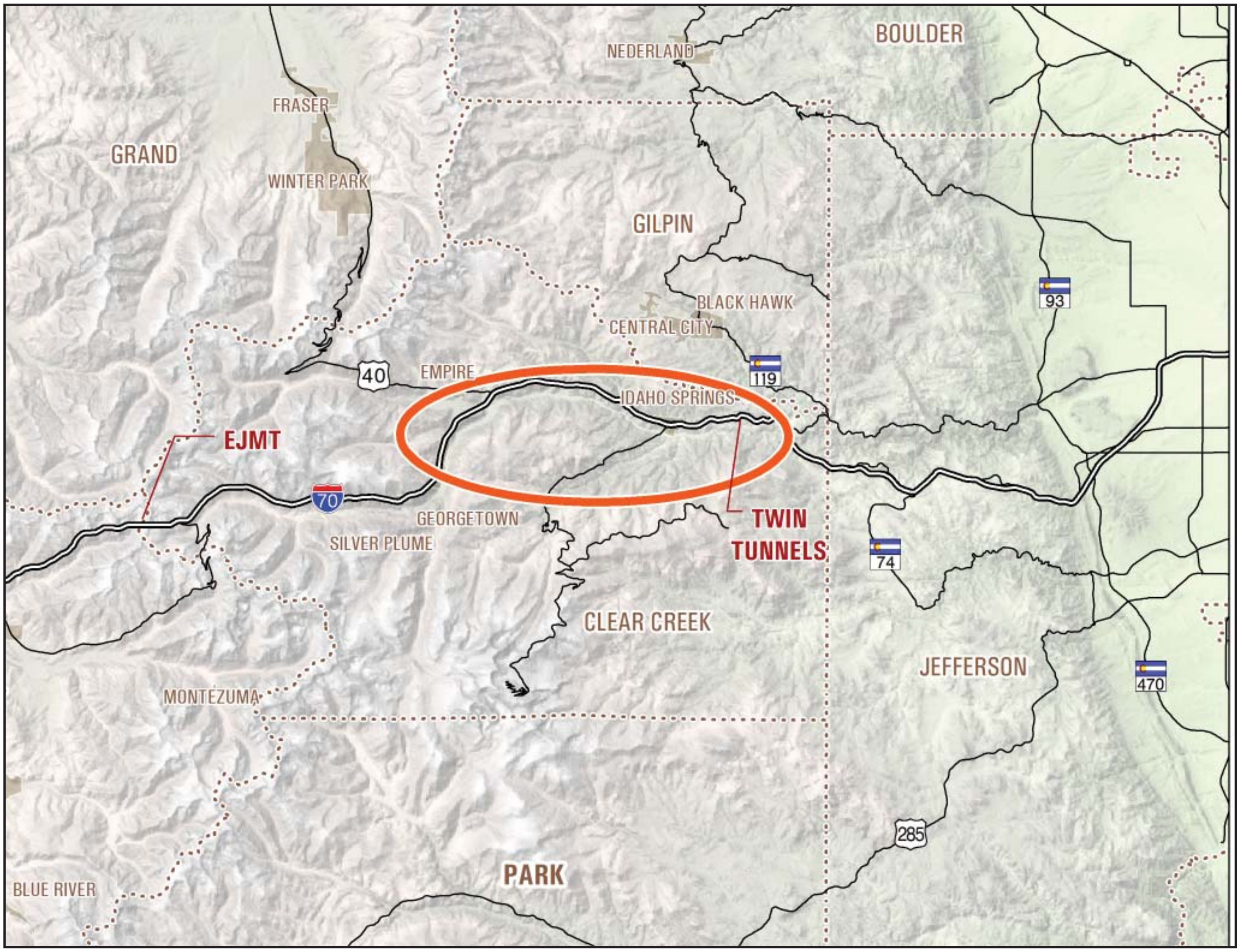
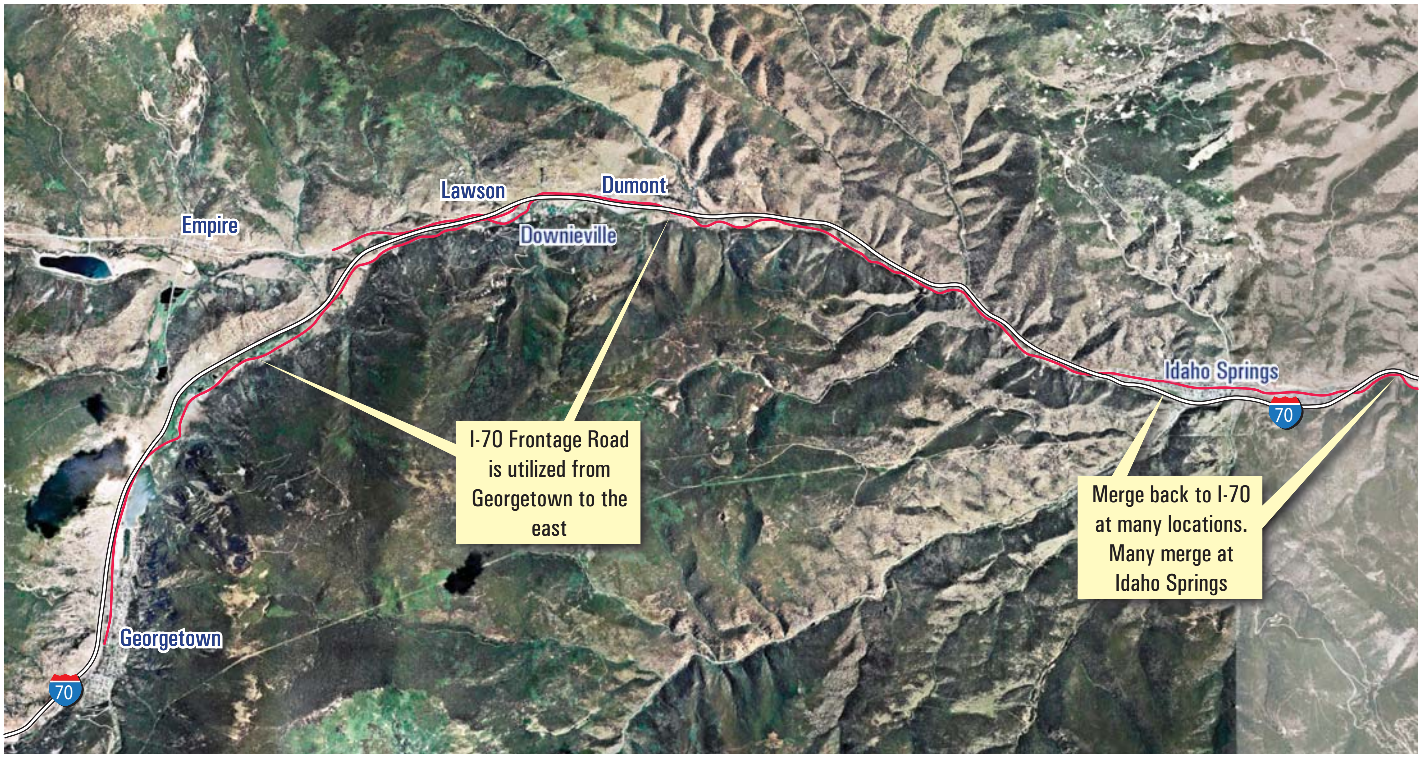


Figure 2. I-70 Profile (West of Denver)

Figure 3. Eastbound Alternate Routes During Congestion



3. Addressing the Problem

Several long-term solutions for I-70 congestion are being evaluated in the ongoing I-70 Mountain Corridor Programmatic Environmental Impact Statement (PEIS). However, CDOT is interested in providing a short-term solution for I-70 motorists while the PEIS is being completed and its recommendations are funded and implemented. One such solution could be a reversible lane.

3.a. What is a Reversible Lane?

Reversible lanes have been used to manage traffic flows for several decades across the United States. However, they have not been used in a unique mountain environment such as the I-70 corridor. The most common permanent application has been to manage traffic flows where there is heavy traffic in one direction and light traffic in the other. Because the direction with the light traffic flow can operate in fewer lanes, one or more of the lanes are reversed in the opposite direction to accommodate the heavier traffic flow.

Reversible lanes are typically implemented with a movable barrier, similar to the one shown in **Figure 4**. The barrier consists of short segments (several feet long) that are hinged together to form a continuous barrier. They have a T-shaped top section that allows a barrier moving machine to pick the barrier up several inches off the pavement and move it laterally the width of a lane. Because the barrier segments have to be pinned together to maintain crashworthiness, breaks in the barrier are usually limited to emergency access.

Figure 4. Movable Barrier and Barrier Machine

3.b. Could a Reversible Lane Work on I-70?

CDOT began considering a reversible lane to address congestion along I-70 during the summer of 2009. CDOT's initial intent was to determine if reversible lanes could address the congestion experienced in this corridor during directional high-volume periods.

The I-70 corridor experiences directional splits (ideal for reversible lane implementation) during several of the periods that have recurring congestion. As an example, congestion often occurs on winter Sunday afternoons. The graph shown in **Figure 5** reflects the average directional split for Sunday afternoons in March 2009.

3.c. What Support Does a Potential I-70 Reversible Lane Have?

In May 2010, the Colorado state legislature approved Senate Bill 10-184. The legislation authorized the High Performance Transportation Enterprise to enter into a transportation demand management contract with CDOT to relieve traffic congestion on I-70 during peak travel times, if a feasibility study demonstrated that a movable barrier system would be viable and that life safety issues would be addressed.

In February 2010, CDOT began the feasibility study, based in part on the concepts developed in 2009. As part of the first phase of this effort, CDOT brought together the Federal Highway Administration (FHWA), the University of Arizona (UA), the University of Colorado at Denver (UCD), and Jacobs Engineering Group Inc. (Jacobs) to form the Phase I project team. The goal of Phase I was to answer the following fundamental questions:

- Do roadway geometry and topography allow construction of transition crossovers that can operate safely? Are there other geometric constraints that would prohibit using the movable barrier technology to create an eastbound reversible lane?
- Is implementing a reversible lane in the eastbound direction on winter Sunday afternoons feasible, considering traffic volumes? Specifically, what would be the impact to westbound traffic?

4. Phase I Reversible Lane Feasibility Evaluation

The Phase I Feasibility Study consisted of two main elements – initial design feasibility and initial traffic analysis.

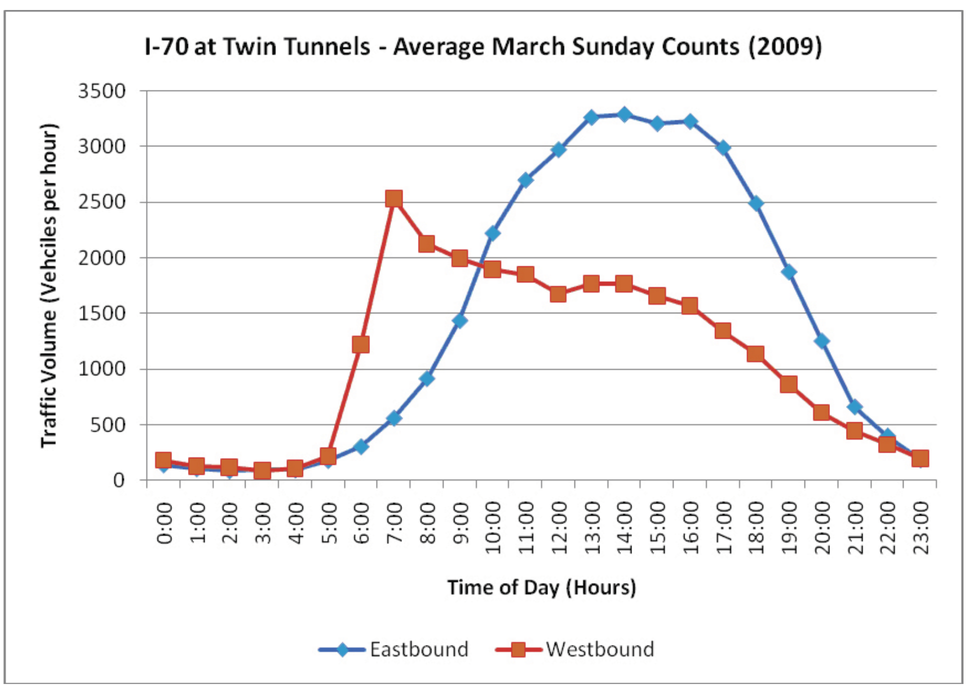
4.a. Initial Design Feasibility

Based on the 2009 efforts by CDOT, a reversible facility had been anticipated between Georgetown and the base of Floyd Hill, a segment of approximately 15 miles. The design feasibility effort focused on roadway widths and the two crossovers required to shift eastbound traffic from the existing eastbound lanes to the reversible lane (in the left westbound lane) and then back to the eastbound lanes. The locations of the crossovers would be used to determine the final length of the facility. For more details on geometric feasibility, refer to Appendix A, which contains the technical memorandum documenting this analysis.

4.a.i. Reversible Lane Design Concept

The overall concept for the reversible lane is to provide a third eastbound lane on I-70 between Georgetown and Floyd Hill. As described in Section 4.a, the current scenario would take a westbound lane and convert

Figure 5. Sunday Traffic Volumes



it to eastbound travel, with a movable barrier separating the directions of travel in the existing westbound roadway.

For this segment, the significant separation between eastbound and westbound lanes (vertical and/or horizontal, depending on location), as well as operational and safety considerations, would preclude access to the reversible lane between the two ends of the facility under consideration. Therefore, motorists entering the reversible lane east of Georgetown would not be able to exit the reversible lane until they reached the east end at Floyd Hill.

4.a.ii. West Crossover

The west crossover is intended to allow traffic to move from the eastbound lanes over to the reversible lane. Design considerations for this option include an area where the difference in elevation between eastbound and westbound lanes is minimal and that appropriate design speeds can be obtained.

Two locations for the west crossover were evaluated. One location was just east of the Georgetown interchange, and the second was just west of the Empire Junction interchange. The location closer to Empire Junction (Milepost 230.5) was selected because it provides a shorter overall facility and avoids conflicts between the reversible lane entrance, the eastbound chain station, and Georgetown interchange traffic (refer to **Figure 6**).

Traffic from US 40 (Empire Junction) would not be able to access the reversible lane. This is intentional because it is expected that overall traffic operations in the existing eastbound lanes would be improved, making this access unnecessary.

4.a.iii. East Crossover

The east crossover would move traffic from the reversible lane back to the eastbound general purpose lanes. In addition, the eastbound crossover lane has to be extended to connect to the existing three-lane cross-section that climbs Floyd Hill. If this connection is not made where there are three existing lanes, traffic from the two eastbound general purpose lanes and the reversible lane traffic would have to merge into two lanes, creating a bottleneck and eliminating the benefits of the reversible lane. A feasible crossover location was found between the Hidden Valley interchange and the base of Floyd Hill that would allow connection of the reversible lane traffic to the third lane climbing Floyd Hill at Milepost 244.0. Based on these crossover locations, an approximately 13.5-mile reversible lane would be possible.

4.a.iv. Shoulders and Twin Tunnels

The typical outside shoulder width along this segment of I-70 ranges from 8 to10 feet, and the inside shoulder varies from 3 to 5 feet. However, there are spot locations that have constrained shoulder width. The Twin Tunnels represent one such pinch point, with shoulders of 3 feet or less on both sides. The Phase I project team had concerns regarding the installation of barriers in areas where the existing shoulders are narrow.

Based on geometric review of the corridor, the westbound lanes could accommodate the reversible lane and movable barrier, but narrower shoulders would result (refer to **Figure**

Figure 6. West Crossover Near Empire Junction (See Appendix A for Details)

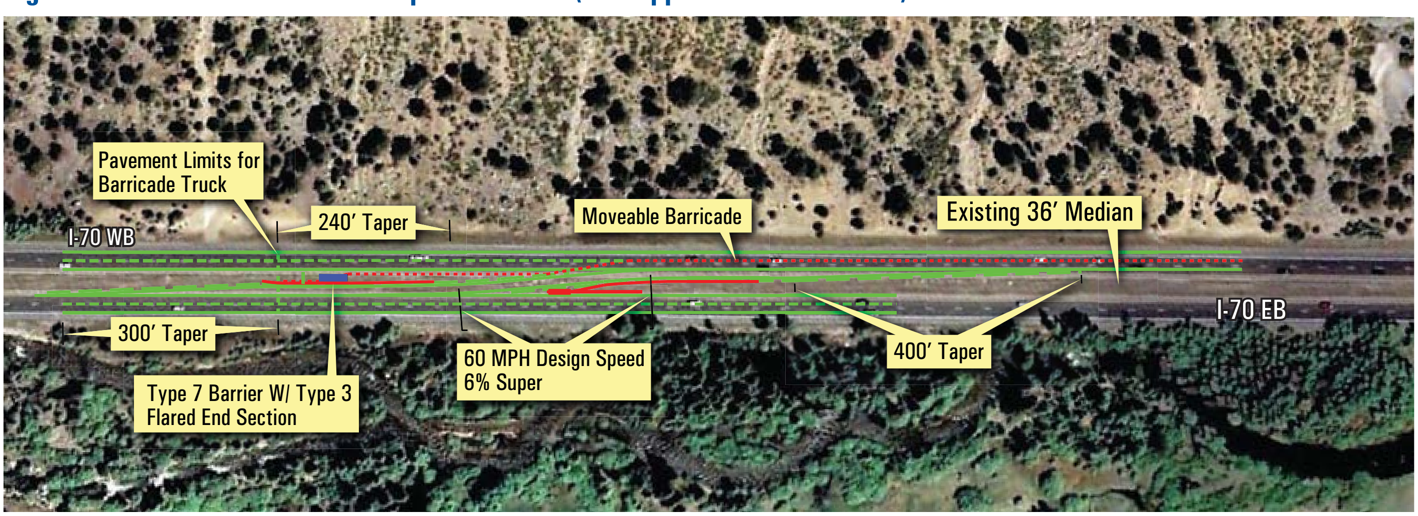
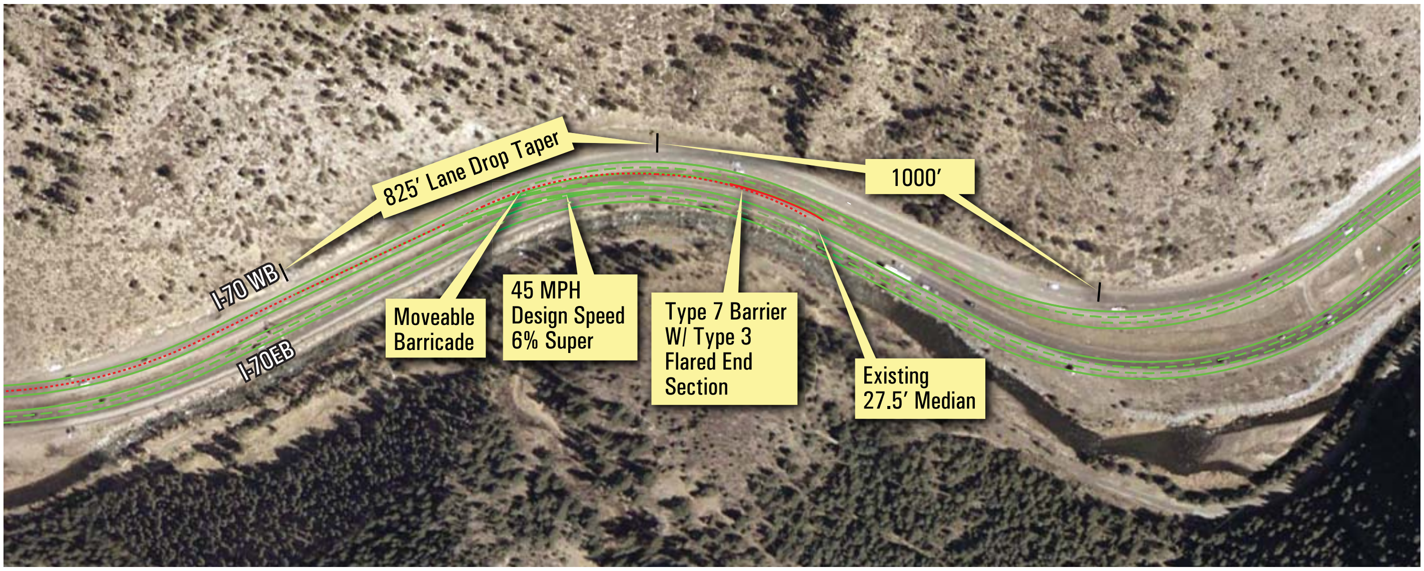


Figure 7. East Crossover at the Base of Floyd Hill (See Appendix A for Details)



8). The westbound Twin Tunnel would have the narrowest cross-section (see **Figure 9**), with shoulders less than 2 feet on both sides with the barrier installed.

4.b. Initial Traffic Analysis

Traffic modeling and analysis were performed by the Phase I team. Analysis tools used were DynusT and VISSIM. DynusT is a dynamic traffic assignment model that routes traffic based on roadway operations. VISSIM is a simulation model that predicts traffic operations as vehicles move through a roadway network. These models were used to study potential options for the reversible lane. The forecasted results are subject to variations, such as economic and demographic changes, variations in vehicle fleets, and changes in motorist behavior.

The analysis team first assembled data depicting existing conditions in the study area. Using these data, the team developed calibrated DynusT and VISSIM models. The models were then used to project conditions with a potential reversible lane. The team focused on high-volume scenarios indicative of the periods when congestion is highest along the corridor. Additional traffic analyses will be performed in subsequent phases to reflect differing volume scenarios. The Phase I traffic analyses are summarized below, and are documented more fully in Appendices B, C, and D.

4.b.i. Feasible Operation Period

The 2009 traffic volumes were analyzed for the weekday and weekend period when congestion typically occurs on the I-70 corridor. The purpose was to identify times when, and in which direction, the implementation of a reversible lane would be feasible and would have the potential of yielding the highest benefit.

Roadway Capacity

Roadway capacity is a readily determined indication of when reversible lanes may be beneficial and could help as-

Figure 8. Typical Westbound Cross-Sections

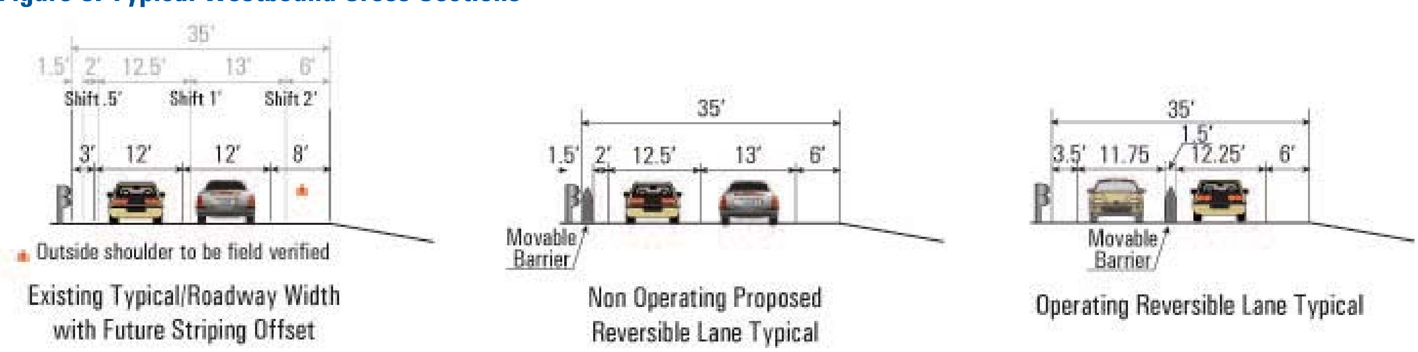
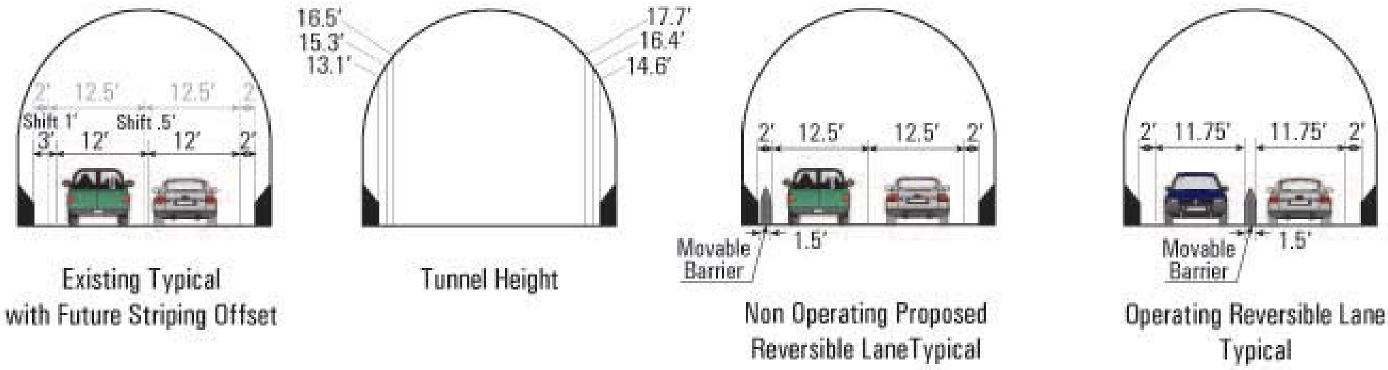


Figure 9. Westbound Twin Tunnel Cross-Sections



sess their impact on the opposite direction travel. A freeway's capacity is often determined by the most constrained section, which in this case is the Twin Tunnels. To determine the capacity of the roadway through the Twin Tunnels, the project team reviewed published literature and Highway Capacity Manual methodologies. Levinson et al. estimated the capacity of the Callahan Tunnel in Boston to be between 1,600 and 1,650 vehicles per hour per lane (vphpl) after installing traffic management improvements[1]. Levinson et al. also cite a New York Port Authority estimate of 1,660 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 1,350 to1,450 vphpl. Lin et al. estimated the capacity of a tunnel in Taiwan after improvements to be 1,300 vphpl in the southbound direction, but only 1,150 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 1,100 to 1,400 vphpl, with the average being about 1,325 vphpl[4].

Using the conclusions from these tunnel studies and the Highway Capacity Manual, the Twin Tunnel capacity during regular operations is estimated to be similar to the capacity of the improved Callahan Tunnel of about **1,600** vphpl. The capacities of the westbound lanes in the Twin Tunnels with the reversible lane in operation were estimated to be about **1,350** vphpl.

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 would not necessarily be free flowing. As volumes increase and approach capacity, speeds would decrease.

The following is a summary of the peak periods and their potential for a reversible lane to provide improved overall operations.

Summer Data Analysis

- Weekday AM (commuters to Denver)
  - Historic data show the average 2009 weekday traffic volumes at the Twin Tunnels never exceed 2,000 vehicles per hour (vph). This value is well below the two-lane capacity of the Twin Tunnels (3,200 vph), so a reversible lane would provide little benefit on an average weekday.
- Weekday PM (commuters from Denver)
  - Similar to summer weekday AM volumes, a reversible lane would provide little benefit on an average weekday.
- Saturday AM (recreational/tourist traffic to the mountains)
  - Westbound average traffic volumes on a Saturday morning peak traffic flow are approximately 2,300

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.*

vph. This value does not exceed the two-lane capacity (3,200 vph) on an average summer Saturday. Therefore, a reversible lane would provide little benefit.

- Sunday PM (recreational / tourist traffic from the mountains)
  - Eastbound lanes operate at or near capacity (3,200 vph) for several hours on Sunday afternoons. However, the westbound volumes are also near or above the one-lane capacity of 1,350 vph during the same time period. Therefore, a reversible lane would provide little overall benefit.

Winter Data Analysis

- Weekday AM (commuters to Denver)
  - Historic data show the average 2009 weekday traffic volumes at the Twin Tunnels never exceed 2,100 vph. This value is well below the two-lane capacity of the Twin Tunnels (3,200 vph), so a reversible lane would provide little benefit on an average weekday.
- Weekday PM (commuters from Denver)
  - Similar to winter weekday AM, a reversible lane would provide little benefit on an average weekday.
- Saturday AM (recreational / tourist traffic to the mountains)
  - The average westbound volume is at or near capacity for one AM peak hour. Therefore, reversible lane operation during this time period could be feasible, although the benefit would be limited since the two westbound lanes are at or near capacity for only one hour.
- Sunday PM (recreational/tourist traffic from the mountains)
  - The average 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 three 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 these evaluations, an eastbound reversible lane operation on winter Sunday afternoons was found to have the potential for greatest benefit. Refer to Appendix B for details of this evaluation.

4.b.ii. Reversible Lane Utilization

The potential utilization of the reversible lane was evaluated using DynusT. This software tool assigns traffic to various roadway facilities based on congestion and available capacity, and responds to potential roadway congestion during this process. Therefore, it was an ideal choice for the I-70 corridor, where winter Sunday congestion in the eastbound lanes would make the reversible lane an alternative choice for corridor motorists. Details of the DynusT analysis are included in Appendix C.

A DynusT model for the study area was developed for the reversible lane. The model includes not only I-70, but also parallel routes and other adjacent roadways in the study area. This allowed the model to assign traffic across different facilities, including the frontage road system, to obtain an accurate depiction of changes in traffic patterns due to the reversible lane implementation. The main focus of the model was the 25-mile segment of I-70 surrounding the reversible lane (15-mile study area plus 5 miles on each end). The model was calibrated to reflect existing conditions along I-70, and then conditions with the potential reversible lane were added. The reversible lane model included the scenario that users would not be able to exit the lane at intermediate points (such as Idaho Springs). Even with this constraint, the DynusT model concluded that approximately one-third of eastbound I-70 travelers at the entrance to the reversible lane on winter Sunday afternoons would use the reversible lane. This would result in reasonable operations for both eastbound general purpose lane and reversible lane travelers.

4.b.iii. Congestion Profiles and Travel Times

As part of the DynusT analysis, travel time and congestion were evaluated along the I-70 corridor. The model was calibrated using the highest observed Sunday afternoon volumes along I-70 in the 2009 to 2010 winter season, which occurred on January 31, 2010. The DynusT travel time and congestion results are shown in Appendix C. Congestion profiles in **Figure 10** through **Figure 13** show free-flow operations with higher speeds in blue and congested operations with lower speeds in red. The horizontal axis represents distance along the 25-mile I-70 reversible analysis segment,

and the vertical axis represents time of day during the analysis period. The two congestion profiles below (see **Figure 10** and **Figure 11**) represent eastbound and westbound congestion under existing conditions.

As can be seen, the eastbound traffic flow has large areas of red, orange, and yellow, which indicate congestion. However, the westbound results are almost entirely blue, showing reasonable operations. **Figures 12** and **13** show conditions with the reversible lane in place. This assumes a high demand scenario based on the January 31, 2010, traffic counts used to calibrate the model.

As **Figure 12** shows, there is considerably less red and orange in the eastbound lanes, indicating improved operations. Some congestion is identified at the east end of the reversible lane, where reversible lane traffic merges back into the eastbound I-70 lanes. However, **Figure 13** shows a large block of red (congestion) where the westbound traffic is forced from two lanes to one lane.

A more detailed evaluation of travel time and congestion was conducted using VISSIM. VISSIM is a traffic modeling tool that reflects vehicle operations on a more refined level than the DynusT model. VISSIM depends on user input volumes as the basis for analysis. Details of the VISSIM analysis are presented in Appendix D. Each interchange and the mainline lanes of I-70 were coded into the simulation model for the same 25-mile segment of I-70 used for the DynusT model. The additional five miles east and west of the reversible lanes study area were included to allow for the evaluation of queues and congestion that may occur approaching the reversible facility. The model was calibrated using the highest observed Sunday afternoon volumes along I-70 in the 2009 to 2010 winter season, which occurred on January 31, 2010. The baseline results are shown in **Figure 14**.

As **Figure 14** shows, the eastbound travel time varies from 59 minutes to 91 minutes for the 25-mile segment. This represents speeds well below free-flow conditions. However, the westbound travel time of between 29 and 35 minutes represents relatively free-flow conditions (speeds near the posted speed limit).

To model a reversible lane scenario in VISSIM, the geometric changes associated with the reversible lane were coded into the VISSIM model, and one-third of the I-70

Figure 10. Existing Eastbound Winter PM Congestion Profile

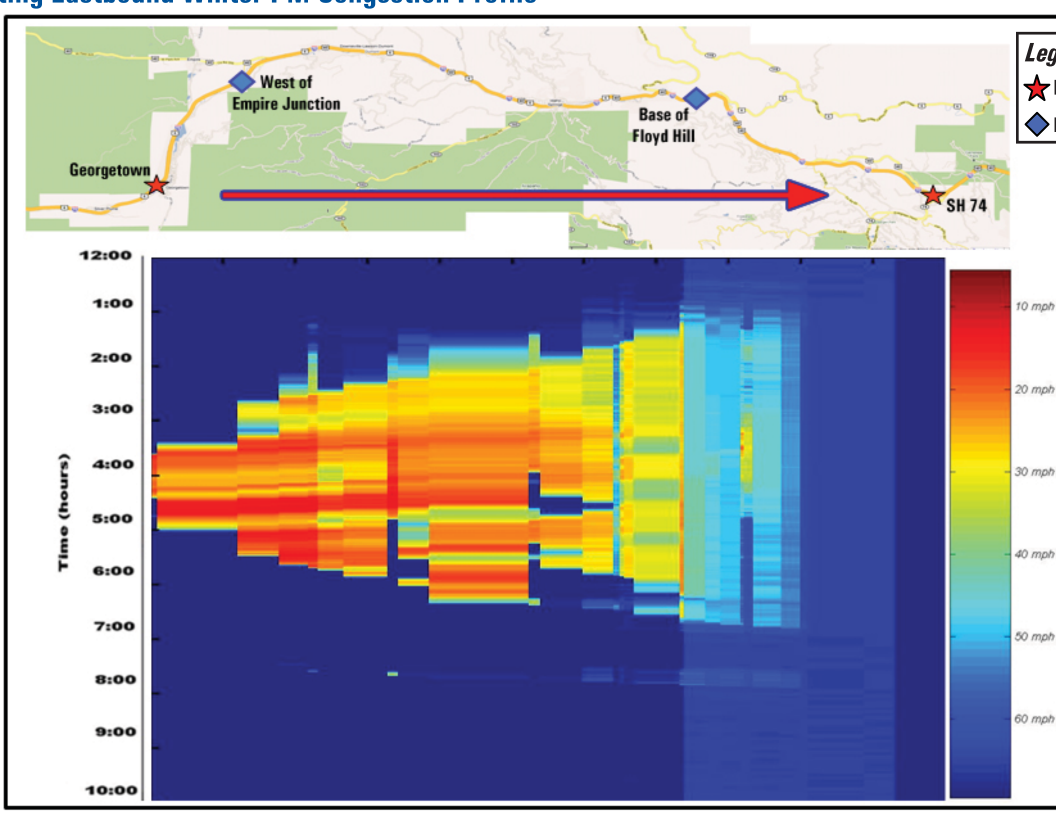


Figure 11. Existing Westbound Winter PM Congestion Profile

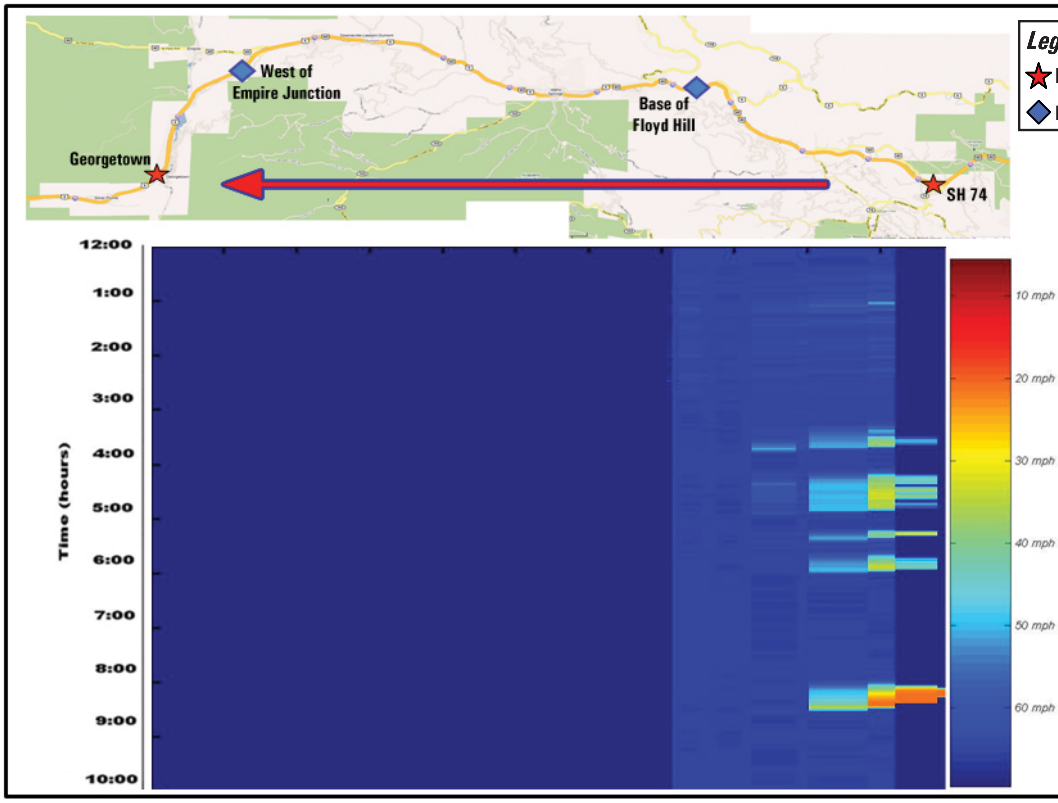


Figure 12. Eastbound Winter PM Congestion Profile with Reversible Lane

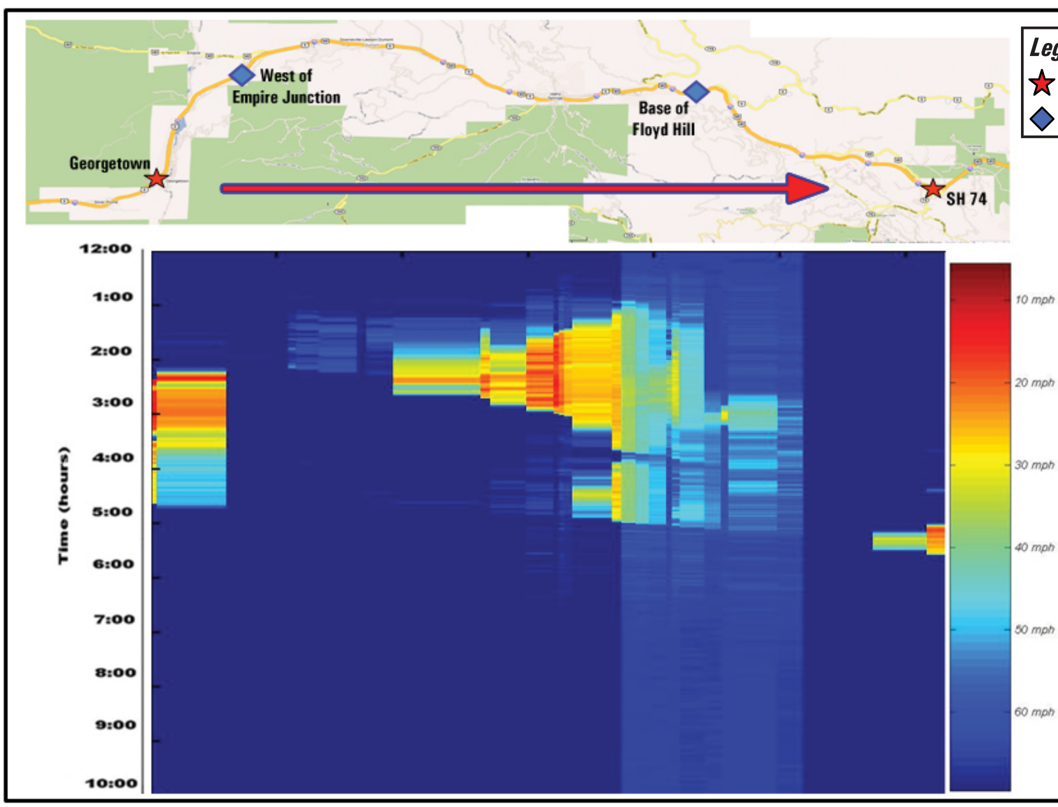


Figure 13. Westbound Winter PM Congestion Profile with Reversible Lane

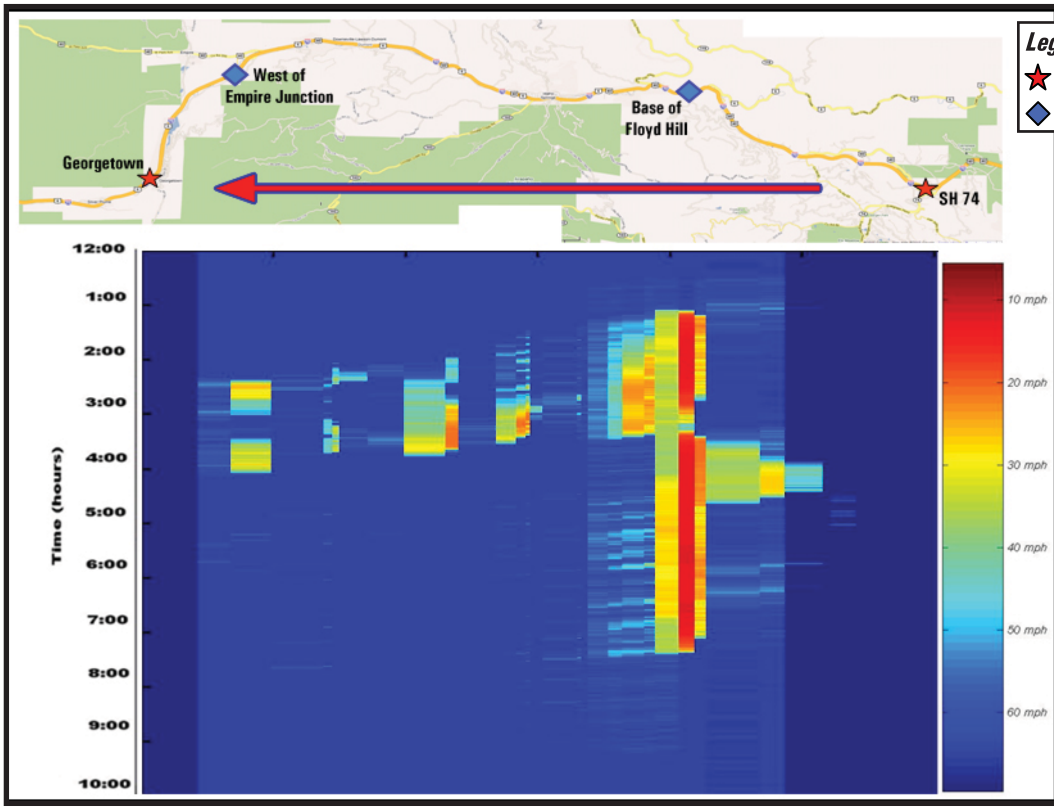
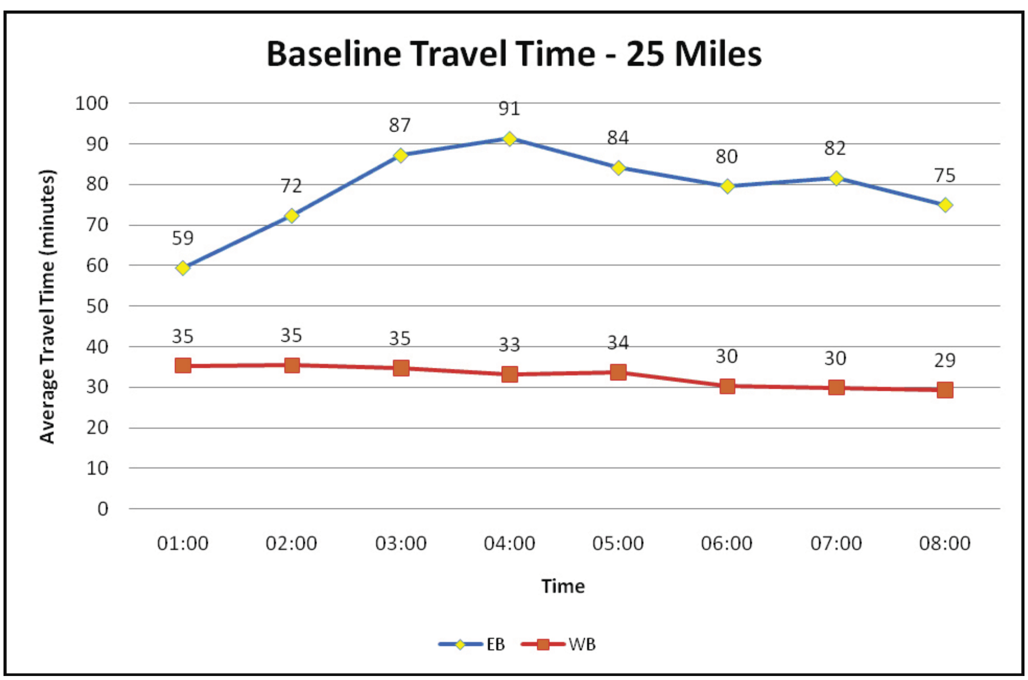


Figure 14. Existing Travel Time Data



eastbound traffic at the entrance to the reversible lanes was diverted into the reversible lane. The reversible lane scenario results are shown in **Figure 15**.

As **Figure 15** shows, the eastbound travel time drops and is much more constant over the analysis period. The travel time varies from 46 minutes to 34 minutes for the 25-mile segment. This represents speeds approaching (but not at) the speed limit for this segment of I-70. However, the westbound travel time of between 40 and 79 minutes represents increased congestion. The majority of this congestion occurs at the westbound lane drop at the base of Floyd Hill. A similar VISSIM model run was conducted with trucks prohibited in the reversible lane and in the westbound direction. These forecasted results are shown in **Figure 16**. In this case, the eastbound travel time does not change appreciably

Figure 15. Travel Time Data with Reversible Lane (All Vehicles)

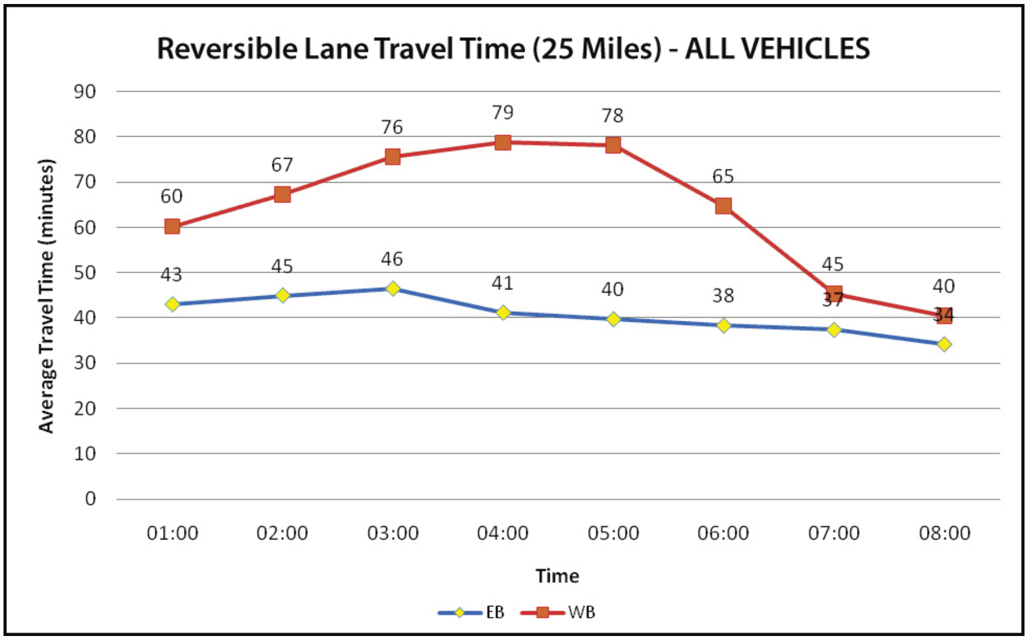
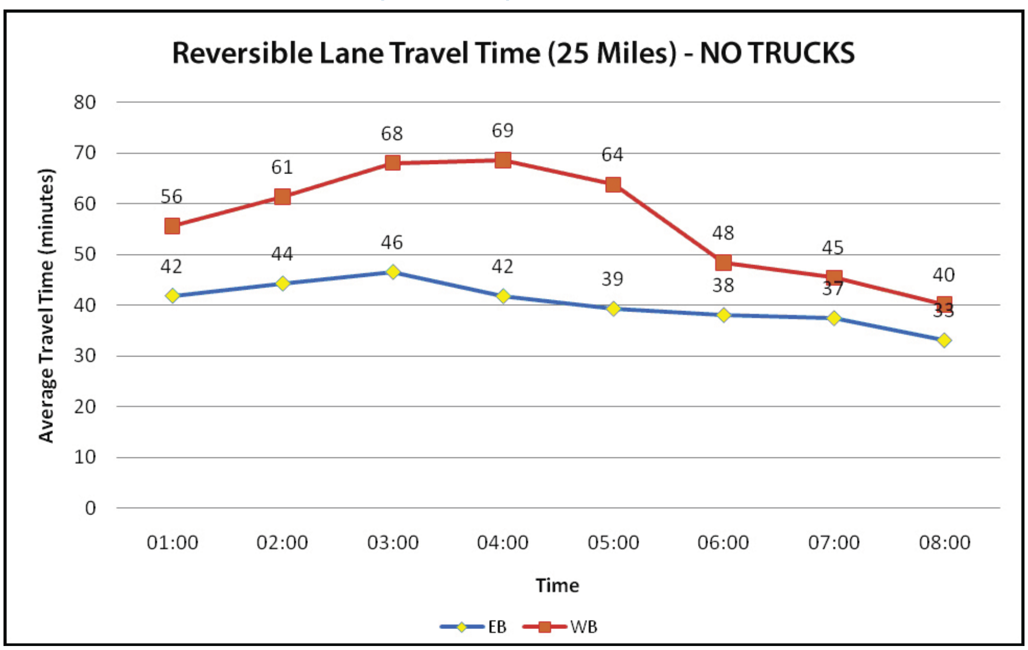


Figure 16. Travel Time Data with Reversible Lane (No Trucks)



from the scenario with trucks. However, westbound travel times improve when trucks are removed from the traffic stream. The travel times are up to 15 percent lower than the all vehicles scenario. The travel time data results are summarized in **Table 1**.

Table 1. VISSIM Travel Time Data*

*Travel times are weighted by vehicle volumes. See Appendix D for details.	EB Travel Time Minutes	EB Speed mph	WB Travel Time Minutes	WB Speed mph	EB Volume vph	WB Volume vph
Existing Average (No Reversible Lane)	79	19	34	44		
Reversible Lane Average (With Trucks)	41	37	69	22		
Reversible Lane Average (Without Trucks)	40	38	60	25		
Percent Time Saved or Increased (Compared to Average with Trucks)	-48%	95%	103%	-50%		
Average Hourly Volume					**2,696**	**1,464**
Existing Peak Hour	91	16	35	43		
Reversible Lane Peak Hour (With Trucks)	46	33	79	19		
Reversible Lane Peak Hour (Without Trucks)	46	33	69	22		
Percent Peak Hour Time Saved or Increased (Compared to Average With Trucks)	-49%	106%	126%	-56%		
Peak Hourly Traffic Volumes					**3,161**	**1,893**
Note: EB = Eastbound, WB = Westbound						

4.b.iv. Vehicle Hours of Travel

The VISSIM model also provides vehicle hours of travel as an output. This measure is the total of all the travel time for each vehicle while traveling in a specified area. Data for the 25-mile I-70 corridor between 1:00 PM and 9:00 PM were extracted from the VISSIM results and are presented in **Table 2**.

As **Table 2** shows, implementation of the reversible lane reduced the total hours traveled in the network by about 13 percent. This indicates that many more eastbound drivers are gaining a travel time advantage while the fewer westbound drivers are experiencing a travel time penalty. The data indicate an overall net system benefit with the reversible lane.

Table 2. VISSIM Vehicle Hours of Travel Data

Scenario	Total Vehicle Hours of Travel	Person-hours of Travel Saved
Existing (no reversible lane)	36,914	--
Reversible Lane (eastbound and westbound trucks)	32,350	11,866
Reversible Lane (no trucks westbound or eastbound reversible lane)	30,849	15,769

Note: Person-hours are based on 2.6 people per vehicle.

4.b.v. Queuing

The DynusT analysis reflected westbound queues of up to 3.8 miles approaching the reversible lane drop. Therefore, this area was a focus of the VISSIM modeling. **Table 3** summarizes the queuing data from the VISSIM model for the westbound direction.

Table 3. Westbound Queue Lengths

Time (PM)	Queue Length (miles) All Vehicles	Queue Length (miles) No Trucks Westbound
1:00	0.8	0.5
2:00	1.6	1.0
3:00	2.5	1.3
4:00	1.8	1.0
5:00	0.9	0.3
6:00	No queue	No queue
7:00	No queue	No queue
8:00	No queue	No queue
9:00	No queue	No queue

For the eastbound direction, as expected, the model indicated that implementing the reversible lane would improve queuing.

4.b.vi. Safety

Several safety concerns were raised during the Phase I analysis. These issues were discussed by the Phase I project team, and several areas for further analysis were defined. These include:

- Potential for collisions in the westbound queues at Floyd Hill.
- Incidents in the reversible lane.
- Narrow shoulders after installation of the movable barrier.

These items will be further evaluated during the Phase II Feasibility Study.

4.b.vii. Impact of Slow-Moving Vehicles on Operations

Trucks, recreational vehicles, and other heavy vehicles operate differently than automobiles, with slower acceleration, longer braking distances, and less maneuverability. These elements are compounded in mountainous corridors, such as along this segment of I-70. The results presented in Section 4.b.iii and Section 4.b.iv show some of the differences that were observed with trucks allowed or excluded from the westbound travel lanes under the reversible scenario. In general, the exclusion of trucks provides some operational benefits to westbound traffic at the merge at the base of Floyd Hill.

4.b.viii. Potential for Diversions

The DynusT model considers alternate route possibilities for traffic, and can adjust traffic to those alternate routes under congested conditions if the alternate routes provide travel time savings.

A review of the DynusT results indicates that there is a diversion of about 10 percent to12 percent of the forecasted westbound traffic. These vehicles were routed outside of the I-70 corridor or otherwise not served by the corridor.

The DynusT results also indicate that the operational improvements along eastbound I-70 affect travel patterns in the study segment. Based on the model output, up to a 23 percent increase in eastbound I-70 mainline traffic volume might be expected. The majority of this traffic was observed to come from the parallel frontage road system shown in **Figure 3**. The model does not include suppressed demand, which will be included in the Phase II Feasibility Study.

4.b.ix. Potential for Reversible Lane Tolling

Tolling scenarios were analyzed in the Phase I Feasibility Study. The tolling scenarios were based upon a congestion-responsive pricing scheme in which the regulation of tolling

Figure 17. Queue at the Top of Floyd Hill

Figure 18. Queue Entering Work Zone

prices was based upon the congestion experienced between the tolled facility and the non-tolled, general purpose lanes. In the Phase I study, the tolled facility was the eastbound reversible lane.

The objective of the congestion-responsive tolling is to maximize flow in the managed lane. The tolling logic aims to maximize flow by maintaining speeds above a defined threshold. Typically, the speed threshold is set to 45 mph. As volumes increase for the general purpose lanes, more drivers would be willing to pay a price to avoid congestion. However, as volumes increase in the tolled facility, the price would also increase to maintain a driving speed of no less than 45 mph in the tolled lanes.

The scope of tolling analysis in Phase I was limited, and results were inconclusive. Tolling will be further analyzed in the Phase II Feasibility Study.

4.b.x Sampling during Emergency Bridge Closure

Supplemental traffic data collection was performed during the emergency bridge closure for the westbound I-70 structure at the base of Floyd Hill. This structure is within 0.5 mile of where the potential reversible lane drop would be installed (as shown in **Figure 7**). It therefore served as a surrogate for what might happen if the reversible lane were implemented.

The Phase I project team collected queuing data and travel time data throughout the closure on Wednesday, June 16, 2010. Simultaneous traffic counts were conducted, and CDOT collected data on their permanent count station at the Twin Tunnels. Refer to **Figures 17** and **18** for photographs of conditions during the lane closure.

The key finding was that considerable westbound queuing occurred. The observed queues went past the top of Floyd Hill (over two miles), and traffic in the queues flowed at less than 10 mph. Vehicular volumes were in the 1,400 to 1,475 vph range. This is consistent with the results from VISSIM and DynusT (refer to **Table 4**).

Table 4. Emergency Bridge Closure Data

Volume	1400 vph – 1475 vph
Volume	1400 vph – 1475 vph
Observed Queue Length	0.9 to 3.8 miles
Speed at Merge Point	10 to 15 mph
Speed in Queue	5 to 12 mph

5. Conclusions

The goal of Phase I was to answer the following fundamental questions:

- Do roadway geometry and topography allow construction of transition crossovers that can operate safely? Are there other geometric constraints that would prohibit using the movable barrier technology to create an eastbound reversible lane?
- Is implementing a reversible lane in the eastbound direction on winter Sunday afternoons feasible considering traffic volumes? Specifically, what would be the impact to westbound traffic?

Key elements and findings of these analyses are in this Summary Report. The overall conclusions are as follows:

- The reversible lane is geometrically feasible.
- Traffic modeling indicates that implementation of the reversible lanes would decrease travel time for the eastbound traffic from on average 79 minutes to 41 minutes, with trucks or 40 minutes without trucks.
- Traffic modeling indicates that implementation of the reversible lanes would increase travel time for the westbound traffic on average from 34 minutes to 69 minutes with trucks, or 60 minutes without trucks.

- Traffic analysis indicates that for Sunday afternoons during the ski season, the reversible lane provides an overall 13 percent travel time benefit to the traveling public in the I-70 corridor.

The Phase I analysis has not revealed compelling evidence to cease further consideration and analysis of the feasibility of the reversible lane strategy. Further, traffic model results indicate it could provide a benefit to the traveling public along I-70, although westbound travelers would be impacted. CDOT has several traffic management tools available to improve conditions at the westbound merge, and will evaluate those tools in the Phase II analysis of the potential reversible facility.

The Phase I project team recommends that several additional factors be examined in a Phase II Feasibility Study, including:

- Safety
- Maintenance
- Snow removal
- Emergency response
- Public education
- Environmental impact
- Modes of operation and project delivery (Public Private Partnership, Toll, No-Toll, Lease-Purchase, funding, procurement)
- Concept of operations and operational enhancements
- Geometric design issues

The Phase II Feasibility Study should follow the I-70 Mountain Corridor Context Sensitive Solutions process, and involve a Project Leadership Team (PLT) and a Technical Leadership Team (TLT). This will ensure that the final decision and approach is reflective of the contributions of the stakeholders and project partners.

Appendix A: Phase I Design Support

(file transmitted separately)

Appendix B: Potential Reversible Lane Time Period Evaluation

(file transmitted separately)

Appendix C: Feasibility Study of a Movable Barrier System along Interstate 70

(file transmitted separately)

Appendix D: Simulation of Zipper Lane Option on I-70

(file transmitted separately)