FINAL March 2018

I-80 CORRIDOR STUDY

MASTER PLAN IMPLEMENTATION REPORT

Wyoming Department of Transportation

MASTER PLAN IMPLEMENTATION REPORT
I-80 CORRIDOR STUDY

Prepared for:

Prepared by:

In conjunction with:

and

FINAL March 2018

Contents

Appendices

Figures

Tables

Acronyms and Abbreviations

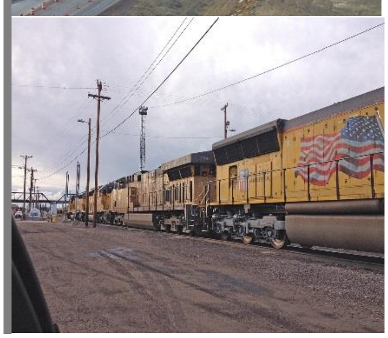
ARRA	American Recovery and Reinvestment Act of 2009
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
BCA	benefit-cost analysis
BCR	benefit-cost ratio
CMAQ Program	Congestion Mitigation and Air Quality Improvement Program
DSRC	dedicated short-range communications
EPA	Environmental Protection Agency
FAST Act	Fixing America's Surface Transportation
FHWA	Federal Highway Administration
I-25	Interstate 25
I-80	Interstate Highway 80
INFRA	Infrastructure for Rebuilding America
ITS	Intelligent Transportation System
LCA	lifecycle cost analysis
LIDAR	Light Detection and Ranging
MAC	media access control address
MOVES	Motor Vehicle Emissions Simulator
mph	mile per hour
MSRP	manufacturer's suggested retail price
NHTSA	National Highway Traffic Safety Administration
O&M	operating and maintenance
P3	public-private partnership
R.E.S.C.U.M.E.	Response Emergency Staging Uniform Management and Evacuation application
RFID	Radio Frequency Identification
RSE	Roadside Equipment

RSU	Roadside Unit
RWIS	Road Weather Information System
SF	Senate File
STSFA	Surface Transportation System Funding Alternatives
TIGER	Transportation Investment Generating Economic Recovery
TMC	Traffic Message Channel
USDOT	United States Department of Transportation
V2I	vehicle-to-infrastructure
V2V	vehicle-to-vehicle
WCA	Wyoming Contractors Association
WTA	Wyoming Trucking Association
WYDOT	Wyoming Department of Transportation

1.0 INTRODUCTION

The Interstate 80 (I-80) Master Plan is a corridor plan that analyzes the current and future conditions along I-80 in Wyoming, developed various alternatives for short- and long-term improvements along the corridor, and assessed federal funding options available for implementation of those improvements. Cost estimate information was developed for improvements, and projects were prioritized based on a benefit-cost analysis when applicable.

The overall goal of the I-80 Master Plan is to improve safety and mobility along I-80 throughout Wyoming.



In the 2017 legislative session, a bill was drafted and introduced as SF0140—I-80 Master Plan. This legislation instructed the Department of Transportation (DOT) to conduct a study and develop a project master plan to identify the needs; rank, in order of importance, the associated improvements; develop a financial plan to improve the safety and mobility of Interstate 80; and identify any possible legislation for consideration. Although the legislation was not passed, WYDOT considered input from the Governor, the Transportation Commission, and the Legislature, and opted to proceed with the study as the timing was critical to support the infrastructure initiatives of President Trump and the United States Congress.

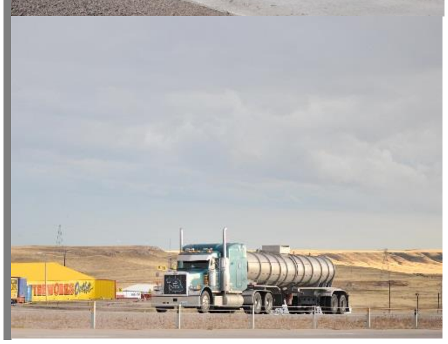
The I-80 Master Plan is a standalone document but builds on previous I-80 planning documents, including the November 2008 *I-25/I-80 Interchange Study,* the August 2008 *Recommended Interstate 80 Safety Improvements to Reduce Fatal and Serious Injury Crashes*, and the November 2009 *Interstate 80 Tolling Feasibility Study, Phase 2*.

The I-80 Master Plan Study (this Study) was conducted under the guidance of a Steering Committee. The Steering Committee was comprised of senior representatives from WYDOT Planning and WYDOT Engineering departments, as well as the Federal Highway Administration (FHWA). The Wyoming Contractors Association (WCA) and the Wyoming Trucking Association (WTA) also attended the Committee meetings.

2.0 EXISTING CONDITIONS

Interstate 80 (I-80) traverses Wyoming for 403 miles, entering the state from Utah; connects the cities and towns of Evanston, Green River, Rawlins, Laramie, and Cheyenne; and exits the state into Nebraska. The highest point of the transcontinental highway is the summit between Laramie and Cheyenne at 8,640 feet in elevation. It is a four-lane divided highway with climbing lanes on five short sections. I-80 has a system interchange with Interstate 25 (I-25) in Cheyenne, the capital city of Wyoming.

I-80 is a primary route for trucks hauling goods across the United States.



2.1 Volumes

Through traffic on I-80 ranges from 10,000 to 20,000 vehicles per day. The highest traffic segments are in the vicinity of Green River, Rock Springs, and Cheyenne. Commercial vehicle trucks form about 50 percent of the traffic volume on I-80. Between Green River and Rock Springs, the truck percentage is about 30 percent because of the higher portion of local and regional traffic between the two cities.

Automobile traffic on I-80 has grown by 65 percent over the past 30 years, while heavy truck traffic has grown by over 150 percent. Figure 2-1 depicts the daily traffic volume in 2015 along with the percentage of trucks by direction for the I-80 corridor.

2.2 Safety

There are many options for evaluating highway safety improvements. These methods vary in their effectiveness when it comes to evaluating the effectiveness of different strategies in enhancing safety benefits along I-80. Based on crash statistics the overall number of crashes in Wyoming has generally been on the decline from 2008 to 2016.

This Study focuses on crash history along the I-80 corridor for a 5-year period from 2012 through 2016. During that timeframe, I-80 crashes accounted for approximately 12 percent of the total statewide crashes. Eighty percent of the total crashes along I-80 were property damage only, the remaining crashes were injury or fatality crashes. The purpose of this Study is to build upon previous safety studies along I-80, and to specifically look at the safety impacts of additional climbing lanes at various locations along the corridor. Figure 2-2 shows the location of severe injury and fatal crashes along I-80 and the specific segments that were studied as part of this analysis.

2.3 Closures

Crashes are the most common type of closure for a roadway system as well as the most unpredictable. Because crashes can occur at any time of the day or year, historical trend maps are the best way to analyze areas with high crash frequencies. I-80 historically has the highest frequency of closures because of crashes of any roadway in Wyoming.

Closures also occur frequently on I-80 because of weather. Adverse winter weather conditions of snow and ice cause the interstate to close. Strong winds are known throughout Wyoming, causing the interstate to be closed to high-profile vehicles during high-wind conditions, which are especially dangerous during the winter.

Figure 2-3 depicts weather closures annually per direction. In either direction, the segment that annually has the most number of weather-related closures is between Rawlins and Cheyenne.

Figure 2-4 displays the duration of weather closures annually per direction. The segment that annually has the longest durations because of weather-related closures is between Rawlins and Laramie.

Appendix A provides a description of the data analysis method for I-80 closures.

Adverse winter weather conditions of snow and ice can cause I-80 to close.

Figure 2-1. 2015 Daily Traffic Volume

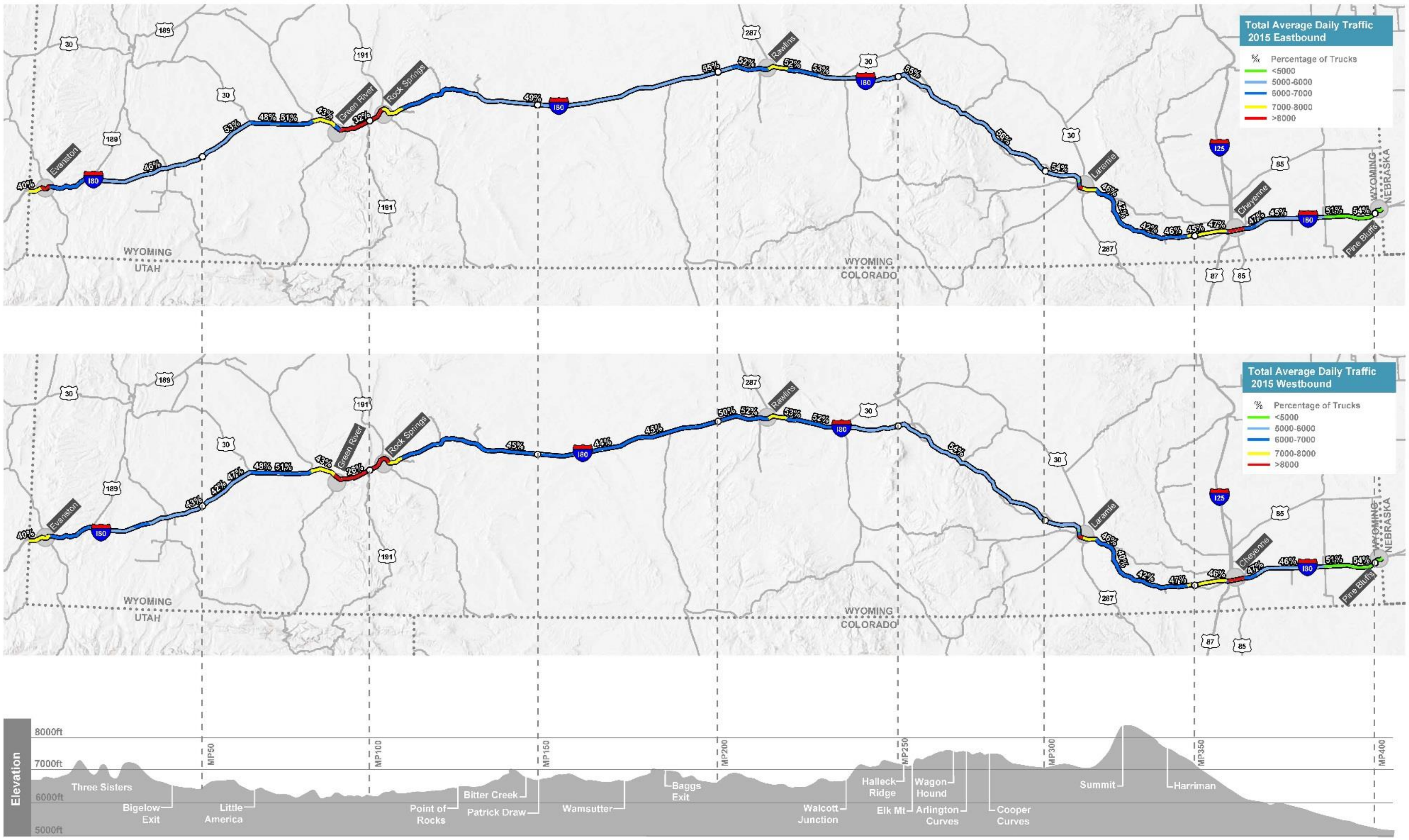


Figure 2-2. Location of Severe Injury and Fatal Crashes Along I-80

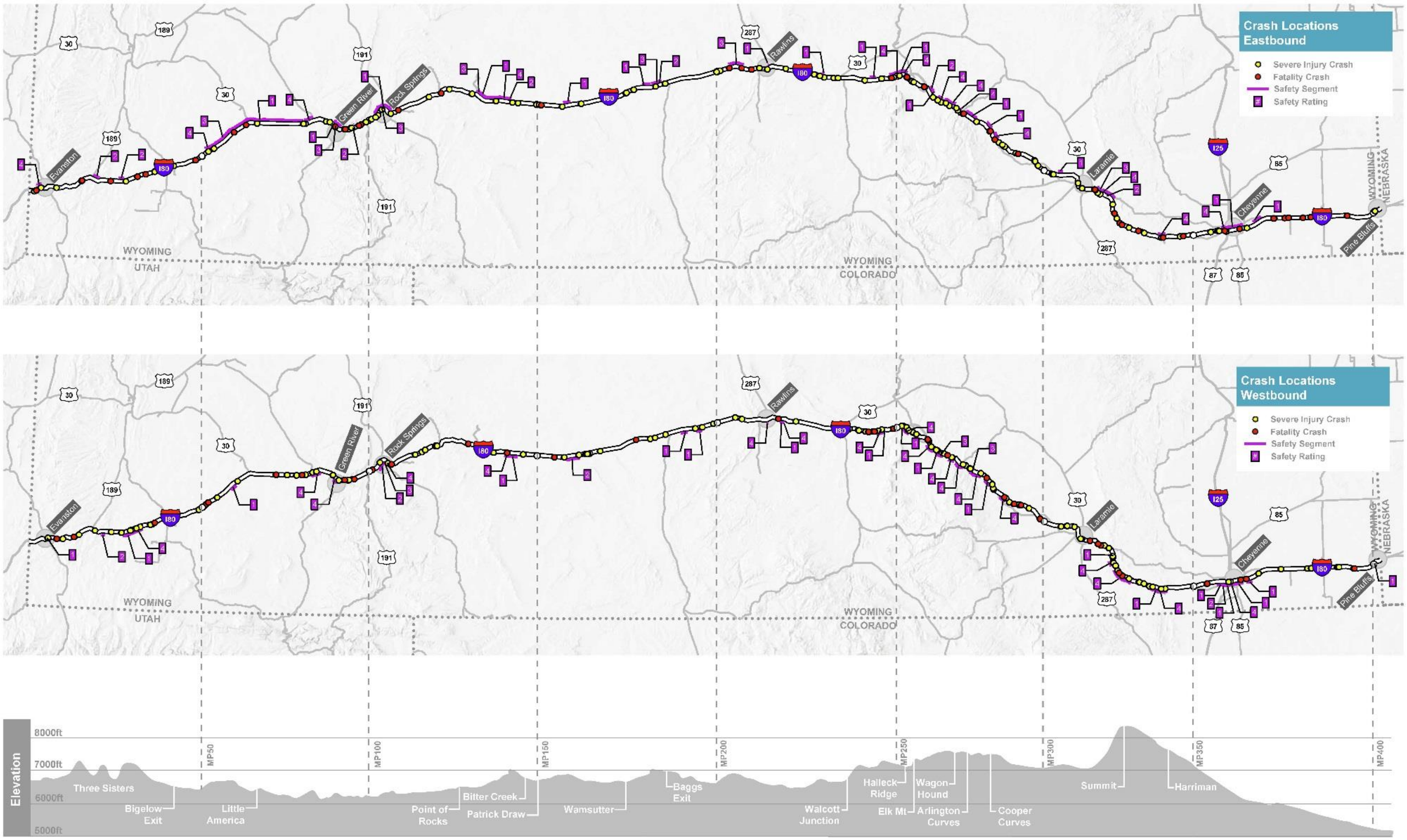
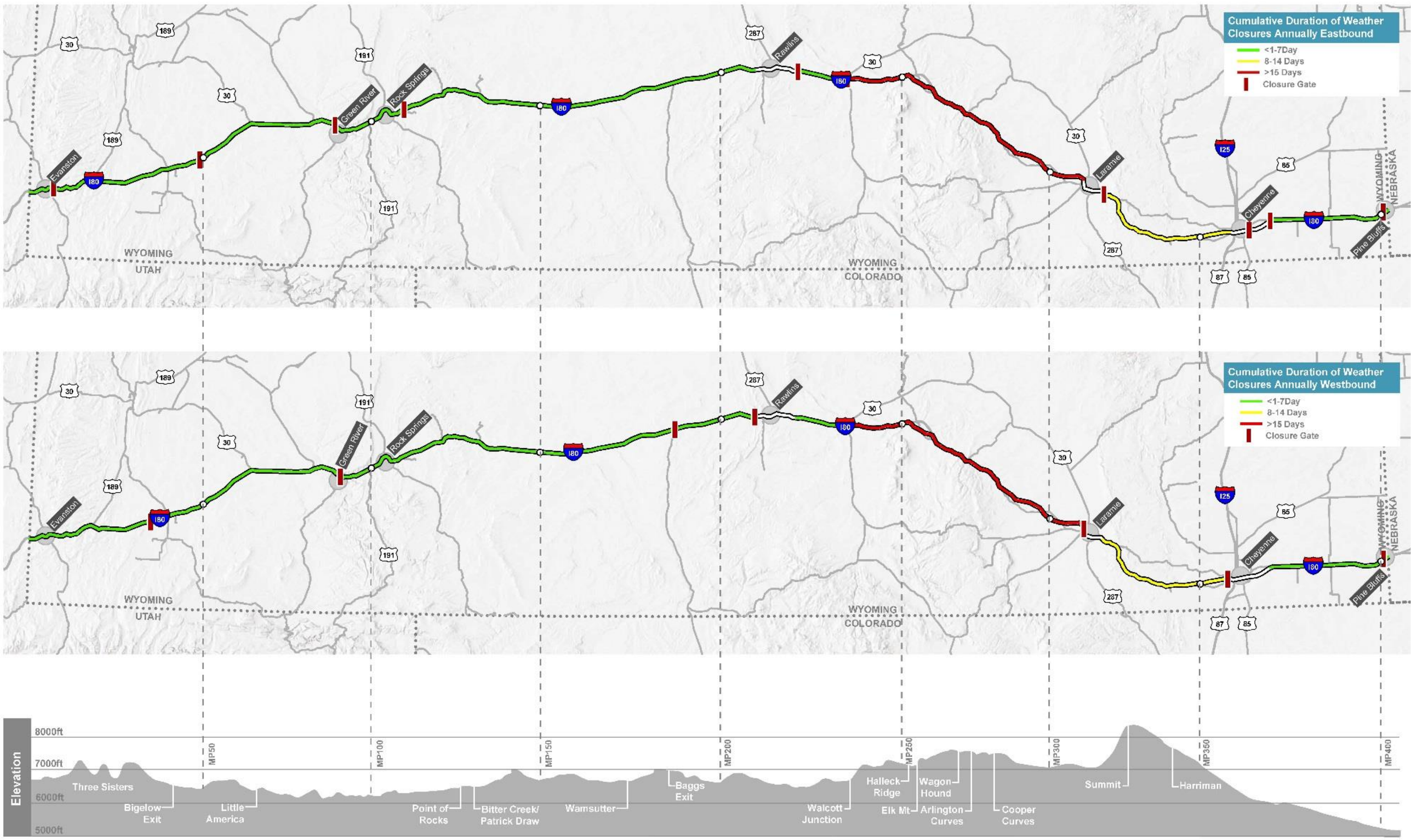


Figure 2-3. Weather Closures Annually Per Direction

Figure 2-4. Cumulative Duration of Weather Closures Annually Per Direction



3.0 ALTERNATIVES ANALYSIS

At the onset of this study, it was recognized that there were a variety of infrastructure investments that needed to be investigated for the I-80 Corridor. These consisted of:

- **Climbing Lanes. Additional climbing lanes to accommodate the heavy freight vehicle traffic.**
- **Additional Lane. A third lane in each direction could enhance safety and mobility.**
- **I-80/I-25 Interchange. The cost estimate from the 2008 study needs to be updated.**
- **ITS. New technology investments need to be identified.**
- **Truck Parking. Additional locations for truck parking are needed.**

3.1 Climbing Lane Locations

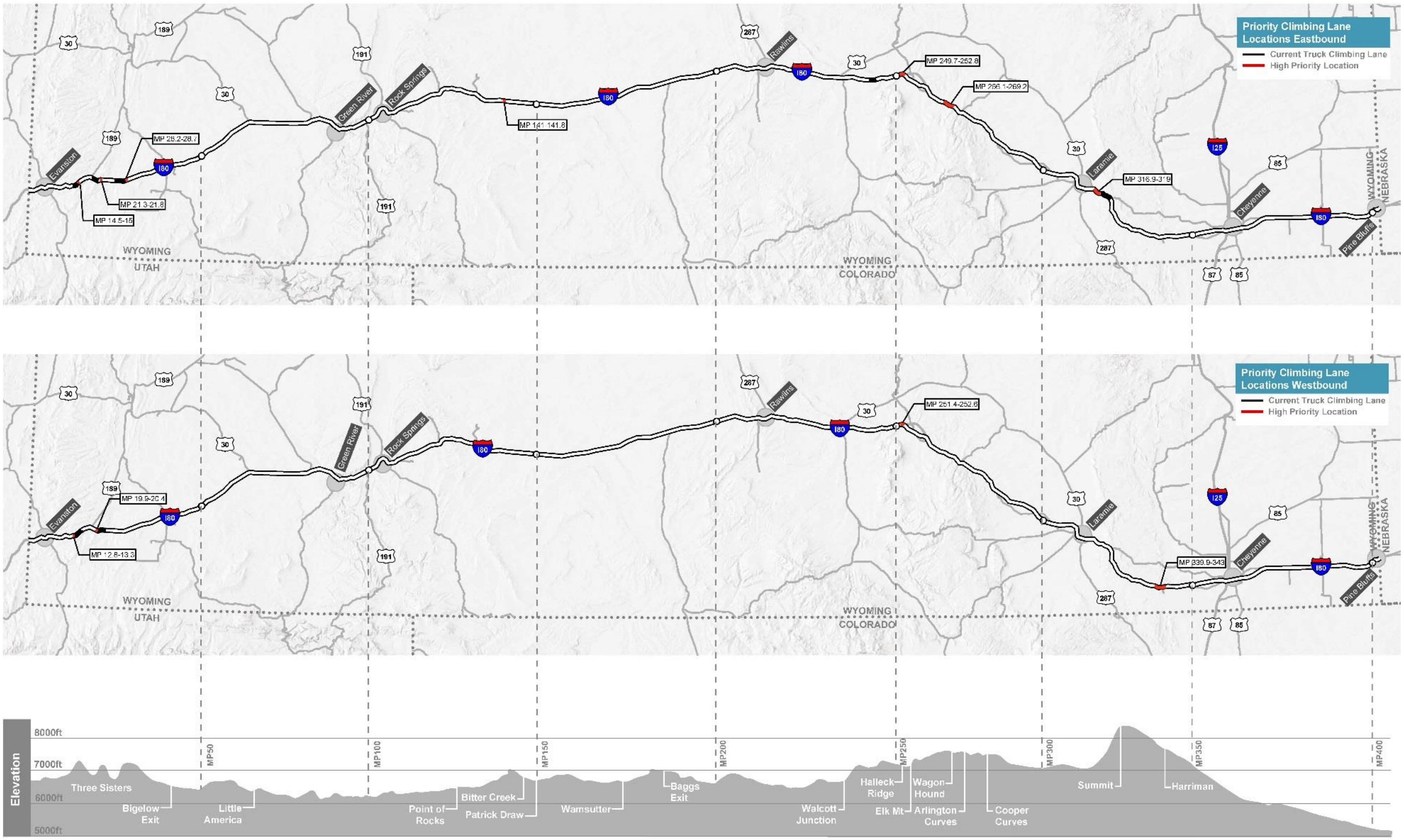
The Steering Committee for this project met and discussed a number of issues that cause periodic non-recurring congestion along the I-80 corridor. A majority of the I-80 corridor is comprised of two lanes in each direction and the roadway is considered to be on rolling terrain. A high percentage of the overall traffic is truck traffic, and is therefore not uncommon to have slow moving trucks passing each other at decreased speeds because of sustained steep grades. Based on this discussion numerous locations for potential additional climbing lanes were identified early on in the study process. Segments that were considered for further study were identified as having grades greater than 3 percent, locations identified in previous studies, and segments identified by the District Engineers. This list was then filtered using additional information including the frequency of roadway closures, the safety rating and the overall length of the segment. Figure 3-1 shows the filtered list of climbing lane segments recommended for further study. Appendix B contains further detail on the filtered list of climbing lane segments. Cost estimate for the segments meeting several of the filtering criteria were developed and further safety analysis was completed, allowing the segments to be prioritized using benefit cost analysis.

3.1.1 Benefit-Cost Analysis (BCA) Overview

This section provides an overview of the approach and assumptions used in this analysis. More details on the methodology are found in Appendix C.

BCA is a systematic approach to compare the benefits and costs of different projects. It can help determine the soundness of alternative investment decisions and support agency decision-making in selecting the best projects that improve user benefits and reduce direct transportation costs.

Figure 3-1. Filtered List of Climbing Lane Segments Recommended for Further Study



During the analysis, the economic benefits of each project are totaled and compared to the total agency cost. The cost effectiveness of each project can be directly compared using the benefit-cost ratio (BCR). The BCR combines multiple measurements of effectiveness into a single measure which can be used to compare projects.

HDR used BCA to assess the impacts of the 11 truck climbing lane projects in the Master Plan. Capital costs for each project were estimated separately taking into account project complexity, as described in Section 3.1.2. The BCA assumed no additional operation and maintenance costs are associated with the improvements. Economic benefits were calculated by comparing conditions in each project to a “No-Build” scenario. The No-Build scenario represents the state when a truck climbing lane is not built.

3.1.2 Cost Estimate Model

This section discusses the cost estimating methodology for all of the different alternatives. Full detail on the cost estimate methodology is included in Appendix D.

Cost estimates were important input into the benefit-cost analysis for the climbing lane locations. In addition, cost estimates were developed for a majority of the improvement alternatives listed above, including:

- Reconstruction of I-80 for three lanes in each direction for two different material types (asphalt and concrete pavement).
- The addition of Intelligent Transportation Systems (ITS) components (expansion of the current pilot program to install radio communications along the corridor).
- An update to the 2008 *I-25/I-80 Interchange Study* cost estimate.

Roadway

Roadway construction costs for this Study were developed based on guidelines provided by WYDOT materials division in addition to a visual inspection of the roadway using Pathway data. Figure 3-2 and Figure 3-3 show the assumed typical sections for widening and reconstruction of asphalt and concrete sections, respectively. In general, it was assumed that the climbing lanes would be constructed by sawcutting the existing pavement, milling the existing pavement, and overlaying the entire cross section with a plant mix wearing course.

Figure 3-2. Typical Sections for Widening

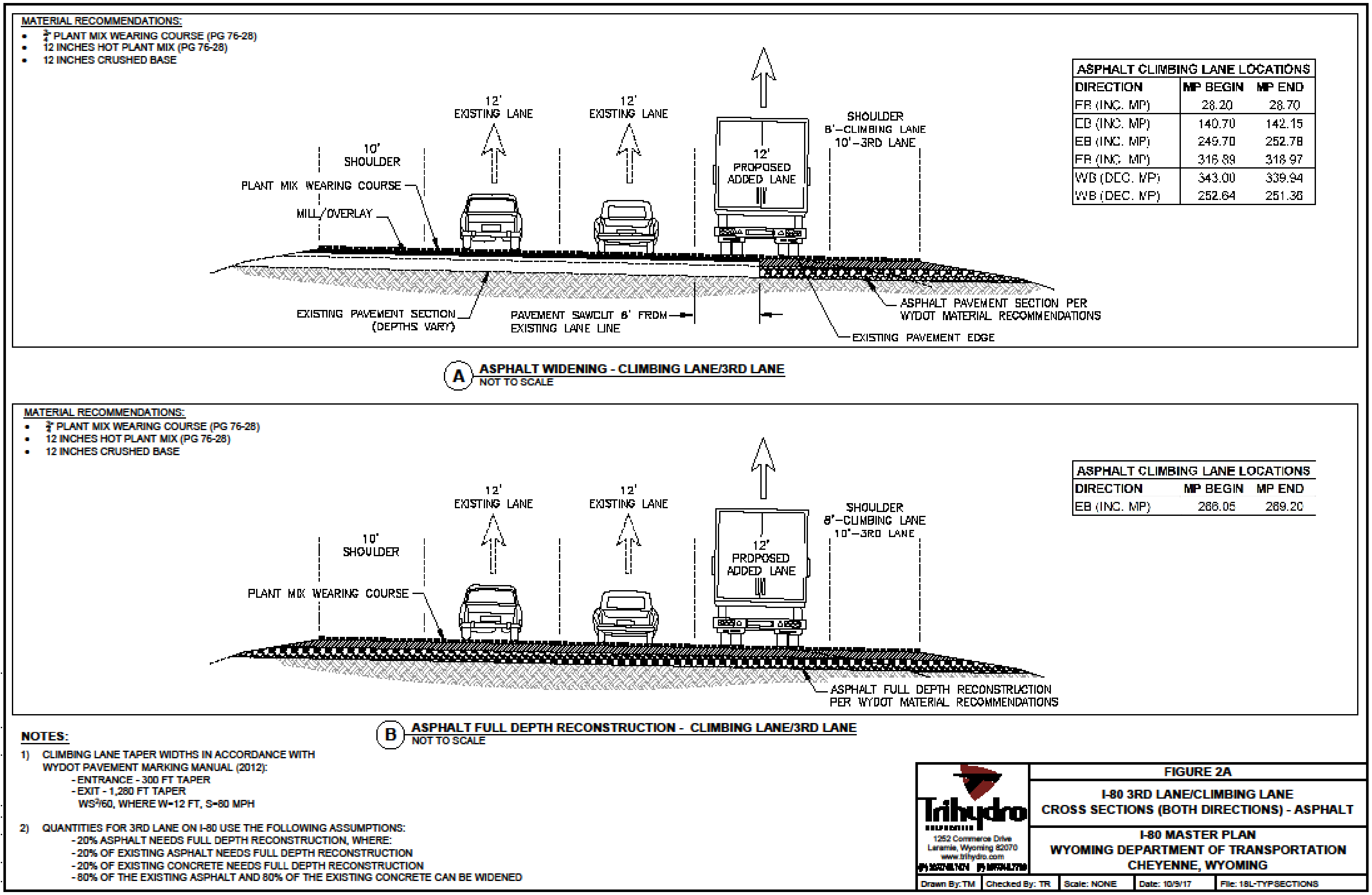
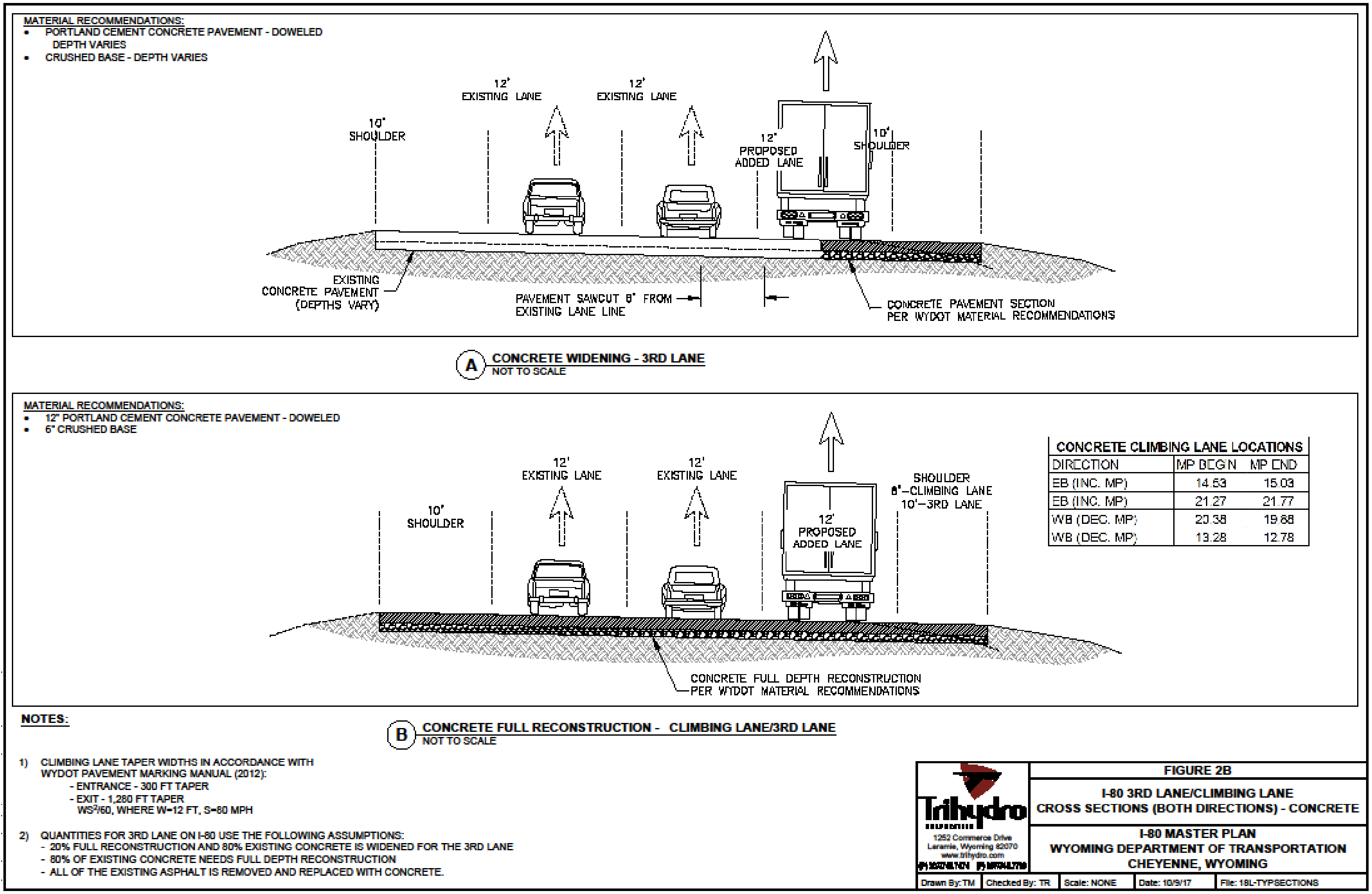


Figure 3-3. Typical Sections for Reconstruction of Asphalt and Concrete Sections



CONCRETE CLIMBING LANE LOCATIONS		
DIRECTION	MP BEGIN	MP END
EB (INC. MP)	14.53	15.03
EB (INC. MP)	21.27	21.77
WB (DEC. MP)	20.38	19.88
WB (DEC. MP)	13.28	12.78

Widening and reconstructed surfacing section thicknesses provided by WYDOT include:

- Asphalt—12-inch hot mix asphalt (HMA) and 12 inches of crushed base material
- Concrete—12-inch concrete and 6 inches of crushed base material.

Other quantities, including tack coat, hydrated lime, and asphalt binder, were estimates based on rates provided by WYDOT. Taper rates for the climbing lanes are in accordance with 2012 *WYDOT Pavement Marking Manual*.

For the "Third Lane" option it was assumed that the full length of the interstate from the Utah state line to the Nebraska state line would be considered. In general, it was assumed that 80 percent of the existing pavement would be viable for use when construction began, and that 20 percent would require full depth reconstruction. Furthermore, it was assumed that 100 percent of the existing concrete section (approximately 100 miles of the 403 total miles) would be utilized in either option. This means that for three lanes in each direction using concrete material type, 100 percent of the existing concrete section is reconstructed, and all of the existing asphalt section is removed full depth and reconstructed out of concrete material. For the asphalt material type, 80 percent of the existing concrete is kept widened/overlaid with a plant mix wearing course. Additionally, 80 percent of the existing asphalt section is maintained and widened, and 20 percent required full depth reconstruction. Pavement depths used for removal quantities are based on existing pavement thickness data provided by WYDOT.

Assumptions were made for unclassified excavation and rock excavation in both cases. Rock Excavation quantity assumes 20 percent of Unclassified Excavation calculation, and is included in sections based on visual verification of expected rock excavation areas (i.e., evidence of vertical face walls, blasting, and others.). Unclassified excavation quantities are estimated from relative elevations obtained from Google Earth. If elevation data produced minimal difference, an average of 40,000 cubic yards per mile was used based on recommendations from WYDOT.

Structures

Structure construction costs for this study included a combination of bridge replacements and bridge widening, as well as replacement or extension of concrete box culverts. Costs for bridge work for the I-80 improvements, whether for the proposed climbing lanes or for the "Third Lane" alternative, were estimated using construction costs applied on a per square foot of bridge deck basis ($/SF of new bridge deck). Culvert replacement or extension work was similarly estimated using a unit cost based on the perimeter of the culvert ($/LF of perimeter, per unit length).

Structure work was quantified using some basic guidelines suggested by WYDOT bridge operations staff. For bridges on I-80, the guidelines recommended replacement of all continuous concrete slab bridges and all bridges with an inventory rating less than 1.0. Bridges not placed in these categories were recommended for widening as required to meet the new proposed roadway cross section. To provide realistic bridge replacement costs, replacement deck area for bridges on I-80 was computed using a bridge length 50 percent more than existing. This 50 percent increase factor accounts for current geometric design requirements for horizontal clearance to obstructions, abutment fill slope geometry and similar considerations which are more stringent than those used in the past. For bridges over I-80, WYDOT operations staff guidelines recommended replacement of all structures over I-80 that would be affected by the construction of new lanes on the mainline. This recommendation impacted only a few bridges for the climbing lane work but affected every bridge over I-80 for the third lane alternative.

I-25/I-80 Cost Estimate Update

An update to the 2008 I-25/I-80 study is discussed in detail below. The layout, assumptions, and quantities developed for the 2008 study were assumed to be vetted and validated as part of the 2008 study. The assumed quantities discussed in this document are taken from the 2008 study and only the unit costs were updated to 2017 dollars.

ITS Cost Estimate Development

The ITS alternatives are presented in detail below. There is a pilot program currently underway for WYDOT that implements communication devices for connected and autonomous vehicle use. The preferred alternative increases the coverage of these units throughout the corridor. As such, pricing assumed for the Wyoming Connected Vehicle Regional Pilot study was used to develop the costs outlined in this document.

3.1.3 Benefits

Benefits are the other key input to the benefit cost analysis. HDR included four categories of economic benefits in the BCA:

- Safety Improvements
- Travel Time Savings
- Vehicle Operating Cost Savings
- Emissions Cost Savings

An overview of the methodology is provided in the sections below and more detailed information regarding BCA assumptions is provided in Appendix C.

Truck climbing lanes allow for safer passing of slower-moving trucks along I-80.

Safety Improvements

Safety improvements are benefits resulting from crash reductions in the study area. Truck climbing lanes allow for safer passing of slower-moving trucks along I-80. Crash reductions are estimated by applying a crash reduction factor to existing crash rates by severity along segments of the project area. The number of crashes in forecast years is estimated by extrapolating traffic data and crash rates into the future. The number of reduced crashes in each project is monetized using economic values from FHWA.[1] In the BCA, safety improvements make up the vast majority of economic benefits.

To calculate safety benefits, years 2012 to 2016 crash data were acquired from WYDOT. For each segment, existing crash patterns (e.g., number, type, severity, lighting conditions, segment or junction, vehicle type) were tabulated. Crash rates were also computed for each segment for all vehicle type crashes and commercial vehicle crashes.

Based on the limited research available for interstate truck climbing lanes, the introduction of truck climbing lanes is expected to have the greatest benefit for crashes that involve a commercial vehicle in a rear-end and sideswipe passing crash. Limited benefits were identified for all other crash types as well. Therefore, the existing crash type distribution was used to separate the existing crash rates into two parts:

1. Crash rate for rear-end and sideswipe passing crashes involving a commercial vehicle.
2. Crash rate for all other crashes.

Using the existing crash rates and future volumes, crash frequency was estimated by year for each westbound and eastbound segment where a truck climbing lane is being considered. Crash predictions were prepared from 2018 through 2048 in increments of 5 years. As noted in the methodology (Appendix E), crash predictions separate rear-end and sideswipe passing crashes involving a commercial vehicle from all other crash types. Furthermore, crash predictions were prepared for two scenarios: No Build without a truck climbing lane and a Build scenario with the proposed truck climbing lane. The estimated frequency for each crash type was separated by crash severity, including fatal injury crash, suspected serious injury crash, suspected minor injury crash, possible injury crash, and property damage-only crash.

Table 3-1 and Table 3-2 summarize the estimated crash numbers per year with or without truck climbing lanes, with the westbound and eastbound segments combined to show the net effect for each direction of travel. Crash predictions by individual segments are available in Appendix E.

For fatal and suspected serious injury crashes, the truck climbing lanes were estimated to prevent 1 crash every 2 to 3 years for westbound travel and 1 crash every 1 to two 2 years for eastbound travel. The results also show that as traffic volumes increase in the future a greater reduction in crashes is expected.

A detailed explanation of the methodology is provided in Appendix E.

The net effect of the proposed truck climbing lanes is an estimated reduction of 6 to 8 crashes each year for westbound I-80 and 10 to 15 fewer crashes each year for eastbound I-80.

[1] Estimating Crash Costs White Paper, Federal Highway Administration, June 14, 2017

Table 3-1 Estimated Crash Frequency for Westbound I-80 Segments (2018–2048)

Year	No Build: No Truck Climbing Lane			Build: With Truck Climbing Lane			Estimated Crash Reduction
	RE+SSW*	All Other	Total	RE+SSW*	All Other	Total	
Total Crashes: All Crash Severities							
2018	3.3	19.5	22.8	1.7	15.6	17.3	5.5
2023	3.6	20.9	24.5	1.9	16.8	18.7	5.8
2028	3.8	22.4	26.2	2.0	17.9	19.9	6.3
2033	4.1	23.9	28.0	2.1	19.1	21.2	6.8
2038	4.3	25.4	29.7	2.2	20.3	22.5	7.2
2043	4.6	26.9	31.5	2.4	21.5	23.9	7.6
2048	4.8	28.4	33.2	2.5	22.7	25.2	8.0
Fatal and Suspected Serious Injury Crashes							
2018	0.2	0.7	1.0	0.1	0.6	0.7	0.3
2023	0.3	0.8	1.0	0.1	0.6	0.8	0.3
2028	0.3	0.8	1.1	0.1	0.7	0.8	0.3
2033	0.3	0.9	1.2	0.2	0.7	0.9	0.3
2038	0.3	0.9	1.3	0.2	0.8	0.9	0.3
2043	0.3	1.0	1.3	0.2	0.8	1.0	0.4
2048	0.4	1.1	1.4	0.2	0.8	1.0	0.4

*Rear-end (RE) and sideswipe (SSW) passing crashes involving a commercial vehicle

Table 3-2. Estimated Crash Frequency for Eastbound I-80 Segments (2018–2048)

Year	No Build: No Truck Climbing Lane			Build: With Truck Climbing Lane			Estimated Crash Reduction
	RE+SSW*	All Other	Total	RE+SSW*	All Other	Total	
Total Crashes: All Crash Severities							
2018	7.7	28.5	36.2	3.1	22.8	25.9	10.3
2023	8.2	30.6	38.8	3.3	24.5	27.8	11.0
2028	8.8	32.6	41.4	3.5	26.1	29.6	11.8
2033	9.3	34.8	44.1	3.8	27.8	31.6	12.5
2038	9.9	36.9	46.8	4.0	29.5	33.5	13.3
2043	10.5	38.9	49.4	4.2	31.1	35.3	14.1
2048	11.0	41.0	52.0	4.4	32.8	37.2	14.8
Fatal and Suspected Serious Injury Crashes							
2018	0.4	1.2	1.6	0.1	1.0	1.1	0.5
2023	0.4	1.3	1.7	0.2	1.0	1.2	0.5
2028	0.4	1.4	1.8	0.2	1.1	1.3	0.5
2033	0.4	1.5	1.9	0.2	1.2	1.3	0.6

Table 3-2. Estimated Crash Frequency for Eastbound I-80 Segments (2018–2048)

Year	No Build: No Truck Climbing Lane			Build: With Truck Climbing Lane			Estimated Crash Reduction
	RE+SSW*	All Other	Total	RE+SSW*	All Other	Total	
2038	0.5	1.6	2.0	0.2	1.2	1.4	0.6
2043	0.5	1.6	2.1	0.2	1.3	1.5	0.6
2048	0.5	1.7	2.2	0.2	1.4	1.6	0.7

* Rear-end (RE) and sideswipe (SSW) passing crashes involving a commercial vehicle

Travel Time Savings

Travel time savings are the benefits to automobiles being able to travel faster as a result of project improvements. Additional truck climbing lanes allow automobiles to safely pass slower-moving trucks, preserving relatively higher speeds and thus reducing travel times. The travel time of automobiles using four-lane facilities depends on whether there are slower vehicles ahead preventing the automobiles from moving at their desired speed. The queuing simulation model assumes automobiles can pass slower-moving trucks in the Build scenario within the project area where truck climbing lanes are provided. The benefits from travel time savings are based on differences between automobile vehicle hours traveled in No-Build and Build scenarios. Reduced travel times are monetized using values of time consistent with United States Department of Transportation (USDOT) guidance.

In developing the travel time savings approach, existing models and research studies on truck climbing and passing lanes were examined. It was found that existing models and studies focused on the impact of truck climbing lanes only on two-lane, conventional highways. Because I-80 is a four-lane facility, this approach is inadequate. On a two-lane conventional highway, vehicles are delayed when encountering only a single slow-moving vehicle. However, on a four-lane freeway, vehicles are delayed only when they encounter a slow-moving vehicle in the left lane passing and even slower vehicle in the right lane.

To account for the complexity of this situation, a basic queuing simulation model was developed to assess the speeds of automobiles interacting with slower-moving trucks traveling uphill. For the simulation, vehicles were divided into three groups: automobiles, passing trucks, and slower moving trucks. The simulation model was run separately for each project as the uphill segment length and annual average daily traffic vary by project.

The automobile speeds used in the simulation were taken directly from field data. Truck speeds were estimated based on the length of the grade using a model developed in National Cooperative Highway Research Program Report 486. It is assumed that passing trucks travel 2 miles per hour (mph) faster. The primary results of the BCA (presented in Section 3.1.4) reflect this assumption. Sensitivity of the BCA results was tested to the assumed speed differential.

The test found that changing the speed did not change the results substantially. Appendix C shows the results of sensitivity testing using 1 and 3 mph speed differentials.

The queuing simulation model provides outputs, such as vehicle miles traveled and vehicle hours traveled. These outputs were used to derive the economic benefits in the BCA. Economic benefits start accruing after construction is complete and are estimated for 20 years (2021 to 2040), discounted at 4 percent annually.

Vehicle Operating Cost Savings

Vehicle operating cost savings are the benefits to roadway users from savings in fuel consumption resulting from project improvements. Truck climbing lanes allow for increased speeds in the project area, which can lead to vehicles traveling at more (or less) fuel-efficient speeds. Fuel consumption is estimated based on vehicle type, fuel consumption rate, average speed, and vehicle miles traveled. The impacts to fuel consumption are monetized using fuel costs per gallon for automobiles and trucks. Other vehicle operating costs were not considered in the BCA because non-fuel costs are based on the miles traveled, which are assumed to be the same in the No-Build and Build scenarios.

Emissions Cost Savings

Emissions cost savings are the benefits of reduced vehicle emissions in the project area. Truck climbing lanes allow for increased speeds in the project area, which can lead to vehicles generating fewer (or greater) emissions. The emissions from automobiles are determined based on vehicle speeds from the queuing simulation model. Emissions rates are estimated using the Environmental Protection Agency (EPA) Motor Vehicle Emissions Simulator (MOVES) model based on characteristics of the study area. Vehicle emissions are monetized throughout the analysis period using values per metric ton as specified by USDOT.

3.1.4 Prioritized Climbing Lane Project List

The results of the BCA produce a prioritized list of climbing lane projects. The BCA compares the cost effectiveness of 11 different truck climbing lane projects in the Master Plan. The cost effectiveness of each project is assessed and ranked using the BCR. A higher BCR indicates a more cost-effective project in terms of user benefits. Table 3-3 shows the prioritized project list ranked by BCR. The total benefits, total costs, and net present value of each project are also presented.

Table 3-3. Prioritized Climbing Lane Locations

BCR Rank	Project	Total Benefits ($ millions)	Total Costs* ($ millions)	Net Present Value ($ millions)	BCR
1	CL-01 EB (MP 14.529-15.029)	$3.4	$0.7	$2.7	5.0
2	CL-10 WB (MP 20.381-19.881)	$2.9	$0.8	$2.1	3.6
3	CL-02 EB (MP 21.268-21.768)	$2.3	$1.0	$1.3	2.2

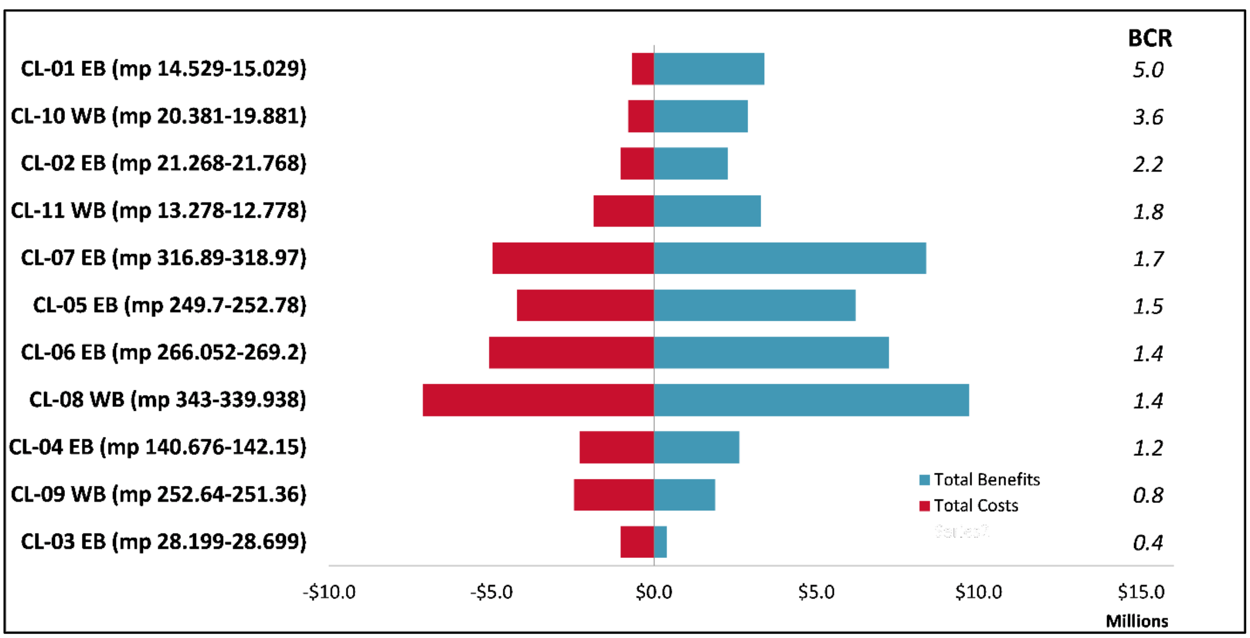
Table 3-3. Prioritized Climbing Lane Locations

BCR Rank	Project	Total Benefits ($ millions)	Total Costs* ($ millions)	Net Present Value ($ millions)	BCR
4	CL-11 WB (MP 13.278-12.778)	$3.3	$1.9	$1.4	1.8
5	CL-07 EB (MP 316.89-318.97)	$8.4	$5.0	$3.4	1.7
6	CL-05 EB (MP 249.7-252.78)	$6.2	$4.2	$2.0	1.5
7	CL-06 EB (MP 266.052-269.2)	$7.2	$5.1	$2.2	1.4
8	CL-08 WB (MP 343-339.938)	$9.7	$7.1	$2.6	1.4
9	CL-04 EB (MP 140.676-142.15)	$2.6	$2.3	$0.3	1.2
10	CL-09 WB (MP 252.64-251.36)	$1.9	$2.5	-$0.6	0.8
11	CL-03 EB (MP 28.199-28.699)	$0.4	$1.0	-$0.6	0.4

* Base costs (and benefit cost ratios calculated using base costs) are shown in this table.

Figure 3-4 shows the total benefits and costs of each project ranked by BCR, which is displayed on the right side of the chart. The total economic benefits generated by each project are represented by the blue bars, and total costs are represented by the red bars.

Figure 3-4. Climbing Lane BCA Results



Based on information presented in Table 3-3 and Figure 3-4, the most cost-effective project is CL-01 EB (MP 14.592-15.029) with a BCR of 5.0. This is the project with the lowest total cost ($0.7 million). However, if costs are ignored, project CL-08 WB (MP 343-339.938) generates the highest overall economic benefit ($9.7 million). Project CL-07 EB (MP 316.89-318.97) has the highest net present value ($3.4 million), which is the value of the benefits net of project costs.

3.2 Additional Lane on I-80

I-80 has two lanes in each direction across its 403-mile span across Wyoming, except for 12 miles that have a climbing lane as a third lane. A third lane in each direction across the state would enhance mobility and improve safety. The third lane could be open to all traffic or be restricted to trucks. The third lane could also be dedicated for the emerging technology of autonomous and connected vehicles. However, as the projected pavement cross section for such a lane is still very early in development, a full cost estimate for this option was not developed as part of this Study. Typical sections for the third lane option are discussed in Section 3.1.2.

3.2.1 Conceptual Cost Estimate

As a first step to begin considering the feasibility of a third lane, the I-80 Master Plan prepared a conceptual cost estimate (Table 3-4). The cost estimate is a planning-level cost using recent /readily available unit costs of WYDOT projects, order of magnitude assumptions for the need to either fully reconstruct or only widen the cross-section. The conceptual cost is prepared for both concrete and asphalt pavement methods. The cost for the third lane is based on the assumptions discussed in Section 3.1.2. When compared to the overall costs of construction for the third lane, right-of-way costs were inconsequential, and may be mitigated as necessary by modifying the alignment and final design.

Table 3-4. Additional Lane Conceptual Cost Estimate

Project Description	Low Cost	High Cost
3rd Lane Statewide (Asphalt)	$2.0 billion	$2.9 billion
3rd Lane Statewide (Concrete)	$3.0 billion	$4.3 billion

3.2.2 Life Cycle Analysis—Pavement Surface Comparison

A lifecycle cost analysis (LCA) was conducted to compare the total costs of adding a third lane along I-80 using concrete pavement compared to asphalt pavement. Both cases would require some modification of existing pavement surfaces so that I-80 would have a consistent surface across all lanes. For example, approximately 100 miles of I-80 currently have concrete surfaces. As described in Section 3.1.2, a portion of these surfaces would need to be replaced with asphalt, while the rest would be overlaid with asphalt under an asphalt pavement alternative.

The LCA compares the two different paving approaches (i.e., asphalt and concrete) to determine which has a lower total present value cost for all three lanes across the freeway. Table 3-5 and Table 3-6 show the capital, annual operating and maintenance (O&M), and rehabilitation costs used in the analysis. Capital costs for the LCA were estimated using the assumptions described in Section 3.1.2. The LCA used the base construction cost estimates because sensitivity tests showed that the upper and lower cost estimates did not change which pavement surface had a lower lifecycle cost. Annual O&M costs were estimated based on historical expenditures on existing surfaces along I-80 from 2007 to 2016. WYDOT provided a standard rehabilitation schedule and estimates for rehabilitation costs.

Table 3-5. Asphalt and Concrete Total Capital Costs and Annual O&M Costs

Expenditure	Asphalt (in millions 2017$)	Concrete (in millions 2017$)
Total Capital	$2,264.0	$3,288.3
Annual O&M	$1.9	$0.2

Table 3-6. Asphalt and Concrete Rehabilitation Costs over Time

Year	Asphalt (in millions 2017$)	Assumed Rehabilitation	Concrete (in millions 2017$)	Assumed Rehabilitation
0	$264.6	Major rehab on existing asphalt to match the condition of the new asphalt pavement.		
10	$308.6	Remove/Replace 2" HPM and WC		
15	$3.1	Crack Seal		
20	$519.0	Remove/Replace 4" HPM and WC	$164.9	Reseal Joints, 5% Slab Replacement
25	$3.1	Crack Seal		

HPM= Hot Plant Mix; WC =Wearing Course

For the LCA, the comparisons were applied to paving costs on a six-lane, 402.14-mile highway with the third lane in each direction and pavement surface improvements built over a 10-year period. Cost comparisons were performed in present value terms (using a 4 percent real discount rate) to account for the differences in the timing of these costs. To compute the present value costs, it was assumed that the entire project would be constructed over a 10-year period by implementing and then maintaining one segment at a time. Each segment is assumed to be equal to one-tenth of the overall program. The present value cost of a single segment is computed and then used as the basis for computing the present value of implementing future segments, assuming all segments are constructed and maintained on similar schedules. The total present value cost summed the discounted costs of all ten segments.

The results indicate that WYDOT could realize a savings of around $301.3 million by using an asphalt road surface (see Table 3-7). The discounted costs for one asphalt segment are about $301.0 million compared to concrete costs of about $336.7 million for a similar segment. The cost advantage for asphalt is due to asphalt requiring only one lane widening and overlay on two lanes compared to concrete requiring full three lane construction. After 10 years of sequential construction and maintenance for additional segments, the grand total costs amount to $2,539.0 million for asphalt and $2,840.3 million for concrete, which is a savings of about $301.3 million for using asphalt over the life of the program.

Table 3-7. Asphalt and Concrete Total Cost Comparison

Costs	Asphalt (in millions 2017$)	Concrete (in millions 2017$)
One Segment (1/10 of program)		
Capital Costs	$226.4	$328.8
Rehabilitation Costs (1/10 values in Table 3-6)	*Varies*	*Varies*
Annual O&M Costs	$0.19	$0.02
Total Costs	$342.0	$345.9
Discounted Total	$301.0	$336.7
Discounted Grand Total—10 Segments	$2,539.0	$2,840.3

3.3 I-25/I-80 Interchange Study Update

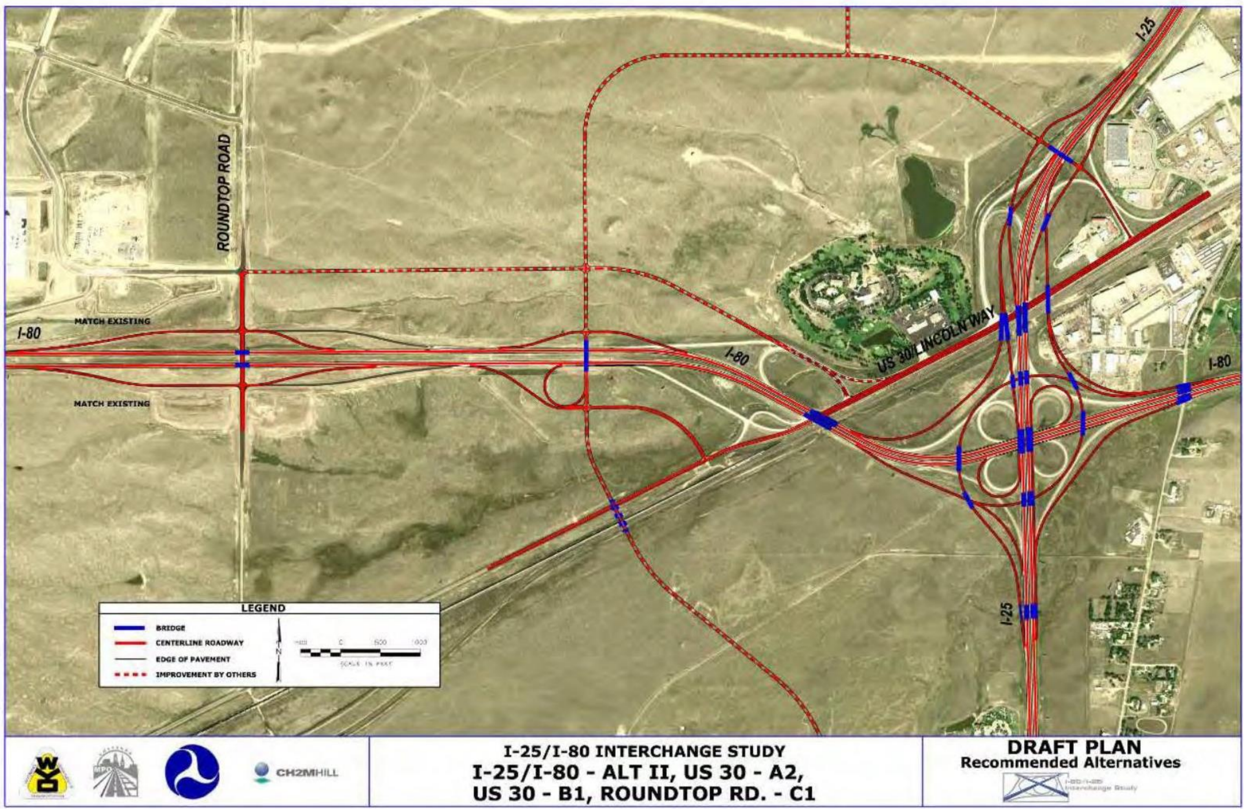
In November 2008 the *I-80/I-25 Interchange Study* (2008 study) was completed by WYDOT, FHWA, and the Cheyenne Metropolitan Planning Organization. The 2008 study provided an analysis of connection alternatives to the existing I-80/I-25 interchange in Cheyenne, Wyoming. Based on a number of screening criteria, the alternative evaluation established a preferred (recommended) alternative. The preferred alternative incorporates the I-25/I-80 interchange, and also the I-80/US 30 (Lincolnway), I-80/Roundtop Road, and I-25/Missile Drive interchanges shown in Figure 3-5.

The project was enveloped into phases to accommodate funding requirements. The phases are defined as follows:

- **Phase I.** I-25/I-80 eastbound to northbound flyover ramp and east side of Lincolnway interchange
- **Phase II.** I-25/I-80 westbound to southbound flyover ramp and west side of Lincolnway interchange
- **Phase III.** Expanded I-25/I-80 loop ramps, Roundtop Road interchange improvements, and Lincolnway I-80 interchange improvements.
- **Phase IV.** Missile Drive improvements.

The preferred alternative in the 2008 study (Alternative II) includes two loop ramps with two flyover urban ramps, which increase design speeds on the loop ramps to 30 mph (rather than the current 25 mph), and the two urban ramps that can incorporate design speeds of 55 mph. The advantages of this alternative include eliminating the weaving segments of the current cloverleaf design, provides more high-speed flow movements, and can be constructed in a phased manner.

Figure 3-5. I-25/I-80 Preferred Alternative



Source: I-80/I-25 Interchange Study, CH2M Hill, 2008.

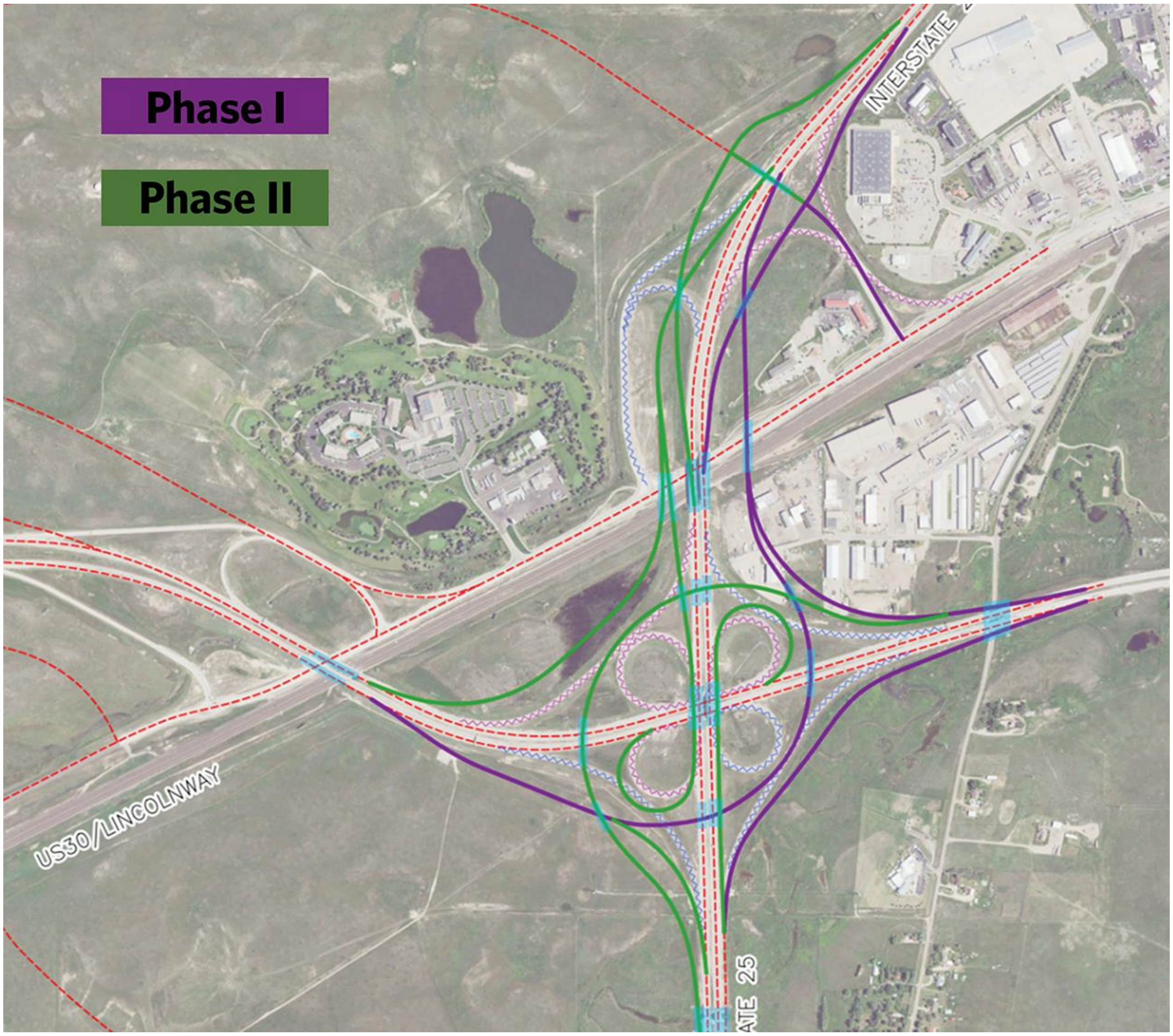
For the I-80 Master Plan, the expanded I-25/I-80 loop ramps in Phase III have been moved to Phase II, and only Phases I and II are to be updated. Figure 3-6 provides the construction stages for Phases I and II. Figure 3-5 provides the full buildout (all phases) scenario. The 2008 study included a cost estimate for each phase, and has been updated to present (2017) dollars for the I-80 Master Plan. The cost summary for each phase is presented in Table 3-8.

Table 3-8. I-25/I-80 Cost Summary

Phase	Cost (2008 Dollars)	Cost (2017 Dollars)
Phase I	$76,800,000	$98,700,000
Phase II	$29,600,000	$39,800,000

Note: Full cost estimate is provided in Appendix D.

Figure 3-6. Construction Stages for I-25/I-80 Phases I and II



3.4 Intelligence Transportation System (ITS)

ITS represents a broad spectrum of technologies that are designed to improve mobility, reduce congestion, and improve travel time reliability and safety through the use of technology. The use of ITS has evolved steadily during the past 2 decades but adoption has accelerated because of the influence of new technologies becoming more cost competitive and efficient. During the past several years, advances in computer processing, the evolution of LIDAR and other on-board sensors, as well as new communications protocols associated with Connected and Autonomous Vehicles have progressed new technology in transportation.

Many early uses of roadside sensors were in-pavement loop detectors that were used both to count and classify vehicles as well as to identify when a vehicle was present. Today's roadside sensors are much more sophisticated than pneumatic loop detectors and are capable of collecting a wide variety of data to benefit traffic operations and maintenance. WYDOT already uses many of these technologies along Interstates, arterials, and other roadways.

3.4.1 Traditional Intelligent Transportation Systems

Traditional ITS systems center around using technology to detect vehicles so that system operations can be modified based upon real-time traffic conditions. Other applications including using technologies to inform travelers of stopped traffic (queue warning), alternative routes, and estimated travel times. This section summarizes some of the more prevalent of these technologies.

Camera Technology Improvements (infrared, auto traffic classification and counting). Still frame traffic cameras are still in use throughout the United States, though some are increasingly being switched to pan-tilt-zoom video cameras. Typical applications of video-based systems include presence detection at signalized intersections and incident detection along freeways. The video cameras can be configured to emulate inductive loop detection as well as to perform vehicle classification and vehicle counting at highway speeds. Usually, the digital video feed from a traffic camera is streamed to a processing center where statistical algorithms scan the images and determine the number and classification of the vehicles. These counts and classifications are then reported to a Traffic Message Channel (TMC) in summary format.

As processing capabilities continue to improve, extracting events and images from digital video feeds is becoming increasingly automated. The latencies with image processing have dramatically improved during the past decade to the point where digital video processing is now being used by some agencies for real-time incident detection and notification. This includes identifying stopped vehicles, vehicles traveling in the wrong direction, and others. With the standardization and conversion to digital images, an agency could conduct emerging video processing techniques and methods using their existing video hardware (i.e., video software processing is no longer strictly tied to the video hardware).

Bluetooth and Wi-Fi. Both Bluetooth and Wi-Fi are standardized communications standards that operate in the 2.4 Ghz band. These communication protocols and chipsets are common in mobile devices such as cellular phones, tablets, in-vehicle infotainment units, and others. In both cases, the transceivers regularly and continuously broadcast "discovery" messages as the devices seek other networks or devices to connect with. These discovery messages contain a media access control address (MAC address). The MAC address of a device is a unique identifier assigned to network interfaces for communications at the data link layer of a network segment. Bluetooth and Wi-Fi equipment mounted at the roadside can "listen" for these discovery messages and capture the unique MAC address without having to connect to the actual Bluetooth or Wi-Fi enabled device. Additional roadside sensors at other points of the transportation network capture the same MAC addresses, which are then matched to derive information on travel origins/destinations, travel time, speeds, and others.

Road Weather Information System (RWIS). A RWIS is an automatic weather stations or Environmental Sensor Station deployed along a roadside. This system includes a number of sensors that can measure atmospheric parameters, pavement conditions, water level conditions, wind speed, barometric pressure, temperature, and other metrics such as visibility and humidity.

Radar is "a nonintrusive technology that uses microwaves to detect the presence of vehicles. Microwaves emanating from the device will reflect off of the metallic surface of the vehicle and can provide the position of the vehicle relative to the device (e.g., which lane it is in). When two radar beams are used in series, characteristics, such as vehicle speed and length, can be obtained. Dual-beam radar antennas can be housed in the same unit; meaning only one device is needed to obtain these parameters. Radar units can be installed in a "front-fire" orientation as illustrated in Figure 3-7, or in a "side-fire" orientation where the microwaves are beamed across the roadway travel lanes. In either case, radar units can provide a number of different data elements including speed, heading, volume, position (lane), and acceleration/deceleration.

Laser and LIDAR Systems. Laser and LIDAR (Light Detection and Ranging) systems use invisible beams of light to detect vehicles in much the same fashion as radar. Fixed Laser and LIDAR systems are not common and are typically used in situations where vehicle detection is critical, such as at toll gantries, ramp meters, and others. Mounted overhead in each travel lane, a Laser and LIDAR system performs well in identifying the presence of a vehicle, speed, heading, and vehicle classification. However, the performance of these systems can be adversely impacted by weather. Because these systems are typically mounted over each travel lane, they are more expensive to deploy than other sensing technologies.

Magnetometers is a class of vehicle detection equipment that uses changes in the earth's magnetic field to detect a vehicle. Found in both wired (microloops) and wireless form, these devices are designed to be mounted directly in the travel lane or buried immediately under the roadway surface. These devices are able to capture information similar to the traditional loop detector such as volume, lane occupancy, speed, and vehicle length. New processing algorithms are being developed and tested that would also enable vehicle classification to be performed with these devices by FHWA and others.

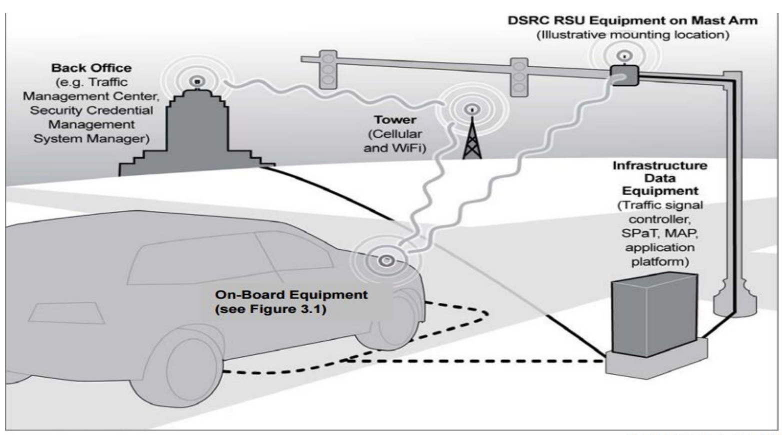
Radio Frequency Identification (RFID). RFID is a technology that has been heavily utilized within the transportation industry during the past 2 decades for tolling operations. RFID technology consists of a "tag," and a "reader." Tags can be either "passive," activated by the energy of the reader, or "active," continuously broadcasting a short message that is then received by the reader. The use of RFID technology for vehicle detection as well as origin/destination studies has increased due to the inclusion of RFID tags inside of an automobile's tires. Although the primary purpose of these tags is to monitor tire pressure, each tag has a unique signature, much like the MAC address of a Bluetooth or Wi-Fi transceiver. Roadside RFID readers can pick up these signatures and use them to determine Origin/Destination along a given route.

3.4.2 Emerging Technologies

Dedicated Short Range Communications (DSRC) and 5G cellular are two rapidly emerging technologies that enable vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications with very low latencies. Connected vehicle technology uses DSRC to allow for secure messages to be sent through enabled devices. DSRC technology utilizes low latency wireless connections using an 802.11 phased modulation wireless router across a spectrum of 5.9GHz band that was dedicated to ITS by the U.S. Federal Communications Commission. Connected vehicle technology consists of point-to-point wireless communication between and among vehicles and infrastructure. Beyond infrastructure- and vehicle-based radios, connected vehicle technology relies upon a communications link to a back office for system management. This is typically done using fiber optic or cellular connectivity. Additional interfaces with infrastructure, such as signal control cabinets or road weather information stations, may also be necessary depending upon the desired application.

There are three components to a Connected Vehicle system as illustrated in Figure 3-7. First, there is the DSRC radio that is on-board the vehicle (On-Board Unit or OBU). This component receives information from the vehicle's sensors and broadcasts DSRC messages from the vehicle to other vehicles and the roadside infrastructure. Connected Vehicle applications that are associated with V2V communications are typically installed on this device. Second, the Connected Vehicle infrastructure component is a pole-mounted DSRC radio frequently referred to as the Roadside Equipment (RSE) or Roadside Unit (RSU). This radio serves the same functionality as the on-board unit, but is also tied back to a central data repository and processing system, which is the third major component of a Connected Vehicle system.

Figure 3-7. Major Components of a Connected Vehicle System



Major components include OBE, RSU, and Back Office Processing

Adoption of DSRC equipment in passenger and commercial vehicles is expected to begin following the adoption of the National Highway Traffic Safety Administration's (NHTSA) final rulemaking that would require DSRC radio's to be included in new passenger vehicles following an initial 3-year phase in period. Although this rulemaking is still awaiting approval from the White House, most of the traditional automotive manufacturers have already developed platforms for their future vehicle fleets. Some, such as the 2017 Cadillac CTS, have already included DSRC in production platforms. Aside from rulemaking activities, DSRC may be first adopted in commercial vehicles as it is an enabling component for truck platooning.

Current activities involving Connected Vehicle equipment include three large Connected Vehicle Regional Pilots currently underway in New York City, Tampa, and along the I-80 corridor in Wyoming. Other deployments include vehicle fleets as part of the Columbus Smart City effort and a variety of deployments stemming from the 2016 and 2017 Advanced Transportation Congestion Mitigation Technology Deployment (ATCMTD) grants.

Competing with DSRC, 5G cellular is another emerging technology that will offer low latency communications for V2V and V2I. Although universal standards for 5G have not yet been adopted or promulgated, existing standards for 4G provide a likely perspective for future 5G standards. Unlike DSRC, 5G is being driven by private industry, primarily the telecommunications firms, which would provide significant opportunities for public/private partnerships for states, cities, and local agencies. However, as with DSRC equipment, adoption of 5G technologies will require roadside equipment in the form of small pico- or micro- cellular broadcasters.

Adoption of DSRC and 5G technologies would occur rapidly and it is expected that within the next decade one or both of these technologies would be ubiquitously available in vehicles and in mobile devices. However, it is recommended that WYDOT continues to deploy these technologies as needed during the next 3 to 7 years as interim solutions until the next wave of technologies have sufficient market penetration. At the same time, WYDOT should recognize that significant investments in these technologies should not be planned for future out-years as these technologies would quickly become obsolete as new in-vehicle sensors and VV2I communications emerges.

Given WYDOT's current leadership position in Connected Vehicles as one of only three nationally sponsored Connected Vehicle Regional Pilots, it is recommended that WYDOT continues to invest in this technology to maintain its leadership position and to enhance the safety and mobility of the traveling public along the I-80 corridor. As 5G technologies emerge, WYDOT could readily intermix DSRC and 5G to create a co-existing network along I-80. Investing in these technologies would enable WYDOT to be early adopters of other new technologies such as truck platooning.

The general recommendation outlined in this document is for WYDOT to increase the coverage rate for DSRC radios to reach a saturation level that would allow WYDOT to effectively monitor the majority of I-80 and would increase the ability of WYDOT to expand the program and to adopt other Connected Vehicle and Dynamic Mobility Applications by extending the existing deployment of DSRC RSUs along I-80 that are being deployed as part of the Wyoming Connected Vehicle Regional Pilot.

The current plans for the Connected Vehicle Regional Pilot call for the installation of approximately 75 DSRC RSUs covering roughly 37 percent of the I-80 corridor. The focus of the RSUs is to provide a basis to achieve the goals of the pilot with a focus on road weather and freight. The RSUs are set to be installed by November 7, 2017. It is recommended to “double down” on this investment with the deployment of an additional 80 RSU units in the corridor. This would enable roughly 80 percent coverage across the entire corridor, which is important to achieve the following:

- **Improve safety warnings and weather-related incidents throughout the corridor,** specifically enhancing localized weather conditions such as black ice or wind-shears. The DSRC radios would provide notification to vehicles of rapidly changing conditions within a moving 11-minute window.
- **Investigate and enhance freight mobility at entry points**, specifically enabling the potential to utilize DSRC as an alternative to older technologies for wireless roadside inspections.
- **Improve WYDOT’s ability to attract and monitor emerging technologies** such as truck platooning, as well as enable remote monitoring of vehicles, and remotely overriding the on-board programming if needed through the DSRC radio linkage—provided the vehicle was not in the 20 percent coverage gap.
- **Maintain Wyoming as a leader in DSRC and Connected Vehicle programs**. This would be the single longest corridor ever instrumented with RSUs in the United States. This could potentially attract the technology community to Wyoming to conduct testing and analysis of potential new vehicle systems.

As an alternative, WYDOT could consider coverage of 90 percent of the corridor, which would increase the ability to monitor and take remote control of vehicles in a larger segment of the corridor by reducing the gap to only 10 percent of the corridor.

Ultimately, investing in DSRC technology is recommended as it represents a relatively low risk opportunity for WYDOT while maximizing the existing and previous investments. For example, in the future if 5G technologies or some other communication protocol rises to dominance such as Miracast Wi-Fi, these radio units can be “retuned” to operate as Wi-Fi routers or can have cellular modems added to transform them into 5G transponders. As new Dynamic Mobility Applications and Connected Vehicle applications are developed, 80 to 90 percent coverage of a corridor would enable WYDOT to implement these applications and further improve safety and mobility of travelers and workers. One application previously tested by USDOT (but has yet to be deployed in part because of DSRC coverage issues) is the Response Emergency Staging Uniform Management and Evacuation application (R.E.S.C.U.M.E.). Among other things, this application provides real-time alerts to first responders and work crews when oncoming vehicles are determined to be a threat of entering an active incident zone. Extending coverage is a significant step to enabling these kinds of applications.

Additional Locations. The proposed additional locations for the increased coverage are depicted in Figure 3-8.

Estimate. Table 3-9 presents a conceptual-level cost estimate of the proposed RSUs along I-80 that would increase coverage to about 80 percent. Cost estimating methodology is discussed in Section 3.1.2 of this document. The cost estimate is based on installing 80 RSUs with 49 requiring major installation including IPv4 and IPv6 (internet) communication, power, and structures. The costs outlined in Table 3-9 include cost for solar power only; cost for in-ground wiring back to a power source is not included.

Assumptions. The cost estimate presented in Table 3-9 assumed the following:

- The RSU cost per unit does not increase from $1,400.
- RSUs are installed at or near the locations listed in Table 3-9.
- The yearly maintenance includes a check on each RSU quarterly and major support and maintenance of 15 units per year (10 percent of the units).

Table 3-9. RSU Installation for 80 Percent Coverage of I-80

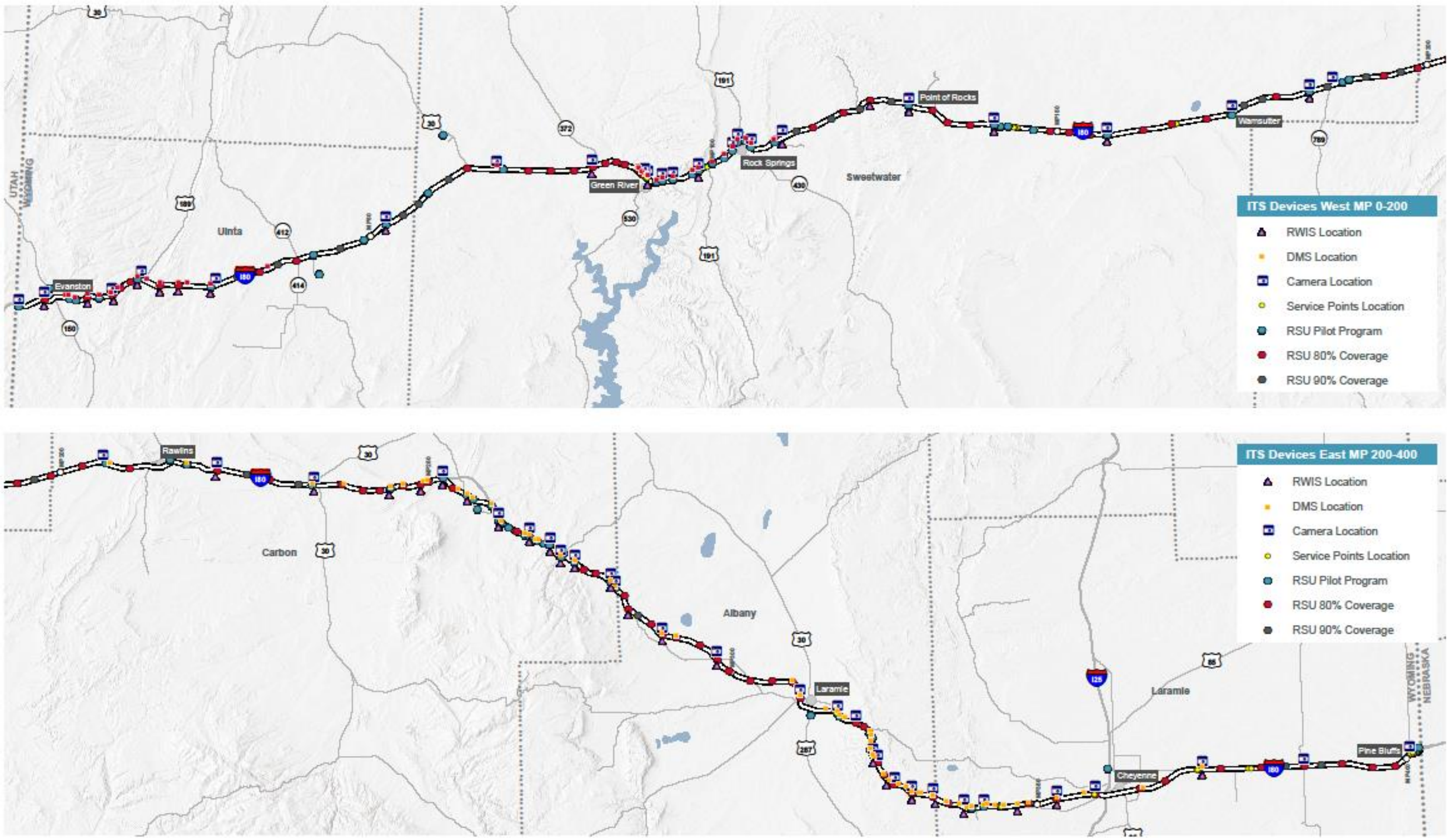
Item	Number	Cost (Each)	Total	Justification
RSUs	80	$1,400	$112,000	Quotes
RSU installation support	—	—	$1,350,000	Pilot estimate
RSU TMC integration	—	—	$12,000	IT estimate
Yearly maintenance	—	—	$180,000	See assumptions
25% contingency	—	—	$413,500	25% contingency

Coverage at 90 Percent

A coverage rate of 90 percent would give I-80 enough DSRC coverage to disseminate information related to road conditions and forecasted information to drivers within a window of less than 1 minute (assuming normal highway speeds) to connected vehicles. This assumes that autonomous vehicles will also use connected vehicle communication technology.

Additional Locations. The proposed additional locations for the increased coverage are provided in Appendix F.

Figure 3-8. Proposed RSU Locations



Estimate. Table 3-10 presents a conceptual-level cost estimate of the proposed RSUs along I-80 that would increase coverage to about 90 percent. Cost estimating methodology is discussed in Section 3.1.2 of this document. The cost estimate is based on installing 100 RSUs with 69 requiring major installation including communication, power, and structures.

Assumptions. The cost estimates presented in Table 3-10 assumed the following:

- The RSU cost per unit does not increase from $1,400.
- RSUs are installed at or near the locations listed in Table 3-10.
- The yearly maintenance includes a check on each RSU quarterly and major support and maintenance of 18 units per year (10 percent).

Table 3-10. RSU Installation for 90 Percent Coverage of I-80

Item	Number	Cost	Total	Justification
RSUs	100	$1,400	$140,000	Quotes
RSU installation support	—	—	$1,750,000	Pilot estimate
RSU TMC integration	—	—	$14,000	IT estimate
Yearly maintenance	—	—	$200,000	See assumptions
25% contingency	—	—	$526,000	25% contingency

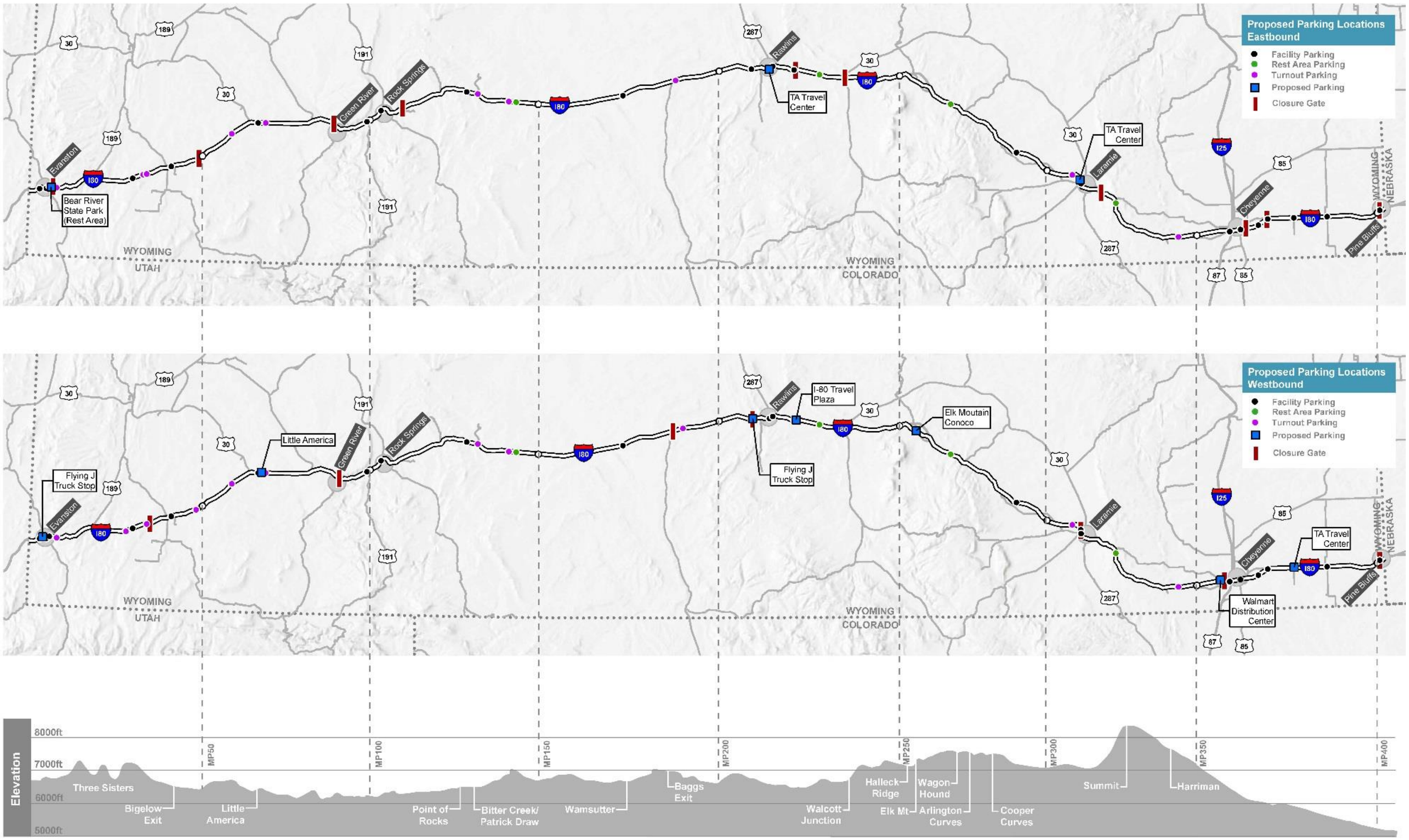
IT = information technology; RSU = roadside unit; TMC = Traffic Management Center

3.5 Truck Parking

Safe, adequate parking for commercial vehicles under a variety of circumstances is an important component of any freight corridor. Road closures, particularly for extended periods of time, necessitate locations for commercial vehicle parking ideally close to areas that can provide facilities for the drivers. Parking spaces along freight corridors are also needed because of new regulations which will tighten the enforcement of required break periods for drivers of commercial vehicles.

Figure 3-9 depicts the locations WYDOT has identified along I-80 for truck parking, categorized as facility (29 sites), rest areas (7 sites), and turn-outs (19 sites). These existing parking accommodations are regularly at overflow conditions when I-80 is closed. Closures of I-80 occur mostly because of either adverse winter weather or high wind conditions. Some sections experience more than 15 closures per year of varying durations (Figure 2-4; Section 2.3). During extended closures, several hundred trucks can queue up in need of safe parking facilities.

Figure 3-9. Locations for Truck Parking Along I-80



The following factors were used to identify candidate locations for implementing additional truck parking locations:

- WYDOT District suggestions
- Proximity to services
- Areas with many closures
- Closure gate locations

Proximity to services is very important for truck parking locations. Truckers need food and other services while the highway is closed. Locations without services require maintenance for trash, and problems arise when rest area facilities are lacking. In addition, placing truck parking locations upstream of closure gates makes the most sense.

Safe, adequate parking for commercial vehicles under a variety of circumstances is an important component of any freight corridor.

The next step for evaluating truck parking involved examining existing truck stops to identify those that might have available land adjacent or nearby. Truck stops that provide services along I-80 were identified and reviewed with aerial images to identify adjacent land that appeared available and suitable. These locations were then further screened by analyzing the locations in relation to closure gate locations. These locations were reviewed by WYDOT Headquarters and District staff. The following candidate locations for additional truck parking were identified:

- Hillsdale Exit 377: TA Travel Center
- Cheyenne Exit 357: Roundtop Road Walmart Distribution Center
- Laramie Exit 310: Curtis Street (TA Travel Center)
- Elk Mountain Exit 255: (Conoco)
- Sinclair—Exit 221: East Sinclair (I-80 Travel Plaza)
- Rawlins—Exit 214: Higley Blvd—Central Rawlins (TA Travel Center)
- Rawlins—Exit 209: Johnson Road—West Rawlins (Flying J Truck Stop)
- Green River/Rock Springs Exit 68: Little America Truck Stop
- Evanston Exit 6: Bear River State Park (Rest Area)
- Evanston Exit 3: Flying J Truck Stop

Appendix G contains aerial images for each of these locations along with observational notes. The next step would be to further investigate parcel boundaries and ownership.

4.0 FINANCIAL STRATEGY

An important part of the overall Interstate 80 (I-80) Master Plan is the plan forward to implementation. One critical component of the implementation plan is the legislative authority and ability to fund the improvements. The Wyoming Department of Transportation (WYDOT) has a diverse portfolio of funding sources. However, the growth potential of the portfolio is weak relative to escalating costs of maintenance and capital expansion, both statewide and on I-80. Between 1996 and 2010 WYDOT's annual funding had an increasing trend, growing from $281 million to $607 million. Annual funding did not pay for all WYDOT's needs, but budgets lagged needs much less than they do today. WYDOT funding has been on a decline since 2010—the reasons for which are many—creating a growing gap between needs and available funds.

A substantial and sustainable new funding source is needed for WYDOT to maintain and grow its system, particularly the I-80 freeway, which is among the costliest elements.

Figure 4-1 shows that historical funding for WYDOT between 1996 and 2010 (blue line) grew substantially, at nearly 7 percent annually. The green trendline shows average funding levels through 2011. However, the red line shows actual funding for WYDOT began to decline on average (note the black trendline) after 2010. Forecast data for 2018 to 2022 extends the historical data forward from 2017, showing expected annual funding levels to hover at just over $600 million.

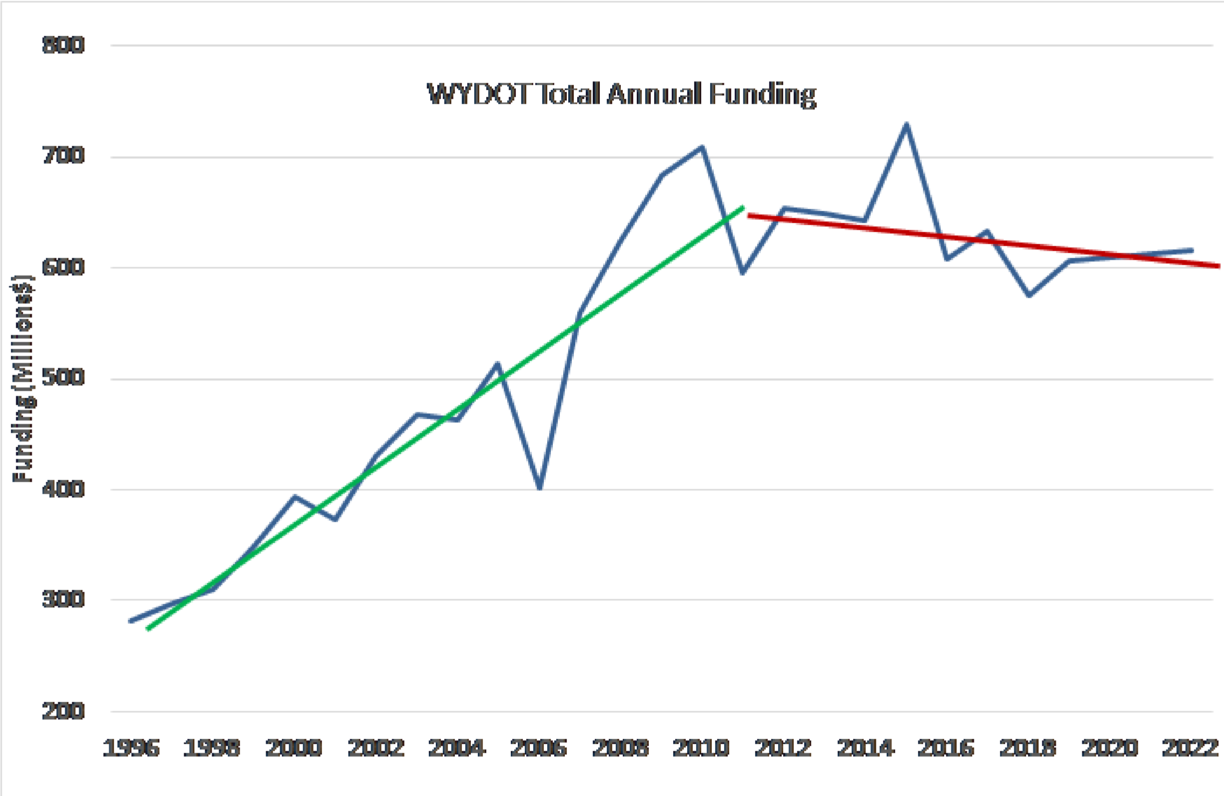
Appendix H contains further details on funding and financial strategies.

WYDOT's funding needs are growing, and there is a clear understanding and agreement among WYDOT management that WYDOT does not have sufficient funding to maintain its assets and pay for future system improvements that will promote safety, commerce, and mobility.

4.1 Federal Funding

Formula-based funding is by far the largest consistent flow of funds from the federal government to WYDOT. In 2017 Wyoming's apportionments from the Federal-Aid Highway Program were approximately $263.5 million with the remainder coming from previous year carry-overs and discretionary grant program funding. In total, WYDOT expects total federal funding to continue at about the level received in 2017 ($296 million) through 2020, when the current funding bill expires.

Figure 4-1. WYDOT Annual Funding History and Forecast (Post 2017)



It is possible, however uncertain, that the Administration and Congress could change the structure of future federal funding by concentrating available dollars on certain types of projects through the available programs in the Fixing America's Surface Transportation (FAST) Act. The Act will expire midway through President Trump's first term, providing his administration the opportunity to overhaul the way federal transportation funding is allocated. For instance, the Trump Administration could focus on rural projects, those that drive economic growth, or projects that use private sector investment to leverage federal dollars.

If federal financing programs are strongly promoted over grant programs, WYDOT may need to reconsider the approach it has taken for many years to avoid issuing debt to pay for transportation infrastructure, particularly if large capital outlays for I-80 or other corridors are desirable. Issuing debt is by no means necessary, even under a tolling scenario, but WYDOT should consider all aspects of the infrastructure packages the Administration and Congress present.

Discretionary federal grant programs have evolved since gaining popularity a decade ago when the American Recovery and Reinvestment Act of 2009 (ARRA) provided $1.5 billion in funding for the Transportation Investment Generating Economic Recovery (TIGER) program. Since then, TIGER has been funded each year and other discretionary grant programs have been developed in subsequent federal highway bills. The FAST Act includes four major discretionary grant programs applicable to highway projects like I-80, including the following:

- TIGER
- Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD)
- Surface Transportation System Funding Alternatives (STSFA)
- Infrastructure for Rebuilding America (INFRA)

Though all are applicable, the INFRA program may be the most applicable. Unlike the Federal Highway Administration (FHWA) Congestion Mitigation and Air Quality Improvement (CMAQ) and the United States Department of Transportation (USDOT) TIGER programs, INFRA grants are somewhat larger, ranging from $5 million to $165 million in the fiscal year 2016 round. INFRA grants can be used to fund up to 60 percent of the project's costs. However, other federal funding may be used to fund project costs up to a maximum federal share of 80 percent. Reductions in the non-federal match requirement for rural projects may be a possibility, however no formal guidelines have been changed allowing this reduction as of this writing.

4.2 Existing Funding Sources

Federal mineral royalties, vehicle registration fees, and motor fuel taxes are the other significant revenue sources for WYDOT. The rates charged for vehicle registrations and motor fuel taxes have been increased in the recent past; however, these revenue sources are not growing fast enough to keep up with construction costs. Indexing these fees/rates to inflation or another metric is one approach to keep their growth in step with escalating costs. A variable registration fee structure, based on vehicle weight, age, or value is another approach other states have used to increase fee revenues.

4.3 New Funding Options

Potential new funding sources could include general sales taxes or focused taxes on certain items, like transient goods and services (hotels, rental cars, and dining establishments), motor fuels, or alcohol and tobacco products. Vehicle operator's license fees, real estate or personal property taxes, and emissions-related fees for large carbon emitters are other options that states use to bolster traditional motor fuel taxes. Appendix H contains the potential revenue that could be generated from a 5 percent increase in the current tax. These types of taxes could be levied statewide or in certain areas, though the conventional approach is to link user benefits to the payment source. For instance, a toll road is a direct pay-for-use fee, where the people that benefit pay the fee, whereas a statewide sales tax dedicated to I-80 improvements would not have a direct link for many people in the northern part of the state. Most successful sales tax ballot initiatives have a geographically diverse portfolio of projects for which the funds are dedicated, which is intended to spread benefits to a greater population of people. The option to include multiple priority projects is one of the primary reasons local option taxes are becoming increasingly popular. For instance, an individual county may issue a sales tax to pay for urban amenities, while another could issue the tax to pay for highway capacity.

4.4 Tolling Study Update

Tolling has been discussed on I-80 for years and remains a technically viable option for funding improvements, if it is deemed a socially acceptable option. Toll revenue forecasts originally developed as part of the 2009 I-80 Tolling Study were revised and adjusted to reflect toll rates on similar rural interstate tollways in the U.S. that range from 15 to 32 cents per mile. Toll rates of 25 cents per mile were assumed for five-axle trucks and 2.5 cents per mile for passenger cars.

Potential gross revenue at the 25 cents per mile rate is estimated to be between $190 million and $223 million annually in 2025, increasing over time with traffic volume and toll rate growth. Annual operating and maintenance costs in 2025, for both toll operations and facility maintenance, are estimated to be approximately $41 million, leaving between $150 million and $182 million for other uses such as pay-as-you-go project funding, reserve funds, or repayment of debt under a toll revenue financing program. If a lower toll rate structure, such as 10 cents per mile for five-axle trucks and 1 cent per mile for passenger cars were adopted, the revenue potential would still be substantial but would cause less diversion from I-80. Under this toll rate assumption, between $60 million and $85 million in annual revenue would be available after paying the $41 million for toll operations and facility maintenance.

The conclusion of the tolling analysis is that there is significant revenue potential from an I-80 tolling program if tolling is found to be a preferred solution for Wyoming. Another important finding from the *I-80 Master Plan Study* is that there are two FHWA programs that would allow tolling on I-80, and neither of these would impact current flows of federal funding to WYDOT. Both the Section 129 Tolling Agreement and the Interstate System Reconstruction and Rehabilitation Pilot Program are suitable fits for I-80, and toll revenues generated under these programs could be used by WYDOT to pay for maintenance or improvements to other Federal-Aid Highways in Wyoming.

If tolling I-80 is desired, legislation that allows tolling must be put in place. This could be structured as a statewide authority by WYDOT, a regional authority by local units of government, or a facility specific authority that limits tolling on I-80. These organizational structures have pros and cons; however, tolling is currently not allowed in Wyoming. Similarly, the mechanisms for toll revenue to be pledged for the repayment of debt must be established, with the State Treasurer's office or another entity of the State having the authority to issue this debt.

4.5 Project Delivery Methods

Design-build and operations-oriented public-private partnerships are additional tools that can be paired with financing to allocate risk away from Wyoming, accelerate delivery, and potentially reduce the cost of the project. These tools are widely used in other states; however, developing the programs to manage these projects take time, organizational change, and education of the local contracting community.

4.6 Financial Summary

There is no 'silver bullet' to fixing WYDOT's funding dilemma, because very few funding approaches are perfectly equitable to all users of the transportation system. A strategically designed portfolio of new funding sources could spread the burden and allow constituent groups to pay their fair share. Financing and delivery tools made available through new legislation would provide additional flexibility for WYDOT to accelerate revenue streams to current year funding and take advantage of private sector innovation. Whatever the funding approaches selected, champions are needed to help constituents, stakeholders, and other elected officials understand the dire nature of the funding issue on I-80, and within WYDOT as a whole. Further details on funding and financial strategies are contained in Appendix H of this document.

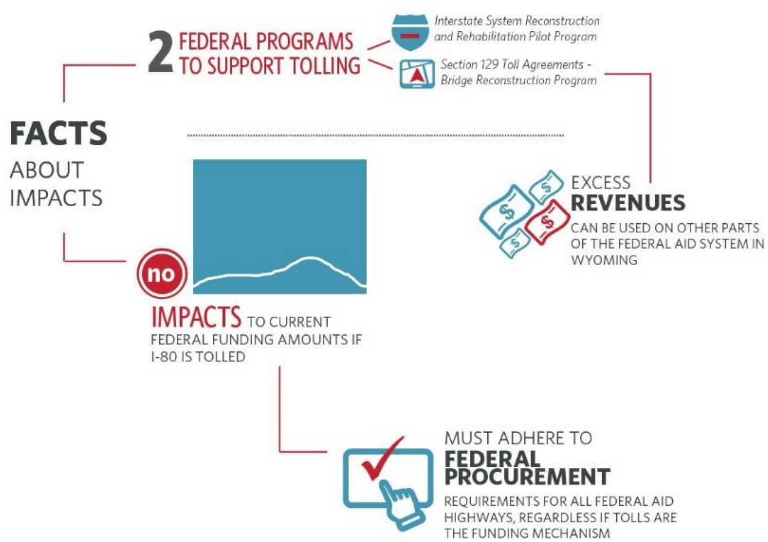
5.0 LEGISLATIVE STRATEGIES

5.1 Required Legislative Changes

Based on the information in this document, the Joint Transportation, Highways, and Military Affairs Interim Committee would make recommendations on how to proceed with implementing the *I-80 Master Plan Study*. Some of the funding, financing, and contracting elements discussed in this document would require changes to state legislation to grant WYDOT or other state entities the ability to carry out elements of the *I-80 Master Plan Study* in ways that create the most value for Wyoming. These elements include tolling, entering into public-private partnerships, issuing debt, and deploying some of the other potential new revenue sources described previously.

5.1.1 Tolling Legislation

Current Wyoming statutes do not allow tolling. Tolling is one of many options to help fund the *I-80 Master Plan Study* projects; however, careful consideration is necessary to avoid undue burden on residents and businesses along I-80. States that do allow tolling have developed specific legislation that provides guidelines for how tolling may be applied and the oversight required during project development, implementation, and operation.



Three primary approaches to public toll project oversight (and ownership) would guide any legislation put in place, they are Statewide Tolling Organization, Regional Tolling Organization, and Single Facility Tolling Authorization.

5.2 Design-Build Legislation

Design-build is a widely used project delivery approach in which designing and constructing a project is combined into one contract. The most common alternative, design-bid-build, involves the project owner (in this case, WYDOT) designing the project to 100 percent completion, then selecting the lowest bid for construction under separate contracts.

The major difference between the two delivery methods is that, with design-bid-build, WYDOT would receive a bid for building what is in the design plan, making WYDOT responsible for delays and costs of construction change orders related to design issues or unforeseen site conditions. With design-build, the contractor is paid a fixed fee and takes responsibility for the design and potential site issues, making the contractor responsible for any design and site-related costs that arise. Transferring these risks to the contractor can create significant benefits for the project owner in the form of price and schedule certainty.

A second significant advantage of using the design-build delivery is design innovation. With design-bid-build, one team works with WYDOT to create a design that fits the DOT’s needs and is reasonably cost-efficient. Then contractors bid on that design based largely on management and unit prices. With design-build, several competing teams are challenged with finding ways to save costs through design innovation. This competitive framework drives bids lower and can results in savings for the owner.

Wyoming statutes [Title 16, Article 7: Construction Contracts with Public Entities (16-6-701)] establish the parameters for state agencies to use design-build project delivery for public buildings; however, design-build is not available for WYDOT to use on highway projects. The content and structure of Statute 16-6-701 is comparable to other states’ design-build statutes for highways and could easily be adapted for this use by adding highways to the list of eligible projects.

The more significant undertaking is the organizational, technical, financial, and legal changes that would need to take place to begin using design-build delivery within WYDOT. Organizationally, the project development and approval process would likely change and potentially require new skill sets, because WYDOT would need to be more focused on risk and performance analysis to ensure that what WYDOT asks for in the request for proposal is what WYDOT actually wants in a finished product. The procurement process and evaluation is also very different, as it is generally based on more than just the low bid. From a technical standpoint, teams might propose design solutions that are outside of what WYDOT typically uses, so supplemental expertise to evaluate alternative technical concepts might be required.

Alternative project delivery (P3, broadly speaking) represents a valuable set of financing and delivery tools that can be used in a variety of ways. States that allow broad use of these tools with appropriate oversight give themselves the flexibility to explore avenues to deliver projects faster, with less public-sector-risk exposure, and potentially at a lower cost.

The keys to success in applying these contracting methods are to (1) understand the goals of using alternative delivery mechanisms, (2) understand what tools will help WYDOT achieve the goals, and (3) deploy the appropriate resources to evaluate the P3 approach for a given project to quantify the value of one delivery method over the another. This is known as a P3 Screening Framework. Developing and adopting a framework customized for Wyoming will be an important first step if P3 legislation is passed. The framework should reflect the mission and goals of the State as well as the organizational structure that will oversee P3 project development and implementation.

5.3 Autonomous and Connected Vehicle Legislation and Policy Changes

Autonomous vehicles are being driven by private industry and are quickly moving into the market. According to the National Council on State Legislatures, "twenty-one states—Alabama, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Illinois, Louisiana, Michigan, New York, Nevada, North Carolina, North Dakota, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Virginia and Vermont—and Washington D.C. have passed legislation related to autonomous vehicles." Further, "Governors in Arizona, Delaware, Massachusetts, Washington and Wisconsin issued executive orders related to autonomous vehicles." Much of this legislation involves requirements on the performance expectations and testing needed for an autonomous vehicle manufacturer to operate vehicles on public roads in the respective State. However, some states, such as Michigan, have essentially created an "open door" policy for autonomous vehicle manufacturers.

The legislative and policy landscape for autonomous vehicles is changing and potentially changing rapidly. In September of 2017, the National Highway Traffic Safety Administration (NHTSA) issues their second version of guidelines related to highly autonomous vehicles titled "Automated Driving Systems (ADS): A Vision for Safety 2.0." This guidance document sets forth NHTSA's interpretation on roles and responsibilities among federal and state agencies, as well as defines terms and conditions associated with performance characteristics of highly autonomous vehicles including defining the "Operational Design Domain," the "Object and Event Detection" and "Fallback position." Additionally, the guidelines set forth a 12 safety priority elements and a voluntary self-assessment for manufacturers. In this guidance document, NHTSA suggests Best Practices for States Regulatory Actions, as well as a division of responsibilities between federal and state governments (Figure 5-1).

Following the issuance of the NHTSA guidelines, the United States House of Representatives passed the SELF DRIVE Act, which was subsequently passed in the Senate Committee on Commerce, Science, and Transportation. The Senate Bill has yet to undergo full vote in the Senate; however, it is expected to garner bi-partisan support. President Trump has indicated his willingness to sign the bill when it is presented following Senate vote and resolution with the House Bill. The SELF DRIVE Act would significantly change the legislative environment for states with regard to highly autonomous vehicles. Ultimately, if the SELF DRIVE Act does not become law, the Wyoming legislature should consider establishing testing and performance requirements for highly autonomous vehicles in Wyoming. And even if the SELF DRIVE Act becomes law, there are still a number of different topic areas that would need to be addressed as discussed above.

Figure 5-1. NHTSA Guidelines 2.0 Recommended Division of Responsibilities between State and Federal Agencies

NHTSA'S RESPONSIBILITIES	STATES' RESPONSIBILITIES
• Setting Federal Motor Vehicle Safety Standards (FMVSSs) for new motor vehicles and motor vehicle equipment (with which manufacturers must certify compliance before they sell their vehicles)[33] • Enforcing compliance with FMVSSs • Investigating and managing the recall and remedy of noncompliances and safety-related motor vehicle defects nationwide • Communicating with and educating the public about motor vehicle safety issues	• Licensing human drivers and registering motor vehicles in their jurisdictions • Enacting and enforcing traffic laws and regulations • Conducting safety inspections, where States choose to do so • Regulating motor vehicle insurance and liability

The following topic areas (discussed in greater detail in Appendix H) are recommended for WYDOT and the Wyoming legislature to consider:

- A technology “neutral” environment
- Licensing and registration procedures for Highly Automated Vehicles
- Traffic laws and regulations that may serve as a barrier to Highly Automated Vehicles
- Administrative oversight
- Notification and permission for testing process.
- Liability and insurance requirements for Highly Automated Vehicles.
- Changes to registration and titling.

6.0 NEXT STEPS IMPLEMENTATION

6.1 General Needs of I-80

Interstate 80 (I-80) is vital to the state of Wyoming and also the nation as an interstate route for people and commerce. Investments are needed to maintain and improve the interstate for the 21st century. Safety is a concern as 12 percent of all crashes in Wyoming occurred on I-80 in the period 2012 to 2016. Further, 70 percent of all crashes on major freight corridors occur on I-80. Investments are also needed to improve mobility because of the high volume of truck traffic, which exceed 50 percent of all traffic in some locations. Available maintenance funds are currently insufficient to properly rebuild the infrastructure components of I-80 as they reach the end of their life cycles.

6.2 Specific Projects and Benefits They Provide

I-25 interchange. There is a pressing need for infrastructure improvements at the I-25/I-80 system interchange. The facility is aged and as a result many of the cloverleaf ramps do not meet current design standards. Safety is a concern because the facility experiences high crash rates. The crash history in this location does not show the full extent of the safety concerns. Multiple side-swipe crashes occur as a result of short weave sections, steep grades, slow-moving heavy vehicles, and sharp curves. For example, the merge between the eastbound-to-northbound and northbound-to-westbound movements creates a hazardous operational deficiency.

Passing lanes. A majority of the I-80 corridor is comprised of two lanes in each direction and the roadway is considered to be on rolling terrain. A high percentage of the overall traffic is truck traffic, and is therefore not uncommon to have two slow-moving trucks passing each other at decreased speeds because of sustained steep grades. This can lead to rear-end and side-swipe crashes and delay for the traveling public. There is a need to improve safety and mobility by adding truck climbing lanes.

From 2012 to 2016, 12 percent of all Wyoming reported crashes occurred on I-80. All but one truck climbing lane location has a Safety Index Rating of 3 or 4, which indicate the highest potential to reduce the number or severity of crashes. Annually, the truck climbing lanes were estimated to prevent 6 to 8 crashes for westbound I-80 and 10 to 15 crashes for eastbound I-80. For both directions, the truck climbing lanes were estimated to prevent approximately one fatal or suspected serious injury crash each year.

Intelligent Transportation Systems (ITS) Infrastructure. ITS provide information and communication technology to enable travelers to move more safely and efficiently. The use of

ITS has evolved steadily during the past 2 decades; however, adoption has accelerated because of the influence of new technologies becoming more cost competitive and efficient. Expanding the Wyoming Connected Vehicle Regional Pilot to increase ITS coverage of the I-80 corridor would enable WYDOT to be early adopters of other new technologies such as truck platooning. Investments in technology would enhance the safety and mobility of the traveling public along the I-80 corridor.

Truck Parking. Safe, adequate parking for commercial vehicles under a variety of circumstances is an important component of any freight corridor. Existing parking accommodations are regularly at overflow conditions when I-80 is closed, typically because of adverse weather. During extended closures, several hundred trucks can queue up in need of safe parking facilities. Parking spaces along freight corridors are also needed because of new regulations which will tighten the enforcement of required break periods for drivers of commercial vehicles.

Third lane across the state. Slow moving heavy vehicles passing one another is an example of non-recurring congestion along I-80, crashes that close or block the interstate are another example. Construction activities that restrict lane use have longer duration impacts to the overall operation of I-80 and freight mobility. The addition of a third lane across the state provides additional capacity for all of the congestion challenges listed above. It is anticipated that an additional lane in each direction across the state could be constructed at a rate of approximately 30 miles per year, allowing for programming of funds and accounting for construction.

6.3 Costs

The costs to complete the projects above vary significantly, with some representing one-time capital improvements and others representing annual investments that would occur continuously. The choice to move ahead with one or more of these items should be based on the needs of I-80 users, the goals of Wyoming with regard to I-80, and the funding available to undertake an I-80 improvement program.

The composition of an I-80 improvement program can be based on improvement projects with high benefit-cost ratios or other needs. Table 6-1 identifies costs for the items discussed above contained in a 10-year program. It illustrates what three conceptual I-80 improvement programs could look like, including:

- Subtotal 1 projects include the first two phases of the I-80/I-25 interchange reconstruction, the eight highest ranking truck passing lane segments, and the ITS improvements that would achieve 90 percent coverage of conduit and power across the 400 miles of I-80 in Wyoming. These projects total approximately $227 million in 2017 dollars and $301 million in year of expenditure dollars if spaced out across a 10-year program as presented in Table 6-1.
- Subtotal 2 includes all projects under Subtotal 1, with the addition of pavement maintenance program funding that will enhance safety and extend the life of the pavement. This annual

maintenance cost is estimated at $13.5 million in 2017 dollars and $197 million over the 10-year program.

- Subtotal 3 includes all projects under Subtotals 1 and 2 with the addition of another major capital project to add a third lane in each direction for the length of the roadway. Some portions of the road are already three lanes wide; however, some of the existing two-lane sections would need to be reconstructed. The total cost of adding the third lane in each direction is estimated at approximately $2.4 billion in 2017 dollars. Assuming that the roadway could be expanded at a pace of approximately 30 miles per year, about 75 percent of the roadway could be expanded to three lanes in the 10-year improvement plan cycle. The cost includes additional third lane, reconstruction of critical bridges, and tunnel expansions in respective sections. The cost of the 10-year program in 2017 dollars would be $2.0 billion with a year of expenditure cost of $2.9 billion.

Together, the items listed in Table 6-1 represent a 10-year I-80 improvement program valued at roughly $2.25 billion in 2017 dollars, and equating to annual spending on I-80 that averages $343 million per year between 2020 and 2029. The total year of expenditure cost of these items is estimated at $3.43 billion.

Table 6-1. 10-year I-80 Improvement Program

	Approximate Total Cost		Approximate Annual Year of Expenditure (YOE) Cost									
I-80 Improvement	**2017 $**	**YOE $**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**
Phase 1 I-25 Interchange	$ 100.0	$ 121.5	45.0	45.0	31.5							
Phase 2 I-25 Interchange	$ 40.0	$ 51.0	5.0	15.0	31.0							
Truck Passing Lanes 1/	$ 6.6	$ 9.3				3.1	3.1	3.1				
Truck Passing Lanes 2/	$ 32.6	$ 50.4				7.2	7.2	7.2	7.2	7.2	7.2	7.2
Truck Parking	$ 45.0	$ 66.0	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
ITS Infrastructure	$ 2.6	$ 3.9	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Subtotal 1	**$ 226.9**	**$ 302.1**	**$ 57.0**	**$ 67.0**	**$ 69.5**	**$ 17.3**	**$ 17.3**	**$ 17.3**	**$ 14.2**	**$ 14.2**	**$ 14.2**	**$ 14.2**
Enhanced O&M for I-80	$ 13.5	$ 197.1	15.7	16.5	17.3	18.1	19.0	20.0	21.0	22.1	23.2	24.3
Subtotal 2	**$ 240.4**	**$ 499.2**	**$ 72.7**	**$ 83.4**	**$ 86.8**	**$ 35.4**	**$ 36.3**	**$ 37.3**	**$ 35.2**	**$ 36.2**	**$ 37.3**	**$ 38.5**
Third Lane Construction	$2,014.9	$2,933.8	233.3	244.9	257.2	270.0	283.5	297.7	312.6	328.2	344.6	361.9
Subtotal 3	**$2,255.3**	**$3,433.0**	**$305.9**	**$328.4**	**$343.9**	**$305.4**	**$319.9**	**$335.0**	**$347.8**	**$364.4**	**$382.0**	**$400.3**

1/ Includes the top four ranked passing lane projects by benefit/cost ratio.
2/ Includes passing lane projects ranked 5 to 8 by benefit/cost ratio.

A variety of funding sources is discussed in Chapter 0 of this document that could be used for the I-80 improvement plan outlined above. Of those outlined, three stand out as having a direct link to transportation, including motor fuel taxes, registration fees, and tolling. Other sources are viable, and as noted above, in use by other states. However, motor fuel taxes and registration fee programs are in place in Wyoming. And tolling is the only potential revenue source significant enough to pay for the third lane scenario estimated in Subtotal 3. The toll rate required to generate $300 million-plus per year in free cash flow would be very high relative to peer-tolled facilities, and could cause significant undesirable traffic diversion from I-80.

Tolling at rates that are significantly lower than peer-tolled facilities could easily cover the improvements contained in Subtotal 2 in Table 6-1, causing relatively little traffic diversion from I-80. If tolling is not implemented, a funding strategy that uses increases in taxes from existing sources (motor fuel tax increase, registration fee increase) or changes to the structure of these sources, which could include indexing of rates or variable fees for different classes of vehicles, could make up the majority of regular funding for I-80 and other needs around the state. Discretionary grant applications could be used to seek project-specific funding for larger portions of the Subtotal 2 package of projects.

The improvement packages outlined above are scalable, meaning that elements can be delayed or removed all together if prioritization and funding availability warrants changing the programs. The funding program is also scalable and should be matched to the program size, and would likely have to include multiple sources of funding, particularly if non-tolling funding sources are targeted.

Costs are rising faster than revenues, and some action is going to be needed to address funding for I-80 and for transportation infrastructure in Wyoming, more broadly. A sustainable funding stream is needed, and the sooner a solution is found, the sooner improvements can be made to help preserve and extend the useful life of I-80 and enhance safety for its users.

Appendix A.
I-80 Closure Analysis Method

CLOSURES

HDR analyzed road closures on I-80 in Wyoming. The initial analysis was based on the closure data provided by WYDOT. All weather-related closures (for example, weather emergency and winter conditions) were categorized by milepost range and by direction. Once categorized, the total time of each closure was calculated. The inputs used for this calculation were the time the closure was added to the WYDOT Travel Information Service database and the time the closure was removed from the WYDOT Travel Information Service database.

The results indicated that the total closure time for each milepost range was exaggerated. The majority of the closures had more than one recorded reason between the added and removed time stamps. For example, a closure might have been initially recorded as a winter conditions closure, updated to a crash-related closure, and then removed as a weather emergency, all within the same event. However, the time during which the closure was categorized as a crash should not count toward the total time of the weather-related closure.

Because of this, HDR conducted a second analysis to eliminate the time during each closure that was not due to a weather-related event. Each status change within a closure was categorized based on the reason for the closure. Once assigned, calculations were revised to include only the time during each closure that was related to weather. Once the total closure times for each milepost range were updated, they were divided by the total number of years of the data provided to produce an annual average closure duration. The same process was applied to the analysis of the number of closures by direction per milepost range.

HDR created four maps for weather-related closures along I-80 in Wyoming from the Wyoming–Nebraska border to the Wyoming–Utah border. The first set of maps displays the number of weather closures annually per direction—one map for the eastbound direction and one map for the westbound direction. In the eastbound direction, the segment that annually has the most number of weather-related closures is between Rawlins and Cheyenne. This segment has more than 10 closures per year on average, with the segment between Rawlins and Laramie having the most number of closures, averaging 14 closures per year. The segments between Rawlins and Rock Springs and between Evanston and Carter/Mountain View have the second-most closures per year, averaging 6 to 10 closures each. The remaining segments of I-80 in the eastbound direction all average less than 6 closures per year because of weather.

In the westbound direction, the segment that has the most number of closures is between Rawlins and Cheyenne. Within this segment, the Laramie-to-Cheyenne segment averages the most closures in the westbound direction at 15 closures per year. The remaining segments of I-80 in the westbound direction all average less than 6 closures per year because of weather.

The second set of maps displays the duration of weather closures annually per direction—one map for the eastbound direction and one map for the westbound direction. In the eastbound direction, the segment that annually has the longest durations because of weather-related closures is between Rawlins and Laramie. The total duration per year of these weather-related closures adds up to 18 days. The segment between Laramie and Cheyenne experiences the second-longest duration of closures annually, between 8 to 14 total days, because of weather. The remaining segments of I-80 in the eastbound direction experience less than a day of closure per year because of weather.

In the westbound direction, the segment that annually has the longest durations because of weather-related closures is between Rawlins and Laramie. The total duration per year of these weather-related closures adds up to 17 days. The segment between Laramie and Cheyenne experiences the second-longest duration of closures annually, between 8 to 14 total days, because of weather. The remaining segments of I-80 in the westbound direction experience less than a day of closure per year because of weather.

Appendix B.
Truck Climbing Lane

TRUCK CLIMBING LANE
LOCATION IDENTIFICATION PROCESS

Segments for Consideration

The Steering Committee for this project met and discussed a number of issues that cause periodic non-recurring congestion along the I-80 corridor. A majority of the I-80 corridor is comprised of two lanes in each direction and the roadway is considered to be on rolling terrain. A high percentage of the overall traffic is truck traffic, and is therefore not uncommon to have slow moving trucks passing each other at decreased speeds due to sustained steep grades. Based on this discussion numerous locations for potential additional climbing lanes were identified early on in the study process. Segments that were considered for further study were identified as having grades greater than 3 percent, locations identified in previous studies, and segments identified by the District Engineers. This list was then filtered using additional information including the frequency of roadway closures, the safety rating and the overall length of the segment. Table B-1 shows the filtered list of passing lane segments recommended for further study. Cost estimate for the segments meeting several of the filtering criteria were developed and further safety analysis was completed, this allowed them to be prioritized using benefit cost analysis.

- Segments with grades >= 3 percent
  - It was assumed that profile grades above 3 percent would have higher potential for causing level of service deficiencies related to reduced truck speed.
  - An excel file containing vertical and horizontal curve reports was sorted to identify profile grades above 3 percent
  - These locations were verified and milepost ranges were identified by using PathWeb along the I-80 corridor. The milepost ranges identified where 3 percent grade begin and end in the eastbound and west bound lane.
  - Within the milepost range, the highest and lowest grades were recorded. The high and low were averaged.
- Segments identified by Districts
  - Profile grades within these segments were checked using PathWeb. The highest and lowest grades were recorded. The high and low were averaged. Profile grades along the entire milepost range were not check checked in the long urban sections near Rock Springs/Green River and Cheyenne. The District requests in these locations are believed to be related to capacity and not truck climbing.

- Segments identified by Prior Study
  - Profile grades within these segments were checked using PathWeb. The highest and lowest grades were recorded. The high and low were averaged.

Filtering Factors

The analysis applied the following factors to produce a filtered list of truck climbing lane locations:

- Segments with high closure locations
- Segments with higher safety concerns
- Segments with high grades
- Length of Segment

The filtered List was prioritized into High, Medium, and Low. Sections listed as High were identified as meeting all of the filtering factors mentioned above, sections listed as Medium met several but not all of the filtering factors mentioned above, and sections listed as Low only met one or two of the filtering factors mentioned above.

Table B-1. Filtered List of Passing Lane Segments Recommended for Further Study

	Eastbound/Increasing																					
	Milepost Data						Truck Speed Model Data			Safety Rating	Number of Road Closures	Total Durations - Days (annualized)	Priority					Profile Grade Data			Comments	
	Begin MP	End MP	Areas that overlap	MP Span		Length-Miles	MP down to 65 MPH	MP Back up to 65 mph	MP Back up to 75 mph	(1 - 4)			Priority Level	District Priority	Prior Study Priority	Pathweb/HDR Review	source	max grade	min grade	average grade	Notes	screening notes
	12.715	14.529	X	12.715	15.029	1.81	N/A	14.392	14.585	no score	9	4					Pathweb/HDR Review				Existing Climbing Lane, Add half mile to End of Climbing Lane	Crest (Grade 0.1%) @ MP 13.752, End of Taper @ MP 14.529;
CL-01	14.529	15.029				0.50				-	-	-	High	D3			District 3 Wishlist					Crest visually seems @ MP 14.369 (-3.9). Not sure if extra 1/2 mile is justified
	18.737	21.268	X	18.737	21.768	2.53	N/A	21.183	21.357	2	9	3					Pathweb/HDR Review				Existing Climbing Lane, Add half mile to End of Climbing Lane	Crest (Grade 0.0%) @ MP 20.858, End of Taper @ MP 21.268
CL-02	21.268	21.768				0.50				-	-	-	High	D3			District 3 Wishlist					Ends just past horizontal curve. Crest visually seems @ MP 21.018 (-3.7%)
	25.208	28.199	X	25.208	28.699	2.99	N/A	28.365	28.713	2	9	3					Pathweb/HDR Review				Existing Climbing Lane, Add half mile to End of Climbing Lane	Crest (Grade 0.0%) @ MP 27.858, End of Taper @ MP 28.199
CL-03	28.199	28.699				0.50				-	-	-	High	D3			District 3 Wishlist					Grades are pretty flat here. Not sure extra 1/2 mile is justified.
CL-04	140.676	142.15		140.676	142.15	1.474	141.061	142.812	143.159	4	7	4	High				Pathweb/HDR Review	4.20%	2.90%	3.55%	Consider running TSPM in this location	High grade, but low closures. High safety. Review limits.
	249.7	252.5								4	14	18		X			District 1 Wishlist	4.10%	-4.50%	-0.20%	EBL Passing Lane, Halick Ridge	
CL-05	250.84	252.78	X	249.7	252.78	3.08	250.949	252.306	252.537	4	14	18	High		X		Prior Study	4.10%	-4.50%	-0.20%	Halick Ridge	Steep grade. High closures, safety. Review limits.
	251.062	251.704								1	14	18				X	Pathweb/HDR Review	4.10%	2.30%	3.20%	Halick Ridge	
CL-06	266.13	269.2	X	266.052	269.2	3.15	266.053	268.600	269.028	4	14	18	High				Prior Study	4.70%	-2.20%	1.25%	Hill near MP 268.088 less than 2%, Do not carry CL past MP 267.114	High grades, high closures, high safety. Review the limits.
	266.052	267.049									14	18				X	Pathweb/HDR Review	4.70%	2.90%	3.80%	Steeper section. Wagonhound Rest Area	
	316.89	318.97								4	12	0 to 10					Prior Study	4.90%	0.40%	2.65%	OP @ MP 318. Extend to CL @ MP 319.097	
CL-07	317.71	317.825	X	316.89	318.97	2.08	N/A Start after Overpass	N/A Connect to Existing CL	N/A Connect to Existing CL	3	12	10	High				Pathweb/HDR Review	3.60%	3.00%	3.30%		Steep grades, High Safety Rating, Consider running TSPM in this location to identify range.
	318.301	318.771								4	12	10					Pathweb/HDR Review	4.90%	1.10%	3.00%		

* Near MP 140.676, Side Hill from MP 140.716 to MP 140.940, Side hill from MP 141.662 to MP 141.891, Overpass at MP 142.150, Truck Turnout from MP 142 to MP 142.690
* Small side hill from MP 249.681 to MP 249.912, sidehill from MP 250.936 to MP 251.077, drainage crossing at MP 251.142, Steep Sidehill from MP 251.534 to MP 251.900, Snow fence at MP 251.568, Snow fence at MP 251.664, Drainage at MP 251.945, Sidehill from MP 252.066 to MP 252.211, Snow Fecne from MP 252.211 to MP 252.256
* Fill required to widen from MP 266.512 to MP 266.849, Overpass at MP 267.169, Drainage crossing at MP 267.832, Side hill from MP 267.883 to MP 268.149, Side hill from 268.490 to 268.571, Sidehill from MP 269.098 to MP 269.178, Drainge at MP 269.20
* Guardrail (drainage maybe?) from MP 316.904 to MP 316.974, Guardrail, overhead information sign, and drainage crossing bewteen MP 317.179 to MP 317.215, Guardrail/drainage from MP 317.435 to MP 317.455, Underpass at MP 318.05, Cut likely from MP 318.15 to MP 318.201, **Culvert at MP 318.3**, Sidehill from MP 318.316 to MP 318.956

For half mile extentions
* **Bridge at MP 13.86**, Steep side hill from MP 14.880 to MP 15.165, Guardrail and steep fill from MP 15.205 to MP 15.486, Bridge at MP 15.647
* Side hill from MP 21.408 to MP 21.528, Overpass at MP 21.738, Sidehill from MP 21.919 to MP 22.044
* Overpass at MP 28.716

Legend		
color	Pathweb	http://pathweb.pathwayservices.com/wyoming/
	Verticle Curve Report	I80 Vertical and Horizontal Curvature Reports
color	Prior Study	Prior Study Climbing Lanes
color	District 1 Wishlist	I-80 Master Plan_D1 wish list
color	District 3 Wishlist	I-80 Master Plan_D3 wish list
color	Existing Climbing Lane	

Table B-1 (cont'd). Filtered List of Passing Lane Segments Recommended for Further Study

	Westbound/Decreasing																						
	Milepost Data						Truck Speed Model Data			Safety Rating			Priority					Profile Grade Data			Comments	
	Begin MP	End MP	Areas that overlap	MP Span		Length-Miles	MP loss to 65 MPH	MP Back up to 65 mph	MP Back up to 75 mph	(1 - 4)	Number of Road Closures	Total Durations - Days (annualized)	Priority Level	District Priority	Prior Study Priority	Pathweb/HDR Review	source	max grade	min grade	average grade	Location Notes	screening notes
CL-08	343	340	X	343	339.938	3.062	342.647	338.754	does not get back up to 75 in a reasonable range	4	15	11	High	X			District 1 Wishlist	4.30%	-1.70%	1.30%	3rd Lane for Climbing	High grades, high closures and safety. Review limits.
	342.725	342.184									15	11					Pathweb/HDR Review	4.30%	2.90%	3.60%	Harriman; OP @ MP 342.56	
	342.62	338.78									15	11			X		Prior Study	4.30%	-1.60%	1.35%	Harriman, OP @ MP 340.65	
	339.989	339.938									15	11					Pathweb/HDR Review	3.20%	2.90%	3.05%	Only above 3% for 0.051 miles. Focus on 1st hill	
CL-09	252.64	251.36	X	252.64	251.36	1.28	252.586	251.781	251.588	4	12	17	High		X		Prior Study	4.30%	-4.70%	-0.20%	Halick Ridge; OP @ MP 252.40; Large Fill @ 251.627	High grades; review limits.
	252.635	252.238									12	17				X	Pathweb/HDR Review	4.30%	2.40%	3.35%	Halick Ridge; OP @ MP 252.40	
	22.746	20.381	X	22.746	19.881	2.365	N/A	20.502	20.328	2	5	1					Pathweb/HDR Review				Existing Climbing Lane, Add half mile to End of Climbing Lane	Crest (Grade 0.1%) @ MP 20.863, End of Taper @ MP 20.381
CL-10	20.381	19.881				0.5							High	D3			District 3 Wishlist					Crest visually seems @ MP 13.629 (-2.6%). Ends just past horizontal curve.
	15.622	13.278	X	15.622	12.893	2.344	N/A	13.463	13.289	no score	5	1					Pathweb/HDR Review				Existing Climbing Lane, Add half mile to End of Climbing Lane	Crest (Grade 0.1%) @ MP 13.795, End of Taper @ MP 13.278
CL-11	13.278	12.778				0.5							High	D3			District 3 Wishlist					Crest visually seems @ MP 20.732 (-2.3%). Ends just past horizontal curve.

- * Likely rock cut from MP 343.015 to MP 342.960 and MP 342.925 to MP 342.735, Bridge at MP 342.569, Likely fill from MP 341 to MP 340.670, Bridge at MP 340.670, Side hill cut from MP 340.585 to MP 340.344
- * Fill from MP 252.670 to MP 252.570, Sidehill from MP 252.479 to MP 252.429, Bridge at MP 252.409, Steep Side hill from MP 252.253 to MP 252.093, Guardrail and likely fill from MP 252.068 to MP 251.988, Sidehill from MP 251.938 to MP 251.823, Steep fill from MP 251.808 to MP 251.312, Guardrail from MP 251.708 to MP 251.287

For half mile extentions

- * Guardrail and steep fill from MP 20.320 to MP 19.703
- * Guardrail and steep fill from MP 13.363 to MP 12.646, culvert crossing at MP 12.9063, Bridge at MP 12.660

Legend		
color	Pathweb	http://pathweb.pathwayservices.com/wyoming/
	Verticle Curve Report	I80 Vertical and Horizontal Curvature Reports
color	Prior Study	Prior Study Climbing Lanes
color	District 1 Wishlist	I-80 Master Plan_D1 wish list
color	District 3 Wishlist	I-80 Master Plan_D3 wish list
color	Existing Climbing Lane	

Appendix C.
Benefit-Cost Analysis (BCA)

BENEFIT COST METHODOLOGY

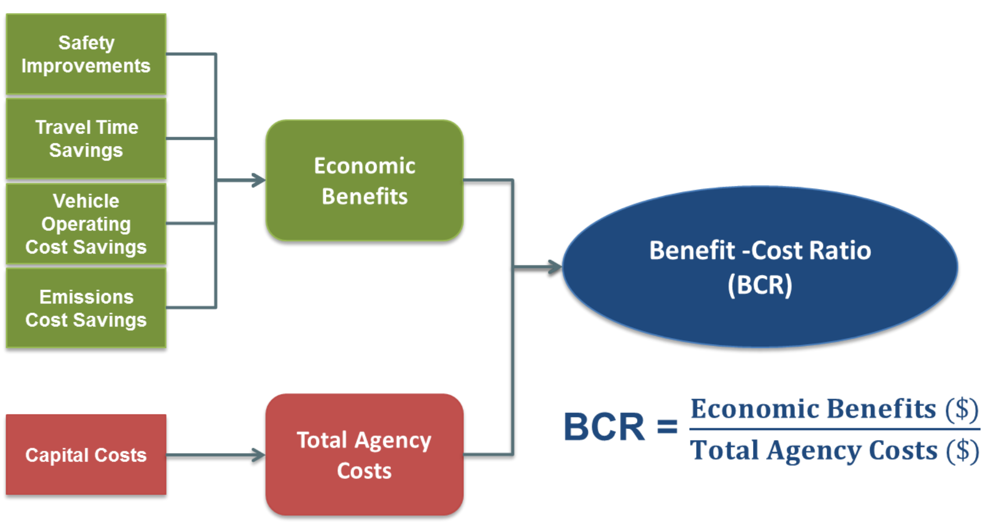
A benefit-cost analysis (BCA) was used to compare impacts and prioritize the proposed truck climbing lane locations. Section 3.1.1 of the *I-80 Corridor Study Master Plan Implementation Report* presents an overview of the BCA methodology, while Section 3.1.4 presents the BCA results and a prioritized project list. This appendix provides additional details on the BCA methodology and assumptions used in the BCA analysis. It also presents complete BCA results and the results of sensitivity testing.

BCA Overview

BCA is a systematic approach to compare the benefits and costs of different projects. It can help determine the soundness of alternative investment decisions and support agency decision-making in selecting the best projects to improve user benefits and reduce direct transportation costs. The BCA was used to assess the impacts of the 11 truck climbing lane projects for the Master Plan. During the analysis, the benefits of each project were summed and compared to the total agency cost.

The cost effectiveness of each project was estimated using a benefit-cost ratio (BCR). The BCR combines multiple measurements of effectiveness into a single measure that can be used to compare projects. Figure C-1 shows how the economic benefits and total agency costs were used to estimate the BCR for each project.

Figure C-1. Calculation of Benefit-Cost Ratio (BCR)



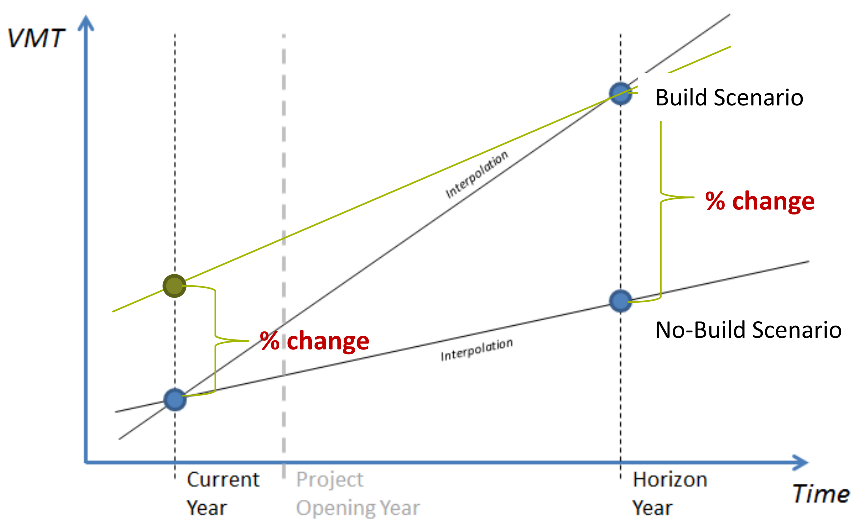
As shown in Figure C-1, four categories of benefits are used to estimate total economic benefits. These include:

- Safety improvements
- Travel time savings
- Vehicle operating cost savings
- Emissions cost savings

Economic benefits were calculated by comparing “Build” conditions for each project to a “No-Build” scenario. The No-Build scenario represents conditions when the proposed truck climbing lane is not present and the “Build” scenario reflects conditions when the project is completed. Conditions in a base year and horizon years are modeled and inputs for the lifecycle are interpolated for the duration of the analysis period.

The forecasts provide data for horizon years in 5-year increments (e.g., 2018, 2023, 2028, etc.). Figure C-2 shows how model outputs were derived for the duration of the analysis period. The chart shows interpolation between the base year and a horizon year for No-Build and Build Scenarios. Similar interpolation occurred for each 5-year increment. The economic benefits generated by each project were determined by directly comparing the outputs between the No-Build and Build scenarios.

Figure C-2. Estimation of Economic Benefits



Capital costs for each project were estimated separately taking into account project complexity, as described in Appendix D (Cost Estimate) of the *I-80 Corridor Study Master Plan Implementation Repo*rt. Figure C-2 summarizes the base construction costs by project. The BCA does not include additional operation and maintenance costs for the projects.

Table C-1. Base Construction Cost by Project

Project Name	Project Description	Base Construction Cost
CL-01	EB (MP 14.529-15.029)	$768,947
CL-02	EB (MP 21.268-21.768)	$1,147,063
CL-03	EB (MP 28.199-28.699)	$1,163,018
CL-04	EB (MP 140.676-142.15)	$2,575,021
CL-05	EB (MP 249.7-252.78)	$4,746,154
CL-06	EB (MP 266.052-269.2)	$5,698,003
CL-07	EB (MP 316.89-318.97)	$5,591,903
CL-08	WB (MP 343-339.938)	$8,004,154
CL-09	WB (MP 252.64-251.36)	$2,769,738
CL-10	WB (MP 20.381-19.881)	$896,297
CL-11	WB (MP 13.278-12.778)	$2,081,138

Queuing Model

In developing the benefit-cost approach, existing models and research studies on truck climbing and passing lanes were examined. It was found that existing models and studies focused on the impact of truck climbing lanes on two-lane, conventional highways. Because I-80 is a four-lane facility, this approach is inadequate. On a two-lane conventional highway, vehicles are delayed when encountering a single slow moving vehicle. However, on a four-lane freeway, vehicles are delayed only when they encounter a slow moving vehicle in the left lane passing an even slower vehicle in the right lane.

To account for the complexity of this situation, a basic queuing simulation model was developed to assess the speeds of automobiles interacting with trucks traveling uphill. For the simulations, vehicles were divided into three groups: automobiles, “fast” trucks, and “slow” trucks. The simulation model was run separately for each project because truck speed, uphill segment length, and average annual daily traffic (AADT) vary by project.

Several projects involved extensions of existing truck climbing lanes (projects CL-1, CL-2, CL-3, CL-10, and CL-11) and were located on downgrades; therefore, the methodology described in this section would not apply. Because of this, travel time savings and other benefit categories stemming from changes in speed and vehicle hours traveled (VHT) were not estimated for these five projects.

Because the other six truck climbing lane projects (CL-4 through CL-9) exhibited a variety of elevations, the queuing model simulation approach was applied. To determine the speed of the trucks to be used in the model, the truck speed profile model (TSPM)[1] developed in NCHRP Report 505 was used to estimate truck performance on the upgrades.

Figure C-3 shows a screenshot from the Inputs page of the workbook, with several of the assumptions (in the top right corner) used in the model runs. The desired speed is 65 miles per hour (mph) and the speed at which the trucks will start is also 65 mph. The weight/power ratio is an important input into the calculation. After careful consideration and consultations, a conservative estimate of 140 for this input was kept, because there is a trend of improving trucks' power while keeping the weight relatively constant. The default weight/frontal area ratio of 0.0 (to use the default values) was also kept, and the elevation level was set to 6,500 (which corresponds to a roughly average elevation of I-80 in Wyoming). All of the inputs described above apply to all six projects without changes.

Figure C-3. Truck Speed Performance Model

TRUCK SPEED PERFORMANCE MODEL

Desired speed (mph) = 65.0
Initial speed (mph) = 65.0
Weight/power ratio (lb/hp) = 140.0 <-- 100 for RVs, 200 for most trucks
Weight/frontal area ratio (lb/ft2) = 0.0 ← enter value or enter zero to use default estimate
Elevation (ft) = 6500.0
Location (legend) =

Calculate Speed Profile

Vertical Profile
(Beginning of first segment must equal 0)

Segment	Position (ft) Begin	Position (ft) End	Percent Grade
1)	0	6473	1
2)	6473	10697	2
3)	10697	11014	1
4)	11014	12202	2
5)	12202	16325	2
6)	16325	17334	3
7)	17334	17619	2
8)	17619	19446	1
9)	19446	19604	2
10)	19604	19868	3
11)	19868	19974	4
12)	19974	21452	5
13)	21452	21669	4
14)	21669	21954	3
15)	21954	22165	2
16)	22165	22429	1
17)	22429	23216	2

The bottom left corner of Figure C-3 show an example of project specific (for CL-07) elevation data. For each of the 17 segments, the start and end positions are indicated in feet. For each

[1] This model is described by National Cooperative Highway Research Program (NCHRP) Report 505 at https://www.nap.edu/read/23379/chapter/15.

segment, the percent grade is input as an integer value. The data on elevation has been collected manually from PathWeb.[2]

The inputs and outputs from TSPM for the six projects are shown in Figure C-4. The bars (ranging in color from dark blue for high positive grade to dark orange for negative grade) show the percent grade entered for each segment. Most of the data entered starts at the mileposts (MP) that are close enough to an actual start of the project. This is because while the elevation data was collected, the grade just before the start of the project was zero for most of the projects. An obvious outlier was project CL-7, where the uphill portion started at least 2 miles (12,000 feet) before the project's starting milepost.

Figure C-4 indicates the portion of the overall segment shown that corresponds to the actual proposed project by the color of the speed curve: the gray curve indicates the road sections that are outside of the truck climbing lane project limits, while the orange curve shows the sections within the project limits.

The speeds curves are estimates of what would be observed if trucks start at speed of 65 mph at the start of the segment shown and continue driving. As the grade increases, the speed decreases. As the grade declines, the truck speed goes back to the desired speed of 65 mph.

The output from these runs are the minimal truck speeds achieved by trucks in each segment before the speeds start to increase again and potentially back to the desired speed (i.e., 65 mph). These speeds are shown as labels next to the right axis in Figure C-4: 51.6 mph for CL-04, 50.5 mph for CL-05, 44.1 mph for CL-06, 45.8 mph for CL-07, 49.7 mph for CL-08, and 52.7 mph for CL-09.

These speeds were used in the simulation model as the speeds of the "slow" trucks. The speeds of the "fast" trucks were estimated by adding 2 mph to the "slow" truck speeds. Cars were assumed to be unaffected by the uphill sections of the road, no matter how steep and how long they were.

For some of the road segments located within the project limits, the truck speeds were very similar to the desired speed of 65 mph. As a result, only the longest continuous sections where the truck speeds fell below 60 mph were simulated. Figure C-5 shows how the simulated lengths of segments were estimated. The red line going across each panel is the 60 mph line. The orange and gray truck speed curve is the same curve as the one introduced in Figure C-4.

The light-brown boxes show the limits of the segments chosen as representative segments for each of the six projects. The labels show that the following lengths of the segments were used in the simulation: 1.1 miles for CL-04, 1.1 miles for CL-05, 1.3 miles for CL-06, 2.1 miles for CL-07, 1.2 miles for CL-08, and 0.6 miles for CL-09.

[2] PathWeb data for Wyoming can be accessed at http://pathweb.pathwayservices.com/wyoming/.

It should be noted, however, that not all projects allow the trucks to get back to the desired speed of 65 mph (e.g. CL-07 is estimated to bring the trucks to the speed of 50.6). In addition, the simulated segment for CL-08 was not extended even though a second short road segment was observed where truck speeds would drop below 60 mph.

Figure C-4. Truck Speed Estimation

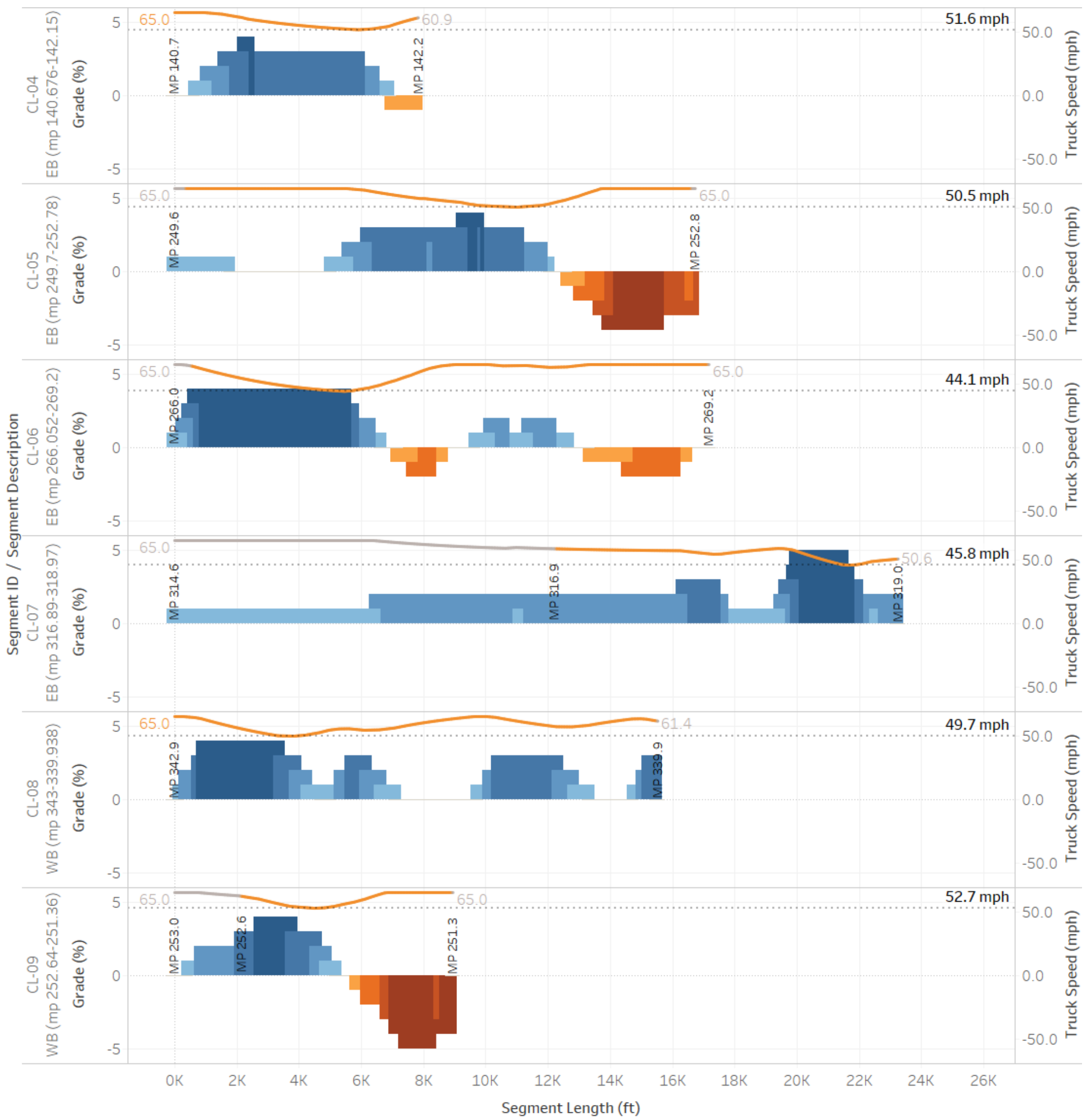
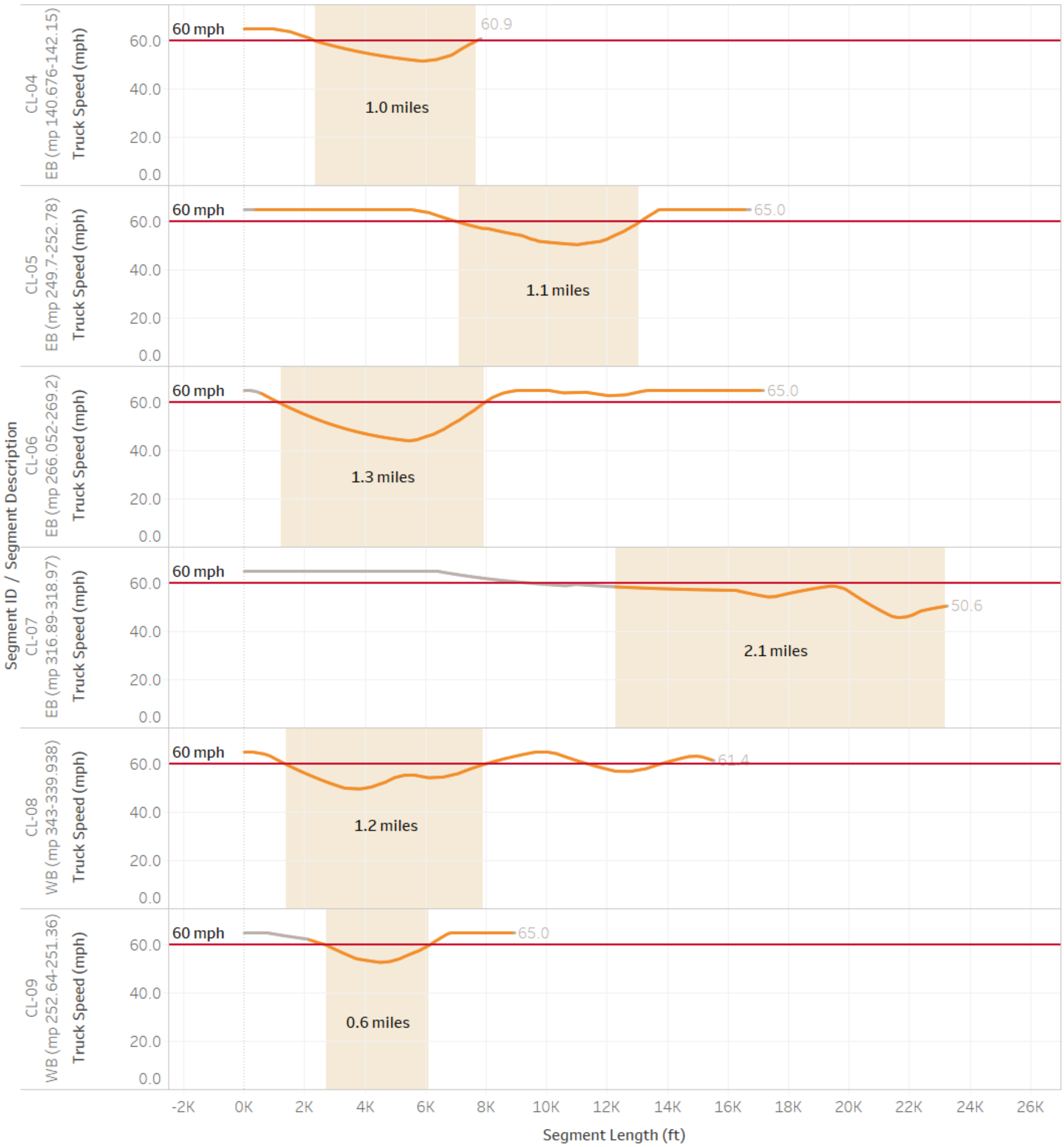


Figure C-5. Simulated Segment Length Estimation



As a result, the following speeds were used for each group of vehicles:

- For automobiles, a free-flow speed of 65 mph was assumed.[3]
- Truck speeds were estimated based on the elevation profile using the procedure described above. It was assumed that fast trucks travel 2 mph faster than the slow trucks. The primary results of the BCA (discussed in Section 3.1.4 of the *I-80 Corridor Study Master Plan Implementation Report*) reflect this assumption.

The sensitivity of BCA results to the speed differential was also tested. The test indicated that modifying this assumption would not change the results substantially. Table C-8 and Table C-9 (page C-17) present the results of sensitivity testing using 1 mph and 3 mph speed differentials.

Based on the AADT for the modeled year (2018, 2028, and 2048) for each of the three vehicle types,[4] the model calculated the number of vehicles of each type that would need to cross the simulated area within the simulation period (10 minutes). After the numbers were determined, two randomized lists of vehicles were created.[5] Each list corresponds to 10 minutes of driving conditions. Both lists were created using the same assumptions; however, only the vehicles in the second list were used to estimate the VHT. The simulation starts with vehicles from the first list. The last vehicle in this list had to enter the simulation segment before the first 10 minutes passed. This is the "warm-up period" for the simulation.

Starting at Minute 10, the vehicles from the second list start entering the simulation segment. Because the three vehicle types have varying speeds, the cars from the second group traveling at 65 mph may be able to reach the "slow" and "fast" trucks that entered the simulation segment in the first group and thus interact outside of the preset groups. The model records the number of seconds it took each of the cars in the second group to reach the finish line at the end of the segment and then converts this to hours. The model ignores the possible interaction between the "slow" and "fast" trucks.

Figure C-6 depicts the various interactions from the simulation model—a slow-moving truck (green arrow) is being passed by a fast-moving truck (blue arrow), while a car is approaching the fast truck (Panel A). The car then gets stuck behind the fast truck and has to drive with the fast truck's speed, waiting for the passing to complete (Panel B). Finally, when the fast truck is able to pass the slow truck, the car can proceed at its preferred speed (Panel C).

[3] The available traffic data for various milepost segments along the I-80 in Wyoming confirmed that 65 mph is a realistic assumption.

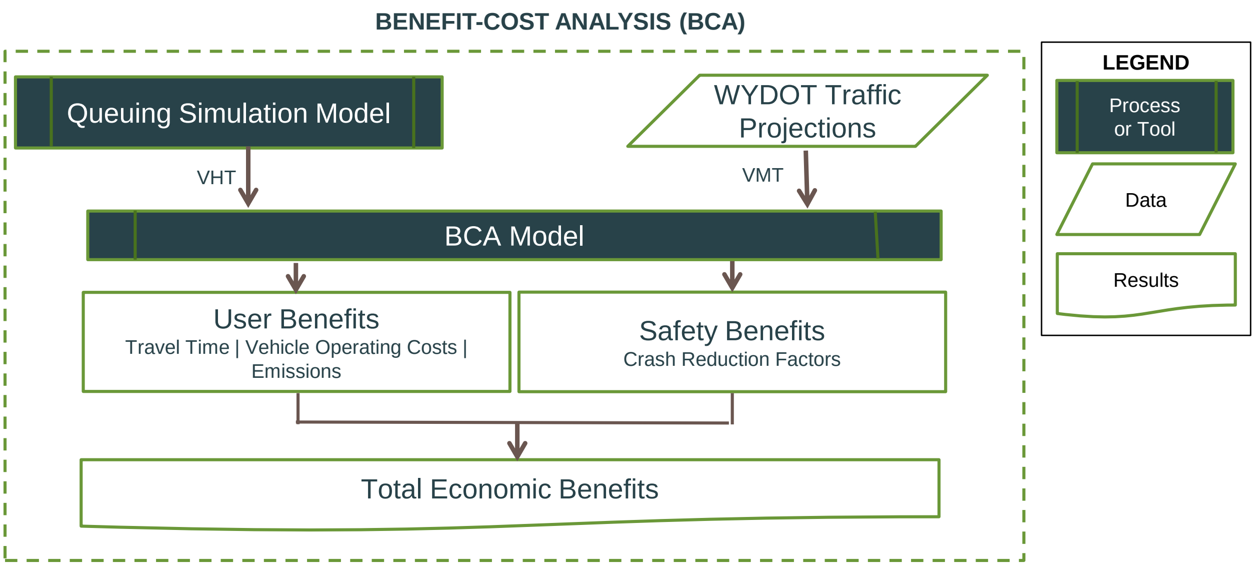
[4] The model assumed that the "slow" trucks represent 50 percent of total truck population, while the other 50 percent is "fast" trucks.

Figure C-6. Estimation of Economic Benefits

Calculation of Economic Benefits

The queuing simulation model provides a single output—VHT for cars in the No Build scenario. The Build VHT and vehicle-miles traveled (VMT) for No Build and Build scenarios are derived from the free-flow speed assumptions (65 mph for cars) and segment lengths. These outputs were used to derive the economic benefits in the BCA. Figure C-7 shows the process by which outputs of the queuing simulation model are converted into economic benefits.

Figure C-7. Process for Estimating Economic Benefits



The remaining sections show the methodology and assumptions used to estimate economic benefits using outputs from the queuing simulation model described above. Economic benefits start accruing after construction is complete and are estimated for 20 years (2021-2040), discounted at 4 percent annually.

Safety Improvements

Safety improvements result from crash reductions in the study area. Truck climbing lanes allow for safer passing of slower-moving trucks along I-80. Crash reductions are estimated by applying a crash reduction factor to existing crash rates by severity along segments of the project area. The safety methodology is outlined in detail in Appendix E of the *I-80 Corridor Study Master Plan Implementation Report*.

After the number of crashes is determined, the number of injuries per crash is estimated using the factors presented in Table C-2 and Table C-3. The tables show the number of events per crash in the westbound and eastbound directions on I-80 and derived as part of the safety analysis outlined in Appendix E of the *I-80 Corridor Study Master Plan Implementation Report*.

Table C-2. Westbound Events per Crash by Severity

Crash Severity	Number of Events Per Crash				
	Fatal Injury	Suspected Serious Injury	Suspected Minor Injury	Possible Injury	No Apparent Injury
Fatal Injury	1.189	0.649	0.541	0.378	1.351
Suspected Serious Injury		1.140	0.349	0.233	0.946
Suspected Minor Injury			1.239	0.109	0.915
Possible Injury				1.266	1.160
Property Damage Only					1.789

Table C-3. Eastbound Events per Crash by Severity

Crash Severity	Number of Events Per Crash				
	Fatal Injury	Suspected Serious Injury	Suspected Minor Injury	Possible Injury	No Apparent Injury
Fatal Injury	1.098	0.268	0.366	0.293	0.415
Suspected Serious Injury		1.228	0.430	0.132	0.649
Suspected Minor Injury			1.305	0.131	0.856
Possible Injury				1.287	0.983
Property Damage Only					1.764

The BCA calculates the number of crash events prevented by severity in the Build scenarios compared to the No-Build. The number of crashes prevented is monetized using values provided by the Wyoming Department of Transportation (WYDOT) from the *Estimating Crash*

Costs White Paper from the Federal Highway Administration, which are summarized in Table C-4.[6]

Figure C-8 presents the methodology and assumptions used to monetize the safety improvements of each project. The costs per accident are assumed to remain constant throughout the analysis period.

Future traffic volumes (AADT) are forecasted for horizon years in 5-year increments beginning in 2018. This data was used to estimate the number of crashes in future years. The BCA accounts for the total number of crashes throughout the entire analysis period. Safety improvements make up the vast majority of economic benefits.

Table C-4. Economic Values of Crashes by Severity

Crash Severity	Cost Per Accident (2016 $)
Fatal Injury	$2,237,000
Suspected Serious Injury	$2,237,000
Suspected Minor Injury	$98,000
Possible Injury	$98,000
Property Damage Only	$39,000

Figure C-8. Safety Improvements Methodology

Number of Crash Events Prevented from Project (events)

×

Crash Severity	Cost Per Event (2016 $)
Fatal Injury	$2,237,000
Suspected Serious Injury	$2,237,000
Suspected Minor Injury	$98,000
Possible Injury	$98,000
Property Damage Only	$39,000

Estimating Crash Costs White Paper, 2017

=

Total Safety Improvement Benefits ($)

Travel Time Savings

Travel time savings are the benefits of automobiles being able to travel faster as a result of project improvements. Additional truck climbing lanes allow automobiles to pass slower-moving trucks, preserving relatively higher speeds and thus reducing travel times. The travel time of automobiles using four-lane facilities depends on whether there are slower vehicles ahead, preventing the automobiles from moving at their desired speed. The queuing simulation model assumed automobiles can pass slower-moving trucks in the Build scenario within the project area where truck climbing lanes are provided.

The benefits from travel time savings were based on differences between automobile VHT in No-Build and Build scenarios.[7] VHT was converted to person-hours by applying assumptions on

[6] Estimating Crash Costs White Paper, Federal Highway Administration, June 14, 2017

[7] Even though the model formally estimates VHT in No-Build and Build scenarios for trucks, the assumption has been made that these VHTs will be the same in the two scenarios.

average vehicle occupancy (1.39 for car, 1.00 for trucks). Reduced travel times were then monetized using values of time consistent with U.S. Department of Transportation (USDOT) guidance. These values were determined by the national median wage rates and average truck driver wages as summarized in Table C-5. The methodology and assumptions used to calculate travel time savings are summarized in Figure C-9.

Table C-5. Value of Time—Cars and Trucks

Vehicle	Value of Time ($/hour)
Cars	$14.10
Trucks	$27.20

Figure C-9. *Travel Time Savings Methodology*

No Build vs. Build Scenario Difference in VHT (Hours)

×

Vehicle	Average Vehicle Occupancy (Persons per Vehicle)
Cars	1.39
Trucks	1.00

Source: INFRA Guidance Appendix A Table 7: Average Vehicle Occupancy

=

Total Person Hours Saved (Hours)

Total Person Hours Saved (Hours)

×

Vehicle	Value of Time ($ / hour)
Cars	$14.10
Trucks	$27.20

USDOT INFRA Guidance

=

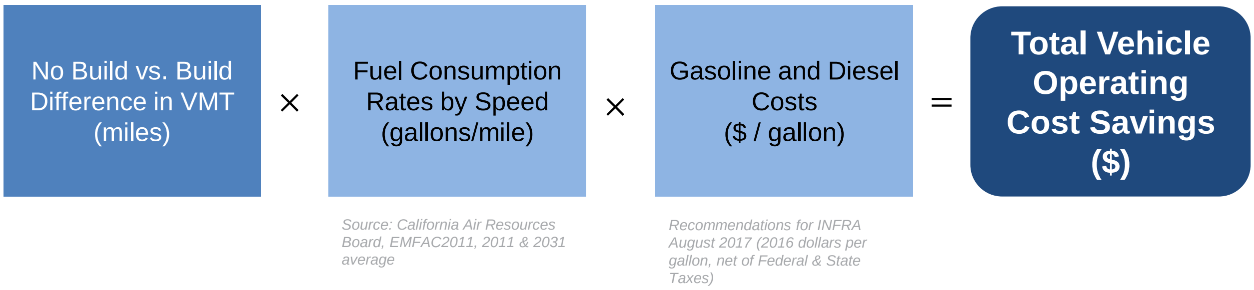
Total Travel Time Savings ($)

Vehicle Operating Cost Savings

Vehicle operating cost savings are the benefits to roadway users from savings in fuel consumption resulting from project improvements. Truck climbing lanes allow for higher speeds in the project area, which can lead to vehicles traveling at more (or less) fuel efficient speeds. Fuel consumption was estimated based on vehicle type, fuel consumption rate, average speed, and VMT. The effects to fuel consumption were monetized using fuel costs per gallon for automobiles and trucks. The methodology used to calculate vehicle operating costs is summarized in Figure C-10.

Other vehicle operating costs were not considered in the BCA because non-fuel costs are based on the miles traveled, which were assumed to be the same in the No-Build and Build scenarios.

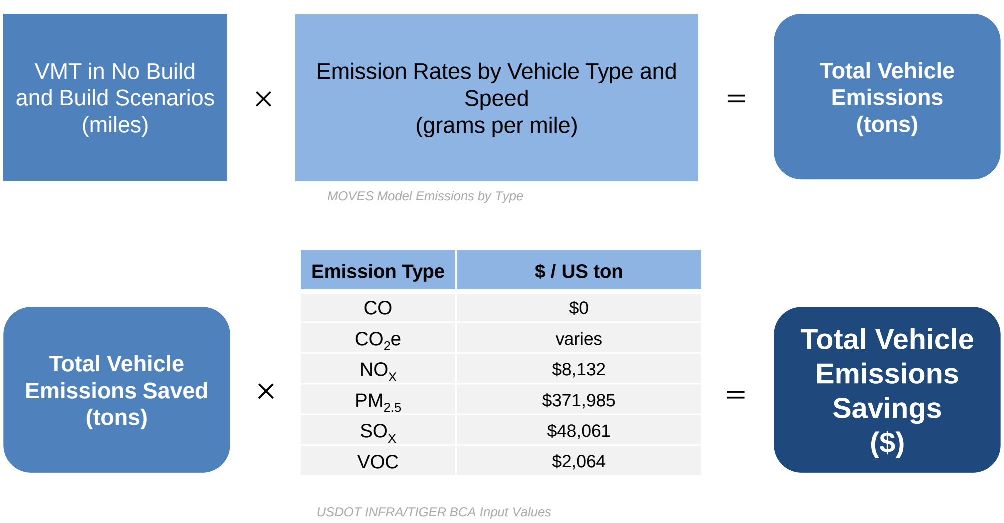
Figure C-10. Vehicle Operating Cost Savings Methodology



Emissions Cost Savings

Emissions cost savings are the benefits of reduced vehicle emissions in the project area. Truck climbing lanes allow for increased speeds in the project area, which can lead to vehicles generating fewer (or greater) emissions. The emissions from automobiles were determined based on vehicle speeds from the queuing simulation model. Emissions rates were estimated using the Environmental Protection Agency (EPA) Motor Vehicle Emissions Simulator (MOVES) model based on characteristics of the study area. The emissions factors for Uinta County were used as representative for emissions along the corridor. Vehicle emissions were monetized throughout the analysis period using values per metric ton as specified by USDOT. Figure C-11 depicts the emissions cost savings methodology.

Figure C-11. Emissions Cost Savings Methodology



Emission Type	$ / US ton
CO	$0
CO_2e	varies
NO_X	$8,132
$PM_{2.5}$	$371,985
SO_X	$48,061
VOC	$2,064

Note: CO_2e is the value of greenhouse gases (CO_2 or other forms) in CO_2 equivalents.

The value of CO_2 emissions varies depending on the year of the analysis. The values used in the model are taken from the USDOT BCA Resource Guide.[8]

1.1.1 Summary of Economic Benefits

A summary of the total economic benefits generated by each project is presented in Table C-6. The projects are ranked by their BCR rank (see prioritized project list in Section 3.1.4 of the *I-80 Corridor Study Master Plan Implementation Report*). As the Table C-6 shows, safety improvements made up the majority of economic benefits in each project area.

Table C-6. Summary of Economic Benefits

BCR Rank	Project	Total Benefits	Safety	Travel Time	Fuel	Emissions
1	CL-01 EB (MP 14.529-15.029)	$3,391,000	$3,391,000	$0	$0	$0
2	CL-10 WB (MP 20.381-19.881)	$2,889,000	$2,889,000	$0	$0	$0
3	CL-02 EB (MP 21.268-21.768)	$2,273,000	$2,273,000	$0	$0	$0
4	CL-11 WB (MP 13.278-12.778)	$3,295,000	$3,295,000	$0	$0	$0
5	CL-07 EB (MP 316.89-318.97)	$8,377,000	$8,304,000	$171,000	-$96,000	-$3,000
6	CL-05 EB (MP 249.7-252.78)	$6,205,000	$6,198,000	$17,000	-$9,000	$0
7	CL-06 EB (MP 266.052-269.2)	$7,230,000	$7,196,000	$80,000	-$45,000	-$1,000
8	CL-08 WB (MP 343-339.938)	$9,709,000	$9,686,000	$55,000	-$31,000	-$1,000
9	CL-04 EB (MP 140.676-142.15)	$2,633,000	$2,625,000	$20,000	-$12,000	$0
10	CL-09 WB (MP 252.64-251.36)	$1,883,000	$1,868,000	$33,000	-$17,000	$0
11	CL-03 EB (MP 28.199-28.699)	$394,000	$394,000	$0	$0	$0

Rounded to nearest thousand dollars

Summary and Prioritized Project List

The BCA compares the cost effectiveness of 11 different truck climbing lane projects in the Master Plan. The cost effectiveness of each project is assessed and ranked using the BCR. A higher BCR indicates a more cost-effective project in terms of user benefits. Table C-7 shows the prioritized project list ranked by BCR. The total benefits, total costs, and net present value of each project are also presented.

[8] USDOT, Tiger BCA Resource Guide, https://www.transportation.gov/policC-initiatives/tiger/tiger-benefit-cost-analysis-bca-resource-guide

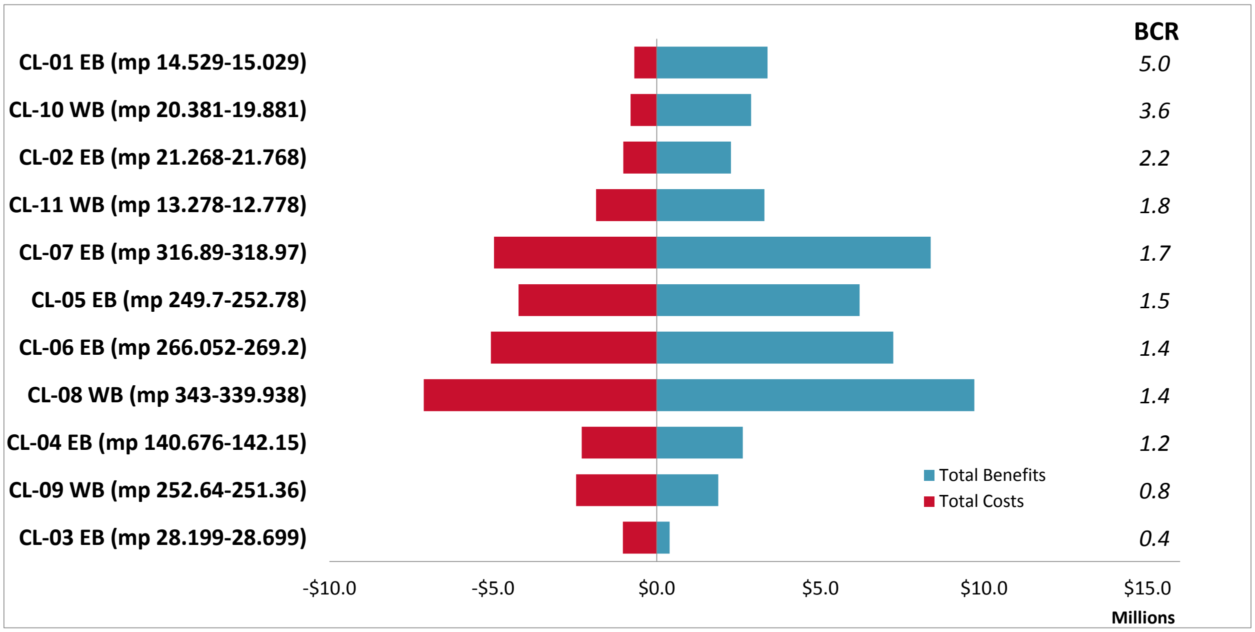
Table C-7. WYDOT I-80 Master Plan Prioritized Project List

BCR Rank	Project	Total Benefits ($ millions)	Total Costs ($ millions)	Net Present Value ($ millions)	BCR
1	CL-01 EB (MP 14.529-15.029)	$3.4	$0.7	$2.7	5.0
2	CL-10 WB (MP 20.381-19.881)	$2.9	$0.8	$2.1	3.6
3	CL-02 EB (MP 21.268-21.768)	$2.3	$1.0	$1.3	2.2
4	CL-11 WB (MP 13.278-12.778)	$3.3	$1.9	$1.4	1.8
5	CL-07 EB (MP 316.89-318.97)	$8.4	$5.0	$3.4	1.7
6	CL-05 EB (MP 249.7-252.78)	$6.2	$4.2	$2.0	1.5
7	CL-06 EB (MP 266.052-269.2)	$7.2	$5.1	$2.2	1.4
8	CL-08 WB (MP 343-339.938)	$9.7	$7.1	$2.6	1.4
9	CL-04 EB (MP 140.676-142.15)	$2.6	$2.3	$0.3	1.2
10	CL-09 WB (MP 252.64-251.36)	$1.9	$2.5	-$0.6	0.8
11	CL-03 EB (MP 28.199-28.699)	$0.4	$1.0	-$0.6	0.4

Figure C-12 shows the total benefits and costs of each project ranked by BCR, which is displayed on the right side of the chart. The total economic benefits generated by each project are represented by the blue bars, and total costs are represented by the red bars.

Based on information presented in Table C-7 and Figure C-12, the most cost-effective project is CL-01 EB (MP 14.592-15.029) with a BCR of 5.0. This is the project with the lowest total cost ($0.7 million). However, if costs are ignored, project CL-08 WB (MP 343-339.938) generates the highest overall economic benefit ($9.7 million). Project CL-07 EB (MP 316.89-318.97) has the highest net present value ($3.4 million), which is the value of the benefits net of project costs.

Figure C-12. WYDOT I-80 Master Plan BCA Results



Sensitivity Testing

Sensitivity testing was conducted as part of the simulation analysis. However, as the benefits were driven primarily by the safety results, the overall ranking of the projects did not change.

The sensitivity scenarios tested how the speed differentials would affect the car VHT. For Scenario 1, fast trucks travel 1 mph faster than the slow trucks. For Scenario 2, fast trucks travel 3 mph faster than the slow trucks. The testing showed there are three effects through which the truck speeds and their differentials play role in the simulations:

1. Overall Truck Speeds (slow trucks and fast trucks)—slower truck speeds make cars drive slower when they get behind the trucks.
2. Truck Speed Differential—Effect 1: a smaller speed differential makes cars wait longer to pass when trapped behind two trucks (i.e., one truck is passing another).
3. Truck Speed Differential—Effect 2: smaller speed differential will make it less likely for a fast truck to catch up with a slow truck to start passing. Thus, even though cars trapped behind trucks with smaller speed differentials will suffer lower speeds longer, the likelihood of getting trapped is lower, as the trucks need to catch up with one another to start passing, which may become very unlikely in short test segments.

The results of the scenario testing are presented in Table C-8 and Table C-9. As shown in the tables, changing the speed differential assumption did not change the rank order of truck climbing lane projects.

Table C-8. Scenario 1 Economic Benefits (1 mph differential)

BCR Rank	Project	Total Benefits	Safety	Travel Time	Fuel	Emissions
1	CL-01 EB (MP 14.529-15.029)	$3,391,000	$3,391,000	$0	$0	$0
2	CL-10 WB (MP 20.381-19.881)	$2,889,000	$2,889,000	$0	$0	$0
3	CL-02 EB (MP 21.268-21.768)	$2,273,000	$2,273,000	$0	$0	$0
4	CL-11 WB (MP 13.278-12.778)	$3,295,000	$3,295,000	$0	$0	$0
5	CL-07 EB (MP 316.89-318.97)	$8,361,000	$8,304,000	$136,000	-$78,000	-$2,000
6	CL-05 EB (MP 249.7-252.78)	$6,204,000	$6,198,000	$14,000	-$8,000	$0
7	CL-06 EB (MP 266.052-269.2)	$7,212,000	$7,196,000	$38,000	-$22,000	-$1,000
8	CL-08 WB (MP 343-339.938)	$9,703,000	$9,686,000	$41,000	-$24,000	-$1,000
9	CL-04 EB (MP 140.676-142.15)	$2,632,000	$2,625,000	$17,000	-$10,000	$0
10	CL-09 WB (MP 252.64-251.36)	$1,883,000	$1,868,000	$33,000	-$17,000	$0
11	CL-03 EB (MP 28.199-28.699)	$394,000	$394,000	$0	$0	$0

Rounded to nearest thousand dollars.

Table C-9. Scenario 2 Economic Benefits (3 mph differential)

BCR Rank	Project	Total Benefits	Safety	Travel Time	Fuel	Emissions
1	CL-01 EB (MP 14.529-15.029)	$3,391,000	$3,391,000	$0	$0	$0
2	CL-10 WB (MP 20.381-19.881)	$2,889,000	$2,889,000	$0	$0	$0
3	CL-02 EB (MP 21.268-21.768)	$2,273,000	$2,273,000	$0	$0	$0
4	CL-11 WB (MP 13.278-12.778)	$3,295,000	$3,295,000	$0	$0	$0
5	CL-07 EB (MP 316.89-318.97)	$8,377,000	$8,304,000	$173,000	-$98,000	-$3,000
6	CL-05 EB (MP 249.7-252.78)	$6,205,000	$6,198,000	$18,000	-$10,000	$0
7	CL-06 EB (MP 266.052-269.2)	$7,225,000	$7,196,000	$70,000	-$40,000	-$1,000
8	CL-08 WB (MP 343-339.938)	$9,710,000	$9,686,000	$57,000	-$33,000	-$1,000
9	CL-04 EB (MP 140.676-142.15)	$2,634,000	$2,625,000	$22,000	-$13,000	$0
10	CL-09 WB (MP 252.64-251.36)	$1,884,000	$1,868,000	$33,000	-$17,000	$0
11	CL-03 EB (MP 28.199-28.699)	$394,000	$394,000	$0	$0	$0

Rounded to nearest thousand dollars.

Appendix D.
Cost Estimate

UPDATED COST INFORMATION

Assumptions for Passing Lane Quantities

- Passing lanes with full width roadway section reconstruction specified by WYDOT
  - Concrete
    - Eastbound MP 14.529—15.029
    - Eastbound MP 21.268—21.768
    - Westbound MP 20.381—19.881
    - Westbound MP 13.278—12.778
  - Asphalt
    - Eastbound MP 266.052—269.200
- Passing lanes with a sawcut and widened construction roadway section
  - Asphalt
    - Eastbound MP 28.199—28.699
    - Eastbound MP 140.676—142.150
    - Eastbound MP 249.700—252.780
    - Eastbound MP 316.890—318.970
    - Westbound MP 343.000—339.938
    - Westbound MP 252.640—251.360
- Rock Excavation quantity assumes 20 percent of Unclassified Excavation calculation, and is included in sections based on visual verification of expected rock excavation areas (i.e. evidence of vertical face walls, blasting, etc.)
- Unclassified excavation quantity estimated from relative elevations provided in Google Earth. If elevation data produced minimal difference, an average of 40,000 cubic yards (CY) per mile was used (see Steering Committee Notes dated 8/31/17)
- Pavement depths used for removal quantities are based on existing pavement thickness data provided by WYDOT.
- Both widened and reconstructed surfacing section thicknesses provided by WYDOT Materials Program and include the following:
  - Asphalt—12” hot mix asphalt (HMA); 12” crushed base material

 > Concrete—12” Concrete; 6” crushed base material

- Other quantities (tack coat, hydrated lime, asphalt binder) were estimated from materials and rates summary provided by WYDOT.
- If in an asphalt sawcut and widened pavement section, a 2-inch mill and overlay quantity was included for the existing pavement.
- Plant mix wearing course quantities include both the traveled way widths and shoulders (6-ft left, 8-ft right)
- Climbing lane taper widths in accordance with WYDOT Pavement Marking Manual (2012):
  > Entrance—300 feet taper, Exit—1,280 feet taper

  > $WS^2/60$, where W=12 feet, S = 80 MPH

Assumptions for Third Lane Quantities

- Assumes the full length of I-80 (400 miles each direction)
- Approximately 100 miles in each direction of concrete and approximately 300 miles in each direction of asphalt.
- Quantity estimates include 80 percent sawcut and widening, with 20 percent full section reconstruction per direction from the WYDOT Materials Program.
  > Concrete option includes removal of existing asphalt cross section and replacement with three lanes of full depth concrete in each direction (refer to cross section)

  > Asphalt option assumes that 80 percent of the existing concrete section will remain and be overlaid. Assumes that 80 percent of existing asphalt remains and is widened per the cross section. Assumes that 20 percent of overall length is full depth removal and replacement with three lanes of full depth asphalt in each direction.
- Unclassified excavation quantity of 40,000 CY per mile (WYDOT provided)
- Materials, rates, and thickness recommendations provided by WYDOT
- Width based on 3-12' wide lanes with 6:1 cross-sectional end tapers for asphalt
- Structures
  > All bridges over I-80 within the widened limits are proposed for replacement.

  > All concrete continuous slab bridges on I-80 are proposed for replacement.

  > All bridges on I-80 with an inventory rating less than 1.0 are proposed for replacement.

  > Proposed bridge width used for replacements or widening is 59’-4” out-out, based on a 10’ inside shoulder, (3) 12’ through lanes, a 10’ outside shoulder and (2) 1’-8” wide curbs.

- Replacement bridge lengths for bridges on I-80 are increased by 50 percent over existing length to account for current geometric design requirements.
- Replacement bridge lengths for bridges over I-80 are increased by 30' over existing length (Two new 12' lanes for I-80 widening, rounded up to 30').
- Replacement bridge widths for bridges over I-80 match existing widths.
- Bridge work for the proposed climbing lane additions includes 3 bridge replacements, 3 bridge widenings and 3 culvert extensions. These are combined quantities for both EBL and WBL directions.
- Bridge work for the proposed “Third Lane” alternative (state border to state border) includes 235 bridge replacements, 95 bridge widenings and 31 culvert extensions or replacements. These are combined quantities for both EBL and WBL directions.
- Bridge work for the proposed “Third Lane” alternative (Laramie to Cheyenne segment) includes 38 bridge replacements, 22 bridge widenings and 4 culvert extensions or replacements. These are combined quantities for both EBL and WBL directions, from MP 310 to 365.1.

Capital and O&M Costs

Expenditure	Asphalt (in millions 2017$)	Concrete (in millions 2017$)
Total Capital	$2,264.0	$3,288.3
Annual O&M	$1.9	$0.2

Asphalt and Concrete Rehabilitation Costs over Time

Year	Asphalt (in millions 2017$)	Assumed Rehabilitation	Concrete (in millions 2017$)	Assumed Rehabilitation
0	$264.6	Major rehab on existing asphalt to match the condition of the new asphalt pavement.		
10	$308.6	Remove/Replace 2" HPM and WC		
15	$3.1	Crack Seal		
20	$519.0	Remove/Replace 4" HPM and WC	$164.9	Reseal Joints, 5% Slab Replacement
25	$3.1	Crack Seal		

HPM= Hot Plant Mix; WC =Wearing Course

Total Costs

	Asphalt	Concrete
One Segment (1/10th of program)		
Capital Costs	$226.4	$328.8
Rehabilitation Costs (see table below)	*Varies*	*Varies*
Annual O&M Costs	$0.19	$0.02
Total Costs	$342.0	$345.9
Discounted Total	$301.0	$336.7
Discounted Grand Total—10 Segments	$2,539.0	$2,840.3

Life Cycle Cost Analysis

All Values in $millions

Factors

Years of Construction	1	Years to build one segment
Construction Segments	10	Number of segments that are built over separate successive 1 year periods
Scenario	2	Low = 1; Middle = 2; High = 3
Start year	2017	
Design Life / Planning Years	30	
Discount Rate	4%	

Calculation Indices and Factors

	Years		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Construction Period	1		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operational Period	30		0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Annual Discount Factor			1	0.96	0.92	0.89	0.85	0.82	0.79	0.76	0.73	0.70	0.68	0.65	0.62	0.60	0.58
Discount Factor for Build Out	8.44		1	0.96	0.92	0.89	0.85	0.82	0.79	0.76	0.73	0.70					

	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047
Construction Period	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operational Period	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Annual Discount Factor	0.56	0.53	0.51	0.49	0.47	0.46	0.44	0.42	0.41	0.39	0.38	0.36	0.35	0.33	0.32	0.31
Discount Factor for Build Out																

Asphalt Cost Per Segment

	Total	Cost / Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Capital	$226.40	$226.40	$226.40	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Rehabilitation		Varies	$26.46										$30.86				
Annual O&M		$0.19	$0.00	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19
Total Annual	$341.99		$252.86	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$31.05	$0.19	$0.19	$0.19	$0.19
Discounted Total	$301.00		$252.86	$0.18	$0.18	$0.17	$0.16	$0.16	$0.15	$0.15	$0.14	$0.13	$20.98	$0.12	$0.12	$0.12	$0.11

	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047
Capital	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Rehabilitation	$0.31					$51.90					$0.31					
Annual O&M	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19	$0.19
Total Annual	$0.50	$0.19	$0.19	$0.19	$0.19	$52.09	$0.19	$0.19	$0.19	$0.19	$0.50	$0.19	$0.19	$0.19	$0.19	$0.19
Discounted Total	$0.28	$0.10	$0.10	$0.09	$0.09	$23.77	$0.08	$0.08	$0.08	$0.07	$0.19	$0.07	$0.07	$0.06	$0.06	$0.06

Concrete Cost per Segment

	Total	Cost / Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Capital	$328.83	$328.83	$328.83	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Rehabilitation		Varies	$0.00										$0.00				
Annual O&M		$0.02	$0.00	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02
Total Annual	$345.94		$328.83	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02
Discounted Total	$336.72		$328.83	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01

	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047
Capital	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Rehabilitation	$0.00					$16.49					$0.00					
Annual O&M	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02
Total Annual	$0.02	$0.02	$0.02	$0.02	$0.02	$16.51	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02
Discounted Total	$0.01	$0.01	$0.01	$0.01	$0.01	$7.53	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01

Build Out Construction Cost

Asphalt - Discounted Grand Total	$2,539.01
Concrete- Discounted Grand Total	$2,840.31

Comparison

Discounted Total Difference	$301.30	**Present Value cost savings from choosing asphalt**

Appendix E.
Safety Methodology

SAFETY METHODOLOGY FOR I-80 MASTER PLAN

As part of the I-80 Master Plan project for the Wyoming Department of Transportation (WYDOT) to perform a full truck climbing lanes analysis on I-80 segments with steep upgrades, HDR evaluated the anticipated changes in crash frequency and severity that can be attributed to truck climbing lanes. The estimated changes in crash frequency and severity will be converted to monetary costs and integrated into the project cost and benefit analysis of locations where truck climbing lanes are being considered. The following summarizes our methods for estimating the changes in crash frequency attributable to the truck climbing lanes using crash rates and observed crash patterns. Because of a lack of research for this countermeasure, an approach had to be developed that made use of available research and data sources to estimate future benefits.

Methodology

To estimate the change in crash frequency and/or severity associated with the proposed truck climbing lanes it was necessary to:

- Identify the study segments and a few basic characteristics of the segments including grade, Average Daily Traffic Volume (ADT), and length.
- Calculate existing crash conditions on each segment including crash rate and crash patterns for all vehicles and commercial vehicles.
- Estimate future crash frequencies assuming the truck lanes are not constructed
- Estimated the potential changes in crash frequency associated with the truck climbing lanes.

The following describes the details and assumptions of each step.

Segmentation

The segments are steep upgrade locations throughout the corridor that are candidates for truck climbing lanes. The grades on the study segments were estimated using Pathwebs Wyoming (http://pathweb.pathwayservices.com/wyoming/). Moreover, the existing climbing lanes were analyzed as well. Table E-1 describes the characteristic of each segment.

Table E-1. Location of Study Segments

Segment	Location		Screening Notes
Westbound Segments			
W1	Start MP	343.00	High grades, high closures
	End MP	339.94	
W2	Start MP	252.64	High grades
	End MP	251.36	
W3	Start MP	20.38	Ends just past horizontal curve
	End MP	19.88	
W4	Start MP	13.28	Ends just past horizontal curve
	End MP	12.78	
Eastbound Segments			
E1	Start MP	14.53	Crest visually seems at MP 14.369 (-3.9)
	End MP	15.03	
E2	Start MP	21.27	Ends just past horizontal curve
	End MP	21.77	
E3	Start MP	28.20	Grades are slightly flat
	End MP	28.70	
E4	Start MP	140.68	High grades, but low closures
	End MP	142.15	
E5	Start MP	249.70	High grades, high closures
	End MP	252.80	
E6	Start MP	266.052	High grades, high closures
	End MP	269.20	
E7	Start MP	316.89	Steep grades
	End MP	318.97	

Existing Crash Conditions

Year 2012 to 2016 crash data was acquired for each segment from WYDOT. For each segment, existing crash patterns (e.g., number, type, severity, lighting conditions, segment or junction, vehicle type) were tabulated. Key summaries are shown in Table E-2.

Table E-2. Crash Pattern Analysis for All Vehicles

Crash Description		Number of Crashes by Study Segment										
		W1	W2	W3	W4	E1	E2	E3	E4	E5	E6	E7
All Crashes												
Year	2012	16	3	1	1	3	1	0	0	8	6	5
	2013	13	2	1	1	2	3	1	5	11	6	6
	2014	17	4	4	3	2	2	0	4	10	4	11
	2015	9	1	0	3	6	1	0	6	7	6	8
	2016	14	4	3	5	5	2	2	4	5	8	10
Severity	Fatal Injury	0	0	0	1	0	0	0	0	0	0	0
	Suspected Serious Injury	2	1	0	0	0	0	0	0	1	2	4
	Suspected Minor Injury	5	3	1	2	3	1	0	1	3	3	2
	Possible Injury	3	0	1	0	0	0	0	1	3	2	5
	Property Damage Only	59	10	7	10	15	8	3	17	34	23	29
Collision Type	Angle	1	0	0	1	0	0	0	1	1	3	5
	Head On	0	0	0	0	0	0	0	0	0	0	0
	Single Vehicle	42	8	4	6	12	5	1	15	28	8	19
	Rear End	4	2	1	2	1	2	0	1	3	5	7
	Backing	3	0	0	0	0	0	0	0	0	0	0
	Sideswipe-Opp Dir	0	0	0	0	0	0	0	0	0	0	0
	Sideswipe-Passing	3	2	2	3	2	1	1	2	2	7	5
	Other	16	2	2	1	3	1	1	0	7	7	4
Crashes Involving Commercial Vehicles												
Year	2012	3	0	0	1	0	1	0	0	1	4	1
	2013	5	1	0	1	1	1	0	2	5	4	2
	2014	3	2	2	2	1	1	0	1	1	1	4
	2015	3	1	0	0	2	1	0	2	3	4	4
	2016	4	3	1	2	1	0	2	0	4	2	3
Severity	Fatal Injury	0	0	0	0	0	0	0	0	0	0	0
	Suspected Serious Injury	1	0	0	0	0	0	0	0	0	0	1
	Suspected Minor Injury	2	2	0	2	0	1	0	0	0	1	0
	Possible Injury	2	0	1	0	0	0	0	0	1	2	4
	Property Damage Only	13	5	2	4	5	3	2	5	13	12	9

Table E-2. Crash Pattern Analysis for All Vehicles

Crash Description		W1	W2	W3	W4	E1	E2	E3	E4	E5	E6	E7
		Number of Crashes by Study Segment										
Collision Type	Angle	1	0	0	1	0	0	0	1	1	2	3
	Head On	0	0	0	0	0	0	0	0	0	0	0
	Single Vehicle	8	3	0	2	2	1	1	1	9	2	1
	Rear End	2	2	1	0	1	2	0	1	2	4	5
	Backing	3	0	0	0	0	0	0	0	0	0	0
	Sideswipe-Opp Dir	0	0	0	0	0	0	0	0	0	0	0
	Sideswipe-Passing	3	2	2	3	2	1	0	2	2	7	5
	Other	1	0	0	0	0	0	1	0	0	0	0

Source: WYDOT crash records, 2012-2016

The crash rates and densities were also computed for each segment for all vehicle type crashes and commercial vehicle crashes. The computation was based on the AADT (2016) obtained from WYDOT Interactive Transportation System map (https://apps.wyoroad.info/itsm/map.html). The results are shown in Table E-3.

Table E-3. Summary of Existing Conditions Crash Rate and Density

	Westbound Segments				Eastbound Segments						
	W1	W2	W3	W4	E1	E2	E3	E4	E5	E6	E7
Total Length (miles)	**3.06**	**1.28**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**1.47**	**3.08**	**3.15**	**2.08**
	All Crashes										
ADT (2016)	7000	5277	6049	6771	6606	6060	5886	5886	5185	5287	7020
Crash Frequency (2012-2016)	69	14	35	31	73	38	26	19	41	30	40
Crash Rate (crashes/mvm)	1.77	1.14	0.60	0.56	1.61	0.76	0.57	2.27	1.55	0.99	1.50
Crash Density (crashes/mile)	22.55	10.94	6.67	6.89	19.47	8.44	6.12	24.36	14.64	9.52	19.23
	Crashes Involving Commercial Vehicles										
Commercial Vehicle ADT (2016)	3019	2276	2609	2921	2849	2614	2539	2539	2236	2280	3028
Crash Frequency (2012-2016)	18	7	11	16	23	13	10	5	14	15	14
Crash Rate (crashes/mvm)	1.07	1.32	0.44	0.67	1.18	0.61	0.51	1.39	1.11	1.15	1.22
Crash Density (crashes/mile)	5.88	5.47	2.10	3.56	6.13	2.89	2.35	6.44	4.55	4.76	6.73

Source: WYDOT crash records, 2012-2016
WYDOT Interactive Transportation System map (https://apps.wyoroad.info/itsm/map.html)

Estimate Future No Build Crash Conditions

There were three inputs to estimating future conditions assuming the truck climbing lanes were not built: existing crash rates, existing crash type distribution and future traffic volumes. Existing crash rates and future traffic volumes were used to estimate future crash frequencies. This method assumed that no other improvements would be made to the corridor and that the crash rates remain the same. This also does not account for potential vehicle and technology improvements that may change future crash patterns. However, without definitive information on how the I-80 corridor safety performance would change in the future, keeping crash rates constant across time provides a stable baseline analysis.

Based on the limited research available for interstate truck climbing lanes (see next section for details) the introduction of truck climbing lanes is expected to have the greatest benefit for crashes that involve a commercial vehicle involved in a rear end and sideswipe passing crash. Limited benefits were identified for all other crash types as well. Therefore, the existing crash type distribution was used to separate the existing crash rates into two parts: (1) crash rate for rear end and sideswipe passing crashes involving a commercial vehicle and (2) crash rate for all other crashes. As an outcome, the existing crash rates by these two crash types were calculated and are summarized in Table E-4. As noted previously, it was assumed the calculated crash rates would continue to represent future no build conditions for the I-80 segments.

Table E-4. Summary of Existing Conditions Crash Rate and Density Existing Crash Rates for Crash Types Observed

Crash Rates	Segment Number										
	W1	W2	W3	W4	E1	E2	E3	E4	E5	E6	E7
All Crashes	1.76	1.14	1.63	2.10	2.99	1.63	0.56	1.20	1.41	0.99	1.50
RE + SSW-Passing involving Commercia l Vehicle	0.13	0.32	0.54	0.49	0.50	0.54	0.00	0.19	0.14	0.36	0.38
All Other Crashes	1.64	0.81	1.09	1.62	2.49	1.09	0.56	1.01	1.27	0.63	1.13

Source: WYDOT crash records, 2012-2016
WYDOT Interactive Transportation System map (https://apps.wyoroad.info/itsm/map.html)

Future traffic volumes were provided by WYDOT. Volume forecasts from 2018 to 2048 were available in increments of 5 years. Table E-5 summarizes the vehicle forecast volumes for each segment.

Table E-5. Segment Forecast Volumes by Year

Segment	Forecast Volumes by Year						
	2018	2023	2028	2033	2038	2043	2048
W1	7,384	7,961	8,538	9,115	9,692	10,269	10,846
W2	6,142	6,587	7,032	7,476	7,921	8,366	8,810
W3	6,947	7,454	7,960	8,467	8,973	9,480	9,986
W4	7,569	8,129	8,689	9,249	9,809	10,369	10,929
E1	7,441	7,983	8,526	9,068	9,610	10,152	10,694
E2	6,945	7,451	7,957	8,463	8,969	9,475	9,981
E3	6,921	7,423	7,925	8,427	8,929	9,431	9,933
E4	6,750	7,242	7,734	8,226	8,718	9,210	9,702
E5	6,043	6,474	6,906	7,337	7,768	8,200	8,631
E6	6,101	6,538	6,975	7,412	7,849	8,286	8,723
E7	7,471	8,041	8,610	9,180	9,749	10,318	10,888

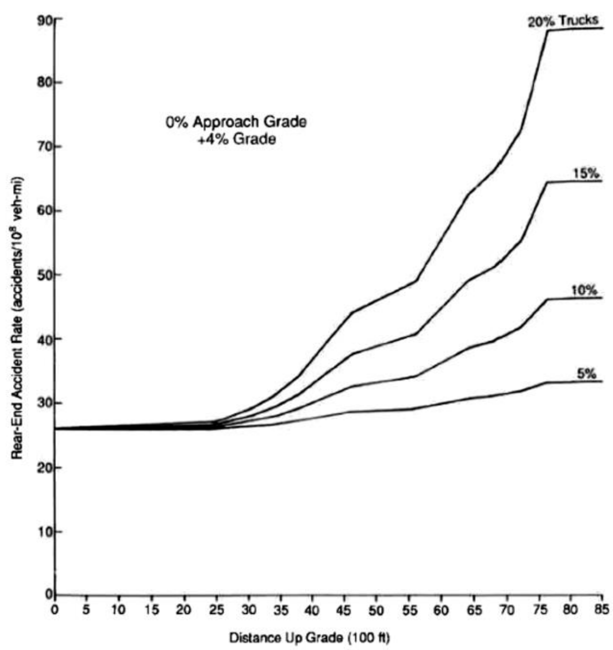
Source: WYDOT

Potential Change in Crash Frequency Associated with the Truck Climbing Lanes

Safety research associated with interstate truck climbing lanes is limited. Therefore, what research is available was used to estimate a crash reduction for a truck climbing lane in each segment.

Safety Considerations for Truck Climbing Lanes on Rural Highways' (St. John and Hardwood, [1991]) shows that steep grades increase the incidence of rear end crashes (expressed as a rate) as a function of length of grade, rate of grade and percentage of trucks in the traffic flow (Figure 1). I-80 volumes from WYDOT indicate that commercial traffic represents

Figure 1. Calculated Rear-End Accident Rates on 4 Percent Upgrade (St. John and Hardwood, [1991])



43 percent of all volume on I-80. However, the published research only looked at truck volumes up to 20 percent. Therefore, the line representing 20 percent trucks was used for the I-80 analysis. Also, the research developed two charts, one for a 4 percent grade and a second for a 6 percent grade. Grades in the study segments were observed to be below 5 percent, so the chart representing 4 percent grade was selected for all segments. It was assumed that constructing a truck climbing lane would have a similar safety performance as a segment with no steep upgrades. For each segment, the total length of upgrades greater than 1.5 percent was used to estimate the expected change in crash rate. For each segment's length of upgrade, the crash rate for that distance was compared to the expected crash rate if there was no upgrade (Figure 1). The percent change in the crash rates was assumed as the crash reduction for commercial vehicle rear end and sideswipe passing crash frequencies predicted for the future year. Crash reduction percentages for each segment are summarized in Table E-6.

In addition, "*Does separating trucks from other traffic improve overall safety?"* published by Lord and Middleton (2005) shows that a New Jersey facility with no trucks allowed experiences a 35 percent to 50 percent reduction in crash rate. Since all heavy vehicles will not move into the truck climbing lane, the benefit was conservatively reduced by half. Since the crash reduction ranged from 35 to 50 percent, the expected crash reduction was assumed to be half of the midpoint. (Note: The midpoint is 42.5 percent and half would be 21.25 percent. The expected reduction was rounded to 20 percent for all segments.)

Table E-6. Summary of Crash Reduction Percentages for I-80 Segments

	Westbound I-80 Segments				Eastbound I-80 Segments						
	W1	**W2**	**W3**	**W4**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**
Total Length (miles)	3.06	1.28	0.5	0.5	0.5	0.5	0.5	1.47	3.08	3.15	2.08
Length with upgrade greater than 1.5% (miles)	0.99	0.50	2.19	1.78	1.70	1.77	2.48	0.67	0.91	1.22	1.59
Crash Reduction percentage of RE + SSW-Passing involving Commercial Vehicles*	50%	15%	70%	70%	70%	70%	70%	25%	45%	60%	70%
Crash Reduction percentage of All Other Crashes	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%

*Using Figure 1, crash reduction estimated based on the crash rate for the segment's length of upgrade (no build condition) and the crash rate for no upgrade (25 rear end crashes/100mvm; assumed to represent build condition) assuming 20 percent trucks. The change in the crash rate was used as the percent reduction in crashes in the build condition.

Estimate of Change in Crashes under Build Condition

The estimated annual number of crashes for each collision type (i.e., rear end and sideswipe passing involving commercial vehicles and all other crashes) were computed for future years using the existing crash rates and forecast volumes. The crash reduction factors were applied to the predicted number of crashes to estimate the crash frequency if the truck climbing lanes were constructed. For the economic analysis, the estimated future crash frequencies were separated by crash severity.

The individual segments had relatively few crashes and the percentage of crashes by severity varies greatly. Therefore, it was determined that a larger sample was needed to disaggregate predicted crashes by severity. For each of the two crash types included in the analysis, the existing severity distribution was reviewed for the study segments combined in each direction as well as the entire I-80 corridor by direction. Table E-7 and Table E-8 outline the comparison of the crash percentages along the segments and the entire corridor rear end and sideswipe-passing crashes involving commercial vehicles and all other crashes.

Only minor differences were observed between the crash percentages calculated for the study segments and the entire corridor. Furthermore, crash numbers collected along the entire corridor had significantly more crashes. Hence, severity distributions for the entire corridor were used to estimate the number of crashes by severity with and without the truck climbing lane.

Table E-7. Number of Crashes and Crash Percentage of Rear End and Sideswipe-Passing Crashes involving Commercial Vehicles

Severity	WB Study Segments	WB Corridor	EB Study Segments	EB Corridor
Fatal	0 (0%)	15 (2%)	0 (0%)	9 (2%)
Suspected Serious Injury	0 (0%)	29 (5%)	1 (3%)	16 (3%)
Minor Injury	4 (27%)	58 (10%)	2 (6%)	50 (9%)
Possible Injury	2 (13%)	62 (10%)	2 (6%)	46 (9%)
Property Damage Only	9 (60%)	441 (73%)	29 (85%)	417 (78%)
Total	**15**	**605**	**34**	**538**

Source: WYDOT crash records, 2012-2016

Table E-8. Number of Crashes and Crash Percentage of All Other Crash Types

Severity	WB Study Segments	WB Corridor	EB Study Segments	EB Corridor
Fatal	1 (1%)	22 (1%)	0 (0%)	32 (1%)
Suspected Serious Injury	3 (3%)	100 (3%)	6 (5%)	98 (3%)
Minor Injury	7 (8%)	272 (8%)	11 (9%)	255 (8%)
Possible Injury	2 (2%)	195 (6%)	9 (7%)	191 (6%)
Property Damage Only	77 (86%)	2,678 (82%)	100 (79%)	2,510 (81%)
Total	**90**	**3267**	**126**	**3086**

Source: WYDOT crash records, 2012-2016

Results

The methodology was applied to estimate crash frequency by year for each westbound and eastbound segment where a truck climbing lane is being considered. Crash predictions were prepared from 2018 through 2048 in increments of 5 years. As noted in the methodology, crash predictions separate rear end and sideswipe passing crashes involving a commercial vehicle from all other crash types. Furthermore, crash predictions were prepared for two scenarios: no build without a truck climbing lane and a build scenario with the proposed truck climbing lane. The estimated frequency for each crash type was separated by crash severities, including: fatal injury crash, suspected serious injury crash, suspected minor injury crash, possible injury crash, and property damage only crash. Table E-9 through Table E-15 summarize the results as described above.

Table E-9. 2018 Estimated Crash Frequency by Segment, Crash Type and Severity

Scenario	Crash Type	W1	W2	W3	W4	E1	E2	E3	E4	E5	E6	E7
No Build: No Truck Climbing Lane	RE + SSW involving Commercial Vehicle	1.05	0.93	0.69	0.67	0.68	0.69	0.00	0.69	0.93	2.54	2.13
	Fatal Injury	0.03	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.02	0.04	0.04
	Suspected Serious Injury	0.05	0.04	0.03	0.03	0.02	0.02	0.00	0.02	0.03	0.08	0.06
	Suspected Minor Injury	0.10	0.09	0.07	0.06	0.06	0.06	0.00	0.06	0.09	0.24	0.20
	Possible Injury	0.11	0.10	0.07	0.07	0.06	0.06	0.00	0.06	0.08	0.22	0.18
	Property Damage Only	0.77	0.68	0.50	0.49	0.52	0.53	0.00	0.53	0.72	1.97	1.65
	All Other	13.50	2.33	1.38	2.24	3.38	1.38	0.71	3.67	8.62	4.39	6.39
	Fatal Injury	0.09	0.02	0.01	0.02	0.04	0.01	0.01	0.04	0.09	0.05	0.07
	Suspected Serious Injury	0.41	0.07	0.04	0.07	0.11	0.04	0.02	0.12	0.27	0.14	0.20
	Suspected Minor Injury	1.12	0.19	0.12	0.19	0.28	0.11	0.06	0.30	0.71	0.36	0.53
	Possible Injury	0.81	0.14	0.08	0.13	0.21	0.09	0.04	0.23	0.53	0.27	0.40
	Property Damage Only	11.07	1.91	1.13	1.83	2.75	1.12	0.57	2.98	7.01	3.57	5.19
Build: With Truck Climbing Lane	RE + SSW involving Commercial Vehicle	0.53	0.79	0.21	0.20	0.20	0.21	0.00	0.52	0.51	1.02	0.64
	Fatal Injury	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.01
	Suspected Serious Injury	0.03	0.04	0.01	0.01	0.01	0.01	0.00	0.02	0.02	0.03	0.02
	Suspected Minor Injury	0.05	0.08	0.02	0.02	0.02	0.02	0.00	0.05	0.05	0.09	0.06
	Possible Injury	0.05	0.08	0.02	0.02	0.02	0.02	0.00	0.04	0.04	0.09	0.05
	Property Damage Only	0.38	0.58	0.15	0.15	0.16	0.16	0.00	0.40	0.40	0.79	0.49
	All Other	10.80	1.86	1.11	1.79	2.70	1.10	0.56	2.94	6.90	3.51	5.11
	Fatal Injury	0.07	0.01	0.01	0.01	0.03	0.01	0.01	0.03	0.07	0.04	0.05
	Suspected Serious Injury	0.33	0.06	0.03	0.05	0.09	0.03	0.02	0.09	0.22	0.11	0.16
	Suspected Minor Injury	0.90	0.16	0.09	0.15	0.22	0.09	0.05	0.24	0.57	0.29	0.42
	Possible Injury	0.64	0.11	0.07	0.11	0.17	0.07	0.03	0.18	0.43	0.22	0.32
	Property Damage Only	8.85	1.53	0.91	1.47	2.20	0.89	0.46	2.39	5.61	2.85	4.15

Table E-10. 2023 Estimated Crash Frequency by Segment, Crash Type and Severity

Scenario	Crash Type	W1	W2	W3	W4	E1	E2	E3	E4	E5	E6	E7
No Build: No Truck Climbing Lane	RE + SSW involving Commercial Vehicle	1.14	1.00	0.74	0.72	0.73	0.74	0.00	0.74	1.00	2.72	2.29
	Fatal Injury	0.03	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.02	0.05	0.04
	Suspected Serious Injury	0.05	0.05	0.04	0.03	0.02	0.02	0.00	0.02	0.03	0.08	0.07
	Suspected Minor Injury	0.11	0.10	0.07	0.07	0.07	0.07	0.00	0.07	0.09	0.25	0.21
	Possible Injury	0.12	0.10	0.08	0.07	0.06	0.06	0.00	0.06	0.09	0.23	0.20
	Property Damage Only	0.83	0.73	0.54	0.53	0.56	0.57	0.00	0.57	0.77	2.11	1.78
	All Other	14.56	2.50	1.49	2.40	3.63	1.48	0.76	3.94	9.24	4.70	6.87
	Fatal Injury	0.10	0.02	0.01	0.02	0.04	0.02	0.01	0.04	0.10	0.05	0.07
	Suspected Serious Injury	0.45	0.08	0.05	0.07	0.12	0.05	0.02	0.13	0.29	0.15	0.22
	Suspected Minor Injury	1.21	0.21	0.12	0.20	0.30	0.12	0.06	0.33	0.76	0.39	0.57
	Possible Injury	0.87	0.15	0.09	0.14	0.22	0.09	0.05	0.24	0.57	0.29	0.43
	Property Damage Only	11.93	2.05	1.22	1.97	2.95	1.20	0.62	3.20	7.52	3.82	5.59
Build: With Truck Climbing Lane	RE + SSW involving Commercial Vehicle	0.57	0.85	0.22	0.22	0.22	0.22	0.00	0.55	0.55	1.09	0.69
	Fatal Injury	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.01
	Suspected Serious Injury	0.03	0.04	0.01	0.01	0.01	0.01	0.00	0.02	0.02	0.03	0.02
	Suspected Minor Injury	0.05	0.08	0.02	0.02	0.02	0.02	0.00	0.05	0.05	0.10	0.06
	Possible Injury	0.06	0.09	0.02	0.02	0.02	0.02	0.00	0.05	0.05	0.09	0.06
	Property Damage Only	0.41	0.62	0.16	0.16	0.17	0.17	0.00	0.43	0.43	0.84	0.53
	All Other	11.65	2.00	1.19	1.92	2.90	1.18	0.61	3.15	7.39	3.76	5.50
	Fatal Injury	0.08	0.01	0.01	0.01	0.03	0.01	0.01	0.03	0.08	0.04	0.06
	Suspected Serious Injury	0.36	0.06	0.04	0.06	0.09	0.04	0.02	0.10	0.23	0.12	0.17
	Suspected Minor Injury	0.97	0.17	0.10	0.16	0.24	0.10	0.05	0.26	0.61	0.31	0.45
	Possible Injury	0.70	0.12	0.07	0.11	0.18	0.07	0.04	0.19	0.46	0.23	0.34
	Property Damage Only	9.55	1.64	0.97	1.57	2.36	0.96	0.49	2.56	6.01	3.06	4.47

Table E-11. 2028 Estimated Crash Frequency by Segment, Crash Type and Severity

Scenario	Crash Type	W1	W2	W3	W4	E1	E2	E3	E4	E5	E6	E7
No Build: No Truck Climbing Lane	RE + SSW involving Commercial Vehicle	1.22	1.07	0.79	0.77	0.77	0.79	0.00	0.79	1.07	2.90	2.45
	Fatal Injury	0.03	0.03	0.02	0.02	0.01	0.01	0.00	0.01	0.02	0.05	0.04
	Suspected Serious Injury	0.06	0.05	0.04	0.04	0.02	0.02	0.00	0.02	0.03	0.09	0.07
	Suspected Minor Injury	0.12	0.10	0.08	0.07	0.07	0.07	0.00	0.07	0.10	0.27	0.23
	Possible Injury	0.12	0.11	0.08	0.08	0.07	0.07	0.00	0.07	0.09	0.25	0.21
	Property Damage Only	0.89	0.78	0.58	0.56	0.60	0.61	0.00	0.61	0.83	2.25	1.90
	All Other	15.61	2.67	1.58	2.57	3.87	1.58	0.75	4.20	9.86	5.01	7.36
	Fatal Injury	0.11	0.02	0.01	0.02	0.04	0.02	0.01	0.04	0.10	0.05	0.08
	Suspected Serious Injury	0.48	0.08	0.05	0.08	0.12	0.05	0.02	0.13	0.31	0.16	0.23
	Suspected Minor Injury	1.30	0.22	0.13	0.21	0.32	0.13	0.06	0.35	0.81	0.41	0.61
	Possible Injury	0.93	0.16	0.09	0.15	0.24	0.10	0.05	0.26	0.61	0.31	0.46
	Property Damage Only	12.80	2.18	1.29	2.10	3.15	1.28	0.61	3.42	8.02	4.08	5.99
Build: With Truck Climbing Lane	RE + SSW involving Commercial Vehicle	0.61	0.91	0.24	0.23	0.23	0.24	0.00	0.59	0.59	1.16	0.74
	Fatal Injury	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.01
	Suspected Serious Injury	0.03	0.04	0.01	0.01	0.01	0.01	0.00	0.02	0.02	0.03	0.02
	Suspected Minor Injury	0.06	0.09	0.02	0.02	0.02	0.02	0.00	0.05	0.05	0.11	0.07
	Possible Injury	0.06	0.09	0.02	0.02	0.02	0.02	0.00	0.05	0.05	0.10	0.06
	Property Damage Only	0.44	0.66	0.17	0.17	0.18	0.18	0.00	0.46	0.45	0.90	0.57
	All Other	12.49	2.13	1.26	2.05	3.10	1.26	0.60	3.36	7.88	4.01	5.89
	Fatal Injury	0.08	0.01	0.01	0.01	0.03	0.01	0.01	0.03	0.08	0.04	0.06
	Suspected Serious Injury	0.38	0.07	0.04	0.06	0.10	0.04	0.02	0.11	0.25	0.13	0.19
	Suspected Minor Injury	1.04	0.18	0.11	0.17	0.26	0.10	0.05	0.28	0.65	0.33	0.49
	Possible Injury	0.75	0.13	0.08	0.12	0.19	0.08	0.04	0.21	0.49	0.25	0.36
	Property Damage Only	10.24	1.75	1.04	1.68	2.52	1.03	0.49	2.74	6.41	3.26	4.79

Table E-12. 2033 Estimated Crash Frequency by Segment, Crash Type and Severity

Scenario	Crash Type	W1	W2	W3	W4	E1	E2	E3	E4	E5	E6	E7
No Build: No Truck Climbing Lane	RE + SSW involving Commercial Vehicle	1.30	1.13	0.84	0.82	0.82	0.84	0.00	0.84	1.13	3.08	2.62
	Fatal Injury	0.03	0.03	0.02	0.02	0.01	0.01	0.00	0.01	0.02	0.05	0.04
	Suspected Serious Injury	0.06	0.05	0.04	0.04	0.02	0.02	0.00	0.02	0.03	0.09	0.08
	Suspected Minor Injury	0.12	0.11	0.08	0.08	0.08	0.08	0.00	0.08	0.11	0.29	0.24
	Possible Injury	0.13	0.12	0.09	0.08	0.07	0.07	0.00	0.07	0.10	0.26	0.22
	Property Damage Only	0.95	0.83	0.61	0.60	0.64	0.65	0.00	0.65	0.88	2.39	2.03
	All Other	16.67	2.83	1.68	2.73	4.12	1.68	0.86	4.47	10.47	5.33	7.85
	Fatal Injury	0.11	0.02	0.01	0.02	0.04	0.02	0.01	0.05	0.11	0.06	0.08
	Suspected Serious Injury	0.51	0.09	0.05	0.08	0.13	0.05	0.03	0.14	0.33	0.17	0.25
	Suspected Minor Injury	1.39	0.24	0.14	0.23	0.34	0.14	0.07	0.37	0.87	0.44	0.65
	Possible Injury	0.99	0.17	0.10	0.16	0.25	0.10	0.05	0.28	0.65	0.33	0.49
	Property Damage Only	13.66	2.32	1.38	2.24	3.35	1.36	0.70	3.64	8.52	4.33	6.38
Build: With Truck Climbing Lane	RE + SSW involving Commercial Vehicle	0.65	0.96	0.25	0.25	0.25	0.25	0.00	0.63	0.62	1.23	0.78
	Fatal Injury	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.01
	Suspected Serious Injury	0.03	0.05	0.01	0.01	0.01	0.01	0.00	0.02	0.02	0.04	0.02
	Suspected Minor Injury	0.06	0.09	0.02	0.02	0.02	0.02	0.00	0.06	0.06	0.11	0.07
	Possible Injury	0.07	0.10	0.03	0.03	0.02	0.02	0.00	0.05	0.05	0.11	0.07
	Property Damage Only	0.47	0.70	0.18	0.18	0.19	0.19	0.00	0.49	0.48	0.96	0.61
	All Other	13.33	2.27	1.34	2.19	3.29	1.34	0.69	3.58	8.38	4.26	6.28
	Fatal Injury	0.09	0.02	0.01	0.01	0.03	0.01	0.01	0.04	0.09	0.04	0.07
	Suspected Serious Injury	0.41	0.07	0.04	0.07	0.10	0.04	0.02	0.11	0.27	0.14	0.20
	Suspected Minor Injury	1.11	0.19	0.11	0.18	0.27	0.11	0.06	0.30	0.69	0.35	0.52
	Possible Injury	0.80	0.14	0.08	0.13	0.20	0.08	0.04	0.22	0.52	0.26	0.39
	Property Damage Only	10.93	1.86	1.10	1.79	2.68	1.09	0.56	2.91	6.81	3.47	5.11

Table E-13. 2038 Estimated Crash Frequency by Segment, Crash Type and Severity

Scenario	Crash Type	W1	W2	W3	W4	E1	E2	E3	E4	E5	E6	E7
No Build: No Truck Climbing Lane	RE + SSW involving Commercial Vehicle	1.38	1.20	0.89	0.87	0.87	0.89	0.00	0.89	1.20	3.27	2.78
	Fatal Injury	0.03	0.03	0.02	0.02	0.01	0.01	0.00	0.01	0.02	0.05	0.05
	Suspected Serious Injury	0.07	0.06	0.04	0.04	0.03	0.03	0.00	0.03	0.04	0.10	0.08
	Suspected Minor Injury	0.13	0.12	0.09	0.08	0.08	0.08	0.00	0.08	0.11	0.30	0.26
	Possible Injury	0.14	0.12	0.09	0.09	0.07	0.08	0.00	0.08	0.10	0.28	0.24
	Property Damage Only	1.01	0.88	0.65	0.63	0.68	0.69	0.00	0.69	0.93	2.53	2.15
	All Other	17.72	3.00	1.78	2.90	4.36	1.78	0.91	4.74	11.09	5.64	8.33
	Fatal Injury	0.12	0.02	0.01	0.02	0.05	0.02	0.01	0.05	0.11	0.06	0.09
	Suspected Serious Injury	0.54	0.09	0.05	0.09	0.14	0.06	0.03	0.15	0.35	0.18	0.26
	Suspected Minor Injury	1.48	0.25	0.15	0.24	0.36	0.15	0.08	0.39	0.92	0.47	0.69
	Possible Injury	1.06	0.18	0.11	0.17	0.27	0.11	0.06	0.29	0.69	0.35	0.52
	Property Damage Only	14.53	2.46	1.46	2.37	3.55	1.44	0.74	3.86	9.02	4.59	6.78
Build: With Truck Climbing Lane	RE + SSW involving Commercial Vehicle	0.69	1.02	0.27	0.26	0.26	0.27	0.00	0.67	0.66	1.31	0.83
	Fatal Injury	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.01
	Suspected Serious Injury	0.03	0.05	0.01	0.01	0.01	0.01	0.00	0.02	0.02	0.04	0.02
	Suspected Minor Injury	0.07	0.10	0.03	0.02	0.02	0.02	0.00	0.06	0.06	0.12	0.08
	Possible Injury	0.07	0.10	0.03	0.03	0.02	0.02	0.00	0.06	0.06	0.11	0.07
	Property Damage Only	0.50	0.74	0.19	0.19	0.20	0.21	0.00	0.52	0.51	1.01	0.65
	All Other	14.18	2.40	1.42	2.32	3.49	1.42	0.73	3.79	8.87	4.51	6.67
	Fatal Injury	0.10	0.02	0.01	0.02	0.04	0.01	0.01	0.04	0.09	0.05	0.07
	Suspected Serious Injury	0.43	0.07	0.04	0.07	0.11	0.05	0.02	0.12	0.28	0.14	0.21
	Suspected Minor Injury	1.18	0.20	0.12	0.19	0.29	0.12	0.06	0.31	0.73	0.37	0.55
	Possible Injury	0.85	0.14	0.08	0.14	0.22	0.09	0.05	0.23	0.55	0.28	0.41
	Property Damage Only	11.62	1.97	1.17	1.90	2.84	1.16	0.59	3.08	7.21	3.67	5.42

Table E-14. 2043 Estimated Crash Frequency by Segment, Crash Type and Severity

Scenario	Crash Type	W1	W2	W3	W4	E1	E2	E3	E4	E5	E6	E7
No Build: No Truck Climbing Lane	RE + SSW involving Commercial Vehicle	1.47	1.27	0.94	0.92	0.92	0.94	0.00	0.94	1.27	3.45	2.94
	Fatal Injury	0.04	0.03	0.02	0.02	0.02	0.02	0.00	0.02	0.02	0.06	0.05
	Suspected Serious Injury	0.07	0.06	0.05	0.04	0.03	0.03	0.00	0.03	0.04	0.10	0.09
	Suspected Minor Injury	0.14	0.12	0.09	0.09	0.09	0.09	0.00	0.09	0.12	0.32	0.27
	Possible Injury	0.15	0.13	0.10	0.09	0.08	0.08	0.00	0.08	0.11	0.29	0.25
	Property Damage Only	1.07	0.92	0.69	0.67	0.71	0.73	0.00	0.73	0.98	2.67	2.28
	All Other	18.78	3.17	1.88	3.06	4.61	1.88	0.96	5.01	11.70	5.96	8.82
	Fatal Injury	0.13	0.02	0.01	0.02	0.05	0.02	0.01	0.05	0.12	0.06	0.09
	Suspected Serious Injury	0.57	0.10	0.06	0.09	0.15	0.06	0.03	0.16	0.37	0.19	0.28
	Suspected Minor Injury	1.56	0.26	0.16	0.25	0.38	0.16	0.08	0.41	0.97	0.49	0.73
	Possible Injury	1.12	0.19	0.11	0.18	0.29	0.12	0.06	0.31	0.72	0.37	0.55
	Property Damage Only	15.39	2.60	1.54	2.51	3.75	1.53	0.78	4.07	9.52	4.84	7.17
Build: With Truck Climbing Lane	RE + SSW involving Commercial Vehicle	0.73	1.08	0.28	0.28	0.28	0.28	0.00	0.70	0.70	1.38	0.88
	Fatal Injury	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.01
	Suspected Serious Injury	0.04	0.05	0.01	0.01	0.01	0.01	0.00	0.02	0.02	0.04	0.03
	Suspected Minor Injury	0.07	0.10	0.03	0.03	0.03	0.03	0.00	0.07	0.06	0.13	0.08
	Possible Injury	0.08	0.11	0.03	0.03	0.02	0.02	0.00	0.06	0.06	0.12	0.08
	Property Damage Only	0.53	0.79	0.21	0.20	0.21	0.22	0.00	0.55	0.54	1.07	0.68
	All Other	15.02	2.54	1.50	2.45	3.69	1.50	0.77	4.01	9.36	4.76	7.06
	Fatal Injury	0.10	0.02	0.01	0.02	0.04	0.02	0.01	0.04	0.10	0.05	0.07
	Suspected Serious Injury	0.46	0.08	0.05	0.07	0.12	0.05	0.02	0.13	0.30	0.15	0.22
	Suspected Minor Injury	1.25	0.21	0.13	0.20	0.30	0.12	0.06	0.33	0.77	0.39	0.58
	Possible Injury	0.90	0.15	0.09	0.15	0.23	0.09	0.05	0.25	0.58	0.29	0.44
	Property Damage Only	12.31	2.08	1.23	2.01	3.00	1.22	0.63	3.26	7.61	3.88	5.74

Table E-15. 2048 Estimated Crash Frequency by Segment, Crash Type and Severity

Scenario	Crash Type	W1	W2	W3	W4	E1	E2	E3	E4	E5	E6	E7
No Build: No Truck Climbing Lane	RE + SSW involving Commercial Vehicle	1.55	1.34	0.99	0.97	0.97	0.99	0.00	0.99	1.33	3.63	3.10
	Fatal Injury	0.04	0.03	0.02	0.02	0.02	0.02	0.00	0.02	0.02	0.06	0.05
	Suspected Serious Injury	0.07	0.06	0.05	0.05	0.03	0.03	0.00	0.03	0.04	0.11	0.09
	Suspected Minor Injury	0.15	0.13	0.09	0.09	0.09	0.09	0.00	0.09	0.12	0.34	0.29
	Possible Injury	0.16	0.14	0.10	0.10	0.08	0.08	0.00	0.08	0.11	0.31	0.27
	Property Damage Only	1.13	0.97	0.72	0.71	0.75	0.77	0.00	0.77	1.03	2.81	2.40
	All Other	19.83	3.34	1.98	3.23	4.86	1.98	1.01	5.27	12.32	6.27	9.31
	Fatal Injury	0.13	0.02	0.01	0.02	0.05	0.02	0.01	0.05	0.13	0.07	0.10
	Suspected Serious Injury	0.61	0.10	0.06	0.10	0.15	0.06	0.03	0.17	0.39	0.20	0.30
	Suspected Minor Injury	1.65	0.28	0.16	0.27	0.40	0.16	0.08	0.44	1.02	0.52	0.77
	Possible Injury	1.18	0.20	0.12	0.19	0.30	0.12	0.06	0.33	0.76	0.39	0.58
	Property Damage Only	16.26	2.74	1.62	2.65	3.95	1.61	0.82	4.29	10.02	5.10	7.57
Build: With Truck Climbing Lane	RE + SSW involving Commercial Vehicle	0.77	1.14	0.30	0.29	0.29	0.30	0.00	0.74	0.73	1.45	0.93
	Fatal Injury	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.02
	Suspected Serious Injury	0.04	0.05	0.01	0.01	0.01	0.01	0.00	0.02	0.02	0.04	0.03
	Suspected Minor Injury	0.07	0.11	0.03	0.03	0.03	0.03	0.00	0.07	0.07	0.13	0.09
	Possible Injury	0.08	0.12	0.03	0.03	0.02	0.03	0.00	0.06	0.06	0.12	0.08
	Property Damage Only	0.56	0.83	0.22	0.21	0.23	0.23	0.00	0.57	0.57	1.13	0.72
	All Other	15.87	2.67	1.58	2.58	3.89	1.58	0.81	4.22	9.85	5.02	7.44
	Fatal Injury	0.11	0.02	0.01	0.02	0.04	0.02	0.01	0.04	0.10	0.05	0.08
	Suspected Serious Injury	0.49	0.08	0.05	0.08	0.12	0.05	0.03	0.13	0.31	0.16	0.24
	Suspected Minor Injury	1.32	0.22	0.13	0.22	0.32	0.13	0.07	0.35	0.81	0.41	0.62
	Possible Injury	0.95	0.16	0.09	0.15	0.24	0.10	0.05	0.26	0.61	0.31	0.46
	Property Damage Only	13.01	2.19	1.30	2.12	3.16	1.29	0.66	3.43	8.02	4.08	6.06

REFERENCES

Lord D. Middleton D. Whitacre J. (2005). Does separating trucks from other traffic improve overall safety? *Transportation Research Record*. Journal of the Transportation Research Board, 1922, 10.3141/1922-20 [Accessed 22 Aug. 2017].

St John, A. and Harwood, D. (1991). *Safety Considerations for Truck Climbing Lanes on Rural Highways*. [ebook] Transportation Research Board, pp.74 - 82. Available at: http://onlinepubs.trb.org/Onlinepubs/trr/1991/1303/1303-008.pdf [Accessed 22 Aug. 2017].

Appendix F.
Intelligence Transportation System (ITS)

INTELLIGENCE TRANSPORTATION SYSTEM (ITS) COST

Intelligent transportation systems (ITS) represents a broad spectrum of technologies that are designed to improve mobility, reduce congestion, improve travel time reliability and safety through the use of technology. The use of ITS has evolved steadily during the past two decades but adoption has accelerated due to the influence of new technologies becoming more cost competitive and efficient. During the past several years, advances in computer processing, the evolution of LIDAR and other on-board sensors, as well as new communications protocols associated with Connected and Autonomous Vehicles.

Many early uses of roadside sensors were in-pavement loop detectors that were used both to count and classify vehicles as well as to identify when a vehicle was present. Today's roadside sensors are much more sophisticated than pneumatic loop detectors and are capable of collecting a wide variety of data to benefit traffic operations and maintenance. WYDOT already uses many of these technologies along Interstates, arterials, and other roadways.

The general recommendations discussed in this document are for WYDOT to increase the coverage rate for DSRC radios to reach a saturation level that would allow WYDOT to effectively monitor the majority of I-80 and would increase the ability of WYDOT to expand the program and to adopt other Connected Vehicle and Dynamic Mobility Applications by extending the existing deployment of DSRC RSUs along I-80 that are being deployed as part of the Wyoming Connected Vehicle Regional Pilot.

The current plans for the Connected Vehicle Regional Pilot call for the installation of approximately 75 DSRC RSUs covering roughly 37 percent of the I-80 corridor. The focus of these RSUs are to provide a basis to achieve the goals of the pilot with a focus on road weather and freight. These RSUs are set to be installed by November 7, 2017. We recommend "doubling down" on this investment with the deployment of an additional 80 RSU units in the corridor. This would enable roughly 80 percent coverage across the entire corridor. This level of coverage is important as it will allow for:

- Improved safety warnings and weather related incidents throughout the corridor, specifically enhancing localized weather conditions such as black ice or wind-shears. More specifically, the DSRC radios would be able to provide notification to vehicles of rapidly changing conditions within a moving 11 minute window.
- Allows for investigation and enhancement of freight at entry points and specifically will enable the potential to utilized DSRC as an alternative to older technologies for wireless roadside inspections.
- Improves WYDOT's ability to attract and monitor emerging technologies such as truck platooning as well as enabling remote monitoring of vehicles and the ability to remotely over-

ride the on-board programming if needed through the DSRC radio linkage – provided the vehicle was not in the 20 percent coverage gap.

- Maintains Wyoming as a leader in DSRC and Connected Vehicle programs. This would be the single longest corridor ever instrumented with RSUs in the U.S. This should attract the technology community to Wyoming to conduct testing and analysis of potential new vehicle systems.

As an alternative, WYDOT could consider coverage of 90 percent of the corridor, which would increase the ability to monitor and take remote control of vehicles in a larger segment of the corridor by reducing the gap to only 10 percent of the corridor.

Ultimately, HDR believes that investing in DSRC technology is recommended as it represents a relatively low risk opportunity for WYDOT while maximizing the existing and previous investments. For example, in the future if 5G technologies or some other communication protocol rises to dominance such as Miracast Wi-Fi, these radio units can be "retuned" to operate as Wi-Fi routers or can have cellular modems added to transform them into 5G transponders. As new Dynamic Mobility Applications and Connected Vehicle applications are developed, 80-90 percent coverage of a corridor will enable WYDOT to implement these applications and further improve safety and mobility of travelers and workers. For example, one application previously tested by USDOT but has yet to be deployed due in part to DSRC coverage issues is the Response Emergency Staging Uniform Management and Evacuation application (R.E.S.C.U.M.E.). Among other things, this application provides real-time alerts to first responders and work crews when oncoming vehicles are determined to be a treat of entering an active incident zone. Extending coverage is a significant step to enabling these kinds of applications.

Additional Locations. The proposed additional locations for the increased coverage are included in Table F-1. Proposed locations are depicted in Figure F-1.

Table F-1. Proposed RSU Locations for 80 Percent Coverage of I-80

Name	Infrastructure	Longitude	Latitude
RSU 1	No infrastructure	–104.1203928	41.1506110
RSU 2	No infrastructure	–104.1778564	41.1488660
RSU 3	No infrastructure	–104.2536449	41.1590768
RSU 4	Web cam	–104.3489304	41.1572664
RSU 5	Service Point	–104.4586730	41.1568151
RSU 6	No infrastructure	–104.5599961	41.1582529
RSU 7	No infrastructure	–104.7005654	41.1366497
RSU 8	DMS	–104.7646862	41.1243260
RSU 9	Web cam	–104.8780605	41.1168821
RSU 10	Web cam	–104.9753577	41.1095709

Table F-1. Proposed RSU Locations for 80 Percent Coverage of I-80

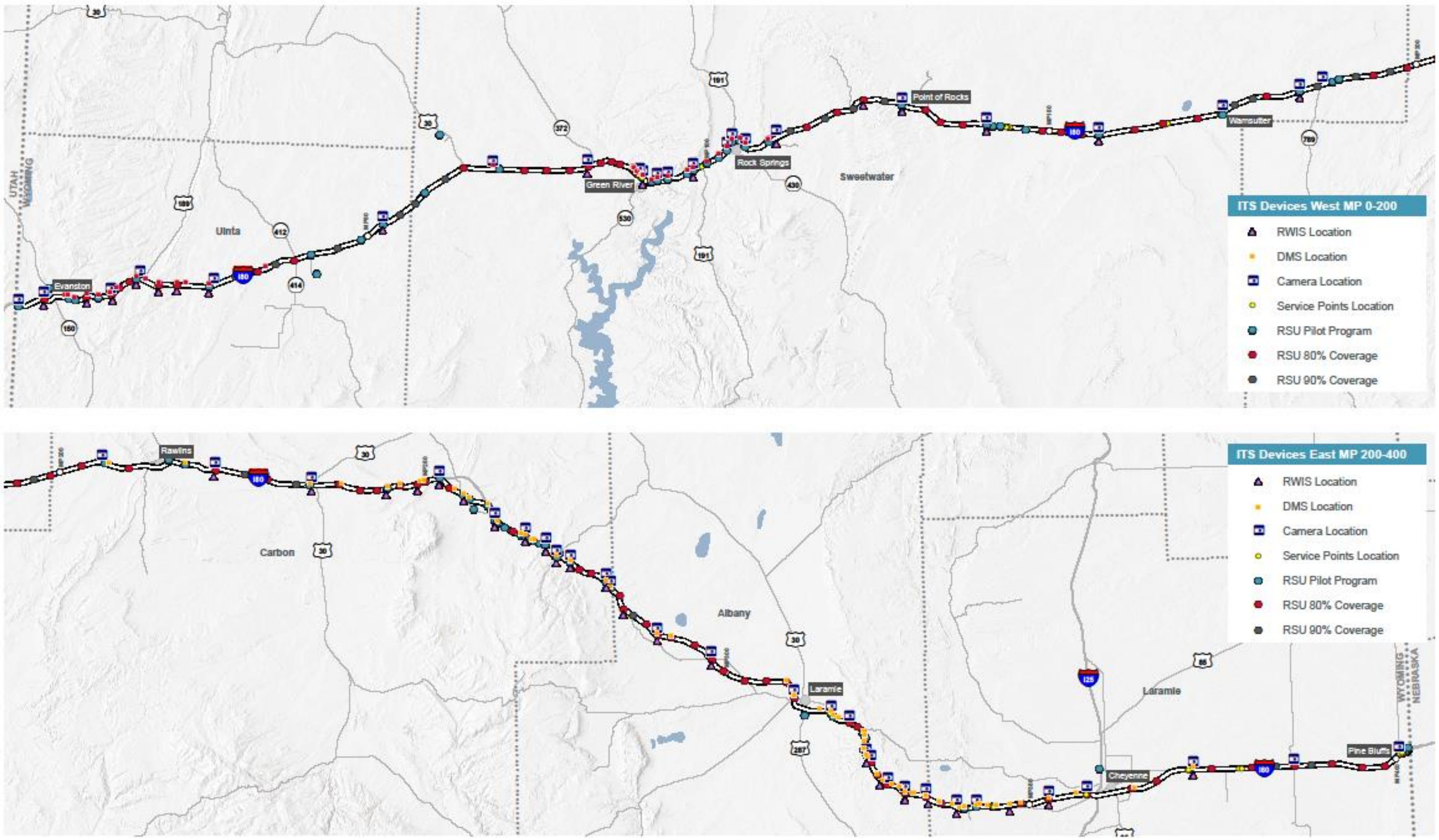
Name	Infrastructure	Longitude	Latitude
RSU 11	VSL	–105.0469163	41.1024245
RSU 12	No infrastructure	–105.2481651	41.1069722
RSU 13	Web cam	–105.2869418	41.1203516
RSU 14	Web cam	–105.3394246	41.1283375
RSU 15	Web cam	–105.3840499	41.1466119
RSU 16	Web cam	–105.4240067	41.1886775
RSU 17	VSL	–105.4095416	41.1652387
RSU 18	Web cam	–105.4758056	41.2662986
RSU 19	No infrastructure	–105.4562509	41.2605495
RSU 20	Web cam	–105.6147279	41.3179969
RSU 21	DMS	–105.6342530	41.3477149
RSU 22	No infrastructure	–105.6859017	41.3512989
RSU 23	No infrastructure	–105.7406616	41.3531030
RSU 24	Web cam	–105.8227158	41.3947108
RSU 25	No infrastructure	–105.7945633	41.3713983
RSU 26	No infrastructure	–105.8660603	41.4227778
RSU 27	Web cam	–105.9606443	41.4437830
RSU 28	DMS	–105.9252338	41.4382244
RSU 29	No infrastructure	–105.9875107	41.4654345
RSU 30	RWIS	–106.0460472	41.4954960
RSU 31	No infrastructure	–106.0548019	41.5216880
RSU 32	No infrastructure	–106.1261272	41.5641512
RSU 33	No infrastructure	–106.1564255	41.5739760
RSU 34	No infrastructure	–106.3258123	41.6480638
RSU 35	No infrastructure	–106.4870453	41.7346215
RSU 36	VSL	–106.5509154	41.7453090
RSU 37	RWIS	–106.5679139	41.7413224
RSU 38	VSL	–106.6129978	41.7384734
RSU 39	No infrastructure	–106.6719246	41.7308425
RSU 40	No infrastructure	–106.7162132	41.7318994
RSU 41	No infrastructure	–106.7693853	41.7433638
RSU 42	Ft. Steele rest area.	–106.9520760	41.7524890
RSU 43	Web cam	–107.0862012	41.7715387
RSU 44	No infrastructure	–107.3082733	41.7765606
RSU 45	No infrastructure	–107.4298096	41.7805289
RSU 46	No infrastructure	–107.5080872	41.7628614
RSU 47	No infrastructure	–107.5942612	41.7482627
RSU 48	No infrastructure	–107.8684902	41.7059848
RSU 49	No infrastructure	–108.0443573	41.6634226
RSU 50	No infrastructure	–108.1332779	41.6521364

Table F-1. Proposed RSU Locations for 80 Percent Coverage of I-80

Name	Infrastructure	Longitude	Latitude
RSU 51	No infrastructure	–108.2053757	41.6403350
RSU 52	No infrastructure	–108.3405161	41.6310014
RSU 53	No infrastructure	–108.3934307	41.6344335
RSU 54	No infrastructure	–108.4407663	41.6369352
RSU 55	No infrastructure	–108.6451721	41.6467490
RSU 56	No infrastructure	–108.7038803	41.6505972
RSU 57	No infrastructure	–108.7405300	41.6731683
RSU 58	RWIS	–108.9004835	41.6921544
RSU 59	No infrastructure	–108.9668655	41.6670133
RSU 60	No infrastructure	–109.0429115	41.6359730
RSU 61	DMS	–109.4738621	41.5385194
RSU 62	VSL	–109.4850750	41.5477249
RSU 63	Web cam	–109.5996764	41.5507339
RSU 64	No infrastructure	–109.5198298	41.5576165
RSU 65	No infrastructure	–109.5406437	41.5627062
RSU 66	No infrastructure	–109.5681095	41.5593024
RSU 67	No infrastructure	–109.6469879	41.5443043
RSU 68	No infrastructure	–109.7060394	41.5432764
RSU 69	No infrastructure	–109.7630310	41.5422486
RSU 70	No infrastructure	–109.9187279	41.5431479
RSU 71	No infrastructure	–110.3437614	41.3547781
RSU 72	No infrastructure	–110.4345703	41.3301623
RSU 73	RWIS	–110.6388701	41.2988534
RSU 74	No infrastructure	–110.6851235	41.2966146
RSU 75	Web cam	–110.8040111	41.2740652
RSU 76	Web cam	–110.9742187	41.2597158
RSU 77	RWIS	–110.8671570	41.2687371
RSU 78	No infrastructure	–110.7852316	41.2890130
RSU 79	No infrastructure	–110.7600403	41.3027645
RSU 80	No infrastructure	–110.4908752	41.3190756

DMS = Dynamic Message Sign; RSU = roadside unit; RWIS = Remote Weather Information System; VSL = Variable Speed Limit

Figure F-1. Proposed RSU Locations



Estimate. Table F-2 presents a conceptual-level cost estimate of the proposed RSUs along I-80 that would increase coverage to about 80 percent. This cost estimate is based on installing 80 RSUs with 49 requiring major installation including IPv4 and IPv6 (internet) communication, power, and structures.

Table F-2**.** RSU Installation for 80 Percent Coverage of I-80

Item	Number	Cost (Each)	Total	Justification
RSUs	80	$1,400	$112,000	Quotes
RSU installation support	—	—	$1,350,000	Pilot estimate
RSU TMC integration	—	—	$12,000	IT estimate
Yearly maintenance	—	—	$180,000	See assumptions
25% contingency	—	—	$413,500	25% contingency

Assumptions. The cost estimate presented in Table F-2 assumed the following:

- The RSU cost per unit does not increase from $1,400.
- RSUs are installed at or near the locations given in Table F-2.
- The yearly maintenance includes a check on each RSU quarterly and major support and maintenance of 15 units per year (10 percent of the units).

Coverage at 90 Percent

A coverage rate of 90 percent would give I-80 enough DSRC coverage to disseminate information related to road conditions and forecasted information to drivers within a window of less than 1 minute (assuming normal highway speeds) to connected vehicles. This assumes that autonomous vehicles will also use connected vehicle communication technology.

Additional Locations. The proposed additional locations for the increased coverage are listed in Table F-3 and illustrated in Figure F-1.

Table F-3**.** Proposed RSU Locations for 90 Percent Coverage of I-80

Name	Infrastructure	Longitude	Latitude
RSU 1	No infrastructure	–104.1203928	41.1506110
RSU 2	No infrastructure	–104.1778564	41.1488660
RSU 3	No infrastructure	–104.2536449	41.1590768
RSU 4	Web cam	–104.3489304	41.1572664
RSU 5	Service point	–104.4586730	41.1568151
RSU 6	No infrastructure	–104.5599961	41.1582529
RSU 7	No infrastructure	–104.7005654	41.1366497
RSU 8	DMS	–104.7646862	41.1243260

Table F-3. Proposed RSU Locations for 90 Percent Coverage of I-80

Name	Infrastructure	Longitude	Latitude
RSU 9	Web cam	–104.8780605	41.1168821
RSU 10	Web cam	–104.9753577	41.1095709
RSU 11	VSL	–105.0469163	41.1024245
RSU 12	No infrastructure	–105.2481651	41.1069722
RSU 13	Web cam	–105.2869418	41.1203516
RSU 14	Web cam	–105.3394246	41.1283375
RSU 15	Web cam	–105.3840499	41.1466119
RSU 16	Web cam	–105.4240067	41.1886775
RSU 17	VSL	–105.4095416	41.1652387
RSU 18	Web cam	–105.4758056	41.2662986
RSU 19	No infrastructure	–105.4562509	41.2605495
RSU 20	Web cam	–105.6147279	41.3179969
RSU 21	DMS	–105.6342530	41.3477149
RSU 22	No infrastructure	–105.6859017	41.3512989
RSU 23	No infrastructure	–105.7406616	41.3531030
RSU 24	Web cam	–105.8227158	41.3947108
RSU 25	No infrastructure	–105.7945633	41.3713983
RSU 26	No infrastructure	–105.8660603	41.4227778
RSU 27	Web cam	–105.9606443	41.4437830
RSU 28	DMS	–105.9252338	41.4382244
RSU 29	No infrastructure	–105.9875107	41.4654345
RSU 30	RWIS	–106.0460472	41.4954960
RSU 31	No infrastructure	–106.0548019	41.5216880
RSU 32	No infrastructure	–106.1261272	41.5641512
RSU 33	No infrastructure	–106.1564255	41.5739760
RSU 34	No infrastructure	–106.3258123	41.6480638
RSU 35	No infrastructure	–106.4870453	41.7346215
RSU 36	VSL	–106.5509154	41.7453090
RSU 37	RWIS	–106.5679139	41.7413224
RSU 38	VSL	–106.6129978	41.7384734
RSU 39	No infrastructure	–106.6719246	41.7308425
RSU 40	No infrastructure	–106.7162132	41.7318994
RSU 41	No infrastructure	–106.7693853	41.7433638
RSU 42	Ft. Steele rest area.	–106.9520760	41.7524890
RSU 43	Web cam	–107.0862012	41.7715387
RSU 44	No infrastructure	–107.3082733	41.7765606
RSU 45	No infrastructure	–107.4298096	41.7805289
RSU 46	No infrastructure	–107.5080872	41.7628614
RSU 47	No infrastructure	–107.5942612	41.7482627
RSU 48	No infrastructure	–107.8684902	41.7059848

Table F-3. Proposed RSU Locations for 90 Percent Coverage of I-80

Name	Infrastructure	Longitude	Latitude
RSU 49	No infrastructure	–108.0443573	41.6634226
RSU 50	No infrastructure	–108.1332779	41.6521364
RSU 51	No infrastructure	–108.2053757	41.6403350
RSU 52	No infrastructure	–108.3405161	41.6310014
RSU 53	No infrastructure	–108.3934307	41.6344335
RSU 54	No infrastructure	–108.4407663	41.6369352
RSU 55	No infrastructure	–108.6451721	41.6467490
RSU 56	No infrastructure	–108.7038803	41.6505972
RSU 57	No infrastructure	–108.7405300	41.6731683
RSU 58	RWIS	–108.9004835	41.6921544
RSU 59	No infrastructure	–108.9668655	41.6670133
RSU 60	No infrastructure	–109.0429115	41.6359730
RSU 61	DMS	–109.4738621	41.5385194
RSU 62	VSL	–109.4850750	41.5477249
RSU 63	Web cam	–109.5996764	41.5507339
RSU 64	No infrastructure	–109.5198298	41.5576165
RSU 65	No infrastructure	–109.5406437	41.5627062
RSU 66	No infrastructure	–109.5681095	41.5593024
RSU 67	No infrastructure	–109.6469879	41.5443043
RSU 68	No infrastructure	–109.7060394	41.5432764
RSU 69	No infrastructure	–109.7630310	41.5422486
RSU 70	No infrastructure	–109.9187279	41.5431479
RSU 71	No infrastructure	–110.3437614	41.3547781
RSU 72	No infrastructure	–110.4345703	41.3301623
RSU 73	RWIS	–110.6388701	41.2988534
RSU 74	No infrastructure	–110.6851235	41.2966146
RSU 75	Web cam	–110.8040111	41.2740652
RSU 76	Web cam	–110.9742187	41.2597158
RSU 77	RWIS	–110.8671570	41.2687371
RSU 78	No infrastructure	–110.7852316	41.2890130
RSU 79	No infrastructure	–110.7600403	41.3027645
RSU 80	No infrastructure	–110.4908752	41.3190756
RSU 81	No infrastructure	–109.9639606	41.5208526
RSU 82	No infrastructure	–110.0391483	41.4698723
RSU 83	No infrastructure	–110.0767422	41.4495782
RSU 84	No infrastructure	–110.2331257	41.3791593
RSU 85	No infrastructure	–110.3903246	41.3455644
RSU 86	No infrastructure	–109.0853977	41.6282427
RSU 87	No infrastructure	–108.9981723	41.6550062
RSU 88	No infrastructure	–108.9243257	41.6735369

Table F-3. Proposed RSU Locations for 90 Percent Coverage of I-80

Name	Infrastructure	Longitude	Latitude
RSU 89	No infrastructure	–108.8451254	41.6894565
RSU 90	No infrastructure	–106.0218215	41.4829105
RSU 91	No infrastructure	–107.9033375	41.7025886
RSU 92	No infrastructure	–107.9492140	41.6889377
RSU 93	No infrastructure	–107.7381134	41.7266148
RSU 94	No infrastructure	–107.5513029	41.7545942
RSU 95	No infrastructure	–107.0104408	41.7633095
RSU 96	No infrastructure	–106.8782187	41.7434758
RSU 97	No infrastructure	–104.6155930	41.1575905
RSU 98	No infrastructure	–104.3065166	41.1585599
RSU 99	No infrastructure	–104.3972397	41.1580429
RSU 100	No infrastructure	–107.6391935	41.7441002

Estimate. Table F-4 presents a conceptual-level cost estimate of the proposed RSUs along I-80 that would increase coverage to about 90 percent. This cost estimate is based on installing 100 RSUs with 69 requiring major installation including communication, power, and structures.

Table F-4. RSU Installation for 90 Percent Coverage of I-80

Item	Number	Cost	Total	Justification
RSUs	100	$1,400	$140,000	Quotes
RSU installation support	—	—	$1,750,000	Pilot estimate
RSU TMC integration	—	—	$14,000	IT estimate
Yearly maintenance	—	—	$200,000	See assumptions
25% contingency	—	—	$526,000	25% contingency

IT = information technology; RSU = roadside unit; TMC = Traffic Management Center

Assumptions. The cost estimates presented in Table F-4 assumed the following:

- The RSU cost per unit does not increase from $1,400.
- RSUs are installed at or near the locations given in 3-7.
- The yearly maintenance includes a check on each RSU quarterly and major support and maintenance of 18 units per year (10 percent).

Appendix G.
Truck Parking

Safe, adequate parking for commercial vehicles under a variety of circumstances is an important component of any freight corridor. Road closures, particularly for extended periods of time, require multiple spaces, ideally close to areas that can provide facilities for the drivers. New regulations which will tighten the enforcement of required break periods for drivers of commercial vehicles could severely impact the current number of parking spaces available and require more spaces throughout freight corridors to ensure that drivers are not forced to take their required breaks at the side of the road or in other unsafe locations – both for them or the rest of the motoring public.

HDR used the following factors to identify candidate locations for implementing additional truck parking locations:

- WYDOT District suggestions
- Proximity to services
- Areas with many closures
- Closure gate locations

Proximity to services is very important for truck parking locations. Truckers need food and other services while the highway is closed. Furthermore, locations without services require maintenance for trash, and problems arise if there are no rest area facilities. HDR also recognized that it is most pragmatic to add truck parking locations upstream of closure gates.

Applying this screening process resulted in the following locations as candidate sites to be considered for additional analysis. Each of these sites are proximate to services with surrounding land for potential additional truck parking.

CANDIDATE TRUCK PARKING LOCATIONS

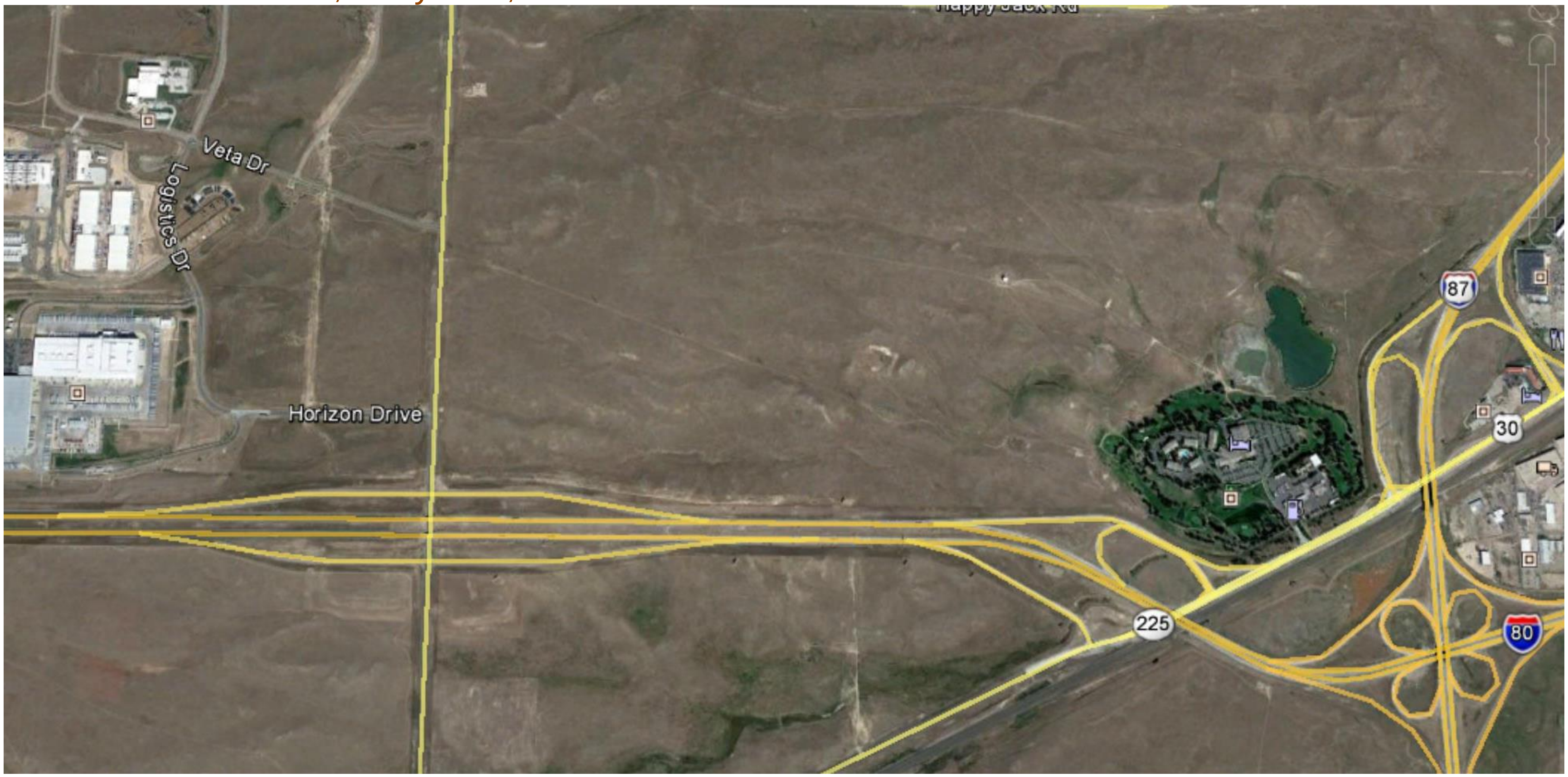
Hillsdale Exit 377: TA Travel Center—Adjacent to Westbound Side

Area Served: Laramie, Cheyenne, Pine Bluffs

There is a lot of potential for truck parking at this location. Currently this location would only work for Westbound Trucks for Closures between Cheyenne and Laramie. Would work for Eastbound Trucks for closures between Cheyenne and Pine Bluffs as well if the Road Closure Gate near Milepost 370 was moved to MP 377 This location would be good for both Pine Bluffs and Cheyenne. **Recommend moving forward.**

Cheyenne Exit 357: Roundtop Road Walmart Distribution Center—Adjacent to Westbound Side

Area Served: Laramie, Cheyenne, Pine Bluffs



This area is located between the Walmart Distribution Center and Little America. The property identified for proposed parking is apparently owned by Little America. This location would need to be developed to provide access to the current Little America facilities.

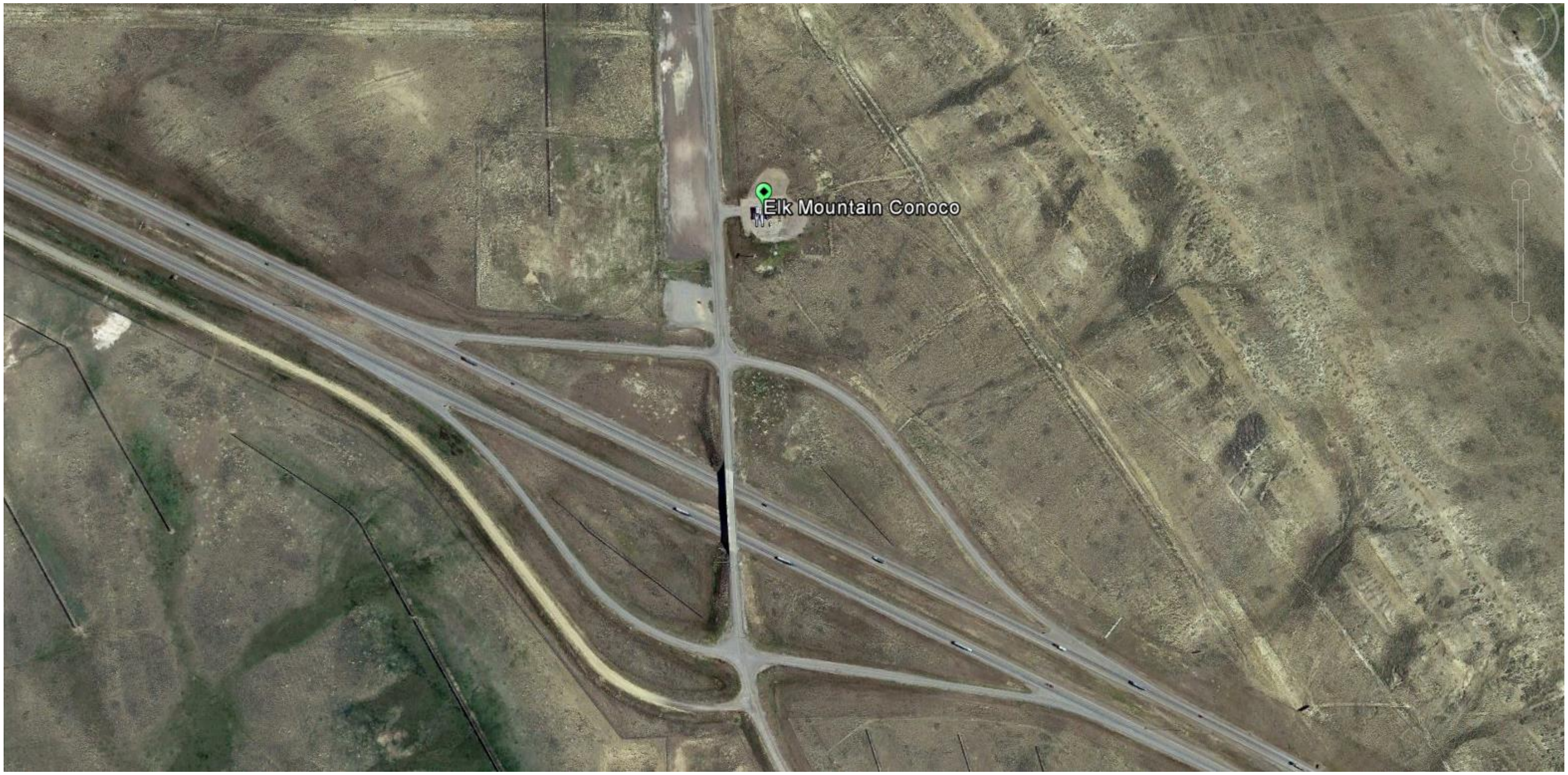
Recommend moving forward.

Laramie Exit 310: Curtis Street (TA Travel Center)—Adjacent to Eastbound Side

Area Served: Rawlins, Laramie, Cheyenne

There is a lot of potential for truck parking at this location. This location works well for Westbound and Eastbound Traffic. The Westbound Closure gate is at Mile Post 310.6 The Eastbound Closure Gate is east of Laramie near Milepost 317.8. This is the best location near Laramie for additional parking. **Recommend moving forward.**

Elk Mountain Exit 255: Elk Mountain Conoco—Adjacent to Westbound Side
Area Served: Rawlins, Laramie



This location was selected as being more suitable than the Wolcott Junction location. A gas station would be able to provide limited services at this location. Parking was identified as being needed at this location along the corridor for other reasons beyond existing services including limitations on driver hours.

Recommend moving forward.

Any of the three of the following would be good candidates for truck parking near Rawlins/Sinclair.

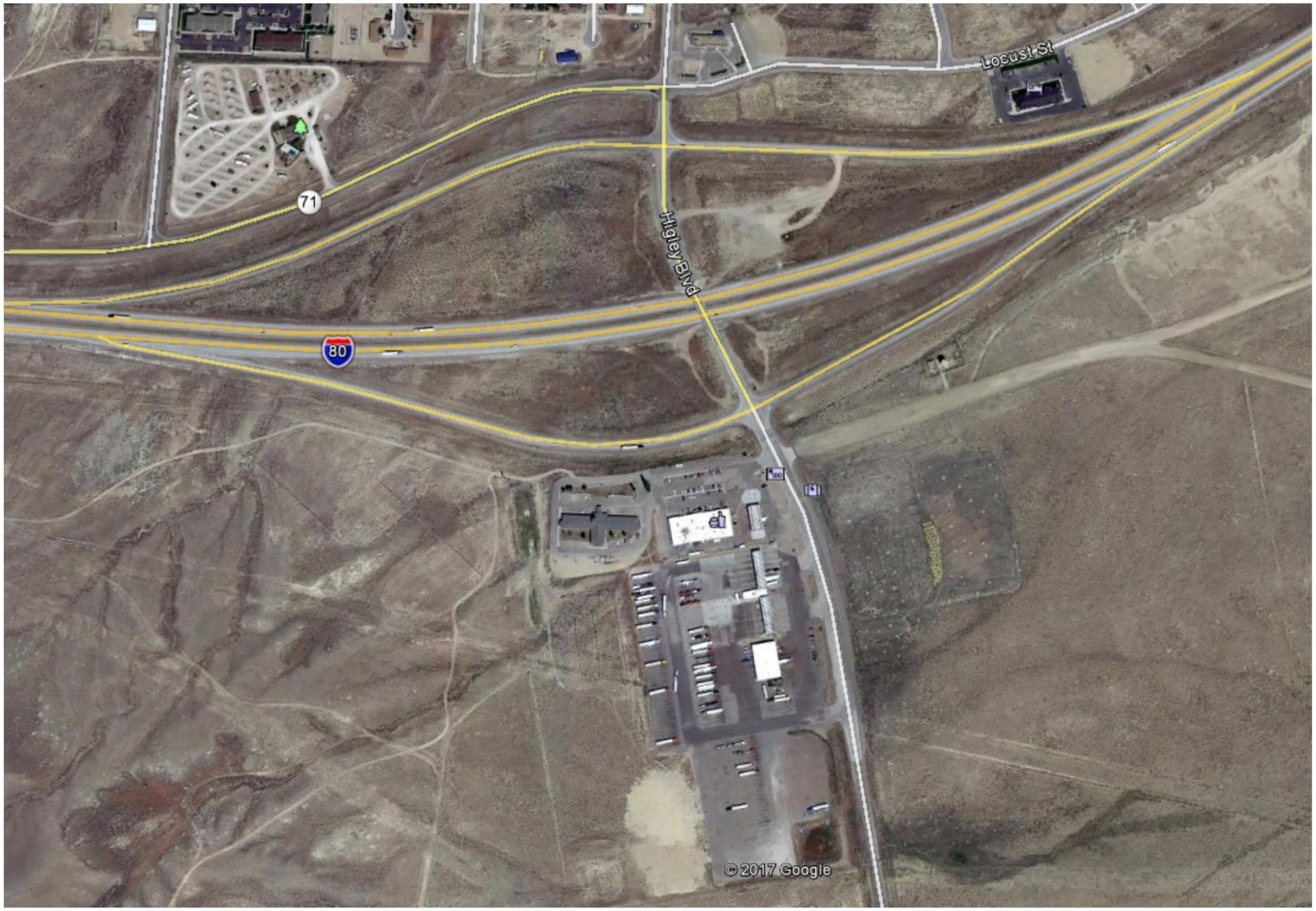
Sinclair Option #1. Exit 221: East Sinclair (I-80 Travel Plaza)0151Adjacent to Westbound Side

Area Served: Rock Springs, Rawlins, Laramie

This Truck Stop is located near the Eastbound Closure gate at MP 221.7. Lots of potential for truck parking.
Recommend moving forward.

Rawlins Option #2. Exit 214: Higley Boulevard–Central Rawlins (TA Travel Center)—Adjacent to Eastbound Side

Area Served: Rock Springs, Rawlins, Laramie



This option provides better access to Central Rawlins (Restaurants, Hotels, etc). This may be the best location in Rawlins. There is a motel and restaurant at this location in addition to truck stop amenities. **Recommend moving forward.**

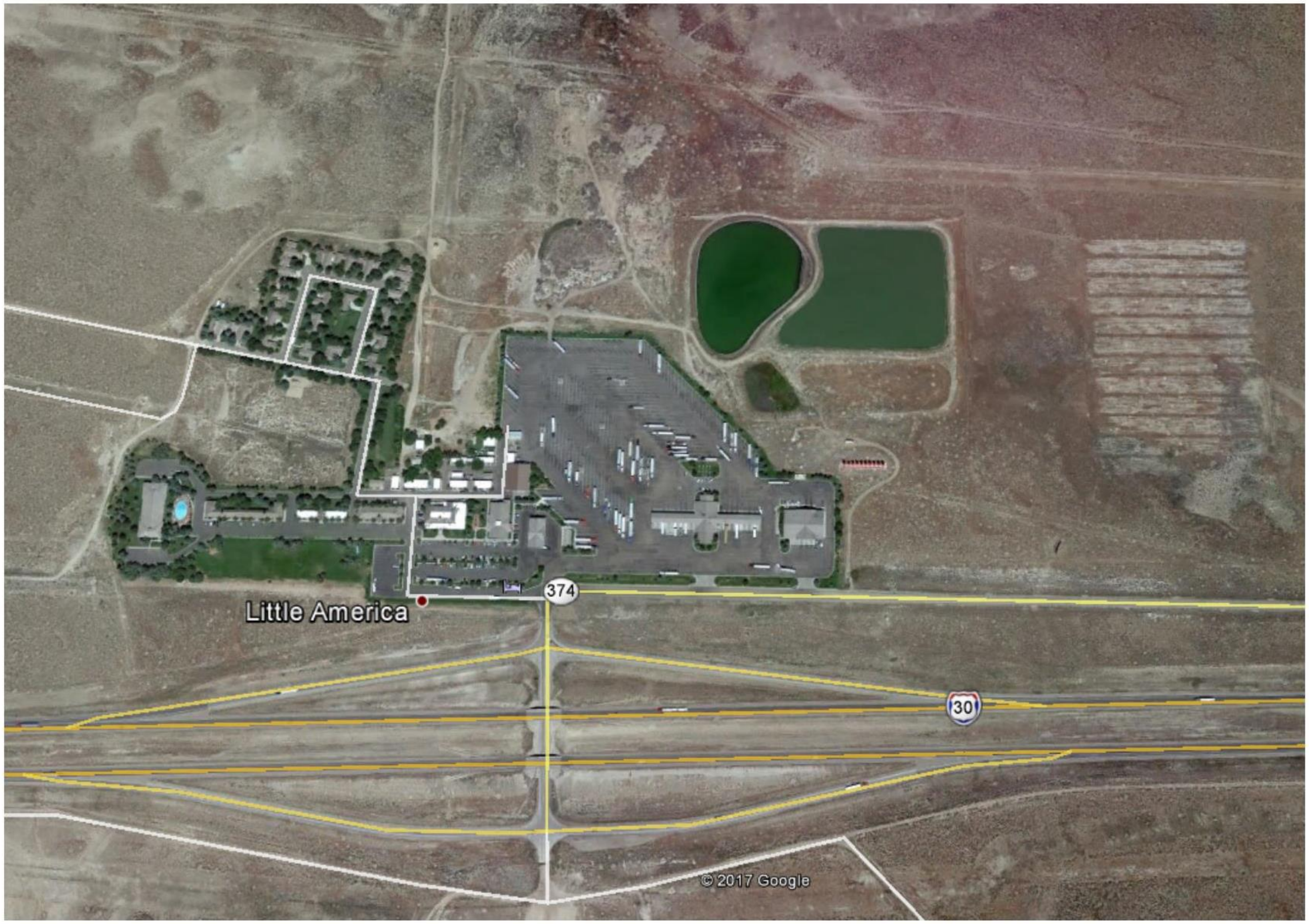
Rawlins Option #3. Exit 209: Johnson Road–West Rawlins (Flying J Truck Stop)—Adjacent to Westbound Side

Area Served: Rock Springs, Rawlins, Laramie

This Truck Stop is located near the Westbound Closure gate at MP 209.6. Lots of potential for truck parking.
Recommend moving forward.

Green River/Rock Springs Exit 68: Little America Truck Stop—Adjacent to Westbound Side

Area Served: Eastbound Trucks Near Green River and Rock Springs



There is potential for additional truck parking at this location. There are not any really good truck stops near Green River or Rock Springs with land available for truck parking. This Truck Stop would be beneficial for Eastbound Trucks assuming road closures at the closure gates at MP 89 near Green River or MP 111 east of Rock Springs. **Recommend moving forward.**

Evanston Exit 6: Bear River State Park (Rest Area)—Adjacent to Eastbound Side

Area Served: Utah Border, Evanston, Green River

There is room to expand parking at this location. However, services would be limited to Rest Area amenities.
Recommend moving forward.

Evanston Exit 3: Flying J Truck Stop—Adjacent to Westbound Side

Area Served: Utah Border, Evanston, Green River

There are a couple of locations for a truck parking at this location. This location works well for Eastbound traffic headed to Green River, and Westbound Traffic heading to Utah. The Eastbound Closure gate is at Mile Post 7. (Assuming there is a Westbound Closure Gate in Utah). Parking sites may be too small.

Recommend moving forward.

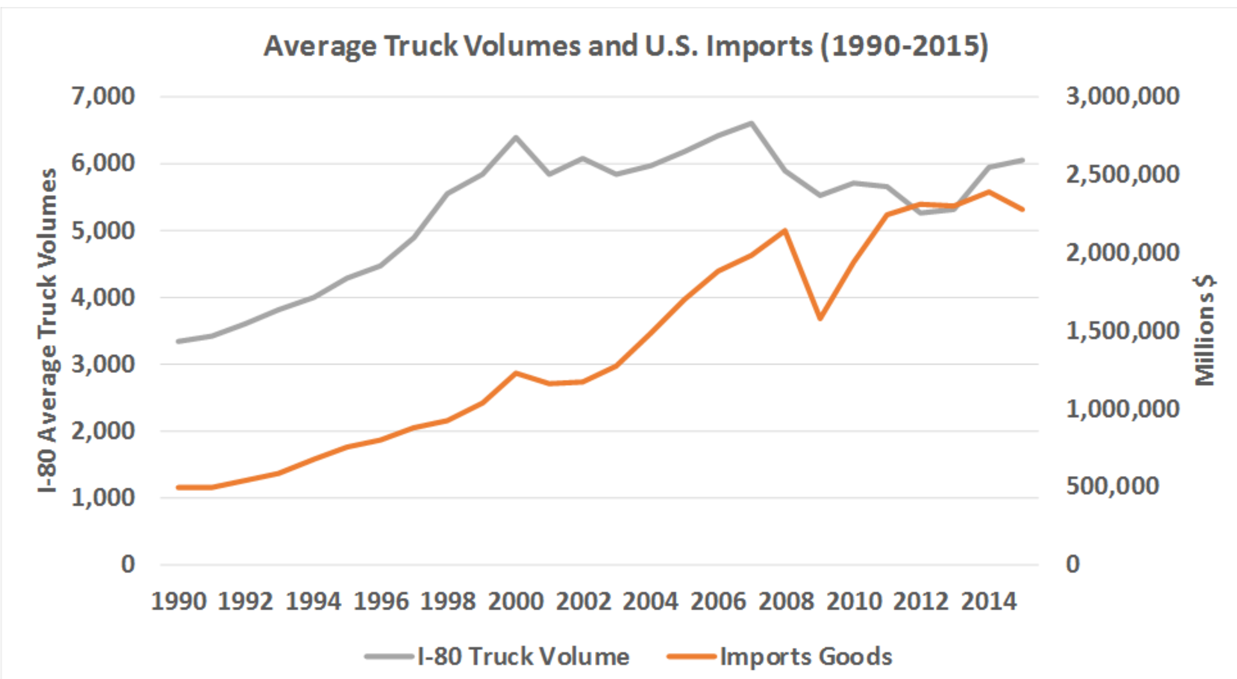
Appendix H.
Funding and Legislative

FINANCIAL STRATEGY

I-80 in Wyoming is a critical component of the nation's transportation system, serving personal and recreational travel needs as well as providing capacity for major commercial operations. Its importance to Wyoming and the United States requires that it be maintained to high safety and operational standards and be expanded if necessary to meet user needs. Meeting these high standards, particularly at a time when the pavement is aging, will require funding at levels significantly higher than WYDOT's typical annual budget can sustain.

Automobile traffic on I-80 has grown by 65 percent over the past 30 years, while heavy truck traffic has grown by 158 percent. Traffic volumes year after year closely mirror U.S. import growth, as shown in Figure H-1, supporting the notion that it is a critical U.S. freight corridor. During periods of national economic growth, such as from 2004 to 2008, I-80 traffic (particularly truck traffic) spiked, while in periods of decline, such as 2008 to 2014, traffic growth moderated. The nature of the economic expansion or decline effects the magnitude of the effect on I-80 volumes, but the relationship between I-80 truck traffic and U.S. import growth is clear.

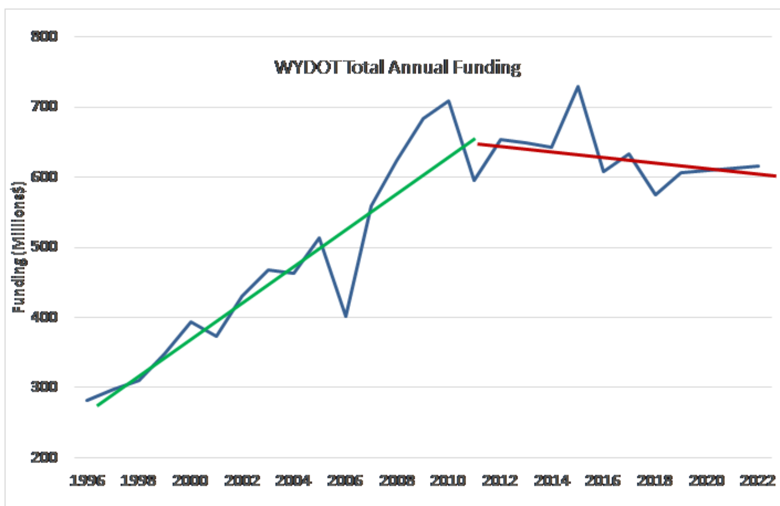
Figure H-1. Comparison of Average Daily Truck Volumes on I-80 and U.S. Imports (1990–2015)



The majority of I-80 in Wyoming was constructed in the 1960s. Certain segments of the roadway have been rehabilitated to varying degrees in the decades since construction, but the expected useful life of the facility when originally designed was between 40 and 50 years. Like many of the nation's interstates, I-80 is becoming more and more expensive to maintain as increasing maintenance costs exceed the funding available from federal and state gas tax revenues. Beyond ongoing maintenance, the portions of the highway will need to be replaced in the future. Making investments in maintenance now will help to further defer replacement costs and extend the life of the highway.

Funding the necessary investments in I-80, along with critical investments in other parts of Wyoming's transportation system, cost the State over $600 million in 2016 and similar amounts in past years. Between 1996 and 2010, WYDOT's annual funding had an increasing trend, growing from $281 million to $607 million. Annual funding did not pay for all of WYDOT's needs, but budgets lagged needs much less than they do today. WYDOT's funding has been on a declining trend since 2010, creating a growing gap between needs and available funds. The reasons for WYDOT's declining funding are many and are described later in this report. However, the fact is that a substantial, sustainable, new funding source is needed in order for WYDOT to maintain and grow its transportation system, particularly I-80, which is among the costliest elements of the system.

Figure H-2. WYDOT Annual Funding History (1996–2017) and Forecast (2018–2022)



Although highway capacity is not constraining mobility in Wyoming, there are many places, particularly on I-80, where passing lanes could improve the ability of automobiles to pass slower-moving trucks. Capital funding for these items would be available only if operations and maintenance costs are funded first, which is becoming an increasingly difficult task. Figure H-2 shows that historical funding for WYDOT between 1996 and 2010 (blue line) grew substantially, at nearly 7 percent annually. However, as Figure H-2 shows, actual funding for WYDOT began to decline on average (note the red trendline) after 2010. Forecast data for 2018 to 2022 extend the historical data forward from 2017, showing expected annual funding levels hovering at just over $600 million.

WYDOT's funding needs are growing, and, WYDOT's management understands and agrees that it does not have sufficient funding to maintain its assets and pay for future system improvements that will promote improved safety, commerce, and mobility. While this report focuses on the improvements associated with the I-80 Master Plan Study, the problem is statewide. Given that I-80 is a significant part of the overall budget, the solution to funding I-80 improvements will surely be at least part of the solution for all of Wyoming.

At the federal level, funding for transportation infrastructure has not grown as quickly as the needs, stemming from escalation of costs, stagnation of fuel tax revenue, population growth, and aging assets. Various state departments of transportation (DOT), specifically in dense population centers, have replaced aging assets and constructed additional capacity to relieve congestion, using creative funding sources and successfully implementing alternative financing mechanisms. In this regard, Wyoming has been fortunate, as its roadway system capacity is generally sufficient for the current population and demand levels. However, interstate commerce and harsh winter weather conditions have caused highways to deteriorate to the point where maintenance costs are significantly outpacing funding levels.

This report expands and updates information provided in the I-80 Tolling Study, which was conducted and presented to WYDOT and the Joint Transportation and Military Affairs Committee in 2009. The prior study was broad in nature, covering virtually all elements of project delivery, with a focus on tolling. This updated report provides additional information regarding a variety of funding approaches that could be applied to I-80 and potentially extended to support WYDOT's statewide budget.

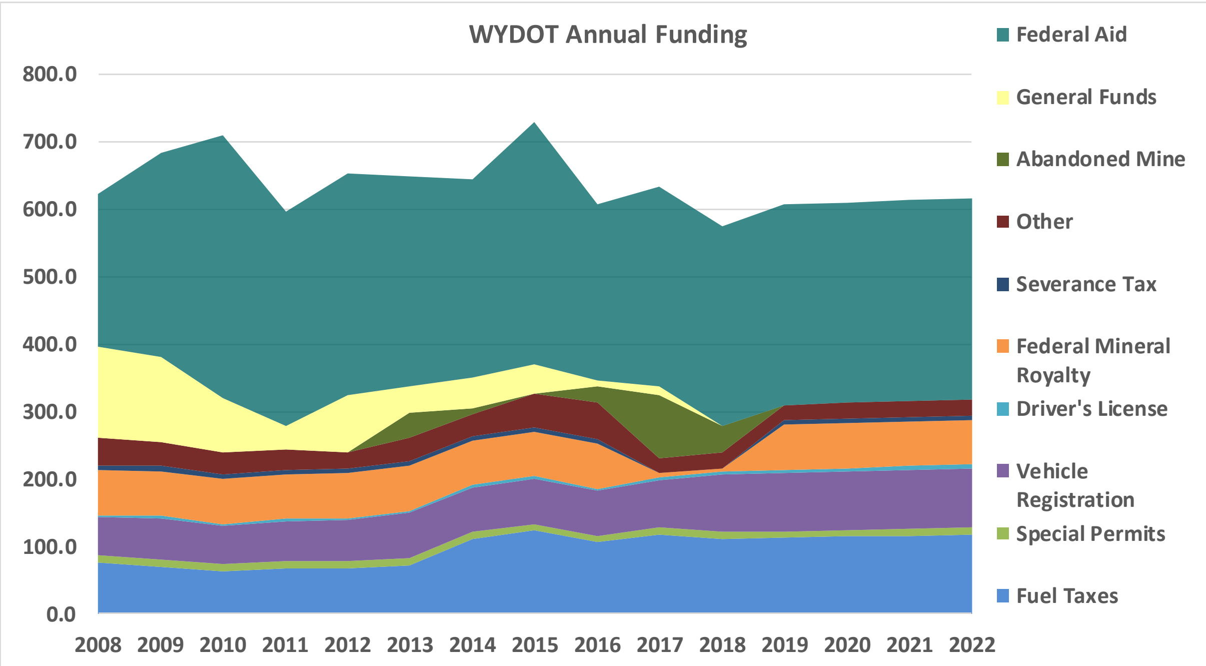
Current WYDOT Funding Sources

WYDOT's current annual funding consists of nine major sources, though about 93 percent of funding typically comes from four sources: fuel taxes (19 percent), vehicle registrations (14 percent), federal mineral royalties (11 percent), and federal funding from the USDOT (49 percent). Figure H-3 shows the size of the various funding sources and how they have fluctuated over the past 10 years. As Figure H-3 shows, federal funding has consistently been the largest source, and that General Fund and Abandoned Mine Lands funding were significant contributors to the overall funding package between 2016 and 2018.

The fuel tax increase passed in 2013 and starting in 2014 increased overall fuel tax revenue from about $72 million in 2013 to $110 million in 2014. Also evident is the vehicle registration fee increase, expected to go into place in 2018, which will increase those revenues from about $68 million to $85 million annually. Notable is that federal mineral royalties and Abandoned Mine Lands revenues alternated in 2017 and 2018, though this did not create a significant impact on WYDOT's overall funding. Each of the four major funding sources is discussed in more detail later in this section.

Figure H-3 also provides a look forward to the expected funding between 2018 and 2022. General Fund and Abandoned Mine Lands funding are not expected to contribute to WYDOT's funding in the future. The overall budget is expected to be just over $600 million annually, though potential changes to federal programs, after the current federal funding authorization expires in 2020, could affect WYDOT's budget.

Figure H-3. Historical and Forecasted WYDOT Funding (2008–2022)



Federal-Aid Formula Funding

As with most state DOTs, the greatest percentage of WYDOT's funding comes from the federal government in the form of federal gas tax revenue. Of WYDOT's total $632 million budget in 2017, about $296 million (47 percent) will come from the federal government.

The current federal authorization for funding to state DOTs—Public Law 114-94, the Fixing America's Surface Transportation Act (FAST Act)—is 5-year legislation (extending through fiscal year [FY] 2020) intended to improve the nation's surface transportation infrastructure, including our roads, bridges, transit systems, and rail transportation network. Each year, Congress reviews appropriation bills to allocate funding for all federal agencies, departments, and programs. This action provides the legal authority for federal agencies to spend money during the upcoming fiscal year on administered programs. The Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) are the main providers of federal transportation funding. These administrations then allocate funding to States based on statutory formulas and to local and state public agencies through competitive discretionary grant programs.

Formula-based funding is by far the largest consistent flow of funds from the federal government. Formulas for highway funding are based primarily on miles of federal-aid roads and population, but several adjustments are made based on historical funding and a variety of other programmatic items. In 2017, Wyoming's apportionments from the overall Federal-Aid Highway Program were about $263.5 million of a total $40.5 billion distributed to the States (less than 1 percent). These apportionments came from the seven programs listed in Table H-1.

Table H-1. Apportionments from the Federal-Aid Highway Program to WYDOT (2017)

Program	Total Dollars (in millions)
National Highway Performance Program	$151.8
Surface Transportation Block Grant Program	75.8
Highway Safety Improvement Program	15.5
Railway-Highway Crossings Program	1.2
Congestion Mitigation and Air Quality Improvement Program	10.5
Metropolitan Planning Program	1.6
National Highway Freight Program	7.1
Total appointment	**263.5**

Source: FHWA Notice 4510.810, Table 1 (https://www.fhwa.dot.gov/legsregs/directives/notices/n4510810/n4510810_t1.cfm)

The remainder of WYDOT's federal funding comes from previous-year carry-overs and discretionary grant program funding. Discretionary grant funding is discussed starting on page H-17 of this document. Discretionary grants are important resources that will be part of WYDOT's funding picture if the programs are in place, and potentially part of a funding package for the I-80 Master Plan Study projects. In total, WYDOT expects total federal funding to continue at about the level received in 2017 ($296 million) through 2020, when the current funding bill expires.

It is possible, however uncertain, that the Trump administration and Congress could change the structure of future federal funding by concentrating available dollars on certain types of projects through the available programs in the FAST Act. The Act will expire midway through President Trump's first term, providing his administration with the opportunity to overhaul the way federal transportation funding is allocated. For instance, the Trump administration could focus on rural projects, those that drive economic growth, or projects that use private-sector investment to leverage federal dollars. It is likely that federal financing programs will be promoted to accelerate projects, particularly revenue-generating projects, thereby allowing private injections of capital to earn returns with less risk.

If federal financing programs are strongly promoted over grant programs, WYDOT might need to reconsider the approach it has taken for many years to avoid issuing debt to pay for transportation infrastructure. Most states have used debt to accelerate projects and many have done so prudently, limiting their exposure to high interest costs and unnecessary risk while promoting job growth and economic expansion. Issuing debt is by no means necessary, but WYDOT should consider all aspects of the infrastructure packages the Trump Administration and Congress present to be sure that WYDOT has all reasonable resources to further its mission of providing a safe, high-quality, and efficient transportation system.

Federal Mineral Royalties

The federal government collects royalties on private mineral production (oil, coal, natural gas, etc.) from federally owned land and distributes about half of these funds back to the states where they were collected. Given that a significant amount of oil, natural gas, and coal production in Wyoming is from federal land, the State receives a healthy annual federal mineral royalty payment from the federal government each year, which it distributes to education funds, local governments, and WYDOT, among others. In fact, Wyoming receives more federal mineral royalties than any other state, and nearly double that of the second-highest recipient (New Mexico).

Table H-2 shows the top eight recipients of federal mineral royalties in FY 2016 and Table 4-3 shows total on-shore disbursements for the past eight federal fiscal years by the federal government and to Wyoming. On average over the past eight years, Wyoming has netted about 49 percent of total U.S. on-shore mineral royalty disbursements.

Table H-2. Federal On-shore Mineral Royalties Received by State (2016)

Top 8 recipients of royalties in 2016

State	2016 Receipts ($ millions)
Wyoming	$664
New Mexico	369
Colorado	84
Utah	68
California	39
North Dakota	33
Montana	23
Alaska	13

Federal mineral royalties are collected based on revenues from natural resource extractions, so they are sensitive to the prices of the primary commodities—oil, natural gas, and coal. The prices of these commodities fell in 2015 and 2016, causing a significant drop in royalties collected and disbursed. As shown in Table H-3, Wyoming received $342 million less in 2016 than in 2014, mainly due to the price of crude oil dropping from over $100 per barrel in 2014 to around $42 per barrel in mid-2016. Natural gas prices also fell significantly in 2016.

Table H-3. Federal On-shore Mineral Royalties Received by Wyoming (2009–2016)

In $ millions

Category	2009	2010	2011	2012	2013	2014	2015	2016
Total U.S. disbursements	1,915	1,783	1,957	2,088	1,964	2,188	1,814	1,316
Wyoming receipts	957	887	972	995	933	1,007	886	664

Current Wyoming law dictates that a set percentage (30.375 percent) of the first $200 million of federal mineral royalties is provided to the State Highway Fund for use by WYDOT. Some additional funding from these royalties is allocated to WYDOT based on bonuses and fringe allocations. For example, between 2007 and 2016, WYDOT consistently received $60.1 million annually, plus an additional $5 million to $6 million in bonuses. Despite the state legislature replacing this source in 2017 and 2018 with Abandoned Mine Land funds, WYDOT expects that it will receive the $66.5 million annually starting again in 2019 and in subsequent years.

Vehicle Registration Fees

Vehicle registration fees are an important component of WYDOT's funding due their stability and reliable growth. People and businesses are required to register their vehicles, and, aside from exceptional years such as 2008 and 2010, registration fee revenue has increased. On average, over the past 10 years, registration fee revenue has increased 2.0 percent annually.

Beginning in FY 2018, registration fees will roughly double from $15 to $30 for motor vehicles and from $12 to $25 for motorcycles. Truck fees will increase based on weight, with fees for heavier trucks and commercial vehicles increasing by about 10 percent. WYDOT expects this fee increase to increase its overall collections by about 25 percent (from $68.2 million in 2017 to just over $85 million in 2018). Even after a doubling of registration fees, Wyoming's fees will be much lower than in many other states. Table H-4 shows the fees in neighboring states.

Table H-4. Vehicle Registration Fees in Neighboring States (2017)

State	Fee	Notes
Colorado	$125	▪ $125 on average for passenger vehicles and light trucks ▪ Registration fees are charged and collected by Counties ▪ An ownership tax, based on value of the vehicle, is charged by the State and ranges from 2.1% of taxable value in the first year to 0.45% after the fifth year (or older)
Idaho	$45–$69	▪ $69 for vehicles 1 or 2 years old ▪ $57 for vehicles 3 to 6 years old ▪ $45 for vehicles 7 or more years old

Table H-4. Vehicle Registration Fees in Neighboring States (2017)

State	Fee	Notes
		▪ Electric vehicles: add $140 per year (neighborhood electric vehicles not included) ▪ Plug-in hybrid vehicles: add $75 per year
Kansas	$30–$40	▪ $30 for vehicles less than 4,500 pounds ▪ $40 for vehicles over 4,500 pounds
Montana	$28–$217	▪ $217 for vehicles 0–4 years old ▪ $87 for vehicles 5–10 years old ▪ $28 for vehicle 11 years old or older
Nebraska	$15	▪ Vehicles less than 14 years old are subject to additional annual motor vehicle tax based on the manufacturer's suggested retail price (MSRP) ▪ Motor vehicle fees range from $25 to $1,900 in the first year, based on MSRP, and decrease as the vehicle ages
Nevada	$33	▪ The State charges an additional governmental service tax based on the value of the vehicle ▪ Some Counties charge a supplemental governmental services tax
North Dakota	$49–$274	▪ $49 to $274 based on weight and number of years the vehicle has been registered
South Dakota	$36–$144	▪ $36 for vehicles 2,000 pounds or less ▪ $72 for vehicles 2,001 to 4,000 pounds ▪ $108 for vehicles 4,001 to 6,000 pounds ▪ $144 for vehicles more than 6,000 pounds
Utah	$43	▪ $43 for vehicles less than 12,000 pounds ▪ Additional uniform age-based fee varies from $10 to $150 depending on age of passenger vehicle
Wyoming	$30	▪ $30 for passenger vehicles ▪ $198 to $1,430 for commercial vehicles, as determined by weight

Source: National Association of State Legislators (http://www.ncsl.org/Portals/1/Documents/transportation/Motor_Vehicle_Registration_Fees_18014.pdf)

Although fees in neighboring states vary significantly based on automobile attributes, Wyoming has one of the lowest registration fees, which does not vary for passenger vehicles. The lowest registration fee among neighboring states is $15 in Nebraska, though vehicles less than 14 years old are subject to an additional annual motor vehicle tax based on the manufacturer's suggested retail price (MSRP). Most other neighboring States levy fees between $30 and $70, with some States levying fees up to several hundred dollars for both new and heavy vehicles. Montana, for example, charges $217 for vehicles that are between 0 and 4 years old at the time of registration.

Motor Fuel Taxes

Motor fuel tax is the largest non-federal source of WYDOT's funding. It consists of three components: gasoline, special fuels (which includes diesel), and sales tax on non-diesel special fuels (propane, butane, natural gas, etc.). The sales tax on special fuels is relatively small, making up less than 1 percent of the total. Taxes on gasoline typically are between 35 and 40 percent of motor fuel tax revenue, while tax on special fuels (primarily diesel) is 60 to 65 percent.

Beginning in FY 2014, the Wyoming motor fuel tax rate increased to 24 cents per gallon for both diesel and gasoline. The change in the tax rate was the first since 1998, and WYDOT expects the increase to generate about $70 million in new tax revenues, of which about two-thirds ($47 million) would go to WYDOT. In the first year of collections, WYDOT's motor fuel receipts increased from $72 million to $109 million, or by about $37 million. The percentage increases in gasoline and special fuels revenue were almost identical (the increase was balanced between automobiles and diesel trucks). However, the associated revenue increases were lower than expected, which is likely due to the overall stagnation in vehicle-miles traveled (VMT).

Table H-5 shows motor fuel tax rates for neighboring states. Wyoming's current rates are lower than in seven of the nine neighboring states. It is also notable that the two states with lower fuel tax rates, Colorado and North Dakota, have much higher vehicle registration fees (Table H-4).

Nationally, there has been much discussion about the sustainability of motor fuel taxes, with federal gas tax receipts falling below expenditures in the Highway Trust Fund for several years. The FAST Act includes $70 billion in transfers from the General Fund of the U.S. Treasury to the Highway Trust Fund. One of the primary factors causing stagnating fuel tax revenue is that motor vehicles are rapidly becoming more fuel-efficient. Since 1991, the fuel efficiency of new passenger vehicles has increased over 28 percent, and that of new light trucks has increased over 23 percent.[1] With new hybrid and electric vehicles quickly gaining market share, and continued improvements in fuel efficiencies for standard vehicle technologies, new passenger vehicles are expected to

Table H-5. Motor Fuel Taxes in Neighboring States (2017)

State	Gasoline Tax Rate ($)	Diesel Tax Rate ($)
Colorado	0.2200	0.2050
Idaho	0.3300	0.3300
Kansas	0.2403	0.2603
Montana	0.3225	0.3250
Nebraska	0.2790	0.2730
Nevada	0.3352	0.2856
North Dakota	0.2300	0.2300
South Dakota	0.3000	0.3000
Utah	0.2941	0.2941
Wyoming	0.2400	0.2400

Source: American Petroleum Institute (http://www.api.org/~/media/Files/Statistics/State-Motor-Fuel-Notes-Summary-July-2017.pdf)
Note: Rates effective July 1, 2017

[1] Bureau of Transportation Statistics, "Table 4-23: Average Fuel Efficiency of U.S. Light-Duty Vehicles," accessed May 31, 2017, https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_23.html.

reach an average of 55.3 miles per gallon and new light trucks of 39 miles per gallon by 2025, per current Corporate Average Fuel Economy (CAFE) standards.[2]

These trends will impact motor fuel tax collections in the future, though the extent to which efficiency will be offset by general population growth and economic activity in the short-term is difficult to judge. In Wyoming, most motor fuel tax receipts are from purchases of special fuels (mainly diesel), and these receipts will be reduced by improvements in the fuel efficiency of heavy trucks (though truck fuel efficiency is not expected to increase as dramatically as that of new passenger vehicles and light trucks between now and 2025). WYDOT estimates that it will receive between $110 million and $118 million in annual combined motor fuel tax revenue between 2018 and 2022, which is within three percent of the average annual collections since the tax rate increase in 2014 ($114.1 million).

Potential New Funding Sources

In addition to the existing funding sources described in Section 4.2 of the *I-80 Corridor Study Master Plan Implementation Report*, other funding mechanisms have been used in other states. The following section describes new potential transportation funding sources for WYDOT's consideration, including new state and local options, discretionary federal grant programs, tolling strategies, and financing programs.

Potential New State and Local Options

Most states allow local government agencies to levy optional taxes or collect fees to pay for priority needs, particularly infrastructure. There is typically a cap to local option tax rates and state-instituted rules about how they can be put in place. However, this flexibility is very helpful in garnering funding for capital programs. Sales, fuel, and property taxes, as well as vehicle registration fees, are common. Table H-6 lists the local option taxes available in neighboring states.

Local option taxes might not raise large sums of money in Wyoming, particularly in areas where the population centers are relatively small. However, stable revenue streams from local option taxes can be applied to financing agreements, creating an obligation of the local government that can be used for infrastructure improvements. Several local governments, such as the five counties through which I-80 passes, could sign an intergovernmental agreement to jointly exercise a local option to generate funding for improvements to I-80. This pooled funding approach could be a way to generate more funding by taxing a larger area with a lower rate.

[2] U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards," *Federal Register*, vol. 77, no. 199 (October 15, 2012): 63027 and 63031, https://www.gpo.gov/fdsys/pkg/FR-2012-10-15/pdf/2012-21972.pdf.

These types of supplemental taxes could also be levied statewide, but raising new taxes or fees statewide to pay for individual infrastructure projects often creates equity challenges. The conventional approach is to link user benefits to the payment source. For instance, a toll road is a direct pay-for-use fee, such that the people who benefit pay the fee. In contrast, a sales tax dedicated to I-80 improvements would not have a direct link, since many people who do not receive a direct benefit would pay the tax. Many sales tax ballot initiatives have a geographically diverse portfolio of projects for which the funds are dedicated, which is intended to spread benefits to a greater population of people in different areas. The option to include multiple priority projects is one of the primary reasons that local options are becoming increasingly popular. For instance, an individual county might issue a sales tax to pay for urban amenities, while another could issue a sales tax to pay for highway infrastructure. The local option provides flexibility for the needs of small areas or specific projects.

Table H-6. Revenue Sources Used by Neighboring States for Roads and Bridges (2016)

State	Local Option Taxes
Colorado	▪ Hotel taxes ▪ Property taxes ▪ Sales taxes ▪ Building permit fees ▪ Vehicle registration fees ▪ Development impact fees
Idaho	No local option taxes for transportation
Kansas	No local option taxes for transportation
Montana	▪ Fuel taxes ▪ Property taxes ▪ Sales taxes ▪ Tax increment financing ▪ Development impact fees
Nebraska	▪ Motor vehicle fees ▪ Property taxes ▪ Sales taxes
Nevada	▪ Fuel taxes ▪ Sales taxes ▪ Hotel taxes ▪ Development impact fees
North Dakota	▪ Fuel taxes ▪ Vehicle registration fees ▪ Property taxes
South Dakota	▪ Sales taxes ▪ Fuel taxes ▪ Wheel taxes ▪ Property taxes
Utah	No local option taxes for transportation
Wyoming	No local option taxes for transportation

Source: AASHTO (http://www.financingtransportation.org/pdf/50_state_review_nov16.pdf)

Wyoming provides cities and counties with the latitude to levy additional sales taxes at the county and city levels for a variety of uses including general funds, specific projects, or contributions toward economic development. Most counties use at least some of the additional taxing authority, which is capped by taxing programs. Other States allow additional types of local option taxes including auto registration fees or property taxes. Regardless of whether these are levied locally or statewide, there is precedent for their use.

The following sections discuss potential new funding sources that Wyoming could consider as statewide initiatives or as local options for use by individual counties. For existing taxes, additional revenue that could be generated from a 5 percent increase in the current tax is discussed below. A common percentage increase is used for ease in making comparisons between options.

Sales Taxes

General Sales Tax. The Wyoming statewide sales tax rate is 4 percent, in addition to some local option sales taxes that vary by jurisdiction. This tax on all goods could be expanded for transportation uses, though equity challenges will need to be addressed if tax revenues are collected for a specific project rather than general WYDOT use across the state. In 2016, Wyoming received about $465 million in sales tax revenue. Given the state rate of 4 percent, this represents a taxable sales base of $11.6 billion. Based on this taxable sales base, a 5 percent tax increase (from 4 percent to 4.2 percent) would generate about $23.2 million in new revenue.

Sales Tax on Fuel. Some states charge sales tax on fuel, allowing them to capture the effects of both positive and negative price changes. In some cases, this tax revenue goes to the same place as other sales tax revenue, while in others it is dedicated to transportation purposes, potentially in the location (district or county) where it was collected. In 2015, revenues from gas and diesel fuel taxes totaled $178 million in Wyoming. Based on the state tax rate of $0.24 per gallon, this revenue represents an estimated 744 million gallons of gasoline and diesel fuel sold. Assuming an average fuel price of $2.50 per gallon, 2015 taxable sales would have been about $1.86 billion. Given this taxable sales amount, a new fuel sales tax of 4 percent would have generated $74.4 million in new revenues that year.

Sales Tax on Transient Goods and Services. Sales or special taxes or fees can be applied to hotel rooms, rental cars, and potentially certain recreational activities. These “transient” taxes and fees are often focused in tourist areas but can also be used more broadly. In Wyoming cities and counties may currently enact a lodging tax, which falls into this category.

In 2016, Wyoming reported $23 million in lodging services revenue. Based on the 4 percent tax rate, this represents $582 million in taxable lodging sales. Applying the same 5 percent tax increase on lodging (from 4 percent to 4.2 percent) would have generated about $1.2 million in new statewide revenues that year, though as noted, some areas already have a local lodging tax. Existing lodging tax rates in Wyoming range from 2 to 4 percent in a small collection of counties and cities.

Sales Tax on Alcohol and Tobacco. Like a transient sales tax, these taxes do not usually generate large amounts of revenue, but they can promote health. Wyoming currently has a 60-cent-per-pack cigarette tax, or 3 cents per cigarette. Other tobacco products are taxed at a 20 percent wholesale tax, and snuff is subject to a 60-cent-per-ounce sales tax. The cigarette tax, at 3 cents per cigarette, generated $19.1 million in revenue in 2015. An increase of 5 percent (from 60 cents to 63 cents per pack) would have brought in an additional $1.0 million that year. A higher tax rate increase than 5 percent maybe achievable, but over the long-term, this revenue stream may decline as tobacco use is discouraged.

Fuel Taxes

Motor fuel taxes make up a major portion of WYDOT's annual funding. Raising the fuel tax rate would certainly generate more revenue because many people have no other option for transportation. However, long-haul truckers might avoid purchasing fuel in Wyoming if the rate is particularly high relative to neighboring states, potentially reducing overall collections. WYDOT's proceeds from motor fuel taxes increased by $37.5 million in the first year after the 10-cent increase went into place, equating to $3.8 million in revenue per penny of tax increase.

Increasing the motor fuel tax in large increments could substantially reduce fuel purchases since consumers tend to be aware of changes in fuel prices, which have a direct effect on household and company purchase decisions. More-frequent and smaller increases, which can be achieved by indexing the gas tax, would likely have a less dramatic effect on people's welfare while maintaining the purchasing power of motor fuel revenues for WYDOT. A few States have linked their gas tax rate to the consumer price index or some other index to establish regular and predictable increases. Obviously, writing automatic future tax rate increases into law is difficult, but regular increases can always be paused in poor economic times while in other times providing stable funding growth every year.

Other states make annual adjustments to their tax rates to account for the DOT's budget the following year. For instance, Virginia has a statutory tax rate floor and has the latitude to change the motor fuels tax rate each year. North Carolina has a statutory formula to establish its gas tax rate each year that takes into account population growth and energy cost inflation. Some States have tried to link taxes to the price of fuel, similar to a sales tax, and have realized above-average tax receipts in high-price years and below-average receipts when the price of fuel falls.

Wide fluctuations in tax revenues would be detrimental to long-term budgeting and should be avoided. However, these tools can help achieve moderate growth in fuel tax revenues. In addition to cost inflation index adjustments, Wyoming needs to consider improvements in vehicle fuel efficiency and overall changes in VMT. Even aligning the gas tax rate to the consumer price index or an energy cost index could lead to declining revenues if overall fuel consumption is declining. Consumption rates and efficiency changes of passenger vehicles and heavy trucks using diesel fuel will also vary, so these classes of vehicles should be treated individually.

Auto and Truck Registration Fees

Revenues from motor vehicle registration fees are relatively stable and the number of vehicles being registered should not change dramatically if the fee is increased. Some households or businesses might reduce the number of cars they have registered, but the roughly $15 increase should not drive decision-making on the matter. The elasticity of the registration fee will be better understood after FY 2018 when the fee increase is in place. Wyoming estimates that registration fee revenue will be about $16.7 million higher in FY 2018 than in previous year due to the fee increase. This would be a 24 percent increase in revenue over the previous year resulting from doubling the fee amount that WYDOT receives.

As shown in Table H-4, some States have variable-fee frameworks based on automobile attributes such as weight and value, though the premises behind these frameworks differ significantly. Weight-based variable fees are structured to address the higher amount of roadway wear that heavier vehicles cause compared to lighter vehicles. The technical basis for this framework is strong, given the many studies showing the increased wear that heavy vehicles, particularly heavy trucks, cause to highways. Value-based variable fees, however, are essentially developed to be progressive fees, under the theory that people with more-expensive vehicles can pay more. While the fairness of this approach can be debated, some states have had great success strengthening their registration fee revenue through this approach, not only increasing fee revenue in the short term but effectively linking fees to price escalation through vehicle prices.

Operator's License Fees

Operator's license fees should in theory be even more stable than registration fees, given that people are unlikely to forgo renewing their licenses due to a fee increase. In FY 2018, Wyoming increased operator's license fees to $40 and $50 for new Class C and commercial driver's licenses, respectively. License renewals were increased to $30 and $40, respectively, in addition to other similar changes to various other types of licenses. Standard licenses must be renewed every four years.

The FHWA reported that Wyoming had 422,450 licensed drivers in 2015, suggesting that raising the fees by $10 would result in about $1.1 million in additional annual revenue (assuming that one-quarter of the licenses expire each year). In addition to increasing fees, Wyoming could consider increasing the frequency of renewals. However, some administrative efficiencies would need to be addressed to ensure that administrative costs do not offset the additional revenues.

Personal Property Tax

In Wyoming, personal property tax is paid on all non-exempt items, though most items not used in a commercial or industrial business are exempt. The collection of personal property taxes is somewhat difficult to track and enforce, and, given the small population in Wyoming, it would most likely not produce a significant amount of revenue. In 2016, Wyoming reported locally assessed values of $281 million in taxable personal property, excluding tax-exempt personal property. Given this assessed value, a property tax rate increase of approximately 5 percent would have generated $91,000 in new revenue that year.

Real Estate Property Tax

Real estate property taxes are not commonly used at the state level for transportation, since they are not linked to a specific facility use or the needs of the people paying the taxes. The ability to use real estate property taxes has been successful in smaller areas where it is easier to make the link between the tax and the benefits of the tax spending. In 2016, Wyoming reported locally assessed values of $8.4 billion in taxable real property, excluding tax-exempt real property. Given this assessed value, 5 percent tax rate increase would have generated $2.7 million in new revenue that year.

Real estate value capture approaches aim to link the beneficiaries of a public infrastructure investment to the project. The tax mechanism is put in place in an area where most taxpayers will reap measurable benefits, thereby creating the link that is missing when the tax is applied over a large area.

Typical value-capture revenue-generating mechanisms include *special assessment districts*, *tax increment financing*, and *developer impact fees*. These mechanisms are all based on the premise that real estate values or development increases because of the infrastructure improvement.

- *Special assessment districts* are designated areas where an additional property tax is collected. In most cases, some majority of the property owners must agree to the additional tax in order to establish the district.
- *Tax increment financing* rests on the assumption that infrastructure improvements spur development and increase land values nearby. Rather than imposing a tax increase, tax increment financing captures a share of the increased tax collections in the area resulting from the increased assessed values.
- *Developer impact fees* are one-time charges imposed on developers when building permits are obtained.

As stated previously, capturing real estate value for infrastructure is most appropriate when a clear link can be made between property owners and the benefits generated from the infrastructure investment. In the case of I-80, some beneficiaries of such an investment live and work along the corridor, but many are from out of state. About 80 percent of the truck trips on I-80 are through trips, meaning they do not originate or terminate within Wyoming. Additionally, the proposed improvements to I-80 are not expected to spur major real estate developments or affect general real estate price trends. For this reason, a local value-capture approach is not appropriate.

On a statewide scale, increasing and dedicating property tax to transportation is a viable mechanism, but these tax collections would need to be allocated to uses across the state so that all residents and businesses could reap the benefits of those investments, not just those along I-80. This tax approach would focus the cost of improvements on residents and business owners in Wyoming, whereas a sales tax would also collect taxes from out-of-state visitors. For this reason, a sales tax would likely be preferable if a broad-based tax approach were put in place for funding transportation.

Cap-and-Trade

California is a leader in greenhouse gas reduction, and, through its cap-and-trade auction program, has generated about $4.5 billion in proceeds since 2012 to invest in projects across the state. The program relies on a statewide, legislatively set cap on emissions of greenhouse gases. The state auctions a certain number of tradable permits to emit greenhouse gasses, equal to the statewide cap, and requires major emitters of greenhouse gases to obtain these permits. Permits are auctioned quarterly, and the proceeds are deposited into a fund used by the state to pay for various projects. The number of permits sold is reduced each year to incentivize businesses to reduce the amount of greenhouse gases they emit (by reducing emissions, they avoid paying for permits that increase in cost each year because of the decreasing quantity).

The cap-and-trade system in California might not be directly transferable to Wyoming, but the concept is proven and could generate revenue while improving environmental conditions if it is thoughtfully constructed. Nationally, electricity generation, transportation, and industry generate over 75 percent of greenhouse gases, and the U.S. Energy Information Administration reported that, as of 2015, about 88 percent of net electricity generation in Wyoming was from coal. Given this statistic alone, a cap-and-trade system could work in Wyoming if the state legislature is willing to put some of the state's financial burden on businesses producing large quantities of greenhouse gases. In California, revenue from the cap-and-trade program is generally used on public projects that are intended to further reduce greenhouse gas emissions.

Mileage-Based User Fees

To account for the decline in MFT revenues due to increasing fuel efficiency, some states are considering charging mileage based user fees (MBUF) based on vehicle miles traveled. Strategies for collecting MBUF vary, and states are studying approaches through pilot programs, ranging from requiring drivers to install a GPS devices which automatically collect and reported a vehicle's distance and location to simply using an annual odometer reading. MBUF systems could be structured to support variable, differentiated pricing schemes where rates could vary based on vehicle type, vehicle weight, emissions, fuel efficiency, and potentially even corroder specific or time of day.

Several states are evaluating the feasibility of MBUF through policy studies and pilots. Oregon successfully completed two road usage charge (RUC) pilots, in 2007 and 2013, which led to the establishment of OReGO, the nation's first legislatively mandated MBUF program. Under OReGO, up to 5,000 volunteer participants are paying 1.5 cents per mile and are receiving credits for any gas taxes paid at the pump. In 2011, Minnesota completed a 500-person, statewide MBUF pilot study which used variable rate, time of day pricing. In March 2017, California completed the California Road Charge Pilot Program, a 9-month pilot where 5,000 vehicles participated in a statewide feasibility study to explore MBUF, reporting VMT, and being assessed a simulated 1.8 cents per mile road charge. Colorado also recently concluded a four month, 100-person MBUF research study and pilot. Other MBUF pilot programs will soon be launched in Washington and Hawaii, and regional pilot studies are being explored through a 14-state western states coalition (RUC West), and the I-95 Corridor Coalition.

In 2016, the federal government, as part of the Fixing America's Surface Transportation (FAST) Act, authorized a five year, $95M Surface Transportation System Funding Alternatives (STSFA) grant program for states or groups of states to explore usage-based transportation funding programs. To date, grants have been awarded to eight states and one consortium of states, totaling $29.7 million.

MBUF programs are not without challenges, many of which are being evaluated through these pilot studies. Technology costs, privacy concerns, data security, administrative costs, equity between rural and urban drivers, driver convenience, and means to maximize MBUF enforcement are all challenges that are being explored by the states conducting pilots. Despite the potential challenges, the collection of mileage-based user fees rather than quantity-based fuel taxes presents a promising option for fair, equitable, and scalable transportation pricing in the long-term.

FAST Act Discretionary Federal Grant Programs

Discretionary grant programs have evolved since gaining popularity a decade ago when the American Recovery and Reinvestment Act of 2009 (ARRA) provided $1.5 billion in funding for the Transportation Investment Generating Economic Recovery (TIGER) program. Since then, TIGER has been funded each year, and other discretionary grant programs have been developed in subsequent federal highway bills. The following four major discretionary grant programs included in the FAST Act are applicable to highways such as I-80.

Transportation Investment Generating Recovery (TIGER)

Congress has appropriated $500 million in FY 2017 discretionary grant funding for transportation projects across the country in the ninth round of the highly competitive TIGER grant program. The purpose of the TIGER grant program is to support innovative projects, including multimodal and multijurisdictional projects that are difficult to fund through traditional federal programs. The FY 2017 TIGER program will give special consideration to projects that emphasize improved access to reliable, safe, and affordable transportation for communities in rural areas, a criterion that could apply to much of I-80. TIGER grant funds have historically been awarded for construction activities, but several rounds have included funds for planning and preliminary engineering.

Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD)

The ATCMTD grant program is administered by the FHWA and is authorized at $60 million each fiscal year from FY 2016 to FY 2020. The program provides grants to highway projects that deploy advanced traveler information systems; management technologies; infrastructure maintenance, monitoring, and condition assessment; advanced public transportation systems; transportation system performance data collection, analysis, and dissemination systems; advanced safety systems; vehicle-to-vehicle and vehicle-to-infrastructure communications; technologies associated with autonomous vehicles; collision-avoidance technologies; intelligent transportation systems (ITS) with the Smart Grid and other energy-distribution and -charging systems; electronic pricing and payment systems; and advanced mobility and access technologies and information systems to support human services for elderly and disabled people.

ATCMTD grant funds are available for both preconstruction and construction activities, though grant recipients are allowed to use only up to 5 percent of the funds awarded each fiscal year to carry out planning and reporting requirements. The core goal of the program is to fund pilot projects. The technology, ITS, and advanced transportation elements resulting from the I-80 Master Plan Study might be suitable candidates for the ATCMTD program. For each fiscal year from 2016 through 2020, a maximum of $60 million, less up to $2 million for DOT administrative expenses, will be available to make 5 to 10 awards not exceeding $12 million each depending on the number of awards and the amount reserved for DOT administrative expenses. In addition, the federal share for the program is 50 percent, requiring grantees to fund half of such projects from non-federal sources.

Surface Transportation System Funding Alternatives (STSFA)

STSFA is a competitive discretionary grant program for states to demonstrate user-based alternative revenue mechanisms that utilize a user fee structure to maintain the long-term solvency of the Highway Trust Fund. The objectives of the program are to test the design, acceptance, and implementation of future user-based alternative funding mechanisms; improve the functionality of the user-based alternative revenue mechanisms; conduct outreach to increase public awareness regarding the need for alternative funding sources for surface transportation programs; and provide information on possible approaches regarding adoption and implementation of user-based alternative revenue mechanisms.

In the FY 2016 STSFA round, eight state DOTs received a total of $14.2 million in grant funds, all relatively small awards. The nature of projects eligible for STSFA grants makes the program more applicable to statewide or regional programs, which might be applicable to the I-80 Master Plan Study projects, particularly if multi-state grant applications are developed. The program requires a pilot initiative and the federal share for the program is 50 percent, requiring grantees to fund half of such projects from non-federal sources.

Infrastructure for Rebuilding America (INFRA)

The USDOT's Nationally Significant Freight and Highway Projects program, named Fostering Advancements in Shipping and Transportation for the Long-term Achievement of National Efficiencies (FASTLANE) during the Obama administration, and now named the Infrastructure for Rebuilding America (INFRA) competitive grant program, could be pursued as a source of federal funds for I-80, given the focus on nationally significant projects that improve freight movement. The program is authorized at $4.5 billion from FY 2016 through FY 2020. The USDOT awarded $759 million to 18 projects in the initial FY 2016 round.

Up to $1.5 billion in FY 2017 and FY 2018 INFRA funds are available for projects and programs that leverage federal funds with private and toll revenues, improve safety, and hold the greatest promise to eliminate freight bottlenecks and improve critical freight movements. Unlike the FHWA Congestion Mitigation and Air Quality Improvement (CMAQ) and USDOT TIGER programs, INFRA grants are somewhat larger, ranging from $5 million to $165 million in the FY 2016 round. INFRA grants can be used to fund up to 60 percent of a project's costs. However, other federal funding may be used to fund project costs up to a maximum federal share of 80 percent. A National Environmental Policy Act (NEPA) analysis does not need to be complete prior to the award, but the project needs to begin construction within 18 months of funding obligation, so an incomplete environmental review could reduce the competitiveness of a project's application.

Tolling Strategies

The I-80 Tolling Study, conducted originally in 2008 and continued in 2009, established that, with enabling legislation and authorization from the FHWA, tolling on I-80 could produce a significant revenue stream. If this revenue stream were accelerated using financing, the bonds could pay for hundreds of millions of dollars in capital improvements after all operations and maintenance costs were accounted for.

The assumptions and inputs to the I-80 Tolling Study were revisited and updated as part of the I-80 Master Plan Study to produce updated revenue projections. These 2017 revenue projections were lower by about 40 percent due to lower assumed traffic projections, higher assumed toll operating costs, and lower-than-previously-assumed truck operating costs that made the option to divert to another route more attractive than staying on I-80 and paying tolls.

The toll revenue analysis was conducted using an economic model that compares the marginal cost of alternative routes with the theoretical tolled cost of taking I-80. It does not consider the many other variables that could affect a trucker's decision to pay a toll or divert to another route, variables including seasonal elements, the type of load the truck is pulling, the trucker's payment terms, company policies, or other considerations. The analysis could be refined by migrating to a set of traditional travel demand models (for freight and auto traffic) and incorporating surveys of truckers' and automobile drivers' tolerances related to paying tolls on I-80.

Toll revenue forecasts were also adjusted to reflect toll rates on similar facilities. The 2009 study increased toll rates until revenues began to drop because of traffic diversion from I-80. This resulted in a theoretical revenue-maximizing toll rate, which obtained the greatest possible revenue from the facility. The identified revenue-maximizing toll rate for I-80 was $130 (in 2008 dollars) to drive the entire route of 400+ miles across Wyoming. This equates to about $160 in 2017 dollars, or 40 cents per mile. In contrast, Table H-7 shows that the toll rates per mile for five-axle trucks on other rural interstate tollways are in the range of 15 to 32 cents per mile.

Table H-7. Comparable Toll Rates for Five-Axle Trucks

Interstate Tollway	Toll Rate per Mile (cents)
Kansas Turnpike	15
Indiana Toll Road	27
NW State Thruway	32
Ohio Turnpike	21
Oklahoma Turnpike	28

Given this information about comparable toll rates, a toll rate of 25 cents per mile for five-axle trucks and 10 percent of this rate (2.5 cents per mile) for passenger cars was assumed. This toll rate would potentially divert between 30 percent and 45 percent of trucks from I-80, depending on the tolling location along the highway. Lower toll rates that would result in much lower diversion rates were also evaluated.

At a toll rate of 25 cents per mile for five-axle trucks, the potential gross revenue is estimated to be $190 million to $223 million annually in 2025, increasing over time with traffic volume and toll rate growth. Annual operating and maintenance costs in 2025, for both toll operations and facility maintenance, are estimated to be about $41 million, leaving $150 million to $182 million for other uses such as pay-as-you-go project funding, reserve funds, or repayment of debt under a toll revenue financing program. A revenue stream of this size could generate over $2.0 billion in funding to pay for capital projects.

If a lower toll rate structure, such as 10 cents per mile for five-axle trucks and 1 cent per mile for passenger cars, were adopted, the revenue potential would still be substantial, but 20 percent or less diversion from I-80 would be expected. Under this toll rate assumption, $60 million to $85 million in annual revenue would be available after paying the $41 million for toll operations and facility maintenance. As much as $1.0 billion in funding for capital projects could be generated with this revenue stream if toll revenue bonds were issued.

The conclusion of the current tolling analysis is that an I-80 tolling program could raise significant revenue if tolling is found to be a palatable solution for Wyoming. Even at toll rates that are much lower than the other tolled interstates listed in Table H-7, tolling on I-80 could raise annual revenues that exceed the revenue currently generated from motor fuel taxes in Wyoming.

Another important finding from the I-80 Master Plan Study is that two FHWA programs would allow tolling on I-80, and neither of these would affect current flows of federal funding to WYDOT. This is a change from 2009 when the I-80 Tolling Study was conducted. Both the

Section 129 Tolling Agreement and the Interstate System Reconstruction and Rehabilitation Pilot Program are suitable fits for I-80, and toll revenues generated under these programs could be used by WYDOT to pay for maintenance or improvements to other federal-aid highways in Wyoming.

Financing Programs

Financing has long been a mechanism for state and local governments to accelerate transportation infrastructure projects. It can help project sponsors realize efficiencies and lower costs from consolidated project delivery, and achieve the user benefits earlier from projects being completed faster. However, financing comes with various costs including interest, the effort to set up financial systems to issue and repay debt, and the uncertainty that funds dedicated to repay debt might be needed for some critical and unforeseen needs in the future. Weighing the benefits and costs of financing can be done in many ways but should be project-specific. In particular, considerations should include the project cost adjusted for delivery risks, the cost of capital, the repayment period, and the benefits realized from early completion, which includes avoiding cost escalation.

One option is to finance capital improvements on I-80 with toll revenues. Assuming a combination of current interest and capital appreciation bonds at rates and debt service coverage ratios in line with today's credit markets for non-recourse toll revenue bonds, between $1.6 billion and $2.1 billion in capital funding could be raised from the forecasted I-80 toll revenues alone. These revenues could also increase if combined with other revenue streams.

The following are some important considerations for Wyoming, given that the State has never issued debt for transportation infrastructure.

- **Revenues Used to Secure Debt Repayment.** The State generates a broad range of revenues from various taxes and fees. These existing revenues, combined with federal funds the State receives and project-based sources such as tolls, could be used to secure debt issued by the State to finance initial capital improvements. The stability and predictability of pledged revenues is a key determinant in the type of credit protections investors will demand, as is the interest rate the State will pay to investors to compensate them for taking on the credit risks associated with the bonds. Bonds secured either with a well-established, broad-based tax source under the State's control or with its full faith and credit would be viewed as the least risky. While there is a long history of federal funding support, this revenue source is not under the State's control and can be subject to changes in federal funding levels and policy. For this reason, it might be considered riskier than the State's full faith and credit or pledge of broad-based, existing taxes. Revenues derived from a project's performance (revenues such as tolls) are riskier, especially for new highway facilities or existing untolled facilities where a user fee would be introduced and traffic diversion would likely occur. Revenue risks for these facilities include:

- The strength of the travel market the facility serves
- Competition from nearby existing or planned untolled facilities
- Dependency on economic growth derived from land development or commercial activities to achieve projected demand
- The ability to design, construct, operate, and maintain the facility within the schedule and cost estimates developed for the project

- **Security Package Offered to Investors.** To mitigate potential revenue risks and secure the highest, most cost-effective credit rating, the State has several options to structure a security package offered to investors.
  - Gross versus New Revenue Pledge: Bonds secured by a pledge of one or more tax sources will typically feature a gross pledge of revenues, which is where the State covenants to pay debt service on its bonds prior to all other obligations. This protects investors from exposure to the State's operations and maintenance obligations and management of its construction program. For bonds secured by user fees or toll revenues, investors will accept a net revenue pledge where debt service is paid after operating expenses and often after contributions to a reserve fund. This ensures that enough revenues are being generated to maintain the facility in a state of good repair to generate the necessary revenues to meet debt service obligations.
  - Debt Service Coverage Ratio: Investors and rating agencies will typically want to see higher coverage ratios for revenue sources subject to volatility, and consequently will accept lower coverage ratios for more-stable revenue sources. Debt service coverage is also a function of the State's funding and financing strategy for its capital plan, where higher coverage ratios indicate a targeted debt program with a strong pay-as-you-go funding component, while lower coverage ratios denote a more highly leveraged capital program focused on the accelerated delivery of projects.
  - Debt Service Reserve Funds and Internal Liquidity: The need for reserve funds is also contingent on the risk profile of pledged revenues. Most gross pledge debt structures featuring reliable and stable revenue sources do not require a debt service reserve fund, which provides internal liquidity in the event of an interruption or severe dip in pledged revenues. User-fee-supported structures typically feature debt service reserve funds to account for potential volatility. Per the requirements governing tax-exempt bonds, debt service reserve funds funded with bond proceeds are set at a level equal to the lesser of 10 percent of gross proceeds, 125 percent of average annual debt service, or maximum annual debt service. In addition to a debt service reserve fund, the State would make covenants with bond holders to maintain a rehabilitation and replacement reserve at a level based on budgeted expenditures and/or the recommendations of a consulting engineer to provide for the state of good repair of the facility. Lastly, a general reserve fund that

receives excess revenues after all debt service and other obligations have been met is available to meet legally permissible purposes, including pay-as-you-go capital projects or early retirement of debt.

> Covenants to Manage Leverage: Typically, bonds will feature covenants to manage the degree of future debt issuance, namely through an additional bonds test, which is calculated based on a minimum debt service coverage ratio, including debt service on the proposed bonds to be issued.

> Rate Covenant: User fee structures will include a security feature whereby fees or tolls are required to be set each year to generate revenues sufficient to meet annual obligations and achieve a minimum debt service coverage ratio.

> Construction Packages: To ensure the on-budget and on-time completion of projects, the State would enter into a design-build contract that establishes specifications for the completion of a project, covers incentives and disincentives, and includes guidance on payment and performance bonds to ensure adherence to the terms of the construction contract. Establishing a comprehensive contract protects the State and bond investors if a contractor defaults. These provisions are particularly important for user fee structures where revenue generation depends on the timely completion of construction.

> Covenants to Operate and Maintain the Project in a State of Good Repair: The State would offer covenants to bond holders that ensure that the project being financed is maintained in a state of good repair, and that the State will take necessary actions to perform periodic inspections and will devote resources and undertake investments based on the recommendations of its consulting engineer. For user fee facilities, this ensures that the project is maintained at a level necessary to generate revenues to meet debt service obligations. For tax-supported debt structures, covenants to maintain a project in a state of good repair provide the State with incentive to continue to meet its debt service obligations.

State governments and project sponsors can pursue a wide array of financing approaches. From a credit standpoint, these approaches range from non-recourse revenue-based debt instruments, which pledge only project-generated revenues, to those backed by the full faith and credit of the State, known as *general obligation bonds*. Most debt issued by government units is tax-exempt, which means that investors do not pay taxes. Therefore, interest rates are considerably lower than corporate debt of the same quality. The following four types of revenue streams and associated bonds are available to Wyoming in structuring debt to help fund the I-80 Master Plan Study projects.

- **General Obligation (GO) Bonds.** As the name suggests, GO bonds are repaid by the issuer using any funding it has at its disposal. Typically, the bond documents state that the issuer pledges its full credit and taxing power to the repayment of the debt, but some funding may be isolated from this broad dedication. For example, previously issued debt or more-senior debt obligations might by law need to be paid before newer, more-junior debt obligations. This "waterfall" of payments can be complex. If GO bonds are issued, Wyoming must establish that the appropriate debt caps and limitations are in place to protect bondholders and the State from unnecessary risk.

Given that Wyoming has issued very little debt, and none for transportation infrastructure, it needs to establish goals for project delivery, develop a framework to conduct debt-related decision-making, and set up monitoring systems to ensure that credit quality expectations of bond holders are met. This is similar to the evaluations related to using public-private partnerships, though arguably simpler and with more-predictable outcomes. WYDOT does not have the power to issue debt, so the Wyoming State Treasurer's Office would likely be the issuing entity on behalf of WYDOT, and should be included in any planning related to debt issuance, credit, or non-traditional project delivery.

- **Dedicated Tax Bonds.** These bonds are secured by one or more taxes to pay debt service. Although these bonds do not benefit from the broad full faith and credit of GO bonds, they are typically considered to have limited credit risk given that the pledge of revenue is derived from one or more dedicated tax sources such as a motor fuel tax, vehicle registration fee, and/or license fee, all of which are considered to be stable and reliable revenue sources. Often, transportation tax sources are constitutionally dedicated to a transportation trust fund, and revenues deposited into the fund are used for transportation and cannot be diverted for any other purpose.
- **Revenue Bonds.** Unlike GO bonds, which pledge all the taxing power of the issuer, revenue bonds typically have a narrow set of repayment sources, potentially only one. This means that they probably carry a higher interest rate due to the lack of revenue diversity, and might have a more complex set of operating requirements or other covenants put in place to improve the credit profile of the revenue stream and reduce the risk to investors. As noted previously, the more revenue risk and the higher the interest rate, the lower the capital funding will be that results from the bond issuance.

  The riskiest revenue bonds are often for greenfield projects, meaning that they have no operating history. These projects' revenue-generating expectations are based on technical studies, with no existing track record. Other revenue bonds with risky revenue profiles are those that rely on strong economic growth, particularly local economic growth. For instance, development impact fee revenue is generated when a builder obtains a permit and pays a fee. If the real estate market changes from healthy to contracting, as occurred nationally in 2008, such a stream can disappear until the real estate market revives. For this reason, a local government seeking to issue debt repaid with development impact fees would need to either provide a GO backstop or pair the impact fee revenues with another revenue stream that is more stable or complementary. This pairing of revenue streams is sometimes referred to as a "double barrel" bond and could be done with any of the state and local tax options.

- **Grant Anticipation Revenue Vehicles (GARVEE).** GARVEEs are debt-financing instruments repaid with future federal-aid highway funds. As of March 2016, 25 States and 3 Territories have issued over $19.1 billion in GARVEEs.

  GARVEE financing is quite simple in structure and is purely used to accelerate projects that would otherwise be paid for incrementally with federal formula funding. With projects in place sooner, costs are lower due to savings associated with reduced exposure to future cost escalation, and the public realizes safety and economic benefits more quickly. Savings from reduced exposure to future cost escalation can be offset by interest costs, but these tradeoffs must be evaluated on a project-by-project basis. GARVEEs can also be paired or can supplement GO or revenue bonds.

  This approach is appropriate for large, long-lived, non-revenue-generating assets. A potential disadvantage of GARVEE financing is a reduction in financial, programmatic, and political flexibility for those years in which debt service consumes a portion of the annual transportation program. Other potential issues include capacity constraints with respect to the availability of contractors, consultants, construction materials, and labor and public agencies, and the possibility of induced inflation in smaller markets as large project delivery demands exceed the supply of qualified people, equipment, and materials to deliver the project.

  GARVEEs are available to States and Territories receiving federal-aid funds. When deployed prudently, they can be very helpful in delivering small projects efficiently without creating major constraints on the DOT's budget. However, unless WYDOT desires to accelerate a major project on I-80, GARVEEs will not change its financial condition, since there are no new revenue sources associated with issuing these bonds. Their issuance would be essentially the same as issuing GO bonds, which might be less expensive, depending on Wyoming's credit ratings relative to the outlook for continued stable flows of federal formula funding to States for highway projects.

- **Federal Government Lending Programs.** Some federal programs extend very low interest rates and favorable repayment terms to state agencies. These have become very popular with project revenue and public-private partnership transactions, but they come with certain strings that "federalize" the project, making it subject to federal rules for environmental approvals, procurement, hiring, and other approvals. Given that I-80 is a federal-aid highway, it is already subject to all federal rules, so the additional constraints that come with federal lending programs do not detract from their appeal.

  The FAST Act established a new National Surface Transportation and Innovative Finance Bureau (the Build America Bureau) within the USDOT to serve as a one-stop shop for state and local governments to receive federal funding, financing, or technical assistance. The Build America Bureau seeks to improve coordination across the USDOT to promote innovative finance mechanisms.

  The Bureau is also tasked with the responsibility to drive efficiency in the permitting process as a dedicated permitting office, in order to reduce the time it takes to break ground on new transportation projects. In addition, the Bureau promotes the best contracting practices and innovative financing and funding opportunities by reducing uncertainty and delays with respect to environmental reviews and permitting.

Administered by the Build America Bureau, the Transportation Infrastructure Finance and Innovation Act (TIFIA) credit program provides financing options (direct loans, loan guarantees, and standby lines of credit) for large projects and public-private partnerships. The key advantage of a TIFIA loan is it allows the borrower to take on subordinate debt at a rate equal to federal treasuries for a term up to 35 years from a project's substantial completion. The FAST Act authorized TIFIA at $285 million for FY 2018 and $300 million for FY 2019 and FY 2020, representing a cut to the TIFIA program from prior levels ($750 million in FY 2013 and $1 billion in FY 2014) that could constrain growth in the program's lending capacity over time.

The major requirements of a TIFIA loan include a capital cost of at least $50 million (or 33.3 percent of a state's annual apportionment of federal-aid funds, whichever is less) or $15 million in the case of ITS, and $10 million for rural projects. TIFIA credit assistance is limited to a maximum of 33 percent of the total eligible project costs, unless the sponsor provides compelling justification for up to 49 percent. Senior debt must be rated investment-grade. The project also must be supported in whole or in part from user charges or other non-federal dedicated funding sources and must be included in the State's transportation plan.

Qualified projects are evaluated by the U.S. Secretary of Transportation against eight statutory criteria including impact to the environment, significance to the national transportation system, and the extent to which a project generates economic benefits, leverages private capital, and promotes innovative technologies. The project's creditworthiness is also evaluated, and credit terms are negotiated between the project sponsor and the Build America Bureau.

Required Legislative Changes

Based on the information in this report, the Joint Transportation, Highways, and Military Affairs Interim Committee will make recommendations regarding how to proceed with implementing the I-80 Master Plan Study. Some of the funding, financing, and contracting elements discussed previously will require changes to state legislation to grant WYDOT or other state entities the power to carry out elements of the Master Plan Study in ways that create the most value for Wyoming. These elements include tolling, entering into public-private partnerships, issuing debt, and deploying some of the other potential new revenue sources described previously.

Tolling Legislation

Current Wyoming statutes do not allow tolling. Tolling is one of many options to help fund the I-80 Master Plan Study projects, but careful consideration is necessary to avoid undue burden on residents and businesses along I-80. States that do allow tolling have developed specific legislation that provides guidelines for how tolling may be applied and the oversight required during project development, implementation, and operation.

Tolling Oversight

Three primary approaches to public toll project oversight (and ownership) would guide any legislation put in place.

Statewide Tolling Organization. If a state government wants to make tolling a broad tool to help fund projects, it could establish authority for the state DOT to promote, evaluate, and develop toll projects as it sees fit. Typically, a group within the DOT acts as a clearinghouse for toll projects, with oversight and approval by the Transportation Commission or another governing body. This group is often established as an enterprise, which is expected to operate like a business—collecting revenues, incurring expenses, and possessing the power to enter into contracts with vendors and issue debt. However, the organization does not need to be an enterprise. In such a case, other state entities, particularly legal and financial entities, would need to handle certain aspects of project evaluation and implementation, which can be demanding and require specialized skill sets and experience.

Another alternative for a statewide tolling organization is an organization outside the DOT, like the Pennsylvania Turnpike Commission or the Oklahoma Turnpike Authority. These operate like enterprises, with powers like those described above. However, these organizations are separate state agencies with governing boards (generally political appointees) separate from those that oversee the DOT.

Regional Tolling Organization. Several states (such as Colorado, Texas, Florida, and California) provide authority to cities and counties to establish local highway authorities that have the power to conduct all operations necessary to plan, finance, build, and operate a toll road. For instance, a group of counties could form a public highway authority under state statute to address a local deficiency in the roadway network. These authorities often have the power to levy and collect other taxes and fees for transportation purposes, subject to appropriate voter referendums. For instance, the E-470 Public Highway Authority in Colorado administers a major toll facility, but it also collects a special $10 vehicle registration fee from certain jurisdictions in its service area. This registration fee was critical to successful financing in the early years of the roadway, before toll revenues grew to be large enough to repay the authority's debt.

Regional tolling authorities are typically formed to address local congestion issues. One of the major benefits is that local elected officials control the authority through their board appointees. This can provide a level of comfort to residents and businesses that their interests are prioritized, but does not automatically solve toll opposition issues. While this approach could be viable for the five counties that I-80 passes through, the I-80 Master Plan Study does not address local congestion issues. A regional approach might also add unnecessary hurdles to project development and implementation that could be streamlined through centralized planning within WYDOT.

Single Facility Tolling Authorization. Some states, particularly those that are new to tolling, have written tolling authorizations for specific facilities. This would be an approach similar to a statewide tolling organization but would be restricted to certain projects or corridors, like those put forward in the I-80 Master Plan Study. The main advantage to this approach is that it provides comfort to lawmakers who want to test a concept before opening it up for broad use. The legislation is typically structured to require the DOT to study the feasibility of an improvement project concept, which would be evaluated and approved by the Transportation Commission or another oversight board. Other constraints can be incorporated into the authorization, including a timeframe to implement the project, thresholds that the financial plan must meet, or requirements that certain benefits be achieved.

The three general organizational approaches discussed above inform the structure of decision-making and potential scope of the tolling authorization. Once a general approach is agreed on, the components of the legislation should authorize the tolling entity to finance, construct, operate, regulate, and maintain the toll facility as well as collect tolls and enforce the payment of tolls.

The legislation establishing tolling in Wyoming will define the primary characteristics of the tolling entity, including the following:

- Organizational structure—Where will the tolling entity be positioned in the hierarchy of state and local agencies or within the DOT? Will any other agency have direct or indirect authority over the tolling entity, and what board will provide approvals and oversight?
- What will be the specified powers of the tolling entity:
  - Issuing bonds to finance projects or to support regular operations?
  - Building, acquiring, operating, and/or maintaining the facility?
  - Entering into contracts, including intergovernmental agreements, with public and private organizations?
  - Setting toll rates, collecting tolls, and regulating the facility?
  - Establishing the legal framework for a civil penalty process to pursue unpaid toll bills and penalize scofflaw behavior?
  - Obtaining and disposing of real property by purchase or other means?
  - Charging fees for the use of owned or leased property?
  - Transferring or receiving money from the State or the DOT?
  - Hiring consulting and engineering services as needed?

  - Reporting to the DOT, the Transportation Commission, or another oversight board regarding regular and project specific operations?

- Procurement—Will the tolling entity be subject to state procurement code, or will a separate set of regulations govern procurement, including the use of design-build or other contracting mechanisms?
- Planning Compliance—What entities will have approval over the projects that can be undertaken?
- Flow of Funds—Where will toll revenue collections, citations, and other revenues be deposited, and how will they be made available for debt services payment, operations, and maintenance? This should be a special fund where the State can deposit funding if needed, but only certain expenses, such as those of the tolling entity and debt service, can be paid from this fund.
- Safety—Will enforcement be provided by state and/or local law enforcement? Will the entity be required to make separate contractual arrangements for law enforcement and emergency services?
- Toll Evasion—Will the tolling entity be able to use electronic enforcement and/or video tolling? How will toll evasion penalties be set? Will local courts have jurisdiction to try cases? Will the revenue from citations be kept by the tolling entity?
- Interoperability—Will transponder interoperability with other toll facilities in the state or neighboring states be required?
- Concessions—Does the tolling entity have the right to lease the facility to a private entity and enter into concession agreements to allow it to collect tolls and otherwise operate and maintain the facility?

Examples of tolling legislation from other states appended to this report include:

- Colorado Statewide Tolling Enterprise
- Colorado Public Highway Authority Act
- Washington State Toll Bridges, Tunnels, and Ferries
- Texas Transportation Code: State Highway Toll Projects (chapter 228)
- Texas Transportation Code: Regional Mobility Authorities (chapter 370)

Design-Build Legislation

Design-build is a widely used project delivery approach in which designing and constructing a project is combined into one contract. The most common alternative, design-bid-build, involves the project owner (in this case, WYDOT) designing the project to 100 percent completion, then selecting the lowest bid for construction under separate contracts.

The major difference between the two delivery methods is that, with design-bid-build, WYDOT receives a bid for building what is in the design plan, so WYDOT is responsible for delays and the costs of construction change orders related to design issues or unforeseen site conditions. With design-build, the contractor is paid a fixed fee and takes responsibility for the design and potential site issues, so it is responsible for any design and site-related costs that arise. Transferring these risks to the contractor can create significant benefits for the project owner in the form of price and schedule certainty.

A second significant advantage of using design-build delivery is design innovation. With design-bid-build, one team works with WYDOT to create a design that fits the DOT's needs and is reasonably cost-efficient. Then contractors bid on that design based largely on management and unit prices. With design-build, several competing teams are challenged with finding ways to save costs through design innovation. This competitive framework drives bids lower and can results in savings for the owner.

Wyoming statutes [Title 16, Article 7: Construction Contracts with Public Entities (16-6-701)] establish the parameters for state agencies to use design-build project delivery for public buildings, but design-build is not available for WYDOT to use on highway projects. The content and structure of 16-6-701 is comparable to other States' design-build statutes for highways and could easily be adapted for this use by adding highways to the list of eligible projects.

The more significant undertaking is the organizational, technical, financial, and legal changes that would need to take place to begin using design-build delivery within WYDOT. Organizationally, the project development and approval process would likely change and potentially require new skill sets, since WYDOT would need to be more focused on risk and performance analysis to ensure that what it asks for in the request for proposal is what WYDOT actually wants in a finished product. The procurement process and evaluation is also very different, as it is generally based on more than just the low bid. From a technical standpoint, teams might propose design solutions that are outside of what WYDOT typically uses, so supplemental expertise to evaluate alternative technical concepts might be required.

Using a basic design-build delivery might not create material financial implications for WYDOT, but WYDOT will need to analyze the various design approaches' impacts on its maintenance and operations costs. Often, design-build is accompanied by long-term operating contracts, tolling, or payment terms that are extended. Adding this financing component would require specialized expertise to compare the costs of various delivery mechanisms and clearly understand the return on investment.

Legal expertise is critical to ensure that the technical and financial elements of design-build are effectively captured in the contract so that risk is transferred to the contractor. Design-build contracts are more complex because they include elements of payment for performance, and a properly written contract will protect WYDOT from unforeseen issues that arise from the construction project.

Finally, and most importantly, giving WYDOT design-build contracting authority will require outreach to Wyoming's contractor community. Many businesses that employ thousands of people across the state have worked on WYDOT construction projects for decades. These firms have thrived in the Wyoming market because the project pipeline has been somewhat consistent and the project sizes have been relatively small. Using design-build contracting could attract competitors from outside Wyoming who have more experience and would put many local contractors at a disadvantage.

If WYDOT were to begin using design-build contracting, it should hold a series of educational worships for contractors to learn about the process, the financial and legal elements, and WYDOT's expectations so that they are more equipped to respond. Piloting or phasing the design-build contracting tools into place with small projects might also help companies adapt. Most large construction firms who do design-build projects around the country are not interested in small jobs (less than $100 million, though every firm has its own investment criteria). Keeping the contract sizes small, at least at first, will also help reduce out-oH-state competition and give local contractors an opportunity to get some experience and become competitive.

As contract sizes increase, there are other ways to keep the local contractor community engaged. The concept of a "filed sub-bid" is one approach, where small components of a larger project are bid separately (in advance) using a traditional design-bid-build approach. The winners of those contracts are kept "on file," and their contracts are required to be included with the proposal of every bidder on the larger design-build procurement. In this regard, WYDOT would be selecting required sub-contractors for all design-build teams at a set price. This might dilute the value of using design-build in the first place, but it is one approach to helping local contractors learn about design-build and get the experience they need to compete on subsequent procurements.

Operations and Maintenance Contracts

Public-private partnerships are usually talked about in terms of a design-build contract that includes some form of long-term operations or maintenance component, and potentially financing. While these structures are becoming more common across the United States, the construction component does not have to be the main feature of the contract. Risk could be transferred using a simple maintenance contract that sets out terms for a private company to perform any or all services required to keep I-80 operating in safe condition. For example, pavement maintenance, rest stop operation, snow removal, emergency and courtesy service, mowing, information dissemination, guardrail and sign replacement, and other functions are all services that could be written into a performance-based contract that transfers cost risk and ensures a specific level of quality.

Performance-based contracts contain terms whereby the private entity must fulfil technical provisions in order for individual items to be paid. Technical provisions can include things such as general pavement smoothness, timely filling of potholes, number of hours when travel lanes are closed for repairs, visibility of signs, light fixtures being maintained in working order, grass being mowed to a certain height, debris and snow being moved from the road in a timely manner, or timely response to disabled vehicles. Specific metrics are assigned to each category of technical provisions, and, if each metric is met, the contractor receives the maximum payment. If, for instance, 3 of 10 metrics are not met, the contractor might receive only 70 percent of its specified payment that month.

Performance-based contracting is also a critical consideration for toll operations. Depending on the contracting structure and vendor agreements, a bifurcated structure could result in a toll equipment systems vendor, a back-office systems vendor, and a back-office operations vendor. Each vendor would have specific performance-based contracts based on the scope of the work it is responsible for. Often there will be performance guidelines that cover transaction processing rates, video image quality, timing for processing and sending toll bills, call processing volumes and call response times at the customer service center, overall staffing levels, and performance reports that are audited daily, weekly, monthly, or annually. A limited number of state agencies have fully taken on responsibility for maintaining toll equipment and operating a customer service center, with most opting to contract out the various services.

Contracting out services is often a more cost-effective way to run toll operations without taking on the significant risk of processing and handling thousands of account transactions daily. This is particularly true for WYDOT, which is not currently equipped with the organizational infrastructure to undertake toll collection, enforcement, and back-office functions. However, the cost of procurement is significant, and toll equipment vendors are often procured on a 10-year cycle, with operations vendors procured on 3- to 10-year cycles, depending on the agency and contract extension options. A full procurement cycle with developing the request for proposal, implementing software systems, testing, and transitioning operations control to the vendor can run upward of $20 million for an established agency.

The FHWA Center for Innovative Finance Support recognizes the National Conference of State Legislators' (NCSL) May 2015 report *Public-Private Partnerships for Transportation: A Toolkit for Legislators* as an authoritative document containing references to the statutes of the 35 states allowing some form of public-private partnerships (P3). A related report by the NCSL published in 2016, *Public-Private Partnerships for Transportation: Categorization and Analysis of State Statutes*, analyzes the key elements of state P3 statutes. Some of the key policy elements are listed below.

- What entities are allowed to enter into P3 agreements, and what projects are authorized?
- Are certain elements of P3 agreements are allowed, such as design-build, private financing, operation and maintenance contracts, etc.? What is the maximum P3 term?

- Is tolling allowed in a P3 agreement? Can existing roads be converted to toll roads? Are high-occupancy/toll (HOT) lanes allowed as part of P3 agreements? Are non-compete provisions allowed for tolled facilities? How are toll rates set, and who has authority to change rates?
- What level of approval is required (legislative, another state or federal agency, a P3 advisory board, some other stakeholder board)?
- Do P3 projects have to be consistent with approved regional or state transportation plans? How are projects evaluated and nominated for consideration as P3s?
- Are both solicited and unsolicited proposals allowed? If unsolicited proposals are allowed, are competing proposals required?
- What are the possible procurement structures? What is are the process and criteria for evaluating proposals?
- How is confidentiality of proprietary information in proposals handled?
- Are unsuccessful proposers paid a stipend?
- What level of public notice or involvement is required?
- What type of financing is allowed? Who may issue debt, and what types of debt are allowed? What types of revenues are allowed to be included in P3 financing (for instance, property or other taxes and fees)?
- What may revenues from P3 projects be used for?
- Are P3 assets exempt from property or possessory interest taxes?
- How are defaults or bankruptcies handled?

Alternative project delivery (P3, broadly speaking) represents a valuable set of financing and delivery tools that can be used in a variety of ways. States that allow broad use of these tools with appropriate oversight give themselves the flexibility to explore avenues to deliver projects faster, with less public-sector-risk exposure, and potentially at a lower cost.

The keys to success in applying these contracting methods are to (1) understand the goals of using alternative delivery mechanisms, (2) understand what tools will help WYDOT achieve the goals, and (3) deploy the appropriate resources to evaluate the P3 approach for a given project to quantify the value of one delivery method over the another. This is known as a P3 Screening Framework. Developing and adopting a framework customized for Wyoming will be an important first step if P3 legislation is passed. The framework should reflect the mission and goals of the State as well as the organizational structure that will oversee P3 project development and implementation.

Autonomous and Connected Vehicle Legislation and Policy Changes

Autonomous vehicles are being driven by private industry and are quickly moving into the market. According to the National Council on State Legislatures, "twenty-one states—Alabama, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Illinois, Louisiana, Michigan, New York, Nevada, North Carolina, North Dakota, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Virginia and Vermont—and Washington D.C. have passed legislation related to autonomous vehicles." Further, "Governors in Arizona, Delaware, Massachusetts, Washington and Wisconsin issued executive orders related to autonomous vehicles." Much of this legislation involves requirements on the performance expectations and testing needed for an autonomous vehicle manufacturer to operate vehicles on public roads in the respective State. However, some states, such as Michigan, have essentially created an "open door" policy for autonomous vehicle manufacturers.

The legislative and policy landscape for autonomous vehicles is changing and potentially changing rapidly. In September of 2017, the National Highway Traffic Safety Administration (NHTSA) issues their second version of guidelines related to highly autonomous vehicles titled "Automated Driving Systems (ADS): A Vision for Safety 2.0." This guidance document sets forth NHTSA's interpretation on roles and responsibilities between Federal and State agencies as well as defines terms and conditions associated with performance characteristics of highly-autonomous vehicles including defining the "Operational Design Domain," the "Object and Event Detection" and "Fallback position." Additionally, the guidelines set forth a 12 safety priority elements and a voluntary selH-assessment for manufacturers. In this guidance document, NHTSA suggests Best Practices for States Regulatory Actions as well as a division of responsibilities between the Federal and State governments (Figure H-4).

Following the issuance of the NHTSA guidelines, the US House of Representatives passed the SELF DRIVE Act, a version of which was also subsequently passed out of the Senate Committee on Commerce, Science, and Transportation. The Senate bill has yet to undergo full vote in the Senate, but is expected to garner bi-partisan support. President Trump has further indicated his willingness to sign such a bill should it be presented following Senate vote and resolution with the House Bill. The SELF DRIVE Act would significantly change the legislative environment for States regarding highly autonomous vehicles. In particular, this act:

- **Establishes a timeline for Federal Regulatory Action:** "Not later than 24 months after the date of the enactment, the Secretary of Transportation shall issue a final rule requiring the submission of safety assessment certifications regarding how safety is being addressed by each entity developing a highly automated vehicle or an automated driving system."

Figure H-4. NHTSA Guidelines 2.0 Recommended Division of Responsibilities between State and Federal Agencies

NHTSA'S RESPONSIBILITIES	STATES' RESPONSIBILITIES
• Setting Federal Motor Vehicle Safety Standards (FMVSSs) for new motor vehicles and motor vehicle equipment (with which manufacturers must certify compliance before they sell their vehicles)[33] • Enforcing compliance with FMVSSs • Investigating and managing the recall and remedy of noncompliances and safety-related motor vehicle defects nationwide • Communicating with and educating the public about motor vehicle safety issues	• Licensing human drivers and registering motor vehicles in their jurisdictions • Enacting and enforcing traffic laws and regulations • Conducting safety inspections, where States choose to do so • Regulating motor vehicle insurance and liability

- **Preempts State's Regulations.** "No State or political subdivision of a State may maintain, enforce, prescribe, or continue in effect any law or regulation regarding the design, construction, or performance of highly automated vehicles, automated driving systems, or components of automated driving systems unless such law or regulation is identical to a standard prescribed under this chapter."
- **Provides Exemptions for Manufacturers.** "LIMITATION ON NUMBER OF VEHICLES EXEMPTED.—All exemptions granted to a manufacturer under subsections (b)(3)(B)(i) through (v) shall not exceed a total of (i) 25,000 vehicles manufactured within the first 12-month period, (ii) 50,000 vehicles manufactured within the second 12-month period, (iii) 100,000 vehicles manufactured within the third 12-month period, and, (iv) 100,000 vehicles manufactured within the fourth 12-month period."

Notwithstanding the assuming that some version of the SELF DRIVE Act will be passed by the Senate and confirmed into law in 2017/2018, there are still a number of potential legislative and regulatory actions that States such as Wyoming should consider. There are several topic areas and considerations that HDR recommends the WYDOT and the Wyoming legislature consider including:

- **Providing a technology "neutral" environment.** The WYDOT legislature should consider examining the existing laws and regulations for antiquated conditions that would prohibit the adoption of highly autonomous vehicles and remove these potential barriers. For example, some states have previously had a regulation on motor vehicle operation that included a provision that the operator “must have at least one hand on the wheel at all times.” Such a provision could be an impediment to adoption of highly automated vehicles.

- **Provide licensing and registration procedures for Highly Automated Vehicles.** If vehicles are becoming “drivers,” there will need to be updated policy and procedures for licensing and registration of these vehicles. In particular, Wyoming and other states will have to consider the technological components, software versions, sensors, and selH-driving algorithms as part of registration and licensing. For example, changing the software versions or sensor package of a vehicle could be considered to be the equivalent of changing drivers in today’s environment.
- **Review traffic laws and regulations that may serve as a barrier to HAVs.** Similar to providing a technology neutral environment, there may be existing traffic laws and regulations that would serve as a barrier to adoption of HAVs. For example, a “no-texting” law that specifies that the person sitting in the driver’s position in the vehicle must use a “hands-free” device might need to be modified to include situations where the vehicle is serving as the driver.
- **Establish Administrative Oversight**. HDR would recommend that WYDOT and associated agencies develop a process and procedure for providing administrative oversight for highly autonomous vehicles to ensure the ongoing safety of these vehicles as part of the licensing and registration process. Again, current systems are designed to track vehicles by VIN number rather than individual components and systems within the vehicle, which may need to change.
- **Notification and Permission for Testing Process.** Although the SELF DRIVE Act would prohibit Wyoming from barring adoption of highly autonomous vehicles based upon performance or to require State specific testing procedures. WYDOT and the Wyoming legislature may wish to consider requiring manufacturers to notify WYDOT when new autonomous vehicles and/or autonomous vehicle systems are being tested within the State. Additionally, requirements restricting the Operational Design Domains for testing and operation of highly autonomous vehicles could be defined by the State to exclude or promote the use of highly autonomous vehicles in certain geographic or roadway types.
- **Liability and Insurance Requirements for HAVs.** State legislatures will be responsible for establishing liability and insurance requirements for highly autonomous vehicles. The requirements may differ significantly from those of manually operated vehicles.
- **Changes to Registration and Titling.** With the ready availability of after-market components for vehicles, it would be possible for an owner to significantly upgrade or downgrade their vehicle’s capability to operate as a highly autonomous vehicle simply by the addition or remove of sensor packages, software/firmware updates, etc. WYDOT and the Wyoming

legislature could consider legislation and/or policy regarding the timing or frequency of the registration and titling processes. For example, one consideration might be to require registration to include make, model, production year as well as the software/firmware versions of the autonomous driving components of the vehicle. A second consideration would be to require vehicles to re-register each time the autonomous vehicle components are changed.

Ultimately, should the SELF DRIVE Act not become law, the Wyoming legislature should consider establishing testing and performance requirements for highly autonomous vehicles in Wyoming. Even if it does become law, there are still a number of different topic areas that will need to be addressed as referenced above.

FUNDING AND LEGISLATIVE CONCLUSIONS AND RECOMMENDATIONS

The goal of this report with regard to funding, financing, and legislative enhancements, is to provide the Wyoming legislature with current and complete information regarding I-80's needs and potential avenues to address those needs. However, there is a funding dilemma in Wyoming that extends beyond I-80 to WYDOT as a whole.

In recent years, motor fuel tax rates and fees were increased, but, as this occurred, other sources of funding for WYDOT were shifted away for use in other parts of state government. Though there are many important components of state government and related funding priorities, WYDOT's construction costs have escalated and its revenues are falling behind the needs. This department-wide issue is reflected in I-80, which requires substantial funding for maintenance, leaving little or no funding for capital projects. At some point, the current conditions on I-80 will deteriorate due to lack of funding, and the facility will need to be replaced at a much higher cost. Now is the time to put new funding instruments in place and give WYDOT the tools it needs to continue providing quality and safe transportation facilities.

Several viable funding sources have been presented in this report—some that are currently in use and others that require new legislation. There is no "silver bullet" approach to fixing the problem, since very few funding approaches are perfectly equitable to all users of the transportation system. A strategically designed portfolio of new funding sources could spread the burden and allow constituent groups to pay their fair share.

For instance, transient occupancy taxes are focused on visitors and vacationers staying in hotels statewide. Registration fees are focused on in-state users of the roadway system but are also statewide in nature. Tolls are focused on the users of a specific facility. Business-oriented taxes such as payroll taxes or cap-and-trade approaches are focused on businesses but without a real connection to the transportation system. Whatever funding approaches are selected, champions are needed to help constituents, stakeholders, and other elected officials understand the dire nature of the funding issue on I-80 and within WYDOT as a whole, and to help garner support for legislation that will give WYDOT the funding and tools it needs to plan and undertake the projects in this I-80 Master Plan Study and beyond.