



## Memorandum

**To:** Steve Gramm, P.E, Planning Squad Leader  
South Dakota Department of Transportation

**From:** Matt Flanagan, Engineer

**Date:** February 23, 2023

**Subject:** SD 73 Reconstruction – Improving Mobility, Safety, and Access to the Pine Ridge Reservation (White River to Kadoka) – 2023 RAISE Grant Application Benefit-Cost Analysis Memorandum

### Introduction

This memorandum summarizes the assumptions, methodology and results developed for the benefit-cost analysis of the No Build and Build Alternatives as part of the SD 73 Reconstruction – Improving Mobility, Safety, and Access to the Pine Ridge Reservation (White River to Kadoka). The objective of a benefit-cost analysis (BCA) is to bring all the direct effects of a transportation investment into a common measure (dollars), and to account for the fact that benefits accrue over an extended period while costs are incurred primarily in the initial years. The primary elements that can be monetized are travel time, changes in vehicle operating costs, vehicle crashes, environmental impacts, capital costs and remaining capital value, and maintenance costs. The benefit-cost analysis can provide an indication of the economic desirability of an alternative, but decision-makers must weigh the results against other considerations, effects, and impacts of the project.

### Project Overview

The South Dakota Department of Transportation (SDDOT) is requesting \$25,000,000 of 2023 Rebuilding American Infrastructure with Sustainability and Equity (RAISE) Grant funding. The requested dollars will cover the construction of three separate project IDs for rural projects in an area of persistent poverty, and on a federally recognized reservation. The project is primarily located along an 8.7-mile stretch of SD 73 roadway from 254th St. (County Highway 79) just south of the White River to the I-90 eastbound entrance ramp in Kadoka. A smaller, 0.87-mile portion of the project lies along SD 248 from SD 73 to 13th Avenue in Kadoka. SDDOT has prioritized this project as its highest 2023 RAISE priority project. Refer to Figure 1 below a project location map.

Figure 1. Project Location Map



SD 73 extends 256 miles north-south across the entire state of South Dakota, connecting with North Dakota Highway 49 to the north and Nebraska Highway 61 to the south. The highway is the primary route for both freight and for tourists within the region. SD 73 is of critical importance to the State of South Dakota because it is a National Highway System Non-Interstate Route (NHSNI) and is on the SD Preferential Truck Route Network.

## Description of Alternatives

For the purpose of this analysis, a No Build and Build Alternative were both under consideration.

### No Build Alternative

The No Build Alternative includes leaving the SD 73 and SD 248 corridors in the current geometric and operational state. Inadequate lighting would persist along SD 248. Intensified maintenance activities that were recently incurred to keep assets along SD 73 operational are expected to continue until it is no longer feasible to keep this segment of SD 73 open to the public. The pavement along a 4.6 mile stretch of SD 73 in the project area is anticipated to reach the South Dakota State's surface

condition index score of zero in year 2037<sup>1</sup>. Pavement at an index score of zero is deemed unsafe to carry traffic of any type. The No Build analysis assumes closure along SD 73 in year 2037.

This analysis identified and monetized the impacts of six total diversion routes associated with the closure of SD 73. Diversion routes were determined through coordination with SDDOT Staff<sup>2</sup>. The routes for cars and heavy vehicles are different, though the intended origin-destination relationship between the two are the same because inadequate facilities cannot safely carry truck traffic. Diversion routes through the Badlands National Park are discouraged by SDDOT unless users are intentionally traveling to the National Park.

Assumed traffic patterns are based on the existing AADT data obtained from the SDDOT Interactive Data Needs Book<sup>3</sup>. Traffic along the project segment of SD 73 is assumed to be traveling in directions noted below<sup>4</sup>:

- 50% travel Northwest/Southeast (Rapid City - SD 73/US 18 Intersection and vice versa)
- 40% travel Northeast/Southwest Diversion (Murdo - SD 73/US 18 Intersection and vice versa)
- 10% travel North/South (Kadoka - SD 73/US 18 Intersection and vice versa)

Due to the rural nature of this portion of SD 73, few alternative regional routes are available that can safely carry traffic. If SD 73 is not improved and unusable, several traffic diversions are required. A map and additional details on diversion routes and assumptions are provided in the BCA Workbook and are shown in Attachment B – “Existing Traffic Routes and Traffic Diversion Routes Due to Closure of SD 73”. Assumed traffic diversions due to the closure of SD 73 in 2037 are described below<sup>5</sup>:

#### Truck Diversion Routes:

- Route #2: Northwest/Southeast Diversion (50% of Traffic)
  - Rapid City - SD 73/US 18 Intersection
  - US 18, SD 79, SD 44
  - 157 total miles, 142 minutes
- Route #4: Northeast/Southwest Diversion (40% of Traffic)
  - Murdo - SD 73/US 18 Intersection
  - US 18 and US 83
  - 87 total miles, 78 minutes
- Route #6: North/South Diversion (10% of Traffic)
  - Kadoka - SD 73/US 18 Intersection
  - US 18, US 83, and I-90
  - 136 total miles, 116 minutes

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<sup>1</sup> Assumed year of closure SD 73 due to pavement failure in year 2037 was obtained through coordination with SDDOT’s Pavement Management Team.

<sup>2</sup> Assumed traffic diversion routes due to pavement failure along SD 73 obtained through coordination with SDDOT Staff.

<sup>3</sup> SDDOT Data Needs Book: <https://apps.sd.gov/hr53needsbook/>

<sup>4</sup> The BCA Workbook allows reviewers to conduct sensitivity analysis using a different percentage of users and vehicle types along existing routes and diversion routes associated with closure of SD 73.

<sup>5</sup> Route ID# Numbers are referenced frequently in the Attachment A – BCA Workbook.

#### Car Diversion Routes:

- Route #8: Northwest/Southeast Diversion (50% of Traffic)
  - Rapid City - SD 73/US 18 Intersection
  - SD 44
  - 108 total miles, 99 minutes
- Route #10: Northeast/Southwest Diversion (40% of Traffic)
  - Murdo - SD 73/US 18 Intersection
  - SD 44 and US 83
  - 63 total miles, 57 minutes
- Route #12: North/Southbound Diversion (10% of Traffic)
  - Kadoka - SD 73/US 18 Intersection
  - SD 73, US 83, and I-90
  - 112 total miles, 95 minutes

#### **Build Alternative**

The Build Alternative consists of reconstructing SD 73 to current SDDOT standards and installing lighting on SD 248. Specific design elements considered in BCA are as follows:

- Reconstructs 8.7 miles of SD 73 roadway to new condition
- Expands and paves roadway shoulders from two feet to six feet and installs edge-line rumble strips along 8.7 miles of SD 73
- Installs lighting on 0.87 miles of SD 248

The project will be constructed in two phases in 2024 and 2025 under three project IDs. The two phases will be considered one project with different letting dates and are described below:

- Phase One of the project involves the reconstruction of 8.7 miles of SD 73 from 254<sup>th</sup> Street (County Highway 79) south of the White River to the I-90 eastbound entrance ramp in Kadoka (PCN 05HV). Specifically, the shoulder widening along SD 73 and installation of lighting along nearly 0.87 miles of SD 248 (PCN 08EH) components are also included in this analysis.
- Phase Two of the project will be a follow-up asphalt concrete (AC) surfacing project, completing surfacing for the entire 8.7-mile project area on SD 73 (PCN 05U4) and includes the installation and grinding of edge-rumble strips.

Throughout the duration of construction of Phase One and Phase Two, SD 73 and SD 248 will remain open to all traffic and posted speed limits maintained. Local traffic and emergency vehicle access will also always be maintained along both project corridors.

The Build analysis relies on the same assumed origin-destination relationship based on existing AADT as is used in the No Build analysis. In the Build analysis, all vehicles traveling along SD 73 are assumed to use their existing routes, but the end destinations are the same as in the No Build analysis. A map and additional details on existing routes and assumptions are provided in the BCA Workbook and are shown in Attachment B – “Existing Traffic Routes and Traffic Diversion Routes Due to Closure of

SD 73". The assumed existing travel routes for vehicles along SD 73 used in the Build analysis are described below<sup>6</sup>.

Existing Truck Routes:

- Route ID #1: Northwest/Southeast (50% of Traffic)
  - Rapid City - SD 73/US 18 Intersection
  - US 18, SD 73, and I-90
  - 147 miles, 123 minutes
- Route ID #3: Northeast/Southwest (40% of Traffic)
  - Murdo - SD 73/US 18 Intersection
  - Via SD 73, and I-90
  - 88 miles, 73 minutes
- Route ID #5: North/South (10% of Traffic)
  - Kadoka - SD 73/US 18 Intersection
  - Via US 18, SD 73, and I-90
  - 53 miles, 50 minutes

Existing Car Routes:

- Route #7: Northwest/Southeast (50% of Traffic)
  - Rapid City - SD 73/US 18 Intersection
  - SD 73, and I-90
  - 109 total miles, 88 minutes
- Route #9: Northeast/Southwest (40% of Traffic)
  - Murdo - SD 73/US 18 Intersection
  - SD 73, and I-90
  - 63 total miles, 51 minutes
- Route #11: North/South (10% of Traffic)
  - Kadoka - SD 73/US 18 Intersection
  - SD 73, and I-90
  - 27 total miles, 26 minutes

## BCA Methodology

The following methodology and assumptions were used for the benefit-cost analysis:

1. **Main Components:** The main components analyzed included:
  - Travel time/delay
  - Vehicle operating costs
  - Crashes by severity
  - Environmental and air quality impacts
  - Initial capital costs: Capital costs were expected to be incurred in years 2024 and 2025

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<sup>6</sup> Route ID# Numbers are referenced frequently in the Attachment A – BCA Workbook.

- Remaining Capital Value: The remaining capital value (value of improvement beyond the analysis period) was considered a benefit and was added to other user benefits. This analysis assumed a 20-year service for all project components.
  - Operating and maintenance costs
2. **Analysis Years:** This analysis assumed that the Build Alternative would be constructed over a two-year period, starting in year 2024, with completion in year 2025. Construction was assumed to be staged such that phase one (PCN 05HV and PCN 08EH) would be constructed in year 2024 and phase two is assumed to be constructed in year 2025. Year 2026 was assumed to be the first full year that most benefits will be accrued from the entirety of the project. The analysis primarily focused on annual benefits for the twenty-year period from 2026 to 2045<sup>7</sup>. Benefits associated with extending shoulder width and installation of lighting along SD 248 were monetized starting in year 2025 based upon anticipated year of phase one completion. The benefits associated with lighting ended in year 2044 at the appropriate time based on the assumed 20-year service life<sup>8</sup> and the benefits associated with all other project components ended in year 2045 at the appropriate time based on their assumed 20-year service life.
  3. **Economic Assumptions:** Value of time, vehicle operating costs, emissions costs, inflation adjustment factors and cost of crashes were obtained from the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated January 2023<sup>9</sup>. The analysis was completed using an assumed discount rate of seven percent. The present value of all benefits and costs was calculated using 2021 as the year of current dollars.
  4. **Development of Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT):** Year 2022 VMT and VHT were calculated along existing routes and diversion routes due to closure of SD 73. The total network VMT and VHT were developed using existing year 2022 AADT and forecast year 2042 obtained from the SDDOT Data Needs Book. Travel time and route lengths were obtained using Google Maps<sup>10</sup>.

SD 73 was assumed to close due to pavement failure in 2037 based on the remaining service life under the No Build Alternative. This information was obtained through coordination with SRST Staff. Detailed descriptions of posted speed limits were anticipated to be maintained during construction of phase one and phase two. Existing traffic routes and anticipated diversion routes associated with the closure of SD 73 in 2037 are described above in the “No Build” and “Build” section of this memorandum.

Assumed diversion routes were approved by SDDOT. Associated mileage and travel times were determined using Google Maps and were compared to trip distances and times along SD 73 (i.e., the route assumed for the Build Alternative). The BCA Workbook contains detailed information regarding pavement service life assumptions, diversion routes, and trip distances and times.

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<sup>7</sup> This analysis assumed a 365-day year to account for benefits incurred on weekends and recreational peaks in the project area.

<sup>8</sup> Service-life assumptions for project components were obtained through coordination with SDDOT staff.

<sup>9</sup> 2023 USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs:

<https://www.transportation.gov/sites/dot.gov/files/2023-01/Benefit%20Cost%20Analysis%20Guidance%202023%20Update.pdf>

<sup>10</sup> Google Maps: <https://www.google.com/maps>

Travel times and trip distances were applied to year 2022 and year 2042 daily traffic volumes to determine VHT and VMT, respectively. Travel time and vehicle operating cost benefits begin in year 2038 after the pavement along the project segment fail and are no longer able to carry traffic. The benefits for the years between 2038 and 2042 were interpolated using an annual growth rate, and benefits for years beyond 2042 were extrapolated using the same growth rate. Total user costs per alternative is the sum of all user costs for the period from 2026 to 2045. Benefits due to change in VMT and VHT were calculated using costs per mile and per hour that account for vehicle occupancy and different vehicle types.

5. **Vehicle Occupancy and Vehicle Types:** Truck and auto travel time costs per hour and costs per vehicle mile traveled were used in addition to vehicle occupancy ratios, and the percent split of autos and trucks traveling on each route. Key assumptions for these areas included:
  - The corridor-wide truck percentage used in the analysis was 19.6 percent and was based on 2022 AADT and heavy vehicle percentages were obtained from the SDDOT Data Needs Book.
  - Vehicle occupancy that was used in the analysis is consistent with values provided by *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated January 2023. The analysis assumed occupancy of 1.67 people per automobile and 1.00 people per truck.
6. **Safety Analysis:** The Build Alternative improves safety in the project area in two ways. First by adding roadway safety elements to SD 73 and SD 248 as part of the project, and secondly by keeping traffic on existing routes and not encouraging traffic to divert to less safe roadways.

This safety analysis made use of five years of crash data along the SD 73, SD 248 and all existing routes and diversion routes described in the “No Build” and “Build” sections of this methodology and was obtained for years 2018 through 2022 from SDDOT to determine average annual crash costs annual number of crashes by severity associated with this project.

The Build Alternative directly improves safety by providing the following elements quantified in this Benefit-Cost Analysis:

- Expands and paves roadway shoulders from two feet to six feet and installs edge-line rumble strips along 8.7 miles of SD 73
- Installation of lighting on 0.87 miles of SD 248
- Allowing traffic to remain on SD 73 and not diverting to less safe roadways

#### Safety Improvements Along SD 73:

Reductions in crashes along the SD 73 corridor were estimated using crash modification factors (CMFs) for the expansion and paving of roadway shoulders from two to six feet and for the installation of edge line rumble strips.

The crash modification factor for the shoulder width treatment "Extend Shoulder Width From two feet to six feet" was obtained using values presented in AASHTO Highway Safety Manual

(HSM) Chapter 12<sup>11</sup>. The crash modification factor was also applied to all crashes throughout the SD 73 project corridor. Note that in the Build Alternative safety benefits associated with shoulder width expansion begin in year 2025, the first full year after construction. After completion of phase one and phase two, the pavement along SD 73 is anticipated to have a 20-year service life, and these safety benefits associated with this improvement are counted accordingly through the end of the analysis period in year 2045.

The crash modification factor for the "Install Edgeline Rumble Strips<sup>12</sup>" was obtained from the Crash Modification Factors (CMF) Clearinghouse database. The crash modification factor was applied to all crashes throughout the SD 73 project area. Note that in the Build Alternative, safety benefits associated with installation of shoulder rumble strips begin in year 2026, the first full year after construction, and end at the end of the analysis period in year 2045.

#### Safety Improvements Along SD 248:

Reductions along the SD 248 corridor were estimated based on existing and future AADT as well as the crash modification factor for "Provide Intersection Illumination<sup>13</sup>" which was obtained from the CMF Clearinghouse database. The crash modification factor was applied to all pedestrian crashes which occurred in dark (evening) conditions throughout the SD 248 project corridor. Pedestrian activity along this segment along SD 248 is anticipated to increase proportionally to the AADT along the project segment of SD 248. In the Build Alternative, safety benefits associated with the installation of lighting begin at the appropriate time in year 2025 and end in year 2044 based on the assumed 20-year service life.

#### Network Crash Reductions

Crash costs and crashes by severity were calculated in the No Build Alternative by assuming the same traffic growth rates, existing travel patterns and crash rates as in the Build Alternative. Crash costs and crashes by severity were calculated using existing crash rates along SD 73 for year 2026 to 2037, the year of pavement failure on SD 73. Analysis of network crashes along existing routes were not calculated along the 8.7-mile segment of SD 73 in the project area in this portion of the analysis. Safety benefits associated with improvements associated with shoulder width expansion and installation of edge-line rumble strips along SD 73 were analyzed separately as described above.

Annual crashes by severity and crash costs for existing year 2022 and forecast year 2042 were calculated based on the change in VMT between the No Build Alternative and Build Alternative caused by the diversions associated with closure of SD 73 described in the "No Build" and Section 4 of this methodology, "Development of Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT)." The shift of traffic to diversion routes associated with closure of SD 73 is expected to result in increased crash costs for the No Build since severe crashes will occur more frequently along diversion routes than those along existing routes using SD 73 in the Build Alternative due to higher severe crash rates.

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<sup>11</sup> Highway Safety Manual (HSM): <http://www.highwaysafetymanual.org>

<sup>12</sup> CMF ID# 606 : [http://www.cmfclearinghouse.org/study\\_detail.cfm?stid=606](http://www.cmfclearinghouse.org/study_detail.cfm?stid=606)

<sup>13</sup> CMF ID# 440: <https://www.cmfclearinghouse.org/detail.cfm?facid=440>



Annual crash costs and crashes by severity for years 2038 to 2045 were calculated by multiplying the base year crashes by the percent change in annual VMT between the base year (year 2021 being the center of the crash analysis period) and the annual VMT along each existing and diversion route associated with users of the SD 73 project segment. Crash cost assumptions for the KABCO scale are consistent with values and methodologies published in the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated January 2023.

7. **Environmental and Air Quality Impacts:** Annual VMT is expected to be impacted by the existing roadway conditions along SD 73, and the eventual pavement failure along the entire project corridor. This pavement failure and other conditions will cause the roadway to shut down in 2037. The change in VMT between the No Build Alternative and Build Alternative was caused by the diversions described in Section 4 of this memorandum “Development of Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT).” Average emission rates per vehicle type were obtained from the Environmental Protection Agency’s Motor Vehicle Emission Simulator (MOVES) version 3<sup>14</sup>. Emission rates per vehicle type are provided in the attached BCA Workbook. Total change in emissions was valued in accordance with the *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, dated January 2023.
8. **Operating and Maintenance Costs:** Changes in annual roadway maintenance costs are expected due to intensified maintenance that will be required to keep the No Build Alternative serviceable compared to what will be required on new infrastructure under the Build Alternative. Anticipated costs for the No Build Alternative and Build Alternatives were provided by SDDOT and are shown in the BCA Workbook.

Note that in the No Build Alternative diversions are expected to occur in year 2038 due to closure of SD 73. Thus, maintenance for this segment of SD 73 is assumed to no longer be necessary and is not quantified.

9. **Calculation of Remaining Capital Value:** Because many components of the initial capital costs have service lives well beyond the 20-year analysis period, the remaining capital value was calculated for the Build Alternative. This value was expressed in terms of 2021 dollars and was added to other project benefits in accordance with USDOT guidance. The assumed service life for the Build Alternative was 20 years and was obtained through coordination with SDDOT staff. In determining the remaining capital value of the Build Alternative, project components were assumed to have a linear depreciation from the time each phase was completed to the end of the benefit-cost analysis period. The remaining capital value quantities were discounted and attributed to other project benefits for the Build Alternative.
10. **Factors Not Quantified:** Several factors were not quantified as part of the analysis that could potentially add to the benefits assumed in the BCA. These factors include the following:
  - Increased travel time reliability in the study area due to a reduction in crashes from safety improvements and enhanced pavement condition.
    - Mitigation of 14 deficient vertical curves with a design speed of 60 mph or less

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<sup>14</sup> Average emission rates per vehicle type were obtained from the Environmental Protection Agency’s Motor Vehicle Emission Simulator (MOVES), version 3

- New pavement markings that are more visible and reflective during adverse driving conditions
- Flattening of backslopes to help with the removal of snow traps and melting
- Improved resiliency to floods and associated detours due to profile enhancements along the corridor. Replacement of three large pipe culverts with box culverts
  - Correction of inslopes to ensure proper roadway drainage

Additional health, social, cultural, and economic benefits to the region are difficult to capture. SD 73 directly connects into the Pine Ridge Reservation, a place experiencing extreme quality of life struggles. In 2016, the Pine Ridge Reservation was the poorest Native American Reservation in the United States, where life expectancy was the second lowest in the western hemisphere, and 80 percent of the people were unemployed. The monetary benefits associated with improved facilities along SD 73, and resulting impacts on access to groceries, general stores, community events, hospitals, and pharmacies may not be fully captured in this analysis.

## BCA RESULTS

The benefit-cost analysis provides an indication of the economic desirability of a scenario, but results must be weighed by decision-makers along with the assessment of other effects and impacts. Projects are considered cost-effective if the benefit-cost ratio is at least 1.0. The larger the ratio number, the greater the benefits per unit cost. Results of the benefit-cost analysis are shown in Table 1. See Attachment A for the complete benefit-cost analysis workbook.

**Table 1 – Total Project Results**

	<b>Initial Capital Cost (2021 Dollars)</b>	<b>Project Benefits (2021 Dollars)</b>	<b>Benefit-Cost Ratio (7% Discount Rate)</b>	<b>Net Present Value (2021 Dollars)</b>
No Build vs. Build	\$21.76 million	\$53.29 million	2.45	\$31.54 million

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**Attachment A**

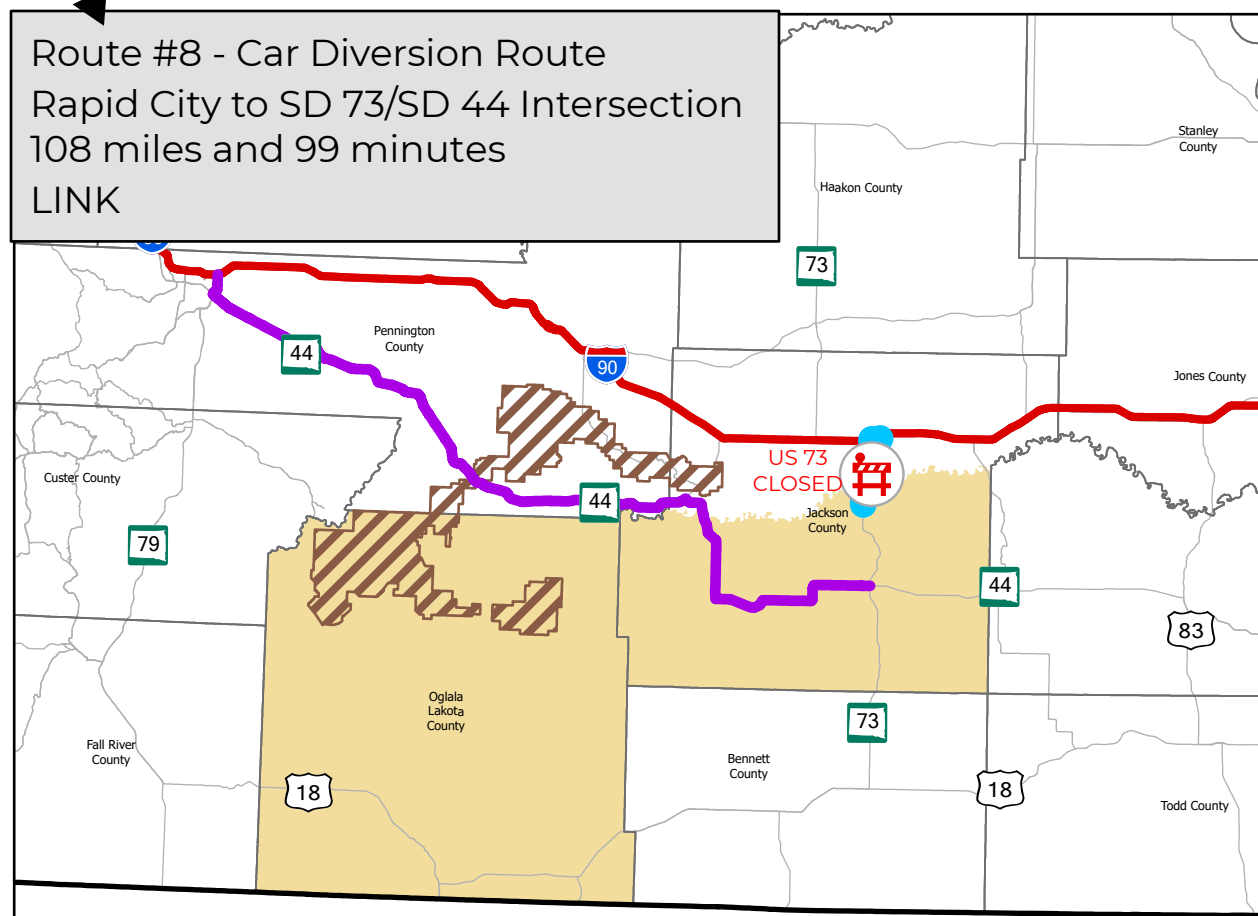
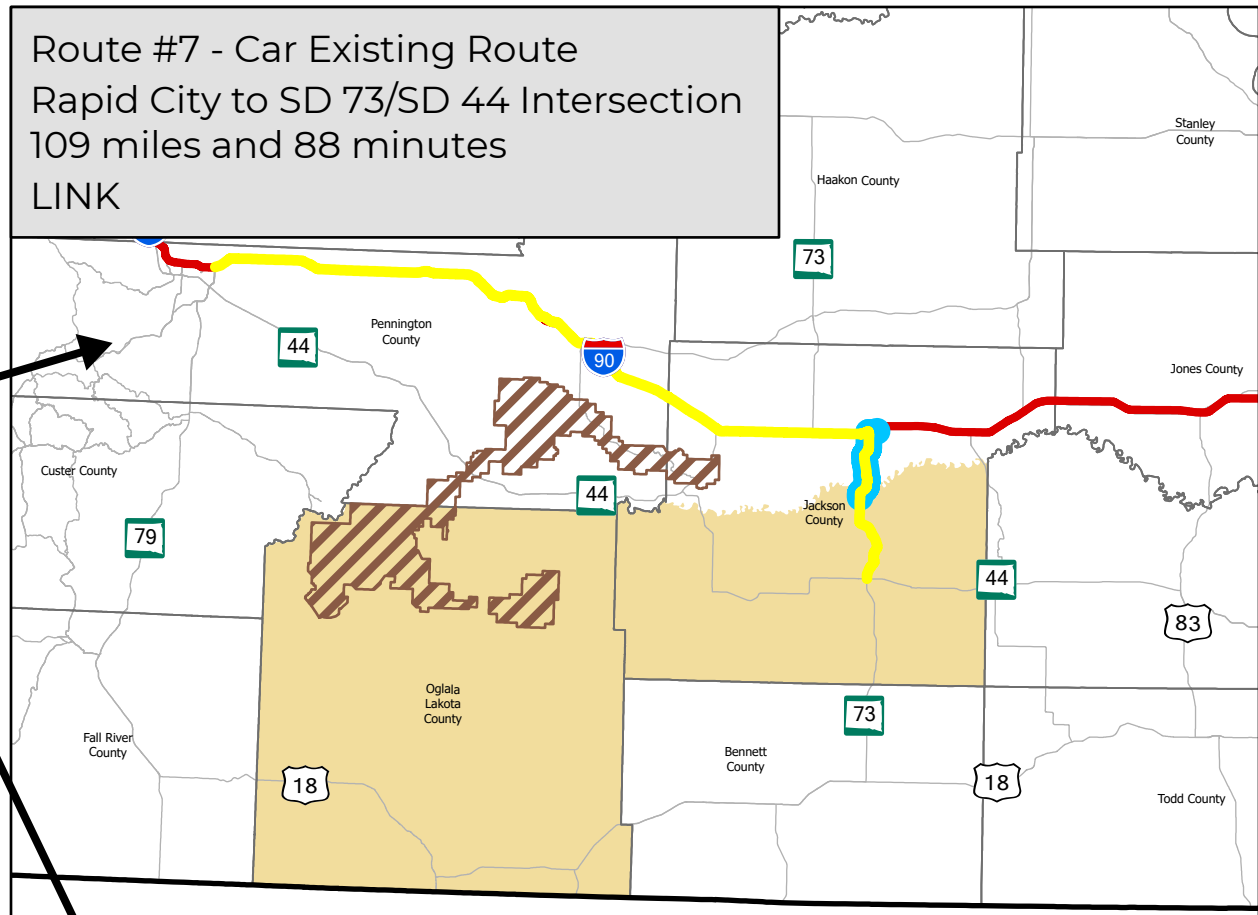
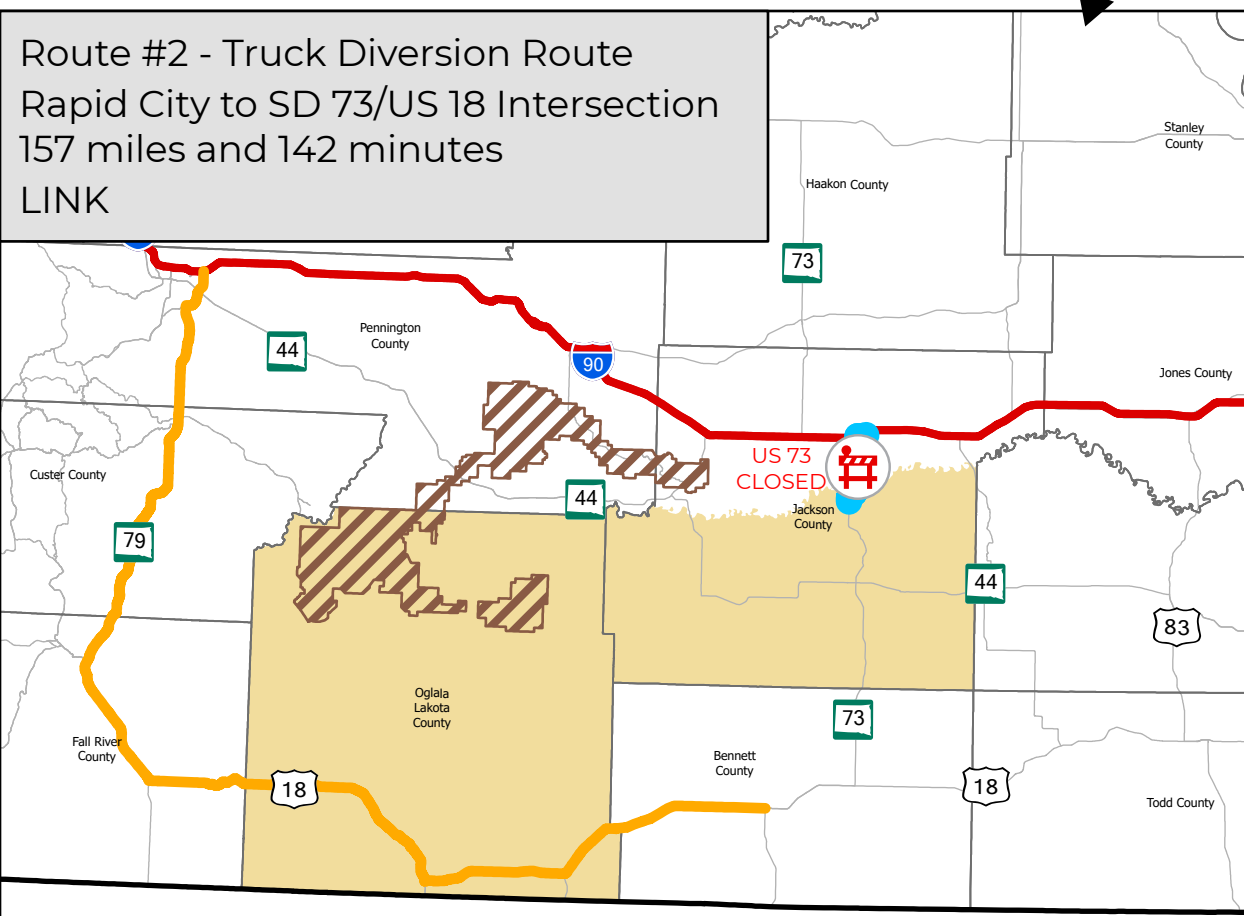
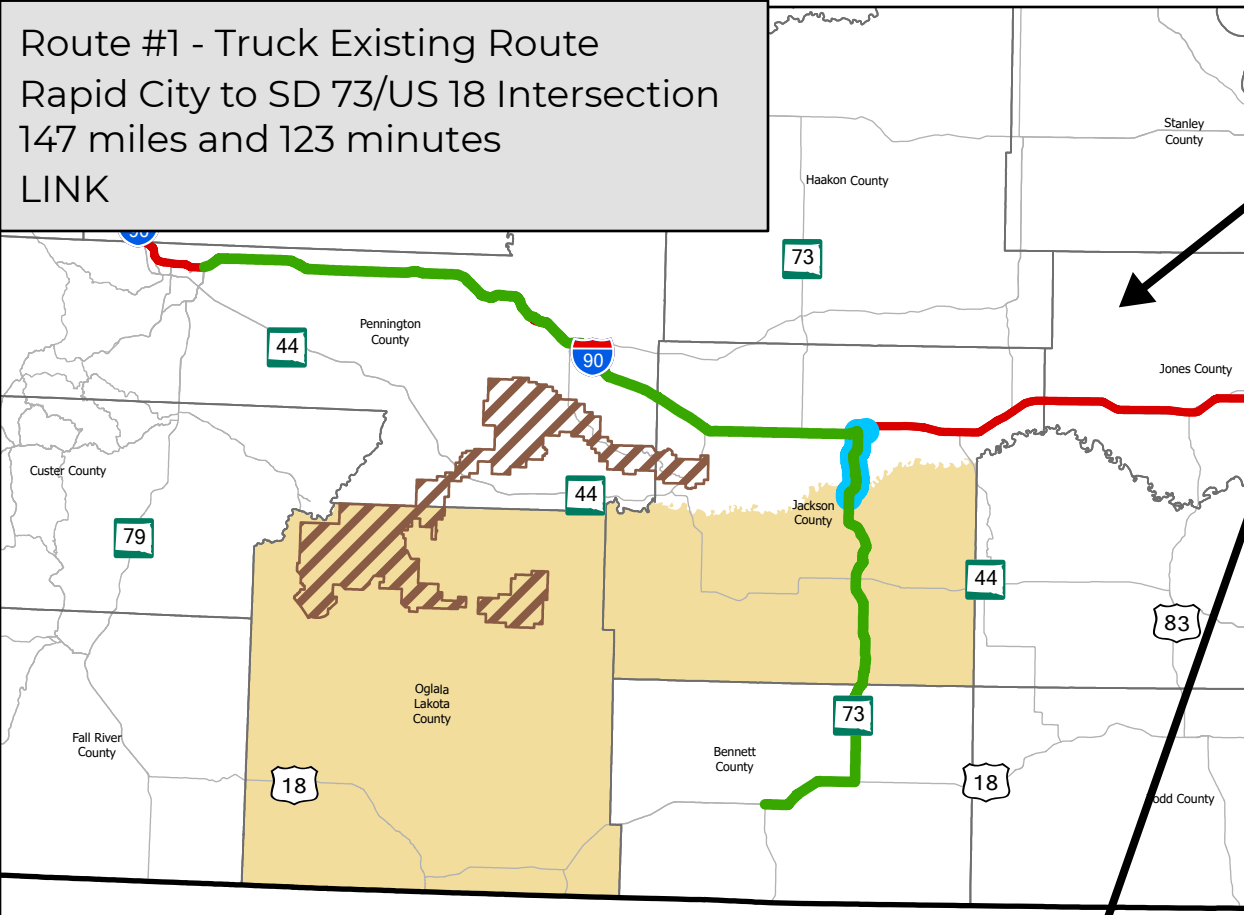
**Benefit-Cost Analysis Worksheet**

**Attachment B**

**Existing Traffic Routes and Traffic Diversion Routes Due to Closure of SD 73**

# SD 73 Reconstruction - Improving Mobility, Safety, and Access to the Pine Ridge Reservation

## Northwest/Southeast Routes



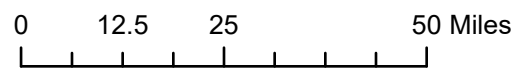
**Truck Routes**

**Car Routes**

### Legend

- Project Area
- Badlands National Park
- Pine Ridge Reservation
- Interstate
- Existing Truck Route
- Truck Diversion Route
- Existing Car Route
- Car Diversion Route
- Road Closure

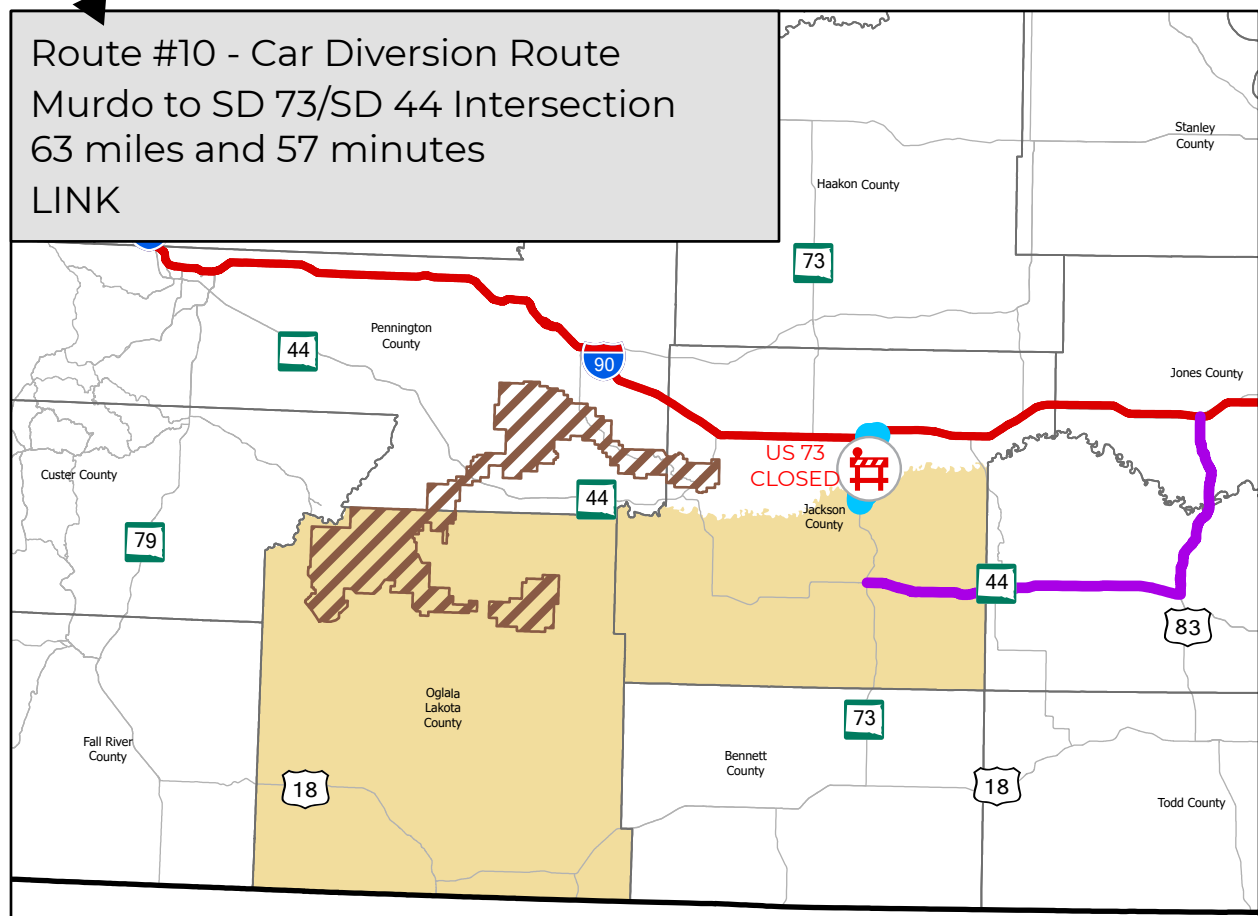
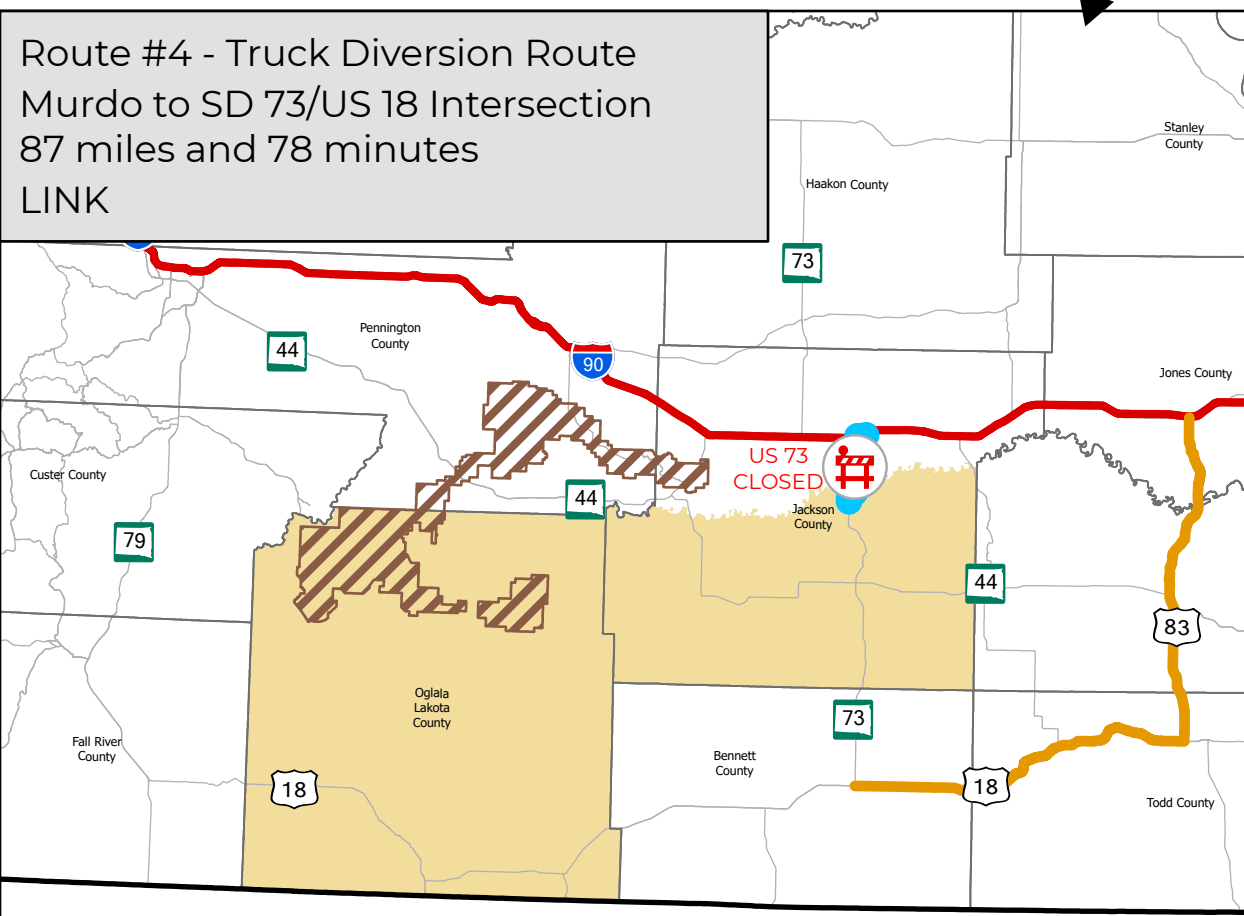
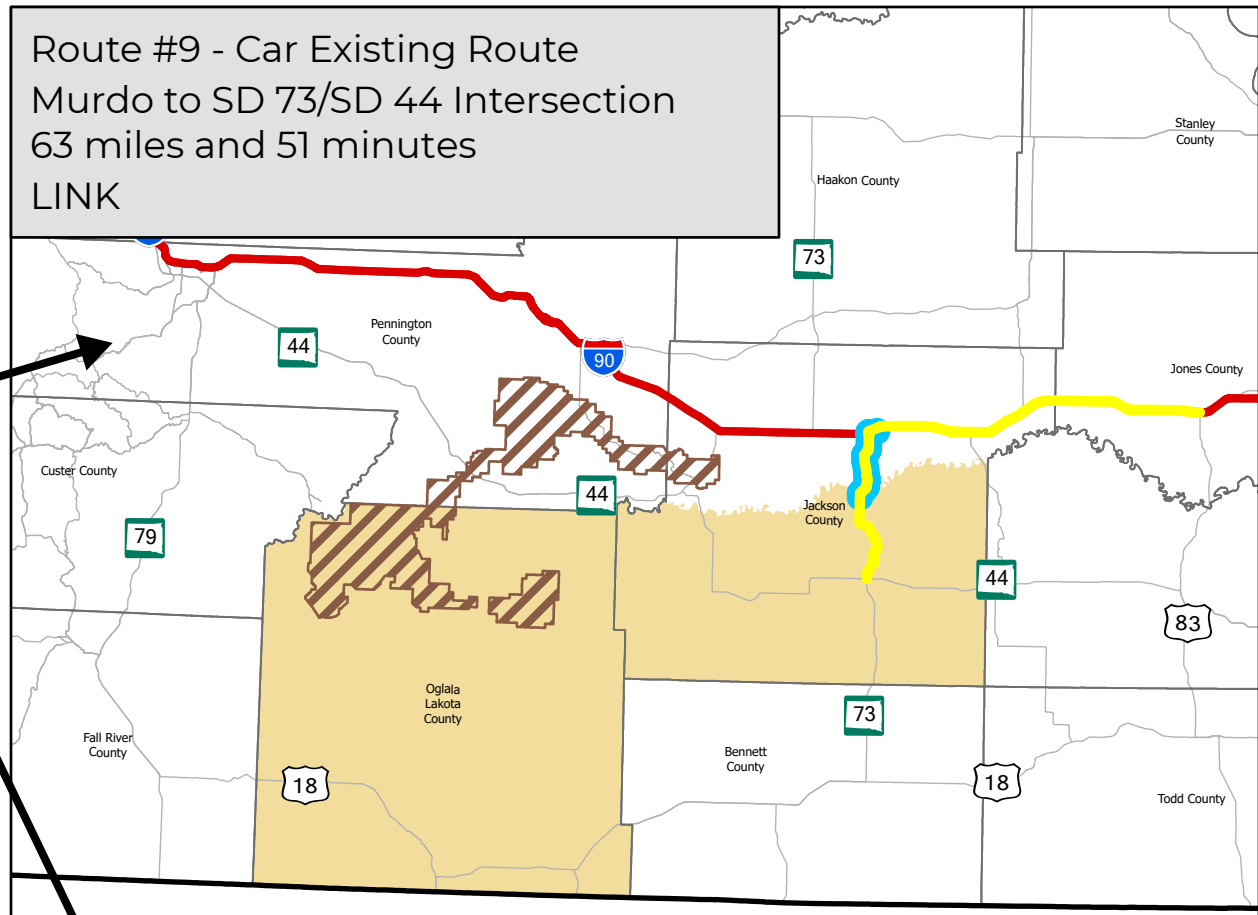
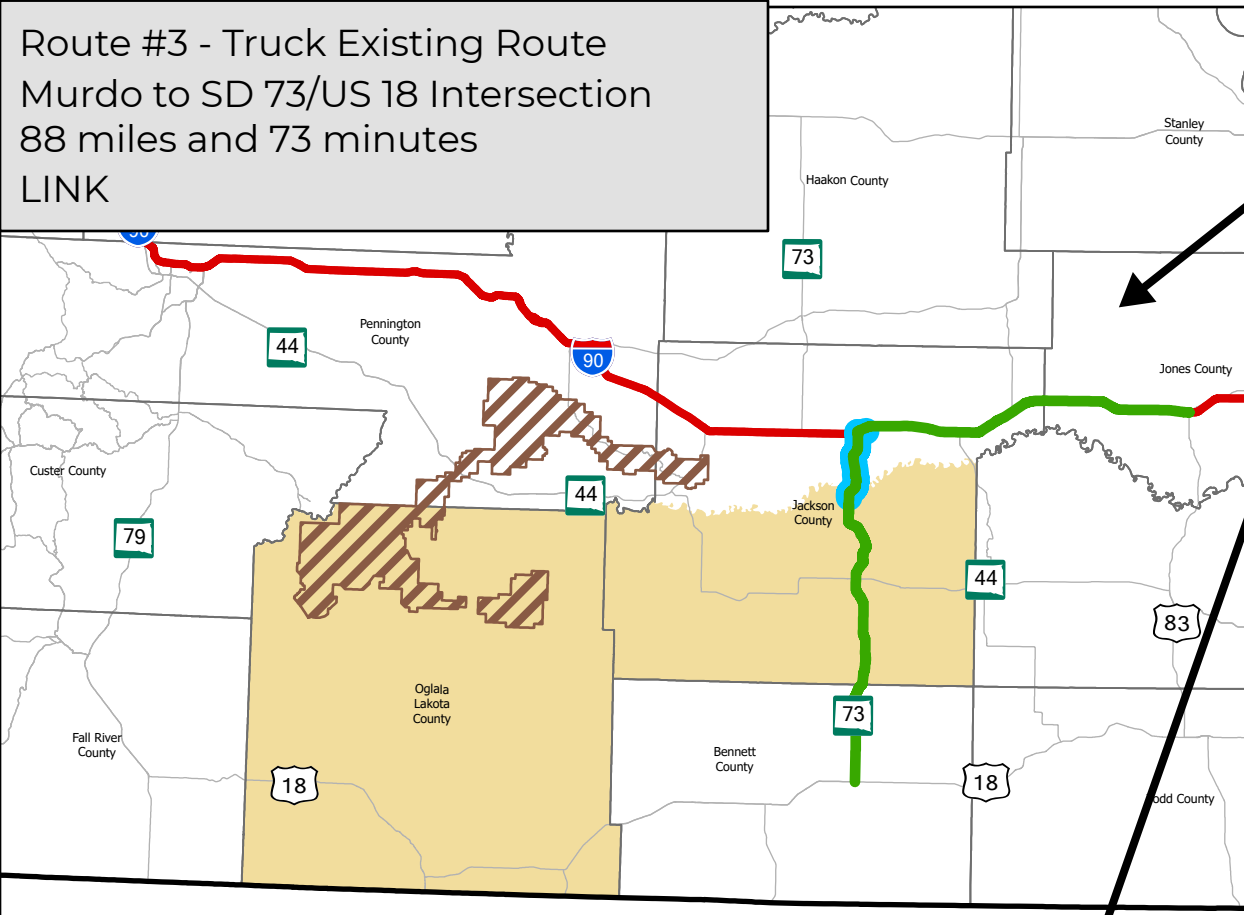
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Note: Travel time along routes used in analysis assumes travel time "without traffic".

# SD 73 Reconstruction - Improving Mobility, Safety, and Access to the Pine Ridge Reservation

## Northeast/Southwest Routes



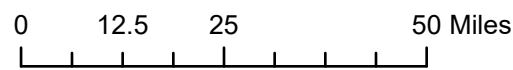
**Truck Routes**

**Car Routes**

### Legend

-  Project Area
-  Badlands National Park
-  Pine Ridge Reservation
-  Interstate
-  Existing Truck Route
-  Truck Diversion Route
-  Existing Car Route
-  Car Diversion Route
-  Road Closure

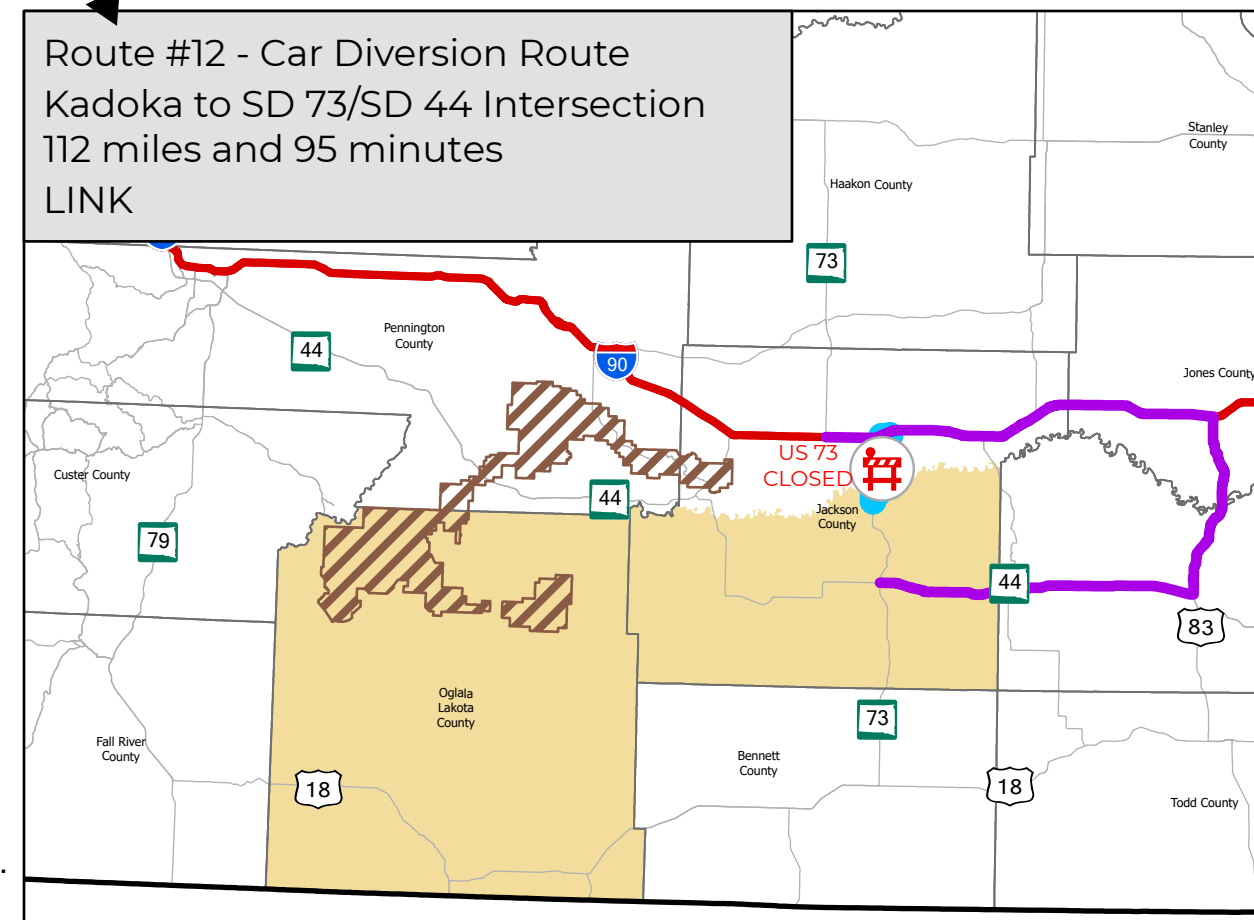
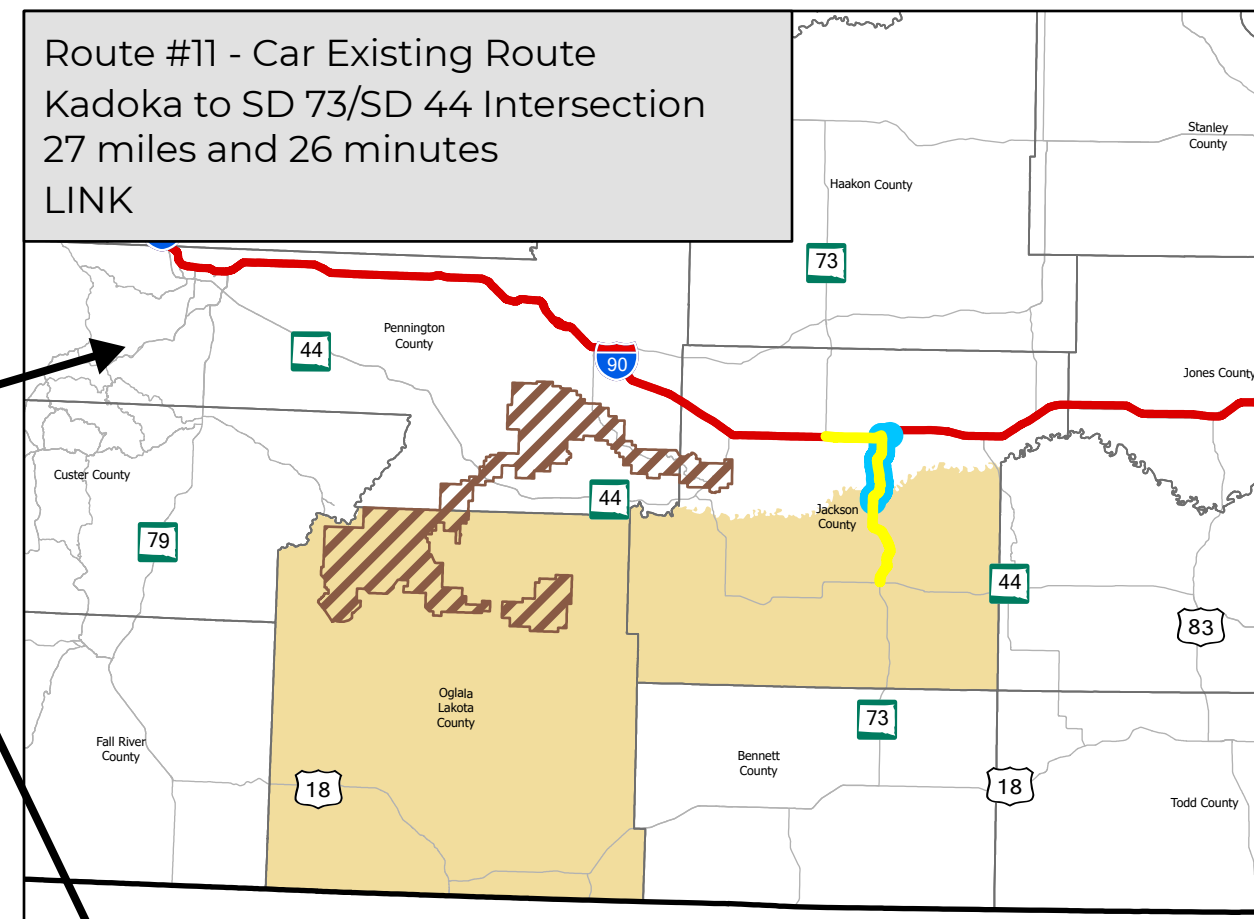
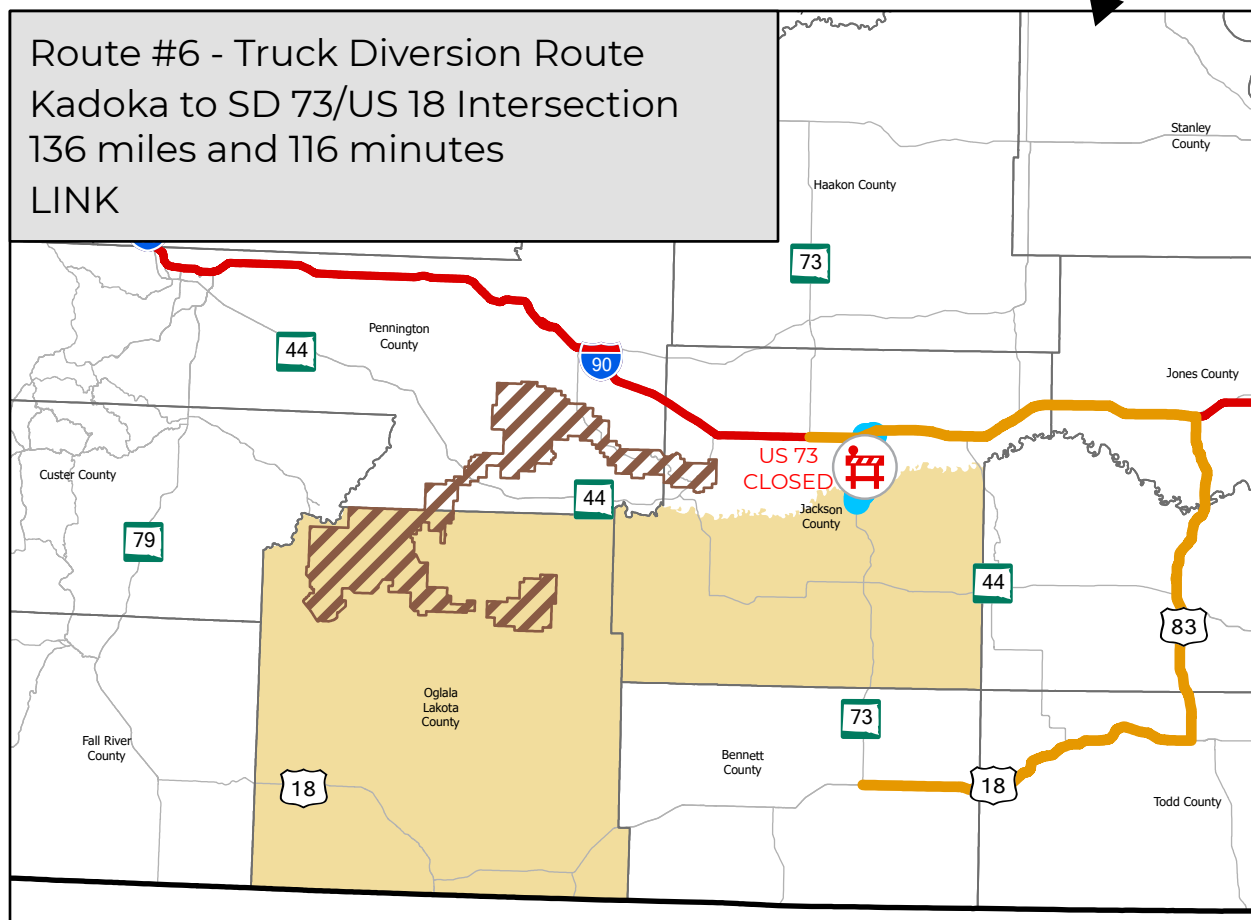
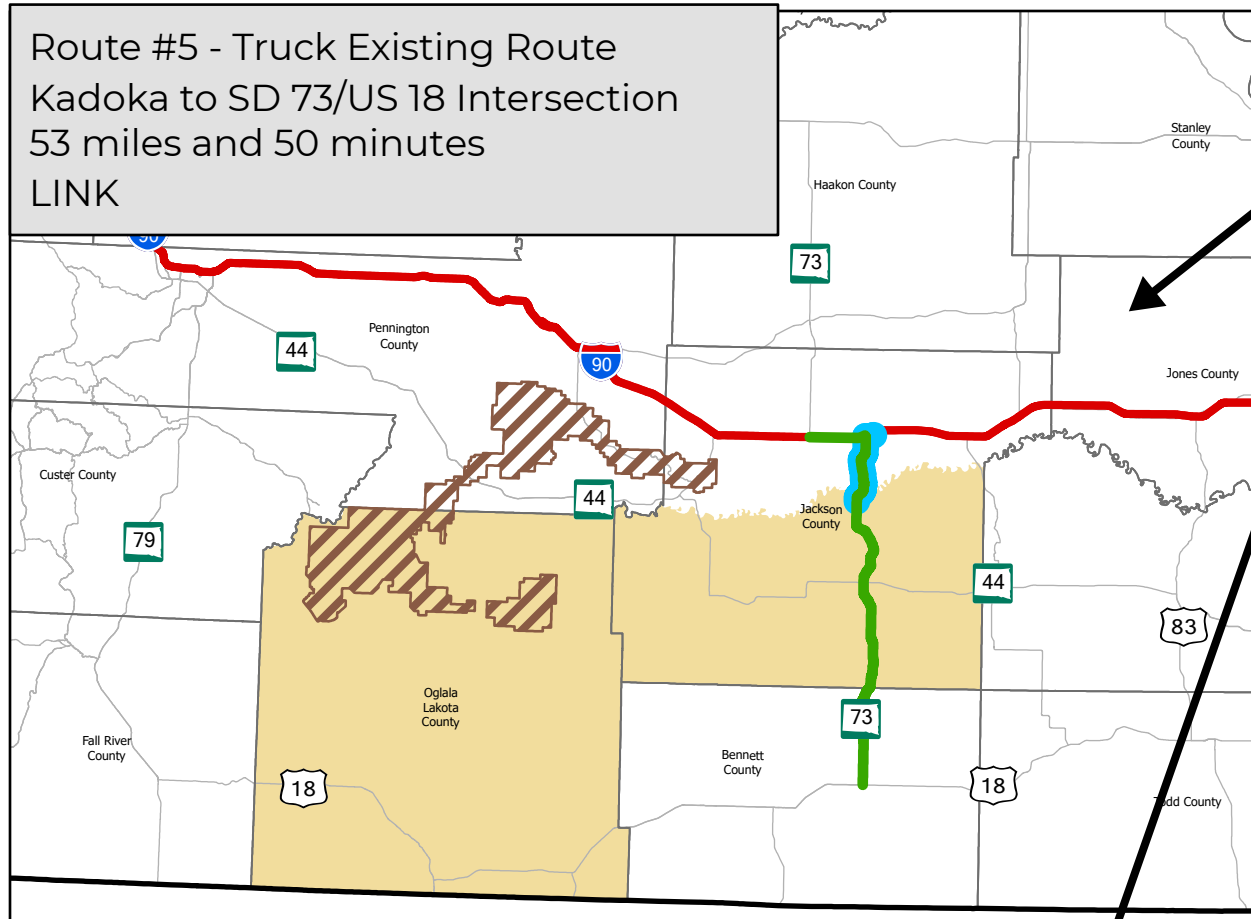
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Note: Travel time along routes used in analysis assumes travel time "without traffic".

# SD 73 Reconstruction - Improving Mobility, Safety, and Access to the Pine Ridge Reservation

## North/South Routes



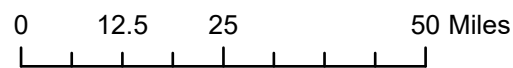
### Truck Routes

### Car Routes

### Legend

-  Project Area
-  Badlands National Park
-  Pine Ridge Reservation
-  Interstate
-  Existing Truck Route
-  Truck Diversion Route
-  Existing Car Route
-  Car Diversion Route
-  Road Closure

N



Note: Travel time along routes used in analysis assumes travel time "without traffic".