

U.S. 81 Realignment Around Chickasha, Oklahoma

Benefit-Cost Analysis Narrative

Introduction

U.S. 81 is part of the National Highway System. It runs north-south, from Texas to the Canadian border and passes through the Chickasha, Oklahoma central business district, where less than ideal conditions slow traffic flow, especially freight and truck traffic. More than a dozen signalized intersections, posted speed limits ranging from 45 miles per hour to 25 miles per hour in the downtown area, and two 90-degree turns result in the slowing of vehicles along this route. Traffic studies have found that truck traffic has increased in recent years, especially due to the energy industry and livestock trade. Oil and gas exploration, production, and transportation due to the nearby South Central Oklahoma Oil Province and Sooner Trend Anadarko Basin have increased heavy truck traffic through Chickasha. Trailers carrying livestock pass through Chickasha along U.S. 81 on their way to the livestock sales facility located east of El Reno on I-40. Annual grain harvesting brings over-sized farm equipment through Chickasha as it uses U.S. 81.

Growth in the wind industry has also contributed to increased traffic through Chickasha on U.S. 81 (see **Figure 1**). New wind farms in Rush Springs, south of Chickasha, as well as those near Minco and Tuttle, north of Chickasha, have generated significant heavy truck demand with the need to move turbine blades and other large wind turbine components. These super oversize vehicles cause significant delays when trying to navigate the two 90-degree turns along the route. Both northbound and southbound traffic are subject to this delay. When coming from the north, the first 90-degree turn is encountered at the U.S. 81 and US 62 intersection. The divided highway aspect of US 62 makes this left turn somewhat easier, but the situation is compounded by the at grade Union Pacific railroad crossing less than a half mile north of the intersection in cases where traffic backs up that far. Southbound traffic contends with the second 90-degree turn at the intersection of Choctaw Avenue and U.S. 81, which is a much more urban setting. Stoplights, streetlights, sidewalks, signs, and utilities closely line the streets, leaving little room for super oversize vehicles to navigate this tight, right turn. These vehicles typically bring traffic in all directions to a standstill while they steer through the obstacles of this intersection.

Figure 1
Wind Turbine Transport on U.S. 81



Source: Google Street View

These difficulties are not solely caused by the wind industry. Mobile homes, as well as large oil and gas and agricultural equipment, cause similar problems, although not to the same extent, due to their relative smaller size.

The Oklahoma Department of Transportation (ODOT) first recognized the need for improvements to U.S. 81 as far back as 1978, and has conducted numerous studies to identify the best solution to accommodate the growing traffic demand. ODOT, working with the Federal Highway Administration (FHWA), seeks to construct a realigned route around Chickasha for U.S. 81. This realignment would be a controlled-access, four-lane highway located west of Chickasha. It would begin at the curve north of the U.S. 81/SH 19 West junction and extend north eight miles to the U.S. 81/US 62 intersection. The realignment would incorporate six interchanges located at U.S. 81, I-44, Country Club Road, Grand Avenue, Iowa Avenue, and US 62.

This preferred alternative was determined through extensive study, public involvement, and detailed analysis. In 2007, ODOT completed a U.S. 81 Corridor Study that recommended construction of a controlled-access four-lane divided realignment of U.S. 81, from its current alignment through the Chickasha central business district to a new alignment west of Chickasha, with interchanges at key cross streets. ODOT then evaluated five different alignments before selecting a realignment of U.S. 81 west of Chickasha as the preferred alternative. Specialist studies were conducted to assess the social, economic, and environmental impacts of the preferred alternative, which garnered additional support for the preferred alternative. **Figure 2** shows the location of ODOT's proposed realigned route relative to the existing U.S. 81 corridor.

By constructing a realigned route for U.S. 81 around the Chickasha business district, congestion along U.S. 81 through the Chickasha central business district will be reduced, through traffic on U.S. 81 will have shorter travel times, and safety along the existing U.S. 81 through Chickasha will be improved.

A benefit-cost analysis (BCA) was developed for ODOT's proposed project. The benefits of the project were evaluated quantitatively or qualitatively in terms of the following characteristics:

- **Economic Competitiveness:** Travel time savings through faster travel speeds, reduced delay, and less congestion from diversion of through traffic from U.S. 81 to the realignment. Also, vehicle operating cost savings from diversion of through traffic from U.S. 81 to the realignment, which reduces travel distance.
- **Safety:** Reduction in fatalities, injuries, and property damage from diversion of through traffic from U.S. 81 to the realigned route.
- **Quality of Life Improvements:** Aspects of the project that are difficult to assign a dollar value, such as reduced noise impacts from less traffic in downtown Chickasha, improved response times for emergency vehicles, and economic development opportunities at the interchanges to be constructed along the realignment.

Figure 2
Location of U.S. 81 and Proposed Realignment Around Chickasha, OK



Source: CDM Smith

Costs associated with ODOT's project include:

- **Pre-construction Costs:** Costs for preliminary engineering, environmental clearance, right-of-way acquisition, and utility relocation.
- **Construction Costs:** Costs for grading and drainage and construction of bridges, interchanges, and surfacing.
- **Maintenance Costs:** Costs to maintain the existing U.S. 81 corridor as well as the new realigned route. Costs include rehabilitation, preservation, reconstruction, silane, joint projects, and general maintenance.

The ensuing sections of this document discuss the following:

- ODOT's project schedule for the realignment,
- BCA analysis period,
- Baseline (no-build) conditions in Chickasha,
- Forecasts of future travel demand for build conditions,
- Project benefits and methodologies used for calculation,
- Project costs and methodologies used for calculation, and
- BCA results.

All spreadsheet references in quotations in this document refer to tabs in the "Model_OKDOT INFRA BCA_V9" Excel spreadsheet (BCA spreadsheet) and cell references in parentheses refer to cells or tables within the referenced tabs. The "BCA Summary" tab provides a summary of all benefits and costs evaluated quantitatively in the BCA. As presented on this tab, 2016 is the base year for the BCA, with all monetary values expressed in 2016 dollars.

Project Schedule

Figure 3 presents ODOT's project schedule for the realigned route around Chickasha. As shown in Figure 3, pre-construction activities occur from 2016 to 2019 and construction occurs from 2020 to 2024. Project completion is slated for 2024, with the realigned route anticipated to open in 2025.

Figure 3
Project Schedule for the Realignment Around Chickasha, OK

ACTIVITY	2016	2017	2018	2019	2020	2021	2022	2023	2024
Survey	█								
Preliminary Engineering	█	█							
Environmental Clearance	█	█	█						
Right-of-Way Acquisition			█	█	█				
Utility Relocation			█	█	█				
Final Design			█	█	█				
INFRA Funding Obligation Deadline					★				
Construct Grading & Drainage on U.S. 81 from north of Quail Road to Rock Hollow Creek					█	█			
Construct bridges from I-44 through Rock Hollow Creek						█	█		
Construct interchanges at Quail Road and U.S. 62 (Turnkey)							█	█	
Construct all remaining surfacing (including U.S. 81 mainline and interchanges)								█	█
Project Completion									★

Source: Oklahoma Department of Transportation

BCA Analysis Period

With the realigned route opening in 2025, the analysis period selected for the BCA is 2016 to 2060. This analysis period was selected for several reasons. First, it provides a period of at least 20 years after the completion of construction during which the full operational benefits and costs of the project can be reflected in the BCA, as recommended in the US Department of Transportation's (USDOT) *Benefit-Cost Analysis Guidance for TIGER and INFRA Applications* published in July 2017. The analysis period was also selected because traffic forecasts for the no-build and build conditions were available for the 2016 to 2060 timeframe. Lastly, although the service life of the realignment is expected to extend beyond 2060, USDOT's *Benefit-Cost Analysis Guidance for TIGER and INFRA Applications* recommends avoiding analysis periods extending beyond 40 years of full operations.

Baseline Conditions (No-Build)

The existing U.S. 81 corridor is constructed as both a divided and an undivided section roadway that is used by traffic traveling through but not destined for Chickasha as well as local traffic destined for Chickasha. The divided and undivided sections of existing U.S. 81 include the following, beginning on the southern end of the corridor:

- South of Grand Avenue: Divided section roadway consisting of two 12-foot lanes in each direction with either a 16-foot or 24-foot median.
- North of Grand Avenue to Choctaw Avenue: Undivided section roadway consisting of two 12-foot lanes in each direction, with five lanes at some of the downtown intersections to accommodate left turn bays.

- Choctaw Avenue to 11th Street: Undivided section roadway consisting of two 12-foot lanes in each direction, with five lanes at some of the downtown intersections to accommodate left turn bays.
- 11th Street to US 62/U.S. 81 intersection west of downtown Chickasha: Divided section roadway consisting of two 12-foot lanes in each direction with a 40-foot median.¹

The U.S. 81 corridor consists of 14 at-grade signalized intersections and posted speed limits ranging from 45 miles per hour outside the urbanized area to as low as 25 miles per hour through downtown. A 90-degree turn exists at the intersection of Choctaw Avenue and U.S. 81, with another located at the US 62/U.S. 81 intersection west of downtown. As previously explained, these turns make it difficult for vehicles carrying super oversize loads, which often cause delays along U.S. 81 as traffic comes to a stop until the vehicles can negotiate through these intersections (see **Figure 4**). Approximately 17 percent of the vehicles traveling on U.S. 81 are trucks.² Super oversize vehicles further add to congestion and delay along U.S. 81, since they travel at slower speeds and often occupy two lanes of the roadway. In addition to these sources of delay, a Union Pacific rail line intersects U.S. 81 north of US 62/81, causing traffic to stop as trains pass through.

Figure 4
Ninety-Degree Turn at Choctaw Avenue and U.S. 81



Source: Oklahoma Department of Transportation

Current and future forecast traffic volumes on U.S. 81 for no-build conditions for the 2016 to 2060 analysis period are presented in **Figure 5**.³ As shown in Figure 5, annual average daily traffic (AADT) is

¹ *U.S. 81 Realignment, Chickasha, Grady County, From Curve North of U.S. 81/SH 19 West Junction North to U.S. 81/US 62 Intersection, Federal Aid Project No. J2-4428(004), State J/P No. 24428(04), Environmental Assessment, US Department of Transportation Federal Highway Administration and Oklahoma Department of Transportation, Approved February 2017.*

² ODOT estimates the current truck factor on U.S. 81 is 17 percent.

³ The forecast of future travel demand was obtained from the *Access Justification Report for US-81 Realignment* prepared by Benham for ODOT in August 2017. This report prepared future (2040) design year traffic for existing U.S. 81 and the bypass for no-build and build conditions using a base year of 2012. Year 2012 design traffic volumes were projected using future trip generations based on potential land use changes, an Origin-Destination study, and induced traffic. ODOT prepared traffic forecasts for the 2040 to 2060 period for existing U.S. 81 and the bypass for no-build and build conditions.

forecast to grow at a compound annual growth rate of 1.3 percent along the corridor throughout the analysis period. This growth, accompanied by the problems faced by super oversized vehicles traversing the corridor, will increase traffic congestion through the Chickasha business district.

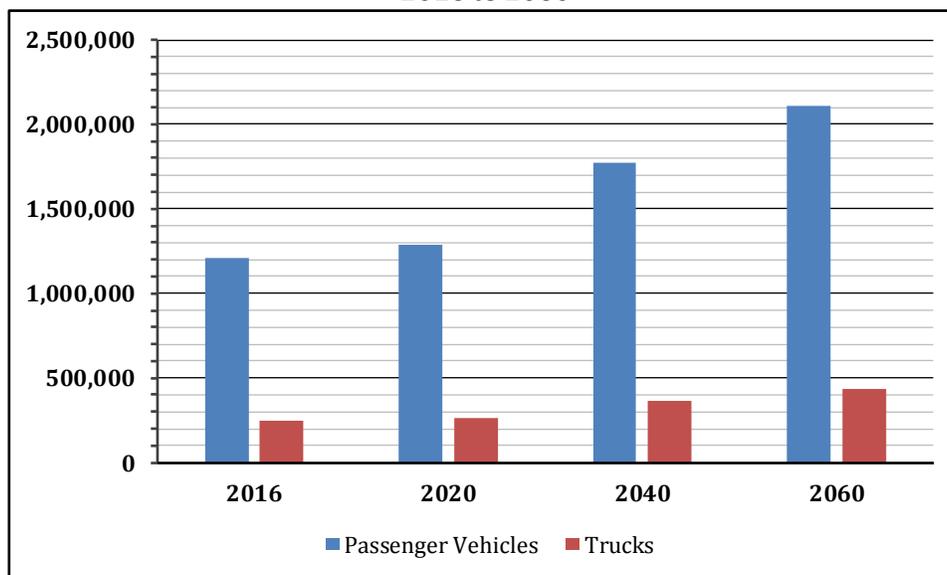
Figure 5
U.S. 81 Annual Average Daily Traffic
No-Build Conditions
2016 to 2060

U.S. 81 Location	2016 AADT	2020 AADT	2040 AADT	2060 AADT	CAGR 2016-2060
U.S. 81 West of 4th Street	12,020	12,810	17,600	21,120	1.3%
U.S. 81 at Iowa Avenue	9,590	10,220	14,060	16,850	1.3%
U.S. 81 North of Grand Avenue	15,880	16,930	23,300	27,900	1.3%
U.S. 81 South of Grand Avenue	17,520	18,670	25,645	30,780	1.3%
U.S. 81 South of I-44	18,840	20,075	27,580	33,090	1.3%
U.S. 81 South of SH-19 East	8,890	9,470	13,010	15,560	1.3%

Source: *Access Justification Report for U.S. 81 Realignment*, August 2017, prepared by Benham; Oklahoma Department of Transportation; and CDM Smith

Figure 6 identifies the projected increase in hours of annual travel time for traffic traveling on U.S. 81 for no-build conditions from 2016 to 2060, based on analysis conducted for this BCA. Annual hours of travel time for passenger vehicles are forecast to grow from 1.2 million hours in 2016 to more than 2.1 million hours in 2060. Annual hours for trucks are projected to increase from approximately 247,100 to 432,400 during the same period.

Figure 6
U.S. 81 Annual Hours of Travel Time Through Chickasha
No-Build Conditions
2016 to 2060



Source: CDM Smith

Congestion and delay are not the only problems affecting U.S. 81. The safety of drivers and passengers traveling on the roadway is also a significant concern. From January 1, 2006 to April 21, 2016, a total of 1,473 crashes occurred on U.S. 81 in Chickasha. This resulted in eight fatalities and 432 injuries. An

analysis of crash data by ODOT found that this segment of U.S. 81 exhibited a collision rate that was approximately 3.5 times higher than the statewide rate for similar roadways.⁴ Nearly three-quarters of these crashes occurred at intersections. Of the eight fatalities, five occurred at intersections.

Figure 7 shows the number of crashes and their severity for 2016. It also provides forecasted crashes by severity for 2020, 2040, and 2060, based on the historic rate of crashes along U.S. 81. As expected, the number of crashes along U.S. 81 in Chickasha is forecast to increase over the analysis period, more than doubling by 2060 if no changes are made to the U.S. 81 corridor.

Figure 7
Crashes Along U.S. 81 in Chickasha
No-Build Conditions
2016 to 2060

Crash Category	2016	2020	2040	2060
Property Damage Only	92	101	145	189
Possible Injury	36	39	55	71
Incapacitating Injury	4	5	10	15
Fatality	1	1	2	2
Total of All Crashes	133	146	212	277

Source: CDM Smith

Construction of a limited access realignment west of Chickasha will reduce congestion along U.S. 81 through the central business district, reduce travel time for traffic traveling through Chickasha, and improve safety along the existing U.S. 81 corridor.

Forecasts of Future Travel Demand for Build Conditions

Future forecast traffic volumes on U.S. 81 and the realigned route for build conditions for the 2025 (when the realignment opens) to 2060 period are presented in **Figure 8**. Traffic volumes throughout this period are projected to grow at a compound annual growth rate of 1.2 percent for both U.S. 81 and the realigned route. It should be noted that induced traffic is not included in Figure 8 and was factored out of the analysis. The no-build (see Figure 5) and build forecasts were used to calculate the economic competitiveness benefits in this BCA.

⁴ *U.S. 81 Realignment, Chickasha, Grady County, From Curve North of U.S. 81/SH 19 West Junction North to U.S. 81/US 62 Intersection, Federal Aid Project No. J2-4428(004), State J/P No. 24428(04), Environmental Assessment*, US Department of Transportation Federal Highway Administration and Oklahoma Department of Transportation, Approved February 2017.

Figure 8
U.S. 81 and Realignment Annual Average Daily Traffic
Build Conditions
2025 to 2060

U.S. 81 Location	2025 AADT	2030 AADT	2040 AADT	2060 AADT	CAGR 2025-2060
U.S. 81 West of 4th Street	9,220	9,990	11,710	14,060	1.2%
U.S. 81 at Iowa Avenue	7,600	8,240	9,700	11,640	1.2%
U.S. 81 North of Grand Avenue	11,990	12,980	15,220	18,270	1.2%
U.S. 81 South of Grand Avenue	14,260	15,440	18,100	21,720	1.2%
U.S. 81 South of I-44	14,790	16,020	18,770	22,520	1.2%
U.S. 81 South of SH-19 East	6,020	6,530	7,670	9,170	1.2%
Bypass Location	2025 AADT	2030 AADT	2040 AADT	2060 AADT	CAGR 2025-2060
North of US 62/81 Interchange	4,820	5,210	6,110	7,330	1.2%
Iowa Avenue Interchange to US 62/81 Interchange	4,660	5,050	5,920	7,100	1.2%
Grand Avenue Interchange to Iowa Avenue Interchange	4,860	5,260	6,160	7,380	1.2%
Country Club Road Interchange to Grand Avenue Interchange	4,550	4,930	5,770	6,910	1.2%
I-44 Interchange to Country Club Road Interchange	4,580	4,960	5,810	6,950	1.2%
South of I-44 Interchange	5,650	6,120	7,180	8,590	1.2%

Source: *Access Justification Report for U.S. 81 Realignment*, August 2017, prepared by Benham; Oklahoma Department of Transportation; and CDM Smith

Project Benefits and Methodologies for Calculation

Three categories of benefits of the realigned route were analyzed in this BCA. These include economic competitiveness, safety, and quality of life improvements. The methodologies for calculating these benefits are discussed in the sections below.

Economic Competitiveness

Economic competitiveness benefits of the realignment around Chickasha were assumed to arise from four sources:

- Time savings from vehicles traveling at a faster speed on the realignment as opposed to the existing U.S. 81 corridor, as well as from the removal of through traffic from Chickasha's downtown.
- Time savings from diversion of super oversize vehicles from the existing U.S. 81 corridor to the realigned route, which would eliminate the delay caused by these vehicles making the 90-degree turns.
- Time savings from the elimination of the at-grade railroad/local street crossing conflict located between the U.S. 81/62 intersection and Reding Road north of downtown Chickasha.
- Vehicle operating cost savings from through traffic traveling a shorter distance on the realignment around Chickasha as opposed to the existing U.S. 81 corridor.

The methodologies for calculating time savings and vehicle operating cost savings in this BCA are discussed below.

Time Savings from Faster Travel on the Realignment and Removal of Through Traffic on Existing U.S. 81

ODOT anticipates approximately one third of the traffic on the existing U.S. 81 corridor will divert to the realigned route once it opens, which will provide time savings benefits for both diverting traffic and traffic that continues to use U.S. 81. The realignment will have a posted speed limit of 70 miles per hour, allowing through traffic not destined for Chickasha to avoid congestion and delay currently caused by 14 signalized intersections, increasing vehicle volumes, lower posted speed limits, and super oversize vehicles. Local traffic destined for Chickasha will benefit since less traffic will be using U.S. 81 and super oversize vehicles will be removed from the corridor. Calculations for these benefits are found on the “Realign-Segment 1-Travel Time” through “Realign-Segment 6-Travel Time” (calculations for travel times on the realignment for build conditions) and “Segment 1-Travel Time” through “Segment 16-Travel Time” tabs (calculations for travel times on existing U.S. 81 for no-build and build conditions) in the BCA spreadsheet.

For discussion purposes, the methodology for Realignment Segment 2 (presented on the “Realign-Segment 2-Travel Time” tab), which would run between the proposed interchanges at Interstate 44 and Country Club Road, is presented below, although the methodology for each of the realigned segments and existing U.S. 81 segments for both no-build and build conditions is the same.

As shown on the “Realign-Segment 2-Travel Time” tab, AADT volumes are shown for the 2012 to 2060 period (K:14 to BG:14). AADT volumes from the *Access Justification Report for US-81 Realignment* prepared by Benham for ODOT in August 2017 were used for the 2012 to 2040 period, with AADT volumes for the 2040 to 2060 period prepared by ODOT. AADT volumes for years in between 2012, 2040, and 2060 were interpolated. The forecast indicates the AADT volume on Realignment Segment 2 in 2025 is approximately 4,580 vehicles (X:14) and is projected to increase to approximately 6,950 vehicles (BG:14) by 2060. The segment was further broken down into northbound and southbound traffic, with northbound and southbound traffic both increasing from 2,290 vehicles in 2025 (X:21; X:28) to 3,480 vehicles in 2060 (BG:21; BG:28). According to ODOT, the truck factor for the realignment is 23 percent (B:16; C:16; D:16) and remains constant throughout the analysis period.⁵ The length of Realignment Segment 2 was measured using a KMZ file showing the location of the realigned route and using Google Earth’s distance measuring tool.

Once the traffic volumes for Realignment Segment 2 were identified, it was necessary to estimate travel speeds and travel times for vehicles traveling on the realigned route. To identify travel speeds and travel times, a separate traffic analysis of existing U.S. 81 and the realignment was conducted for no-build and build conditions. In that analysis, U.S. 81 and the realignment were divided into segments based on changes in cross section, speed limit, daily traffic volume and/or number of lanes. Segment attributes included the percentage of trucks, traffic signals per mile, typical green time to cycle time ratio for estimating capacity and traffic signal control delays, speed limit, and number of through lanes.

Daily, peak period, peak hour, and off-peak operating speeds were derived using the Margiotta delay equations from National Cooperative Highway Research Program (NCHRP) 387. This approach was selected due to sensitivity to key network attributes affected by the project which include variations in speed limit, facility classification, traffic signal density, access management and number of traffic lanes,

⁵ For existing U.S. 81, the truck factor for no-build conditions is 17 percent and decreases to 14 percent for build conditions due to the diversion of trucks to the bypass.

as well as the ability to estimate delay on a daily basis rather than only the peak hour. The forecasts of traffic volumes were applied to the analysis of applicable segments of the network to estimate speeds and delays.

From this traffic analysis, northbound peak hour (O:35 through BG:35), southbound peak hour (O:46 through BG:46), northbound off-peak (O:57 through BG:57), and southbound off-peak (O:68 through BG:68) travel speeds for the segment matching Realignment Segment 2 in the BCA were used to calculate travel times along the segment. For example, in 2025, the northbound peak hour speed for Realignment Segment 2 from the traffic analysis was estimated to be 67 miles per hour (X:35), and northbound off-peak speed was estimated to be 67.1 miles per hour (X:57).⁶ These speeds were used to calculate segment travel time as 1.5 minutes for northbound peak hour (X:37) and 1.5 minutes for southbound peak hour (X:59) in 2025. These travel times were then applied to projected traffic volumes to calculate minutes of passenger vehicle time and truck time per day for peak hours (K:91 through BG:92 and K:158 through BG:159) and off-peak hours (K:225 through BG:226). Minutes of travel time per day were converted to hours per day, which were then converted to annual hours of travel time for peak hours (K:102 through BG:103 and K:169 through BG:170) and off-peak hours (K:236 through BG:237). Annual hours of travel time were then monetized for peak hours (K:106 through BG:107 and K:173 through BG:174) and off-peak hours (K:240 through BG:241) using the recommended values of time of \$19.60 per passenger vehicle per hour and \$27.20 per truck per hour on the “Recommended Values” tab. This same process was used for southbound traffic on the “Realign-Segment 2-Travel Time” tab.

The “Travel Time Grand Totals” table (J:282) sums all calculations on the “Realign-Segment 2-Travel Time” tab. Vehicle travel time in minutes per day (O:289 through BG:290) was converted to travel time in hours to estimate total passenger vehicle and truck travel times per day for 2016 through 2060 (O:293 through BG:294). Passenger vehicle and truck travel times per day were then converted to total annual passenger vehicle and truck travel times for 2016 through 2060 (O:297 through BG:298). Finally, annual passenger vehicle and truck travel times were monetized (O:305 through BG:306) using USDOT’s recommended values of time of \$19.60 per passenger vehicle per hour and \$27.20 per truck per hour on the “Recommended Values” tab.

The results for all existing U.S. 81 and realigned segments for no-build and build conditions were summed on the “Travel Time & VOCs” tab. Results for existing U.S. 81 in no-build conditions are shown in the table titled “Segments-Travel Time.” As shown in this table, total annual travel time in 2016 is more than 916,600 hours for passenger vehicles (non-discounted value of nearly \$18.0 million) and more than 187,700 hours for trucks (non-discounted value of \$5.1 million). By 2060, total annual travel time increases to 1.6 million hours for passenger vehicles (non-discounted value of \$31.6 million) and more than 330,600 hours for trucks (non-discounted value of \$9.0 million).

Results for traffic traveling on existing U.S. 81 and the realignment for build conditions were summed in the table titled “U.S. 81 & Realignment Segments – Travel Time.” This table shows that once the realignment opens in 2025, total annual travel time in 2025 for both routes is nearly 863,000 hours for passenger vehicles (non-discounted value of \$16.9 million) and more than 162,800 hours for trucks (non-discounted value of \$4.4 million). By 2060, total annual travel time increases to 1.3 million hours for passenger vehicles (non-discounted value of \$25.8 million) and 248,300 hours for trucks (non-discounted value of nearly \$6.8 million).

⁶ No differentiation in speeds between cars and trucks was made in the traffic analysis.

Time Savings from Diversion of Super Oversize Vehicles to the Realignment

Currently, vehicles traveling on U.S. 81 are frequently subject to delay when super oversize vehicles steer through the intersections at Choctaw Avenue and U.S. 81 and US 62/U.S. 81 west of downtown Chickasha. This delay would be eliminated once the realigned route opens, since it is assumed these vehicles would no longer travel on the existing U.S. 81 corridor. Calculation of this delay for no-build conditions is found on the “Oversize Load-Choctaw & U.S. 81” and “Oversize Load-U.S. 81 & US 62” tabs in the BCA spreadsheet. For discussion purposes, the methodology used for calculating vehicle delay at the Choctaw Avenue and U.S. 81 intersection on the “Oversize Load-Choctaw & U.S. 81” tab is presented below, although the methodology for the US 62/U.S. 81 intersection is the same.

According to the *Access Justification Report for U.S. 81 Realignment* prepared for ODOT, AADT approaching the Choctaw Avenue and U.S. 81 intersection from the north, south, east, and west for no-build conditions in the 2016 base year is approximately 17,000 vehicles (R:14) and is projected to increase to 29,860 vehicles (BJ:14) by 2060. The truck factor is 17 percent (B:16; C:16; D:16) and remains constant throughout the BCA analysis period. Vehicle volumes at the intersection were further broken down to northbound/southbound total volume (Table – M:19), eastbound/westbound total volume (Table – M:26), northbound/southbound AM peak volume (Table – M:34), eastbound/westbound AM peak volume (Table – M:41), northbound/southbound PM peak volume (Table – M:49), and eastbound/westbound PM peak volume (Table – M:56). These traffic volumes were used to estimate hourly northbound/southbound and eastbound/westbound off-peak volumes (Table – A:26 and Table – A:75) for the base year of 2016, with northbound/southbound AM and PM peak hours (C:31 and C:40) and eastbound/westbound AM and PM peak hours (C:79 and C:88) assumed to occur during the 8:00 AM to 9:00 AM and 5:00 PM to 6:00 PM hours, respectively. The hourly off-peak volumes for northbound/southbound and eastbound/westbound traffic for 2016 were then extrapolated through the analysis period (Table – M:64 and Table – M:72) using the same growth rates as total and peak hour traffic.

ODOT estimates that 625 super oversize vehicles traveling on U.S. 81 each year cause significant traffic delays due to the 90-degree turns at Choctaw Avenue/U.S. 81 and US 62/U.S. 81. According to Chickasha’s City Manager, each super oversize vehicle causes traffic to stop at each intersection for approximately 25 minutes.

Based on this information, the analysis divided 625 vehicles by 261 days (B:114) based on the assumption that the super oversize vehicles only travel through the intersection on weekdays. This calculation yielded 2.4 super oversize vehicles traveling through the intersection per weekday each year. Multiplying 2.4 vehicles by 25 minutes for the vehicles to clear the intersection and traffic to return to normal conditions yields 59.9 minutes of delay per weekday (B:117). Fifty percent of this delay was allocated to peak hours (E:117) and the other 50 percent was allocated to off-peak hours (E:116). Based on these allocations, the analysis assumed 29.9 minutes of delay occur during peak hours (D:117) and 29.9 minutes occur during off-peak hours (D:116).

Scenarios where super oversize vehicles travel through the intersection during the 11:00 AM to 12:00 PM hour (i.e., off-peak hour) and 5:00 PM to 6:00 PM hour (i.e., peak hour) were created on the “Oversize Load-Choctaw & U.S. 81” tab (Table – M:438 and Table – M:791). To calculate vehicle delay for traffic at

the intersection during passage of the super oversize vehicles during both hours, the formula below was used:⁷

$$V = (1/2) ((qTG^2)/(1-q/d))$$

where:

V = vehicle delay

q = intersection arrival rate in vehicles per minute

TG = traffic stop time

d = intersection departure rate in vehicles per minute

The following formula was used to calculate q :

$$q = y/t$$

where:

q = intersection arrival rate in vehicles per minute

y = cumulative number of vehicles arriving at the intersection during the hour

t = time in minutes

For example, the intersection arrival rate in passenger vehicles per minute in 2016 for northbound/southbound traffic on U.S. 81 during the 5:00 PM to 6:00 PM peak hour is 8.2 passenger vehicles (R:798).

The following formula was used to calculate d :

$$d = y/(t - TG)$$

where:

d = intersection departure rate in vehicles per minute

y = cumulative number of vehicles departing the intersection during the hour after the super oversize vehicle has passed through

t = time in minutes

TG = traffic stop time

For example, the departure rate in passenger vehicles per minute in 2016 for northbound/southbound traffic on U.S. 81 during the 5:00 PM to 6:00 PM hour is 16.5 passenger vehicles (R:802).

The calculations for the vehicle arrival and departure rates as well as the traffic stop time were used in the vehicle delay formula to calculate total vehicle delay for northbound/southbound and eastbound/westbound traffic at U.S. 81 and Choctaw Avenue during the 11:00 AM to 12:00 PM and 5:00

⁷ The analysis used the methodology at: <https://www.portoflosangeles.org/EIR/APL/DEIR/Appendix%20H2%20-%20At%20Grade%20Crossing%20Memo.pdf>

PM to 6:00 PM hours used in the scenarios. For example, on the “Oversize Load-Choctaw & U.S. 81” tab, the passenger vehicle delay in minutes in 2016 for northbound/southbound traffic on U.S. 81 during the 5:00 PM to 6:00 PM peak hour is 7,408.3 minutes (R:806).

Northbound/southbound and eastbound/westbound vehicle delay in minutes was converted to delay in hours for the 11:00 AM to 12:00 PM and 5:00 PM to 6:00 PM hours and then summed to estimate total passenger vehicle and truck delay per day for 2016 through 2060 (R:1552 through BJ:1553). Passenger vehicle and truck delay per day was then converted to total annual passenger vehicle and truck delay for 2016 through 2060 (R:1556 through BJ:1557). Finally, annual passenger vehicle and truck delay were monetized (R:1564 through BJ:1565) using USDOT’s recommended values of time of \$19.60 per passenger vehicle per hour and \$27.20 per truck per hour on the “Recommended Values” tab.

The results of the analyses for the Choctaw Ave/U.S. 81 and US 62/U.S. 81 intersections were summed on the “Travel Time & VOCs” tab in the table titled “Super Oversize Vehicle – Delay.” As shown in this table, total annual delay in 2016 is 280,855 hours for passenger vehicles (non-discounted value of \$5.5 million) and 57,525 hours for trucks (non-discounted value of \$1.6 million). By 2060, total annual delay increases to 481,350 hours for passenger vehicles (non-discounted value of \$9.4 million) and 98,590 hours for trucks (non-discounted value of \$2.7 million).

It is important to note that the assumptions made in this analysis for the frequency of super oversize vehicles traveling through the 90-degree turns on U.S. 81 and the duration of delay caused by those vehicles have the largest influence on the results of the BCA and could significantly change the outcomes if varied. Traffic analysis for frequency of the super oversize vehicles that travel through the 90-degree turns on U.S. 81 requires a manual delay measurement that is not typically collected from traffic counts. Typical automated traffic count devices such as road tubes, blue tooth, and system loop devices used to measure traffic volumes, speed, and vehicle classification would not be appropriate to measure the delay associated with the stopped traffic. The current technology of the wireless/blue tooth signal collection would collect the delay but would not be able to determine that the delay is associated with the super oversize vehicle traffic control. A method to collect long-term data for the annual frequency and duration of events would be a permanent video camera installation at the intersections wired with continuous power and a wireless signal to transfer video files to a Microsoft Cloud server. The video could be sped up and manually reviewed to measure the actual occurrences of these events for the duration of a year. Once the frequency, time of weekday occurrence, and duration of events is collected, a more accurate delay estimation can be calculated.

Time Savings from Removal of At-Grade Railroad/Local Street Crossing Conflict

Another source of delay for vehicles traveling on U.S. 81 north of downtown Chickasha, although not nearly as significant as the delay from the super oversize vehicles, is the at-grade Union Pacific railroad crossing located between the US 62/81 intersection and Reding Road. Calculation of delay for vehicles waiting for trains to pass at this crossing is found on the “Union Pacific RR Crossing-Delay” tab in the BCA spreadsheet. Note that this delay only occurs in no-build conditions, because this segment of U.S. 81 becomes part of the realignment in build conditions, and a bridge is constructed over the railroad.

The calculation of delay at the railroad crossing followed the same methodology used to calculate delay from the super oversize vehicles. According to the *Access Justification Report for U.S. 81 Realignment* prepared for ODOT, AADT on U.S. 81 north of the US 62/U.S. 81 intersection in the base year of 2016 is 4,412 vehicles (B:15) and is projected to increase to 7,760 vehicles (D:15) by 2060. The truck factor is 17 percent (B:16; C:16; D:16) and remains constant throughout the BCA analysis period. Data regarding

train activity on the Union Pacific Railroad was obtained from USDOT's Crossing Inventory Form, which was supplemented with assumptions made for this analysis (Table – A:109). The analysis assumed four trains per day, two occurring between 6:00 AM and 6:00 PM and two occurring between 6:00 PM and 6:00 AM. Trains were assumed to be 135 cars in length, with each car measuring 49 feet in length.⁸ According to the USDOT Crossing Inventory Form, trains are traveling at a typical speed of 20 to 40 miles per hour over the crossing. For this analysis, a speed of 30 miles per hour was used.

Gate-down time per train was calculated based on the length and speed of the train (Table – A:129). The speed of 30 miles per hour was converted to 2,640 feet per minute. Based on ratios, it is estimated that the trains take two minutes and 36 seconds to pass through the crossing. Thirty seconds are then added to this calculation, with 25 seconds accounting for the gates going down prior to the train's arrival at the crossing and five seconds accounting for a delay before the gates go back up after the train has passed.⁹ Total gate-down time for the trains is therefore three minutes and six seconds in the analysis.

To calculate vehicle delay for traffic approaching the railroad crossing, the same formulas used to calculate vehicle delay generated by super oversize vehicles were used, since average delay for railroad crossings is computed in the same manner. Gate-down time is used in the formulas instead of traffic stop time.

As an example of the results of the calculations on the "Union Pacific RR Crossing-Delay" tab, the total passenger vehicle delay in minutes in 2016 for northbound traffic on U.S. 81 during the 8:00 AM to 9:00 AM peak hour is 212.3 minutes (R:302).

Northbound and southbound vehicle delay in minutes was converted to delay in hours for each hour of the day that a train was assumed to travel through the intersection and then summed to estimate total passenger vehicle and truck delay per day for 2016 through 2060 (R:1576 through BJ:1577). Passenger vehicle and truck delay per day was then converted to total annual passenger vehicle and truck delay for 2016 through 2060 (R:1580 through BJ:1581). Finally, annual passenger vehicle and truck delay were monetized (R:1589 through BJ:1590) using USDOT's recommended values of time of \$19.60 per passenger vehicle per hour and \$27.20 per truck per hour on the "Recommended Values" tab.

The results of the analysis were summed on the "Travel Time & VOCs" tab in the table titled "Union Pacific Railroad Crossing – Delay." As shown in this table, total annual delay in 2016 is 8,915 hours for passenger vehicles (non-discounted value of \$174,700) and 1,826 hours for trucks (non-discounted value of \$49,700). By 2060, total annual delay increases to 15,672 hours for passenger vehicles (non-discounted value of \$307,100) and 3,210 hours for trucks (non-discounted value of \$87,300).

Total Time Savings – No-Build versus Build

Based on the travel time and travel delay analyses described above, it was possible to calculate time savings for build conditions compared to no-build conditions. These calculations are shown in the table titled "No Build Segments Minus Build U.S. 81 and Realignment Segments" on the "Travel Time & VOCs" tab and are summarized in **Figure 9** below. As shown in Figure 9, time savings generated by construction of the realignment increases from more than 651,600 hours in 2025 (non-discounted

⁸ http://www.bnsfhazmat.com/wp-content/uploads/2015/06/4185_Field_Guide_To_Tank_Cars1-opt.pdf Page 36

⁹ Based on <http://www.seattle.gov/transportation/docs/121105PR-CoalTrainTrafficImpactStudy.pdf> Page 13 and

<http://www.caltrain.com/assets/engineering/engineering-standards-2/criteria/CHAPTER7.pdf> Page 7-19

value of \$11.8 million) to approximately 979,100 hours by 2060 (non-discounted value of \$17.8 million).

Figure 9
Time Savings for Build Conditions Versus No-Build Conditions
2025 to 2060

	2025	2030	2040	2060
NO-BUILD				
Annual Hours of Travel Time/Delay	1,677,472	1,816,565	2,131,368	2,543,813
BUILD				
Annual Hours of Travel Time/Delay	1,025,834	1,111,256	1,303,751	1,564,708
DIFFERENCE				
Time Savings (Annual Hours)	651,638	705,309	827,616	979,105
Time Savings (Annual \$)	\$11,840,600	\$12,816,400	\$15,043,900	\$17,820,200

Source: CDM Smith

The monetized values of time savings from the “No Build Segments Minus Build U.S. 81 and Realignment Segments” table on the “Travel Time & VOCs” tab were transferred to the “BCA Summary” tab for the years in which benefits are accrued (Rows 20 and 21). The time savings benefits for build conditions versus no-build conditions amount to a total non-discounted value of nearly \$542.9 million during the BCA’s 2016 to 2060 analysis period.

Vehicle Operating Cost Savings

Construction of the realigned route around Chickasha would also produce economic savings from reduced vehicle operating costs due to the realignment’s shorter travel distance. To estimate this benefit of ODOT’s project, annual vehicle miles traveled (VMTs) were calculated during the same analysis used to conduct vehicle travel times on the existing U.S. 81 corridor and the realignment. The methodology is described using the same “Realign-Segment 2-Travel Time” tab that was used to explain the methodology for travel time calculations. On the “Realign-Segment 2-Travel Time” tab, VMTs were calculated by multiplying annual vehicle volumes throughout the analysis period by the length of the road segment. For example, for northbound AM peak hour traffic in 2025, 140 passenger vehicles in 2025 (X:83) were multiplied by 1.65 miles (B:28), which is the length of the realigned segment, to arrive at 230 VMTs (X:87). Total VMTs per day for this segment of the realignment for each year of the analysis period were summed in “Travel Time Grand Totals” table (J:282). This process was used for no-build and build conditions in the “Realign-Segment 1-Travel Time” through “Realign-Segment 6-Travel Time” tabs and “Segment 1-Travel Time” through “Segment 16-Travel Time” tabs in the BCA spreadsheet.

The results for all existing U.S. 81 and realigned segments for no-build and build conditions were summed and converted to annual VMTs in the tables on the “Travel Time & VOCs” tab. Results for existing U.S. 81 in no-build conditions are shown in the table titled “Segments-Travel Time.” As shown in this table, annual VMTs in 2016 is more than 31.8 million for passenger vehicles and more than 6.4 million for trucks. By 2060, annual VMTs increase to nearly 55.5 million for passenger vehicles and nearly 11.4 million for trucks.

Results for traffic traveling on existing U.S. 81 and the realignment for build conditions were summed in the table titled “U.S. 81 & Realignment Segments – Travel Time.” This table shows that once the realigned route opens in 2025, annual VMTs in 2025 for both routes is nearly 34.8 million for passenger vehicles and nearly 7.2 million for trucks. By 2060, annual VMTs increase to 53.0 million for passenger vehicles and to more than 10.9 million for trucks.

Total Vehicle Operating Cost Savings – No-Build versus Build

Similar to total time savings, it was possible to calculate vehicle operating cost savings for build conditions compared to no-build conditions. These calculations are shown in the table titled “Vehicle Operating Costs” on the “Travel Time & VOCs” tab. The differences in annual VMTs between U.S. 81 for no-build conditions and U.S. 81 and the realignment for build conditions were calculated in the “No Build Segments Minus Build U.S. 81 and Realignment Segments” table. Annual VMTs from that table were then monetized using USDOT’s recommended values of \$0.40 per mile for passenger vehicles and \$0.96 per mile for trucks from the “Recommended Values” tab. **Figure 10** summarizes the vehicle operating cost savings for build conditions versus no-build conditions. Construction of the realignment reduces VMTs by 2.2 million in 2025 (non-discounted value of \$1.1 million) and 2.9 million in 2060 (non-discounted value of \$1.4 million).

Figure 10
Vehicle Operating Cost Savings
for Build Conditions Versus No-Build Conditions
2025 to 2060

	2025	2030	2040	2060
NO-BUILD				
Annual Vehicle Miles Traveled	44,221,714	47,880,802	56,132,693	66,810,645
BUILD				
Annual Vehicle Miles Traveled	41,962,595	45,438,381	53,278,193	63,876,531
DIFFERENCE				
Annual Vehicle Miles Traveled	2,259,120	2,442,421	2,854,500	2,934,115
Vehicle Operating Cost Savings (Annual \$)	\$1,096,700	\$1,185,700	\$1,385,700	\$1,420,900

Source: CDM Smith

The monetized values of vehicle operating cost savings from the “Vehicle Operating Costs” table on the “Travel Time & VOCs” tab were transferred to the “BCA Summary” tab for the years in which benefits are accrued (Rows 24 and 25). The vehicle operating cost savings for build conditions versus no-build conditions amount to a total non-discounted value of nearly \$47.9 million during the BCA’s 2016 to 2060 analysis period.

Safety

An additional economic benefit of the realignment is the reduction in fatal, injury, and property damage collisions as a result of routing through traffic on U.S. 81 around Chickasha instead of through the downtown area. Collisions are often extremely costly in terms of loss of life, lost productivity due to injury, and vehicle or other property damage. To compute crash benefits associated with the proposed project, collision data for U.S. 81 was provided by ODOT. In the BCA spreadsheet, the safety analysis calculations are found on the “Safety-Severity” and “Safety-Valuation” tabs.

The number of crashes for five consecutive years between July 1, 2011 and June 30, 2016 (the latest years complete data were available) was calculated on the “Safety-Severity” tab (D:6 through H:11) for the existing U.S. 81 project area between approximately 16th Street (south of Hwy 19) to the U.S. 81/62 intersection west of downtown Chickasha. The July 2011 to June 2016 five-year collision totals were as follows:

- Property Damage Only (PDO) – 496
- Possible Injury - 132
- Non-Incapacitating Injury – 70
- Incapacitating Injury – 16
- Fatal – 4
- Total – 718

The analysis estimated year 2040 collisions for the project area for no-build and build conditions to determine crash reductions of the project. The estimated number and severity of collisions for no-build and build conditions were provided for the three most severe collision types. Possible injury and property damage only collisions were calculated using the percent growth in the projected three most severe collision types. The growth rates were 61 percent for no-build conditions and 38 percent for build conditions. The collision data between 2012 and 2040 for each severity level was annualized to produce the year by year collision data. These annual growth rates were extended to 2060 to match the BCA analysis period. The year by year collision reductions by severity category are shown in “Table 2” on the “Safety-Valuation” tab (B:27 through BH:32).

To monetize the collision savings, the total costs associated with each type of accident were obtained from USDOT’s *Benefit-Cost Analysis Resource Guidance for TIGER and INFRA Applications*, which uses in the Abbreviated Injury Scale (AIS). USDOT’s guidance also provided the conversion factors, methodology to convert the available project collision data into seven collision severity tiers of the AIS, and monetized values for the seven severity tiers, which are shown in “Table 2” (A:37 to C:77) on the “Safety-Valuation” tab. The total costs ranged from \$9.6 million for a fatal collision to \$28,800 for an AIS 1 minor injury collision. The monetized costs for each AIS collision severity category are shown in “Table 2” (A:81 to BH:93). **Figure 11** identifies the collision reductions for build conditions versus no-build conditions and value of avoided crashes as calculated in this analysis. As shown in Figure 11, construction of the realignment reduces total crashes by 13 in 2025 (\$10.2 million) and by 46 in 2060 (\$11.8 million).

Figure 11
Crash Reductions for Build Conditions Versus No-Build Conditions
2025 to 2060 (Note 1)

Crash Category	2025	2030	2040	2060
NO-BUILD				
Property Damage Only	112	123	145	189
Possible Injury	43	47	55	71
Incapacitating Injury	6	8	10	15
Fatality	1	1	2	2
Total of All Crashes	163	179	212	277
BUILD				
Property Damage Only	104	111	125	158
Possible Injury	40	43	48	60
Incapacitating Injury	6	6	8	12
Fatality	1	1	1	2
Total of All Crashes	151	161	182	231
DIFFERENCE				
Property Damage Only	8	12	20	31
Possible Injury	3	4	7	11
Incapacitating Injury	1	1	2	3
Fatality (Note 1)	1	1	1	1
Total of All Crashes	13	18	30	46
Value of Avoided Crashes (\$)	\$10,172,000	\$10,458,000	\$11,030,000	\$11,830,800

Note 1: Use of decimal values in the crash figures may affect arithmetic calculations.

Note 2: Fatalities were rounded up for values less than 1 in the analysis.

Source: CDM Smith

The results of the analysis were transferred to the “BCA Summary” tab for the years in which benefits are accrued (Rows 32 – 40). The safety benefits generated by construction of the realignment include the following:

- 1,160 total vehicle crashes avoided during the BCA analysis period (AW:32 to AW:35), which includes 36 fatalities, and
- Total non-discounted value of \$401.0 million in collision savings during the BCA analysis period.

Quality of Life Improvements

The sections above quantified those aspects of the project that could be estimated with a dollar value. It should be noted that there are additional benefits associated with this project that are difficult to assign a dollar value to. The U.S. 81 realignment project has the potential to positively impact the quality of life for residents of Chickasha. The benefits of the project will include the following.

- The realigned route will provide better response times for emergency vehicles to parts of Chickasha. Ambulances transporting patients to and from Grady Memorial Hospital, located on W. Iowa Avenue, will have easy access to the realignment via the W. Iowa Avenue interchange, approximately one mile from the hospital. The Chickasha Police Department is located just east of the Grady Memorial Hospital, so it would benefit from its ease of access, as well.

- Less traffic through Chickasha on U.S. 81 means reduced noise impacts. Because a significant portion of the diverted traffic is expected to be truck traffic, the reduction in noise could be substantial and contribute significantly to a better quality of life along the existing U.S. 81 corridor.
- The realignment will bring economic development opportunities to Chickasha, especially at the interchange locations. Traffic using the realigned route will need services at the interchanges, prompting the growth of businesses at these locations.
- Due to congestion and bottlenecks along U.S. 81, the City of Chickasha receives as many as three calls per day from truckers requesting to reroute. Not only does this put large vehicles in neighborhoods not accustomed to this type of traffic, it also requires the Chickasha Police Department to assist with getting these vehicles safely through the city several times per month. The construction of the realignment will eliminate these rerouting requests and allow law enforcement to focus on other duties.

Without extensive study, it is not possible to estimate the financial value of these benefits. Nevertheless, it is safe to say that these benefits are over and above those quantified in the BCA.

Project Costs

Costs associated with the U.S. 81 realignment project include the following:

- Pre-construction costs,
- Construction costs, and
- Maintenance costs.

Data sources for these costs, or the methodologies used to calculate them, are described below.

Pre-Construction Costs

ODOT provided costs for preliminary engineering, environmental clearance, right-of-way acquisition, and utilities relocation to be completed during the 2016 to 2019 period prior to construction. These costs were provided in 2017 dollars and were adjusted to 2016 dollars using the Consumer Price Index values on the “CPI” tab (O:23 and N:22). These costs are shown in Rows 68 to 70 on the “BCA Summary” tab and amount to a total non-discounted value of \$23.0 million (AW:68 to AW:70) during the BCA analysis period.

Construction Costs

ODOT provided costs for construction of the realignment, which would begin in 2020 and finish in 2024.¹⁰ These costs were provided in 2017 dollars and were adjusted to 2016 dollars using the Consumer Price Index values on the “CPI” tab (O:23 and N:22). These costs are shown on the “BCA Summary” tab in Row 71 and amount to a total non-discounted value of \$233.5 million (AW:71).

Maintenance Costs

ODOT provided estimated maintenance costs per lane-mile in 2017 dollars for the existing U.S. 81 corridor and for the realigned route. These costs are presented on the “Maintenance Costs” tab and include costs for pavement rehabilitation, preservation, and reconstruction, as well as silane, joint projects, and general maintenance. Total maintenance costs per year for no-build and build conditions

¹⁰ Construction activities include construction of grading and drainage, bridges, interchanges, and highway surfacing.

were calculated from the information provided by ODOT in the “No Build” (AJ:48) and “Build” (AJ:56) tables on the “Maintenance Costs” tab. Total build costs for the existing U.S. 81 corridor and realignment were then subtracted from no-build costs to estimate net maintenance costs in the “No Build Minus Build” table.

Net maintenance costs were transferred to the “BCA Summary” tab in Row 10 and adjusted to 2016 dollars using the Consumer Price Index values in cells O:23 and N:22 on the “CPI” tab. Note that the maintenance costs are shown on the benefits side in the “BCA Summary” tab. They are shown as negative benefits (i.e., disbenefits), as required in USDOT’s *Benefit-Cost Analysis Guidance for TIGER and INFRA Applications*. Total maintenance costs/disbenefits amount to a total non-discounted value of nearly \$36.4 million (AW:12) during the BCA analysis period.

BCA Results

Figure 12 presents the results of the BCA, expressed in terms of net present value (NPV) and benefit-cost ratio (BCR), using a discount rate of 7 percent. NPV is calculated as follows:

$$\text{Benefits} - \text{Costs} = \text{NPV}$$

A BCR is calculated as follows:

$$\text{Benefits} \div \text{Costs} = \text{BCR}$$

Figure 12
BCA Results

Benefits with 7% Discount Rate	\$189,362,000
Costs with 7% Discount Rate	\$176,353,000
NPV	\$13,009,000
BCR	1.07

Source: CDM Smith

As shown in **Figure 12**, the BCA achieves an NPV of \$13.0 million and a BCR of 1.07.