APPENDIX D. BENEFIT COST ANALYSIS REPORT

BCA TABLE OF CONTENTS

1. OVERVIEW OF APPROACH

The benefit cost analysis (BCA) has been conducted following the guidance from the USDOT contained in Benefit-Cost Analysis Guidance for Discretionary Grant Programs (March 2022)[30].

1.1 GENERAL ASSUMPTIONS

- All costs and benefits in the BCA are expressed in 2020 constant dollars discounted to the year 2020 (year zero for discounting). Costs and benefits have been adjusted where needed to 2020 dollars based on the inflation guidance provided by the USDOT Table A-7.
- The period of operation is assumed to be 25 years, a compromise between recommended 20 years for replacement infrastructure versus 30 years for new infrastructure.
- All monetary values are discounted using a 7 percent discount rate, with the exception of carbon emissions, which are discounted at 3 percent.
- Because the number of train crossings and volume of vehicular traffic are relatively consistent over the course of an entire week, including weekends, all daily values (e.g., modeled daily travel delay savings) are annualized using 365 days per year.

2. PROJECT COSTS

2.2 CAPITAL COST

Total capital costs have been estimated by project engineers at $26.0 million in 2021 dollars (slightly less in 2020 dollars), including a total construction cost of $20 million. Previously incurred costs (primarily in 2019) included $1.35 million for environmental and engineering and $4.60 million for right-of-way and utilities. Previously incurred bond issuance costs ($2.17 million) have been excluded from the BCA, as these are financial exchanges and not resource costs. The previously incurred capital costs are about $ 6.37 million in 2020 dollars. The construction costs are assumed to be incurred and split evenly between 2023 and 2024. The discounted future year build capital cost in 2020 dollars is $15.79 million.

Periodic major rehabilitation and repair costs have not been included, nor have routine maintenance costs. Initial engineering estimates indicate that these costs will be about the same under Build and No-Build conditions. Cost reductions associated with the maintenance and operation of the grade crossing protection and pavement installations are included as project life cycle cost ***benefits*** rather than as cost offsets, since they are not road related but rather are current expenses incurred by the railroad.

[30] https://www.transportation.gov/sites/dot.gov/files/2022-03/Benefit%20Cost%20Analysis%20Guidance%202022%20%28Revised%29.pdf

A salvage value has also been included, reflecting a useful life of 40 years for the new infrastructure, considered a reasonable engineering estimate for new highway facilities constructed with current materials and technology. The salvage value is approximately $1.37 million in 2020 dollars. The discounted cost of $20.79 million (in 2020 dollars) is calculated by subtracting the salvage value ($1.37 million) from the total build capital cost of $22.16 million (in 2020 dollars). The total capital build cost of 22.16 million is the sum of the previously incurred cost of $6.37 million and the future capital cost of $15.79 million.

Table D.1 – 90% Engineering Cost Estimate, 2021 $s

	BOND FUNDS		STATE FUNDS		FEDERAL FUNDS		RAISE FUNDS	TOTAL PROJECT COSTS
	Incurred	Future	Incurred	Future	Incurred	Future		
Environmental & Engineering	$1.35							$1.35
ROW & Utilities	$4.60							$4.60
Construction		$5.00		$5.00			$10.00	$20.00
Total included in BCA	$5.95	$5.00		$5.00			$10.00	$25.95

Source: Project Engineer, Poe Engineering

2.2 MAINTENANCE AND REHAB COSTS

Engineering estimates indicate that these costs will be about the same under Build and No-Build conditions. Cost reductions associated with the maintenance and operation of the grade crossing protection (gates, lights) and pavement installations are not included in the construction cost but are included as project life cycle cost benefits rather than as cost offsets, since they are not road related but rather are current expenses incurred by the railroad.

2.3 SALVAGE VALUE

A salvage value has also been included at the end of the 25th and final year of analysis, reflecting a useful life of 40 years for the new infrastructure. The forty-year assumption is considered by project engineers to be a reasonable estimate for new highway facilities constructed with current materials and technology. The salvage value was computed utilizing straight line depreciation.

3. PROJECT BENEFITS INCLUDED IN THE BCA

3.1 TRAVEL TIME SAVINGS FOR VEHICULAR TRAFFIC

Benefits have been calculated based on a queuing analysis of delay caused by the frequent blockages when the 30-plus daily trains move through the at-grade crossing. The following **Table D.2** highlight the key input assumptions. The analysis is conducted for the year 2040, and all resulting delay values are adjusted downward prior to 2040 based on the compound annual rate of growth in daily traffic – that is, the annual numbers prior to 2040 work "backward" from that year based on the growth curve.

Table D.2 – Key Traffic Inputs to Queuing Analysis

Daily Traffic	15500
Avg Passenger Vehicle Occupancy	1.7
Percent Trucks	7%
Duration of Train (Minutes)	3.92
Discount Rate	0.07
Cycle Length between Train Arrivals (	2706.77
"red" time (seconds)	234.00
Green Ratio g/C	0.91
Capacity Per Lane (PCE / HR)	1000
Saturation Flow Rate	4000
SH-37 Hourly Capacity PCE (w.r.t. cros	3654.2

Source: City of Moore, High Street Consulting, Poe Engineering

Estimated delay reflects the number of trains, the hourly volumes of traffic over a twenty-four-hour period, the probability of traffic during each hourly interval of being blocked, the roadway capacity, and the speed at which queues dissipate after a blockage is ended by the gate control equipment.[31]

3.2 TRAVEL RELIABILITY IMPROVEMENT FOR VEHICULAR TRAFFIC

While about seven percent of vehicles each day are held up when trains pass, the train movements are not fixed by a rigid schedule, and thus uncertainty in travel is introduced. This analysis calculates reliability benefits based on buffer time that travelers are likely to build into their schedules to offset the risk of late arrival. The analysis assumes that trucks and passenger vehicles use that buffer based on a probabilistic calculation of a potential stoppage. Specifically, the analysis estimates a buffer time applicable to drivers who are *not* delayed by a blockage, weighted by a seven percent probability of being delayed. The buffer is assumed to be equal to the average delay, which is between three and four minutes per train. Drivers who are blocked have already incurred that delay penalty, calculated in travel time delay, and thus are not

[31] The analysis utilizes the methodology for traffic queuing analysis contained in "Traffic Signal Systems Operations and Design" by Michael Kyte and Tom Urbanik, 2012, Pacific Crest (Plainfield, IL).

"double penalized" by buffer and delay. The value estimated in this category does not include the economic costs of delay to emergency vehicles, which are calculated separately using a different methodology based on survival probabilities.

Buffer time for passenger vehicles and trucks are calculated utilizing the formula:

Buffer time$_m$ = (total trips$_m$ - trips actually delayed$_m$) x average delay when gates down x probability of delay

where m equals mode (passenger vehicle, commercial vehicle).

The value of buffer time is then estimated based on the average value of time for passengers and for commercial vehicles. The reliability benefits are shown in **Table D.3**.

Table D.3. Reliability Benefits – 2040

	2040
Auto	
Total daily auto trips	16247
Daily auto trips delayed	1038
Daily auto trips not delayed	15209
Average length of delay at a crossing (minutes)	3.9
Daily auto buffer time not delayed (hours)	63.1
Daily value of auto buffer time (not delayed)	$ 1,130
Annual value of auto buffer time (undiscounted)	$ 412,564
Truck	
Total daily truck trips	1223
Daily truck trips delayed	78
Daily truck trips not delayed	1145
Average length of delay at a crossing (minutes)	3.9
Daily truck buffer time not delayed (hours)	4.8
Daily value of truck buffer time (not delayed)	$ 146
Annual value of truck buffer time (undiscounted)	$ 53,432
Total annual reliability benefit (undiscounted)	$ 465,996

Source: City of Moore, High Street Consulting, Poe Engineering

3.3 AIR EMISSIONS REDUCTIONS:

Emissions reductions were estimated based on the reductions in delay hours for traffic. Rates of emissions (kg per vehicle hour) for cars, small trucks, and large trucks were obtained from the MOVES3 model, and are consistent with emissions rates currently employed in EBP's TREDIS model. Emissions reductions for NOx, SOx, CO_2, and $PM_{2.5}$ were obtained from MOVES3 and monetized based on the DOT BCA guidance.

3.4 FUEL COST SAVINGS

Fuel consumed while vehicles idle at the grade-crossing have been estimated based on average rates of fuel consumed per vehicle hour of idling as reported by the U.S. Office of Energy Efficiency and Renewable Energy. Fuel prices net of fuel taxes are applied to gallons saved.

3.5 BIKE AND PEDESTRIAN TIME SAVINGS

The pedestrian bridge will shorten walk and bike times for the average local walk and bike trip in and around the study area. Travel time savings have been valued at $32.40 per hour, as per 2022 BCA guidance. The bike and walking time savings are shown in **Table D.4**.

Table D.4. Bike and Ped Time Savings

Annual park visitors/passes		68907
Daily park visitors/passes		189
	minutes/trip	estimated daily two-way trips
walk time differential (build vs. no build)	8	50
bike time differential (build vs. no build	2.25	50

Source: City of More; HighStreet Consulting and Poe Engineering

3.6 CRASH REDUCTIONS

Vehicle Crashes: Crash reductions include vehicle-train incidents (three injury-related incidents over the past 47 years), and rear-end collisions in and around the study area, which are reasonably assumed to be associated with stopped vehicles during times when the crossing gates are down. Half of historic rear-end collisions are assumed to be associated with the at-grade crossing.

Accident data utilized to establish vehicular accident rates under future 2040 traffic levels were estimateed based on the following data provided by ODOT. The 10-year accident rates are shown in **Table D.5**.

OKLAHOMA Transportation

Table D.5. 10-Year Vehicular Accident Rates Proximate to the At-Grade Crossing

Collisions By Type Of Collision

Type Of Collision	2010				2011				2012				2013				2014			
	Fat	Inj *	PD	Tot	Fat	Inj *	PD	Tot	Fat	Inj *	PD	Tot	Fat	Inj *	PD	Tot	Fat	Inj *	PD	Tot
Rear-End (front-to-rear)		3	7	10		4	5	9		4	3	7		2	5	7		5	7	12
Head-On (front-to-front)																				
Right Angle (front-to-side)			2	2		2		2		1		1		1		1		1		1
Angle Turning		1	3	4		3	4	7		3	3	6		1	5	6		2	5	7
Other Angle																				
Sideswipe Same Direction							1	1			2	2			1	1			1	1
Sideswipe Opposite Direction											1	1								
Fixed Object							1	1												
Pedestrian																				
Pedal Cycle																				
Animal																				
Overturn/Rollover																				
Vehicle-Train																				
Other Single Vehicle Crash																		1		1
Other															1	1				
Total		4	12	16		9	11	20		8	9	17		4	12	16		9	13	22
Percent		2.2	6.5	8.6		4.9	5.9	10.8		4.3	4.9	9.2		2.2	6.5	8.6		4.9	7.0	11.9

Collisions By Type Of Collision

Type Of Collision	2015				2016				2017				2018*				2019*			
	Fat	Inj *	PD	Tot	Fat	Inj *	PD	Tot	Fat	Inj *	PD	Tot	Fat	Inj *	PD	Tot	Fat	Inj *	PD	Tot
Rear-End (front-to-rear)		3	9	12		4	9	13		3	4	7		2	1	3		4	8	12
Head-On (front-to-front)															1	1				
Right Angle (front-to-side)			1	1			1	1												
Angle Turning		1	3	4		2		2		2	1	3		3	6	9			8	8
Other Angle																				
Sideswipe Same Direction							1	1											2	2
Sideswipe Opposite Direction																				
Fixed Object			2	2											1	1				
Pedestrian									1			1								
Pedal Cycle																				
Animal																				
Overturn/Rollover																				
Vehicle-Train																				
Other Single Vehicle Crash																				
Other			1	1			1	1												
Total		4	16	20		6	12	18	1	5	5	11		5	9	14		4	18	22
Percent		2.2	8.6	10.8		3.2	6.5	9.7	0.5	2.7	2.7	5.9		2.7	4.9	7.6		2.2	9.7	11.9

* INCLUDES SUSPECTED SERIOUS, NON-INCAPACITATING, AND POSSIBLE INJURIES.

Bike/Ped Crashes: In addition to auto/vehicle related crashes, the crash reduction benefits for this application reflect the sole cyclist fatality that occurred at the crossing in 2017 and discussed in the Safety merit criteria section. While only one such event has occurred, the possibility of a future fatality should not be dismissed, as the geometry of the at-grade crossing presents a potential hazard as described by the City of Moore police officer. Accordingly, the safety analysis includes an annual probability of such fatalities occurring in the future without the grade crossing elimination project. A conservative estimated probability was set at .04 assuming one such fatal event could occur over the next 25 years under the No-Build condition.

3.7 EMERGENCY RESPONSE BENEFIT

Based on the City of Moore Police Department records, 115 emergency service vehicles were forced to detour while trains were passing through or stopped at the SH-37 at-grade crossing. Assuming only one percent of those vehicles involve life threatening, time sensitive emergencies, and further assuming the detour results in delay equal to about half the “red time” at the crossing, the economic cost of lives lost from such delay has been calculated. Based on research published by FEMA, the probability of survival falls by about six percent as a result of the response time increase. Over the entire analysis period, the possibility of a life lost due to emergency response delay is about 25 percent. The emergency response analysis is shown in **Table D.6**.

Table D.6. Emergency Response Analysis

	2026
Emergency Vehicles Delayed per Year	336
Percent of Emergency Vehicles in Life Critical Situation	0.01
Average Delay Time per Vehicle (minutes)	2
Survival Probability without detour	0.1107
% reduction in survival probability from detour	6.0%
Survival Probability with detour	0.10406
Change in Survival Probability per Delayed Trip	0.00664
Economic Cost Based on Survival Rate	$241,025

Source: EBP

3.8 NOISE REDUCTIONS

Academic research indicates that there is a house price decrease associated with locations exposed to high levels of train horn noise. The econometric research, in a hedonic price case study of Pennsylvania locations, found that for noise levels significantly above an acceptable base level of 50 dB, house prices were reduced by about $5,000[32]. Based on this and the elevated dB levels associated with train horn noise in Moore, and further based on an assumption of about 100 households exposed to intense train horn noise, a one-time economic cost of about $2 million was estimated. This one-time benefit has been entered in the BCA model in the year 2026, the first full year of opening the new underpass

3.9 LIFE CYCLE COST SAVINGS

The project will save approximately $18,000 per year in costs incurred by the railroad to maintain and operate crossing protection and pavement installations for the grade crossing. This is based on information provided by the BNSF.

[32] William K. Bellinger, "The economic valuation of train horn noise: A US case study", Transportation Research, Part D 11 (2006) 310–314. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1090.8905&rep=rep1&type=pdf

BCA RESULTS

Table D.7 provides the results of the BCA. The Benefit Cost Ratio (BCR) is 1.33, with a Net Present Value (NPV) of $6.9 million. This represents a 62 percent return on investment (ROI) on the requested federal grant funding. All cost and benefits shown in the table are discounted to the year 2020, based on when they are incurred. The discounted capital costs, including the previously incurred $5.95 million, the $20 million for future construction, and the discounted salvage value (a cost offset), result in a net discounted capital cost of $20.8 million[33]. Total discounted benefits equal $27.7 million. The undiscounted cost is most relevant for funding assessment, but must be discounted for consistent benefit cost analysis purposes.

[33] *Future costs are discounted in the usual way, which reduces the "face value" of the $20 million construction cost as well as the salvage value, which occurs at the end of the 25th year; the $5.95 M which was previously incurred in 2019 is also discounted to 2020, but in this case the discounted value is higher than the "face value".*

Table D.7: Summary BCA Results

DISCOUNTED 2020 COSTS	
Build Capital Costs (previously incurred and future)	$22.16
Annual O&M and Periodic Rehab Cost (Build - No Build)	$ -
Salvage Value	$(1.37)
Total	**$20.79**
DISCOUNTED 2020 BENEFITS	
Travel Delay Savings - Vehicles	$11.60
Travel Time Savings - Bike and Pedestrian	$1.80
Emissions Benefits (CO2)	$0.47
Emissions Benefits (All Other)	$0.13
Noise Reduction (one time capitalization effect)	$1.43
Travel Reliability Benefits - Vehicles	$3.92
Emergency Vehicle Response	$0.79
Crash Reductions Benefits	$7.12
Fuel Cost Savings	$0.21
At-Grade Crossing Protection Elimination (Life Cycle Cost Savings)	$0.22
Total	**$27.69**
SUMMARY	
Benefit Cost Ratio	**1.33**
Net Present Value	**$6.90**
SHARE OF BENEFITS	
Travel Delay Savings - Vehicles	41.9%
Travel Time Savings - Bike and Pedestrian	6.5%
Emissions Benefits	2.2%
Noise Reduction Benefits	5.2%
Reliability Benefits	14.2%
Emergency Response Benefits	2.8%
Crash Reductions Benefits	25.7%
Fuel Cost Savings	0.8%
At-Grade Crossing Protection Life Cycle Cost Savings	0.8%