# Technical Memorandum: Benefit-Cost Analysis for the SLIC Grade Separation and Safety Improvements Project

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| Date: | July 15, 2019 |
| Subject: | Benefit-Cost Analysis for the SLIC Grade Separation and Safety Improvements Project |

## Project Description

The *SLIC Grade Separation and Safety Improvements Project* (hereafter called the "Project") will deliver safer and less congested access between US-31 (East Main Street traversing the heart of the City) and the Vietnam Veterans Boulevard (SR-386), a freeway that serves as a major transportation lifeline for the surrounding neighborhoods.

The Project will:

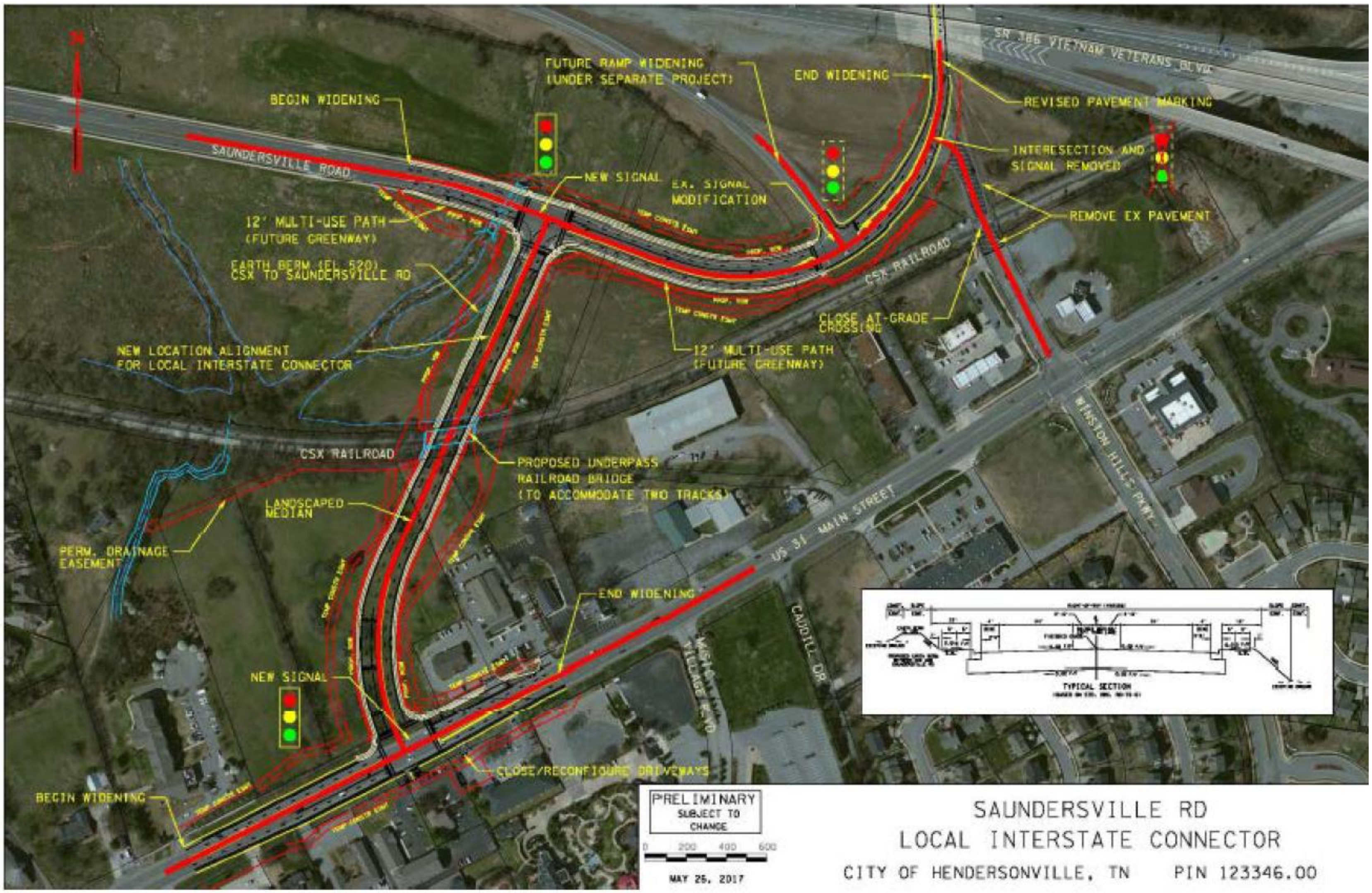
- Eliminate an existing at-grade rail crossing that is closed for trains 14 times per day, causing road traffic to queue up a connecting interchange ramp and onto the SR-386 (Vietnam Veterans Boulevard) freeway so that oncoming freeway traffic approaches the vehicle queue at speed (65 mph) with the potential for a serious crash;
- Create a new grade-separated rail crossing to maintain flow of vehicles and freight operations;
- Create a new road alignment between US-31 (East Main Street) and Local Route 6098 (Saundersville Road);
- Add lighting from the interchange along Saundersville Road and to the new connector road to improve visibility;
- Upgrade two nearby signalized intersections and provide signals at new intersections; and
- Widen US-31 to add turn lanes for the connector road and realign Saundersville Road for a new intersection with the connector road.

Collectively, these investments will improve safety, mobility and connectivity by:

- Replacing an at-grade crossing with a grade separated crossing:
  - eliminates queued vehicles on the SR-386 freeway, which are currently a significant hazard
  - removes the potential for rail and vehicle conflicts;
  - provides a reliable 24-hour route for emergency response vehicles serving the surrounding neighborhoods, and;
  - increases mobility throughout the area;
- Adding better lighting, which improves visibility and safety—several recent crashes have cited lighting as a factor; and
- The connector can accommodate bike lanes that will fill a gap in the future bicycle/greenway network by connecting the bike lanes along US-31.

Figure 1 displays a plan view of the Project, while Table 1 is the project matrix that summarizes the impacts of the Project and the results of the benefit-cost analysis.

**Figure 1– Plan View of the Project**



## Table 1 – Project Matrix

| Current Status/Baseline & Problem to be Addressed | Change to Baseline or Alternatives | Types of Impacts | Affected Population | Economic Benefit ($2017 M, 7% Discount Rate) | Page Reference in BCA |
|---|---|---|---|---|---|
| At-grade road-rail crossing causes long queues of vehicles when road crossing is closed, with queues extending onto highway SR-386 and posing a significant safety hazard. | A grade-separate road-rail crossing will eliminate queues caused by a closed crossing and significantly increase safety of the traveling public. | **Safety** | | | |
| | | At-grade Crossing | Auto and truck drivers in the study area | $0.4 | 8 |
| | | Road Impacts | Auto and truck drivers in the study area | $2.4. | 8 |
| | | Emergency Services | Residents of the study area | $0.4 | 10 |
| Traffic flow on Saundersville Road is inefficient because of the lack of appropriate turning lanes and sight lines. | The reconfiguration of Saundersville Road will increase the efficiency of traffic movements, resulting in reduced delays to the traveling public and increased safety by reducing unexpected queues in travel lanes. | **Economic Competitiveness** | | | |
| | | Travel Time Savings | Auto and truck drivers in the study area | $37.7 | 10 |
| | | Truck Vehicle Operating Savings | Truck drivers on the national network | $0.8 | 12 |
| | | Vehicle Operating Cost Savings at Grade Crossing | Auto and truck drivers in the study area | $0.04 | 12 |
| | | Construction Delays | Auto and truck drivers in the study area | -$1.7 | 13 |
| Station for emergency services is located near the at-grade road-rail crossing and emergency vehicles are delayed from responding to a large portion of their service area when the road crossing is closed. | A grade-separate road-rail crossing will eliminate delay for emergency vehicles responding to emergency calls. | **State of Good Repair** | | | |
| | | Residual Value | TDOT; Taxpayers | $0.7 | 13 |
| | | **Environmental Sustainability** | | | |
| | | Emissions Savings (auto) | All residents and non-residents | $0.04 | 13 |
| | | Emissions Savings (truck) | All residents and non-residents | $0.02 | 13 |

# Introduction

This technical memorandum estimates the long-term benefits associated with the Project. The Project described in this application would support the region's economy over the long-term by reducing travel delays, increasing safety, and reducing emissions. The long-term benefits relate to four of the goals identified in the BUILD 2019 Notice of Funding Opportunity (NOFO): Safety, Economic Competitiveness, State of Good Repair, and Environmental Sustainability.

The balance of this memorandum describes the overall analysis approach, the benefits by identified goal, costs, and the results of the analysis. The results are the net benefits of the discounted streams of anticipated benefits and costs and the Benefit-Cost Ratio (BCR) of the Project at a 7 percent discount rate.

# Overall Analysis Approach

The Benefit Cost Analysis (BCA) was conducted in accordance with guidance provided in the United States Department of Transportation's (USDOT) *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (December 2018).[1] If the USDOT BCA guidance did not provide a method for estimating an impact, the project team consulted industry research and Federal Emergency Management Agency (FEMA) guidance for the best practice and information on which to base the method and assumptions.

The benefits and costs quantified in the benefit-cost analysis are in 2017 dollars discounted to a 2019 base year. As directed in the USDOT BCA guidance, the benefits of the capital investment have been estimated over a 30-year analysis period. The last element of the Project's construction will be completed in 2023, with a benefits analysis period of 2024-2053.

The benefits were analyzed using several tools, including GradeDec.NET and a spreadsheet model developed for the analysis. The spreadsheet model presenting the BCA analysis (HendersonvilleBUILD_BCA.xlsx) is provided as supporting information with this Technical Memorandum. GradeDec.NET and the calculation inputs used for the overall BCA are discussed below.

## ***GradeDec.NET***

Interactions between trains and road users at grade crossings generate negative community impacts through two primary road-rail interactions: accidents and roadway delays while crossings are blocked by trains. Roadway delays at grade crossings increase travel times, vehicle operating costs, and emissions while vehicles idle at blocked grade crossings. These interactions are a safety concern for the community as well as a drain on its economic competitiveness, as productivity and access are negatively impacted. The Federal Railroad Administration (FRA) online tool GradeDec.NET[2] was used to estimate the benefits of improvement to the rail crossing. The safety analysis within GradeDec.NET is based on the USDOT Accident Prediction and Severity Model (APS) and Resource Allocation Method.

The GradeDec.NET analysis was run with 2017 values. The benefits evaluated for the Project through GradeDec.NET were:

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[1] U.S. DOT, 2018 Benefit-Cost Analysis Guidance for Discretionary Grant Programs, https://www.transportation.gov/sites/dot.gov/files/docs/mission/office-policy/transportation-policy/14091/benefit-cost-analysis-guidance-2018.pdf

[2] https://gradedec.fra.dot.gov/

- Safety
- Travel time savings
- Vehicle operating cost savings
- Vehicle emissions reductions
- Network benefits

The GradeDec.NET benefits were incorporated into the benefits sections below. However, because a separate travel time delay model was completed for the Project, the value of the travel time savings and network benefits from GradeDec.NET were not included the analysis to avoid double-counting.

## ***Calculation Inputs***

The BCA used multiple values and assumptions for calculation inputs in GradeDec.NET and the spreadsheet model. A list of calculation inputs are provided in the BCA workbook (see Inputs tab in the file HendersonvilleBUILD_BCA.xlsx) as well as in Table 2. The BCA workbook also contains the spreadsheet model.

### Table 2- BCA Calculation Inputs

| Input | Value | Source |
|---|---|---|
| Dollar Year | 2017 | |
| Discount Rate | 7.0% | |
| Discount Year | 2019 | |
| Construction Year 0 | 2020 | AECOM |
| Operations Year 0 | 2024 | AECOM |
| Estimated Capital Costs (2017$) | $15,384,922 | |
| Estimated annual O&M cost as a share of total capital costs | 1% | Assumption |
| Annualization Factor | 260 | |
| Variation factor | 1.02 | TDOT, accounts for day and month seasonality |
| AADT Growth | 1.5% | TEER |
| Growth in travel time savings post-2040 | 1.5% | |
| Truck share used in simulation | 2% | |
| Ratio of PM peak hour delays to daily delays | 50% | Estimate based on simulation and engineering judgement |
| | | |
| Vehicle Occupancy, Auto | 1.68 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| Vehicle Occupancy, Truck | 1 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| Vehicle Operating Cost, light duty vehicle, 2017$ per mile | $0.39 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| Vehicle Operating Cost, commercial trucks, 2017$ per mile | $0.90 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| Value of Time, personal (2017$) | $14.80 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| Value of Time, business (2017$) | $26.50 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| Value of Time, all purposes (2017$) | $16.10 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| Value of Time, truck (2017$) | $28.60 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| Truck operating savings per hour (2017$) | $42.70 | Table 9 ATRI Operational Cost of Trucking 2018. Includes fuel, oil, truck/trailer lease, repair, maintenance, driver benefits, tires, and insurance. Excludes driver time (valued in travel time savings); http://atri-online.org/wp-content/uploads/2018/10/ATRI-Operational-Costs-of-Trucking-2018.pdf |
| | | |
| O-No Injury (2017$) | $3,200 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |

| Input | Value | Source |
|---|---|---|
| C-Possible Injury (2017$) | $63,900 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| B-Non-incapacitating (2017$) | $125,000 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| A-Incapacitating (2017$) | $459,100 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| K-Killed (2017$) | $9,600,000 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| U-Injured (severity unknown) (2017$) | $174,000 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| # of Accidents Reported (unknown if injured) (2017$) | $132,200 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| PDO Crashes per vehicle (2017$) | $4,300 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| | | |
| Passenger Car Emission Rates per Mile, VOC, 2013-2024 | 0.6 | http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf |
| Passenger Car Emission Rates per Mile, Nox, 2013-2024 | 0.91 | http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf |
| Passenger Car Emission Rates per Mile, PM25, 2013-2024 | 0.01 | http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf |
| Passenger Car Emission Rates per Mile, CO2, 2013-2024 | 532 | http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf |
| Passenger Car Emission Rates per Mile, VOC, 2025-2034 | 0.27 | http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf |
| Passenger Car Emission Rates per Mile, Nox, 2025-2034 | 0.28 | http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf |
| Passenger Car Emission Rates per Mile, PM25, 2025-2034 | 0.01 | http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf |
| Passenger Car Emission Rates per Mile, CO2, 2025-2034 | 434 | http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf |
| Passenger Car Emission Rates per Mile, VOC, 2035- | 0.21 | http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf |
| Passenger Car Emission Rates per Mile, Nox, 2035- | 0.2 | http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf |
| Passenger Car Emission Rates per Mile, PM25, 2035- | 0.01 | http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf |
| Passenger Car Emission Rates per Mile, CO2, 2035- | 397 | http://www.apta.com/gap/fedreg/Documents/NS-SS_Final_PolicyGuidance_August_2013.pdf |
| Passenger Car Gasoline Consumption Per mile | 0.04149 | http://www.epa.gov/otaq/consumer/420f08024.pdf |
| Short tons per Metric Ton | 1.1015 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| LDGV Emissions Rates g/hr VOC | 2.683 | nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVXV.TXT |
| LDGV Emissions Rates g/hr NOX | 3.515 | nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVXV.TXT |
| Truck Emissions Rate g per hour VOC (average of 8a and 8b trucks) | 3.868 | Source: https://www3.epa.gov/otaq/consumer/420f08025.pdf, Class 8 trucks include long-haul semi-tractor trailer rigs ranging from 33,001 lbs to >60,000 lbs |
| Truck Emissions Rate g per hour Nox (average of 8a and 8b trucks) | 39.0515 | Source: https://www3.epa.gov/otaq/consumer/420f08025.pdf, Class 8 trucks include long-haul semi-tractor trailer rigs ranging from 33,001 lbs to >60,000 lbs |
| Truck Emissions Rate g per hour PM2.5 (average of 8a and 8b trucks) | 1.092 | Source: https://www3.epa.gov/otaq/consumer/420f08025.pdf, Class 8 trucks include long-haul semi-tractor trailer rigs ranging from 33,001 lbs to >60,000 lbs |
| Volatile Organic Compounds (VOCs) (2017$/short ton) | $2,000 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| Nitrogen oxides (NOx) (2017$/short ton) | $8,300 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| Particulate matter (PM2.5) (2017$/short ton) | $377,800 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| Sulfur dioxide (SO2) (2017$/short ton) | $48,900 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| | | |
| Social Cost of Carbon | 2017$ per Metric Ton | |
| 2017 | $1.00 | USDOT Benefit-Cost Analysis Guidance for Discretionary Grant Programs, December 2018 |
| 2018 | $1.00 | |

| Input | Value | Source |
|---|---|---|
| 2019 | $1.00 | |
| 2020 | $1.00 | |
| 2021 | $1.00 | |
| 2022 | $1.00 | |
| 2023 | $1.00 | |
| 2024 | $1.00 | |
| 2025 | $1.00 | |
| 2026 | $1.00 | |
| 2027 | $1.00 | |
| 2028 | $1.00 | |
| 2029 | $1.00 | |
| 2030 | $1.00 | |
| 2031 | $1.00 | |
| 2032 | $1.00 | |
| 2033 | $1.00 | |
| 2034 | $1.00 | |
| 2035 | $2.00 | |
| 2036 | $2.00 | |
| 2037 | $2.00 | |
| 2038 | $2.00 | |
| 2039 | $2.00 | |
| 2040 | $2.00 | |
| 2041 | $2.00 | |
| 2042 | $2.00 | |
| 2043 | $2.00 | |
| 2044 | $2.00 | |
| 2045 | $2.00 | |
| 2046 | $2.00 | |
| 2047 | $2.00 | |
| 2048 | $2.00 | |
| 2049 | $2.00 | |
| 2050 | $2.00 | |

## Benefits

Benefits are presented by four of the goals identified in the BUILD 2019 NOFO: Safety, Economic Competitiveness, State of Good Repair, and Environmental Sustainability.

### ***Safety***

There are multiple safety benefits expected from the Project: the Project will result in increased safety at the road-rail crossing, reduced crashes on the roadways, and reduce response time for emergency services.

A number of analytical tools were applied to develop the supporting information for the safety analysis; these include a traffic simulation, a GradeDec.NET analysis of the crossing hazard, and a predictive safety analysis of the road alignment/shoulder improvements, as well as the intersection improvements. Each modeling tool captured an important element of the proposed BUILD Project.

Tools and models failed the Project team, however, when it came to the assessment of the queuing on SR-386, Saundersville Road, and East Main Street. Neither the traffic simulation work nor the predictive safety analysis captured that critical element of the Project. More discussion is included in the Road Impacts section.

The changes in crashes were valued based on the KABCO score. KABCO refers to the letters used to designate five levels of crash severity used by police at a crash scene, and each type of injury has a different associated economic cost. The values of injuries and property damage only (PDO) are shown in Table 2.

### *Road-Rail Crossing*

The exposure of vehicles to at-grade crossings results in a likelihood of an incident (accident) as trains travel through the crossing. The risk of incidents will be eliminated with the Project as the at-grade crossing will be removed and a new grade-separate crossing constructed. This section summarizes the safety benefits that result from the grade-separated crossing.

GradeDec.NET was used to estimate the reduction in accidents from removing the at-grade crossing. GradeDec.NET used a time-of-day correlation factor between rail and highway traffic to predict the number of accidents by severity that could occur at crossings. The safety analysis method for grade crossings predicts the number of accidents each year based on the number of daily trains, the annual average daily traffic (AADT), the time-of-day exposure correlation factor, the number of tracks, and the number of highway lanes crossing the tracks.

The predicted crashes are then allocated across categories of severity (fatal, injury, and property damage only [PDO]). The estimated crashes by severity are based on the maximum speed, APS factors for fatal accidents and casualty accidents for grade crossings, number of through trains, and number of tracks.

In order to estimate the safety benefits experienced at the crossing, a scenario was run in GradeDec.NET. The scenario establishes the baseline for the existing rail traffic by predicting the costs of crashes associated with the existing alignment compared to with the Project considering the same train traffic and auto traffic but with a grade separation in place. GradeDec.NET estimated the net benefits over the analysis period.

The net results are positive safety benefits for the Project due to the reduction in traffic interactions at the grade crossings, which reduces the likelihood of road-rail accidents. **Discounting at 7 percent, the safety benefits at the rail crossing yield $0.4 million in 2017 dollars.**

### *Road Impacts*

The Project has the potential to impact the number and type of accidents throughout the study area. While the Project will create an additional conflict zone with the new intersection on Main Street, it will also result in a significant reduction in queued vehicles on SR-386, Saundersville Road, and Main Street.

A predictive safety model was created to estimate the impacts of the project elements on the roads in the study area. The model estimated an increase in accidents, which is attributed to conflict zones created by the new intersection on Main Street and new project roadway segment. The safety model estimated an increase in accidents valued at $1.1 million at a 7 percent discount rate. However, due to modeling limitations, the model was unable to capture the impacts of the new road configuration and the increased capacity of turn lanes, which will reduce queued traffic affecting the travel lanes. When a train closes the road-rail crossing during the evening rush hour, vehicles are often queued onto SR-386 where the posted speed limit is 65 mph. While no fatalities have been recorded to date due to queuing on SR-386, the situation is considered a significant safety hazard by TDOT.

The Work Zone literature devotes considerable discussion to ways to mitigate queuing, but that literature is generally silent on the likelihood of a crash associated with the formation of the queue itself. There are no commonly reported crash reduction factors for the elimination of freeway queues, as there are for rumble strips, warning signs, and other safety treatments. The Project team infers that the absence of a common set of crash reduction factors for the elimination of queues on freeways is because queues are an aberration in general highway travel and generally do not occur in a predictable way outside of work zones.

A review of the literature completed for this application identified the following information as it relates to the crash risk associated with freeway queues (or the crash reduction benefit from removing queues, by contrast):

- The crash involvement rate in Bottleneck Front, Back of Queue, and Congestion states are approximately 5 times higher than the one in Free Flow traffic states;[3]
- There is a large amount literature on how to manage the risk of queueing in work zones, places where the driver is warned in advance that there may be a queue ahead with orange cones and blinking arrows as opposed to the unmarked conditions on SR-386, for example;[4]
- Highway queues may lead to secondary crashes through distraction and rubbernecking;[5] and
- In a test of a freeway "queue warning system operation, the crash frequency recorded at the I-94 test site was 9.34 crashes per vehicle miles traveled (VMT) and 51.8 near-crashes. This was a 22 percent decrease from the 11.9 crashes per VMT recorded at the site in 2013 monitoring data, and a 54 percent decrease from the 111.8 near-crashes recorded there in 2013." The article highlights the value of measuring near-misses, as well as actual crashes.

Multiple transportation experts have assessed the queuing at the crossing and concluded that it is a serious hazard that is likely to result in a fatality if not addressed. In June of 2015, the *Hendersonville Standard* reported that TDOT had indicated that their engineers believe the queue could yield a fatality. (The article is provided with the Supplemental Materials.) The article cites a TDOT spokesperson saying that,"….there are safety issues that are of great concern to the department, concerns that could ultimately force the department to close the ramp. …."In a letter to the City cited March 12, 2015, Paul Degges, deputy commissioner and chief engineer for TDOT, said the Saundersville Road residential area had grown to the point that leaving the current at-grade railroad crossing was no longer feasible. "This residential growth and the associated increase in traffic volumes has now approached the safety and operational limitations of the traffic signal interconnect at the CSX at-grade railroad crossing," the letter states. "It has now been observed that under the preempted signal conditions (all red phase during train passage) Saundersville off-ramp vehicle queues are extending into the eastbound travel lanes on mainline State Route 386. This stopped condition on a high-speed facility (65 mph) creates the potential for severe crashes including fatalities."

Given this, the Project team applied a 90 percent[6] reduction in rear-end crashes in the study area, including eastbound SR 386, east- and west-bound Saundersville Road, and East Market

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[3] Yeo, Hwasoo , Kitae Jang , Alexander Skabardonis , Seungmo Kang. Accident Analysis & Prevention, Volume 50, January 2013, Pages 713-723.

[4] FHWA web resources for example

[5] One literature review found that "overheating of engines and truncated spacing between vehicles due to incident related congestions accounts for 60 percent of total freeway congestion [25], these factors significantly increases the likelihood of secondary incidents deteriorating congestion, clearance time, and safety [3] [10][26]. The likelihood of a secondary crash increases by 2.8 percent for each minute of delay in clearing the primary incident. Causes include the dramatic change in traffic conditions, including the rapid spreading of queue length, and the substantial drop in traffic speed, as well as rubbernecking [7]. Secondary crashes due to congestion resulting from a previous crash are estimated to represent 20 percent of all crashes." as written in Rohit Reddy Saddi, 2009, Thesis on "Studying the Impacts of Primary Incidents on Freeways to Identify Secondary Incidents," University of Nevada.

[6] National Transportation Safety Board. Safety Recommendation H-01-10 and H-01-11, May 25, 2001, https://static.tti.tamu.edu/tti.tamu.edu/documents/4413-1.pdf

Street, in order to estimate the benefit of removing the queue from SR-386. The crash data are for 2014-2019. This approach yields a conservative estimate that misses much of the quantitative benefit because:

- The whole queue is removed but the estimation only takes credit for 90 percent of the reduction;
- Near-misses and other crash types that could result from queuing such as sideswipes are omitted from the estimate;
- It relies only on the crash history over the past six years;
- Secondary crashes that are caused by the first crash are omitted as they may be in other locations due to rubbernecking or other types of crashes than rear-end types.

The analysis estimated a reduction in accidents valued at $3.5 million at a 7 percent discount rate.

The net results are positive road safety benefits for the Project; however many of the safety benefits of the Project could not be captured and the benefits are believed to be underestimated. **Discounting at 7 percent, the safety benefits to the roadways yield $2.4 million in 2017 dollars.**

### *Emergency Services*

Emergency services provide a vital service to communities during times of need, such as when there is a fire or when emergency medical care is needed. The ability for emergency services to respond quickly is essential to reducing damages and decrease injuries and fatalities. However, emergency response is delayed when an at-grade crossing is closed for a train.

A fire station is located south of the current at-grade crossing and response times are delayed to a portion of the service area when the at-grade crossing is closed for train traffic. When trains are crossing, emergency services must use an alternate route or another station must respond, which adds at least two minutes to the average response time.

To estimate the benefits of the grade separation element of the Project, the FEMA method[7] for estimating the loss of emergency services was followed. Information related to number of delays, call volume, response times, and size of service area was provided by the Hendersonville Fire Chief.

With the removal of the at-grade crossing, the net results are positive safety benefits for the Project due to the reduction in response time for emergency services. **Discounting at 7 percent, the safety benefits at the rail crossing yield $0.4 million in 2017 dollars.**

## ***Economic Competitiveness***

Improvements related to the Project will result in travel time savings for roadway users and truck vehicle operating savings. To account for construction activities, traffic delays were also accounted for in the analysis.

### *Travel Time Impacts*

There are two areas where the Project will result in travel time savings: the Project will reduce wait times at the road-rail crossing and travel time on the local roads.

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[7] Presented in the USDOT's *Benefit-Cost Analysis Guidance for Discretionary Grant Programs* (December 2018) and described in FEMA's *Benefit-Cost Analysis Re-Engineering (BCAR), Development of Standard Economic Values* Version 6.0, December 2011

At-grade crossings result in increased travel times for drivers on the road and their passengers as they wait for trains to travel through the grade crossing. The travel time delays will be eliminated when the at-grade crossing is removed from service and replace by a grade-separated crossing. In addition to reducing vehicle queueing when a train is crossing, the Project will also realign Saundersville Road, which will improve the flow of traffic and result in additional travel time savings. This section summarizes the travel time savings benefits that result from the Project.

While GradeDec.NET calculates the average grade crossing block time, it does not fully capture the highway vehicle delays and the realignment elements of the Project. To capture the delay reductions, current (2019) and future (2040) traffic forecasts for both the baseline and Project scenarios were modeled using Synchro/SimTraffic (Version 10). Details of the modeling and analysis completed for the Project are provided in *Traffic Analyses Documentation* (June 2019), which is included as supporting documentation.

The Synchro/SimTraffic model estimated the reduced delays for the peak travel hour of the day (evening rush hour); however, it did not provide an estimate of reduced delays for the entire day. As a result, efforts were made to estimate a relationship between delay reductions associated with the Project during the evening peak and delay reductions for the remainder of the day. To assist in determining delays caused by trains, the project team observed the rail crossing from 6:00 am to 6:00 pm. The observer recorded the number of trains, duration of road closure, and number of vehicles delayed (Table 3). The observations show that vehicles are delayed throughout the day, with the number of vehicles delayed increasing just prior to the evening rush hour. However, the field observations did not capture the additional delays for the traffic to clear once the train passed. As was shown from the drone footage[8] recording the traffic back-up, a train crossing near the evening rush hour can result in traffic delays that take over an hour to clear.

**Table 3- Field Observation of Traffic During Rail Closures**

| Time of Closure | Duration of Closure (M:S) | Number of Vehicles Queued During Closure | | | | |
|---|---|---|---|---|---|---|
| | | Saundersville Road | | SR-386 | Winston Hills Road | |
| | | West Bound | South Bound | Off-Ramp | North Bound | South Bound |
| 6:24AM | 5:32 | 11 | 7 | 0 | 10 | 7 |
| 6:39AM | 2:08 | 3 | 3 | 0 | 10 | 8 |
| 8:20AM | 2:25 | 13 | 10 | 0 | 10 | 9 |
| 9:35AM | 2:05 | 9 | 7 | 0 | 3 | 7 |
| 11:41AM | 2:38 | 10 | 16 | 0 | 11 | 8 |
| 12:19PM | 3:33 | 16 | 16 | 3 | 10 | 6 |
| 3:29PM | 3:45 | 15 | 20 | 17 | 11 | 6 |
| 4:42PM | 4:41 | 25 | 23 | 40 | 10 | 11 |

As a result of the field observations of vehicles delayed throughout the day, it was estimated that the modelled peak rush hour delay represented between 20 percent and 30 percent of the total delays for a day. Additional research was also conducted to assist in determining the relationship between AADT and traffic during the peak hour. According to information from the State of Washington (Figure 2), traffic volume during peak rush hour would represent 0.116 (11.6 percent) of the AADT when AADT is approximately 12,000. The findings indicate that trains could delay a

[8] The drone footage recorded traffic congestion (and delays) following a train that passed through Hendersonville a little before 5:00 PM on a weekday. The footage showed that heavy congestion was still present an hour after the event. The drone footage is included with the application as supporting documentation.

large portion of the AADT even during non-peak hours. However, based on engineering judgement, a conservative value of 50 percent was selected for the analysis.

**Figure 2 - Relationship of Peak Hour Traffic to Daily Traffic**

| AADT | Average *K*-Factor | Number of Sites Included in Average *K*-Factor | | |
|---|---|---|---|---|
| | | Urban | Recreational | Other Rural |
| 0–2,500 | 0.151 | 0 | 6 | 12 |
| 2,500–5,000 | 0.136 | 1 | 6 | 8 |
| 5,000–10,000 | 0.118 | 2 | 2 | 14 |
| 10,000–20,000 | 0.116 | 1 | 2 | 15 |
| 20,000–50,000 | 0.107 | 11 | 5 | 10 |
| 50,000–100,000 | 0.091 | 14 | 0 | 4 |
| 100,000–200,000 | 0.082 | 11 | 0 | 0 |
| >200,000 | 0.067 | 2 | 0 | 0 |

Note: *K*-factors are for the 30th-highest traffic volume hour of the year.
Source: Washington State DOT (*5*).

The results are a travel time savings due to the construction of the grade-separated crossing and the realignment of Saundersville Road. The results of the analysis estimate that the net hours saved on a daily basis will be 162 hours in 2024, which increases to 1,003 hours by 2040. After 2040, the travel time savings assumed to grow by 1.5 percent annually. Time savings were estimated for both automobiles and trucks and monetized based on the calculation inputs presented in Table 2. **Discounting at 7 percent, the travel time savings yields $37.7 million in 2017 dollars.** Using a less conservative value of 25 percent for the factor of peak hour delays to daily delays would increase the travel time savings to $75.5 million.

The travel time savings and network time savings from the GradeDec.NET analysis were excluded from the analysis due to the possibility of double counting.

Of particular note for the benefit cost analysis, the baseline does not assume a ramp closure as discussed in the Road Impacts section, as TDOT has not moved forward with that action. If the ramp were closed, it would increase VMT and congestion in the area, likely yielding a higher travel time impacts than that presented in this analysis.

### *Truck Operating Costs*

The travel time savings of the Project result in operating cost savings for trucks, which decreases the costs of moving freight and increases economic competitiveness of the nation. The operating cost per hour for trucks was found in the ATRI Operational Cost of Trucking,[9] which is inclusive of fuel, oil, truck/trailer lease, maintenance, driver benefits, tires, and insurance and totals $42.70 per hour. Driver time was excluded because it was already included in the Travel Time Savings benefit.

Multiplying the total travel time savings by the percentage of trucks (2 percent) and the truck operating cost per hour results in the truck operating savings. **Discounting at 7 percent, the truck operating cost savings yields $0.8 million in 2017 dollars.**

### *Vehicle Operating Costs at Grade Crossings*

The travel time savings of the Project results in operating cost savings for vehicles delayed because of closure of the at-grade crossing when trains are passing. GradeDec.NET provides an

[9] Table 9 ATRI Operational Cost of Trucking 2018. Includes fuel, oil, truck/trailer lease, repair, maintenance, driver benefits, tires, and insurance.

estimate of the vehicle operating savings based on the calculation inputs. **Discounting at 7 percent, the vehicle operating cost savings yields $42,000 in 2017 dollars.**

### *Construction Impacts*

Construction activities cause traffic delays. While much of the construction activity will not be occurring on existing roads, there will be delays from construction vehicles, the realignment of Saundersville Road, and construction of the new intersection at Main Street. The anticipated delays caused by the construction activities were estimated and included in the BCA. The analysis assumed that most of the activities impacting traffic will occur during off-peak hours, impacted traffic will experience a reduction in speed from a free flow condition of 45 mph down to 25 mph, and traffic would be impacted for the full construction period. **Discounting at 7 percent, the travel time delays due to construction would be $1.7 million in 2017 dollars.**

A temporary rail bypass will be built prior to the construction of the underpass. As a result, there are not anticipated to be any delays to rail activities during the construction period.

## State of Good Repair

The State of Good Repair captures the remaining value (residual value) of the Project elements after the analysis period. Construction of the new roadway and bridges will have residual value after the end of the 30-year analysis period, because the useful life of these elements is longer than 30 years. Roadways and utilities have useful lives of 60 years, and bridges have a useful life of 75 years, while land (right-of-way) does not depreciate. The analysis used a straight-line depreciation to estimate the remaining value for all assets besides land (the value of land was added to the total value of the other assets), with the remaining value discounted from the final year of the analysis period (2053). The estimate of the residual value only included the value of hard structures (e.g., pavement, bridge), not professional services or site preparation work (e.g., earthwork, seeding). **The residual value for the Project discounted at 7 percent is $0.7 million**.

## Environmental Sustainability

Improvements related to the Project will result in travel time savings for roadway users and therefore reduced emissions for both automobiles and trucks.

### *Auto Emissions*

The time savings from the travel demand model were used to estimate emissions savings for automobiles. Annual volatile organic compounds (VOC) and nitrogen oxides (NOx) savings were estimated based on rates found from the EPA.[10] The tons of reduced emissions were monetized using the recommended value of emissions from USDOT BCA guidance as shown in Table 2. In addition to the time savings, reduced vehicle idling at grade crossings results in auto emissions savings. **In total, the Project results in auto emissions savings of $0.04 million, discounted at 7 percent.**

### *Truck Emissions*

Based on the travel time savings, trucks also save time when the Project is operational. Based on emissions rates per idling hour as found in EPA guidance,[11] the tons of VOC, NOx, and particulate matter with a diameter less than 2.5 micrometers ($PM_{2.5}$) were estimated. The tons of

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[10] EPA, Idling Vehicle Emissions for Passenger Cars, Light-Duty Trucks, and Heavy-Duty Trucks, EPA420=F-8-025, October 2008, nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVXV.TXT

[11] EPA, Idling Vehicle Emissions for Passenger Cars, Light-Duty Trucks, and Heavy-Duty Trucks, EPA420=F-8-025, October 2008, nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVXV.TXT. Class 8 trucks include long-haul semi-tractor trailer rigs ranging from 33,001 lbs to >60,000 lbs

reduced emissions were monetized using the recommended value of emissions from USDOT BCA guidance as shown in Table 2. **In total, truck emissions savings from the Project total $0.02 million, discounted at 7 percent.**

## Costs

The estimated capital costs and operations and maintenance (O&M) costs were evaluated in the BCA.

### *Capital Costs*

Approximately $581,000 has been spent on the project for preliminary environmental and engineering work to date. The remaining capital costs for the Project include the costs for the purchase of land, utilities, construction, soft costs, and contingency. The costs of the project elements (including soft costs and contingencies) are shown in Table 4.

**Table 4 – Remaining Construction Costs in 2019$**

| Cost | Right-of-Way Cost | Utilities Cost | Construction Cost | Total |
|---|---|---|---|---|
| Remaining Cost | $3,391,000 | $2,096,000 | $10,545,000 | $16,034,000 |

The capital costs are applied over a four year construction period, beginning in April 2020 and ending in December 2023. **The total capital costs of $16.6 million (project expenses so far and remaining construction costs) were converted to 2017 dollars ($15.9 million) and discounted at 7 percent over the four year construction period for a present value of $13.6 million.**

### *Operating and Maintenance Costs*

The project requires annual and periodic O&M to keep the roads, rail, and bridges in a state of good repair. Maintenance begins in 2024, as the first full year of operation, and the O&M costs are the incremental difference between the current O&M costs for the corridor compared to the costs to maintain the new roadway segments, bridge, and intersections.

The average annual O&M costs are estimated as 1 percent of the total capital costs, which is approximately $154,000. **The total O&M costs over the analysis period and discounted at 7 percent is $1.5 million.**

## Results

Table 5 summarizes the discounted value of the Project benefits and costs discussed in this memorandum. Taken in total and using a 7 percent discount rate, the Project provides $39.3 million dollars of benefits over the analysis period. Compared to a similarly discounted cost estimate, the Benefit Cost Ratio for the Project is 2.9, a solid return on these critical investments. The net benefits total $25.6 million.

### Table 5 – Total Project Benefit-Cost Analysis (2020-2053 in 2017 $M)

| Category | Value |
|---|---|
| **Costs** | |
| Capital Costs | $13.6 |
| **Total Costs** | **$13.6** |
| | |
| **Benefits** | |
| **Safety** | |
| Safety at Grade Crossings | $0.4 |
| Road Impacts | $2.4 |
| Emergency Services | $0.4 |
| ***Subtotal Safety Benefits*** | ***$3.2*** |
| **Economic Competitiveness** | |
| Travel Time Savings | $37.7 |
| Truck Operating Cost Savings | $0.8 |
| Vehicle Operating Cost Savings at Grade Crossings | $0.04 |
| Construction Delays | -$1.7 |
| ***Subtotal Economic Competitiveness Benefits*** | ***$36.8*** |
| **State of Good Repair** | |
| Residual Value | $0.7 |
| ***Subtotal State of Good Repair Benefits*** | ***$0.7*** |
| **Environmental Sustainability** | |
| Auto Emissions Savings | $0.04 |
| Truck Emissions Savings | $0.02 |
| ***Subtotal Environmental Sustainability Benefits*** | ***$0.05*** |
| | |
| Operating and Maintenance Costs | -$1.5 |
| **Total Benefits** | **$39.3** |
| | |
| **Results** | |
| **Net Benefits** | **$25.6** |
| **BCR** | **2.9** |

## List of Supporting Information

AECOM, HendersonvilleBUILD_BCA.xlsx (Excel spreadsheet with BCA calculations by benefit type and summary)

AECOM Safety Analysis.pdf

AECOM, *Traffic Analysis Documentation.docx*

City of Hendersonville, Saundersville-Winston Hills Parkway Drone Video.mp4 June 2019

GradeDec.NET, *GradeDec_Years1-10.pdf*

GradeDec.NET, *GradeDec_Years11-20.pdf*

GradeDec.NET, *GradeDec_Years21-30.pdf*