South Boulder Road Reconstruction & Multimodal Improvements

Intersection Improvement Analysis: South Boulder Road at Cherryvale Road

Submitted to:

Boulder County
Public Works Department
2525 13th Street
Boulder, CO 80304

Prepared by:

Otak, Inc.
371 Centennial Parkway
Suite 210
Louisville, CO 80027

August 2025

Otak Project No. 20818

DRAFT REPORT

Table of Contents

Page

FIGURES

APPENDICES

I. INTRODUCTION

This report documents the analysis and conclusions for the intersection study of South Boulder Road and Cherryvale Road in Boulder County, Colorado.

The intersection is located north of US-36 at the crossroads of a principal and minor arterial roadways. South Boulder Road is a four-lane divided principal arterial roadway connecting to US-36 and the City of Boulder to the west of the intersection, and the City of Louisville to the east of the intersection. Cherryvale Road is a two-lane undivided minor arterial roadway connecting to Baseline Road and the surrounding neighborhoods to the north of the intersection, and CO-170 in the Town of Superior to the south of the intersection. The intersection of these two roadways is currently controlled with a traffic signal which experiences operational challenges during peak periods and has a history of both injury and property-damage-only crashes.

The goal of this study is to determine the optimal intersection alternative to enhance mobility and safety while ensuring improvements are cost-effective and minimize environmental impacts for the intersection of South Boulder Road and Cherryvale Road (see Figure 1). An analysis of the intersection's operational needs and evaluation of alternatives, including turn lane modifications and a roundabout concept, was conducted to determine the most appropriate design and implementation of improvements.

A. Study Objectives

The study included a comprehensive technical analysis and assessment of all factors for this intersection, with the involvement of Boulder County staff. The primary objectives to ensure the project goal is accomplished are as follows:

1. Evaluate the existing conditions.
    a. Determine existing mobility and safety issues.
2. Develop alternative intersection and traffic control options.
    a. Develop concept plans of alternatives.
    b. Evaluate the alternatives.
    c. Determine the mobility and safety improvements provided by the alternatives.
3. Compare alternatives to determine the acceptable benefit to cost ratio
    a. Analyze various benefit factors to estimated costs including
        - Safety
        - Operations
        - Environmental
4. Select the preferred alternative.
    a. Develop 30% plans to inform the remainder of the roadway reconstruction segment

The study assessed traffic conditions and needs at the intersection, considering the current and long-term needs of South Boulder Road. Signalization modifications, lane configurations, and roundabout traffic control alternatives were evaluated to develop a preferred alternative for the intersection that meets the study goals.

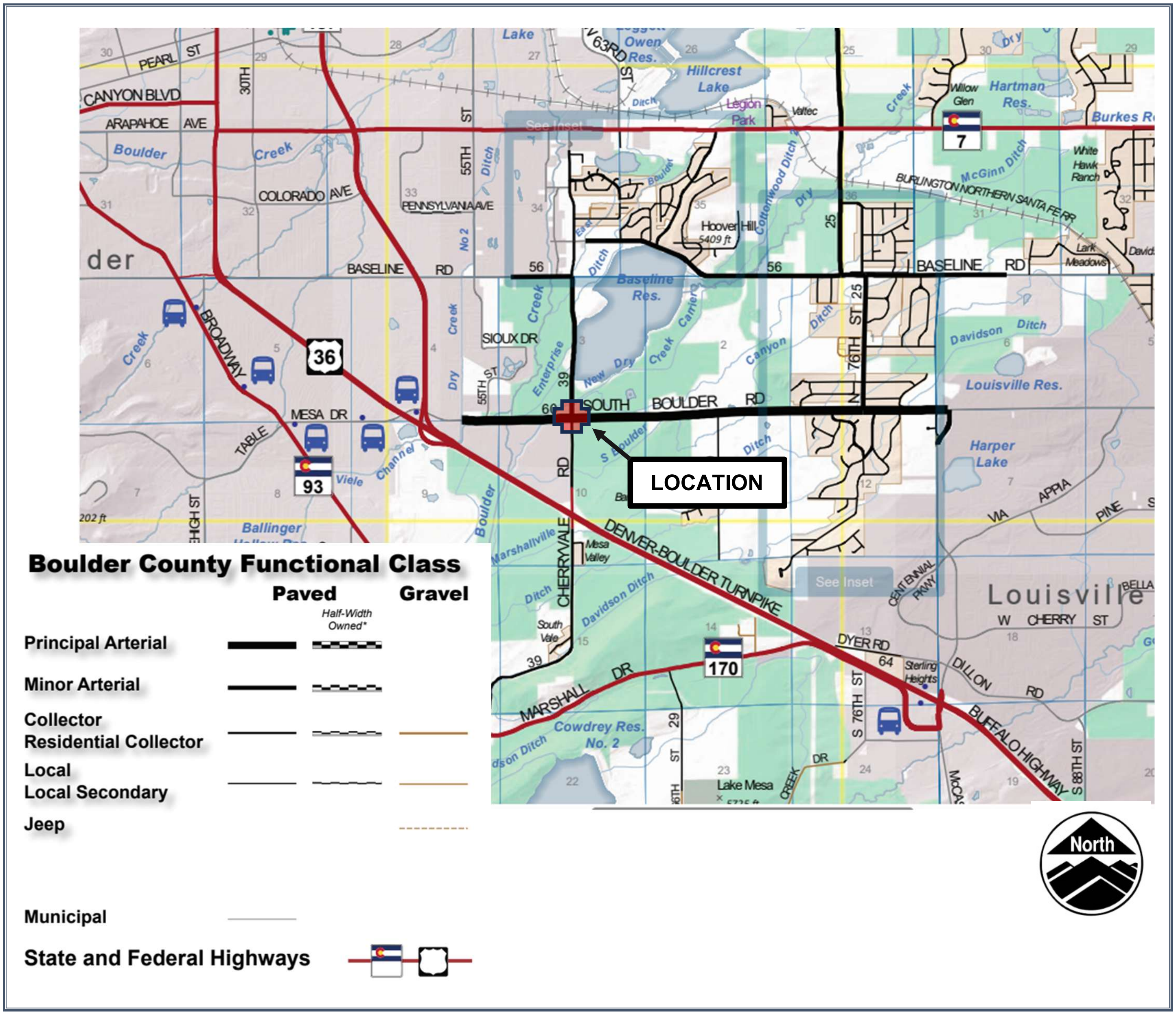

Figure 1. Location Map

Not to scale

II. BACKGROUND

A. Location

The intersection of South Boulder Road and Cherryvale Road is located in Boulder County, near the eastern portion of the City of Boulder. Boulder is a city at the foothills of the Rocky Mountains and is located about 25 miles northwest of Denver.

Boulder's population is approximately 108,250 (2020 census). The intersection is 2 miles west of US-36 along South Boulder Road and 1 mile south of Baseline Road along Cherryvale Road. South Boulder Road has a functional classification in Boulder County as a Principal Arterial, and Cherryvale Road i9s functionally classified as Minor Arterial roadway. Principal and Minor Arterials typically link urban areas and rural Principal Arterials to larger towns and other major traffic generators, capable of attracting trips over similarly long distances. Arterials service medium length trips, and their emphasis is primarily on mobility as opposed to access. They connect with principal arterials, other minor arterials, and collector streets. Connections to local streets should be avoided if possible.

North and west from the intersection, both South Boulder Road and Cherryvale Road connect to commercial destinations and interchanges with US-36. South and east of the intersection, these roadways connect to residential, educational, and recreational land uses. The intersection serves a high volume of vehicular traffic given its proximity to the highway as well as local retail and education destinations along these routes. As the communities of Boulder, Louisville, and Superior continue to grow, the traffic volumes through the intersection are expected to increase.

B. Roadways and Intersection

South Boulder Road consists of a four-lane divided roadway, and Cherryvale Road is a two-lane undivided section approaching the intersection. The posted speed limit is 45 mph on South Boulder Road and 40 mph on Cherryvale Road. At the intersection, all approaches have left turn lanes and right turn lanes are provided on the north, east, and west approaches. The intersection operates under signalized control with protected-permissive left turn phasing in the eastbound and westbound directions. The northbound and southbound left-turn movements operate with permitted phasing. The existing signalized intersection experiences some congestion during the peak hours but operates with no existing capacity deficiencies. All four legs of the intersection have bikeable facilities that are not in conformance with current Boulder County Multimodal Transportation Standards, and there is an absence of sidewalk to push button locations, pedestrian ramps at the crosswalk locations, and truncated domes. ADA non-compliant transit stops are located on the intersection far sides in the eastbound and westbound directions.

See Figure 2 for the existing intersection layout.

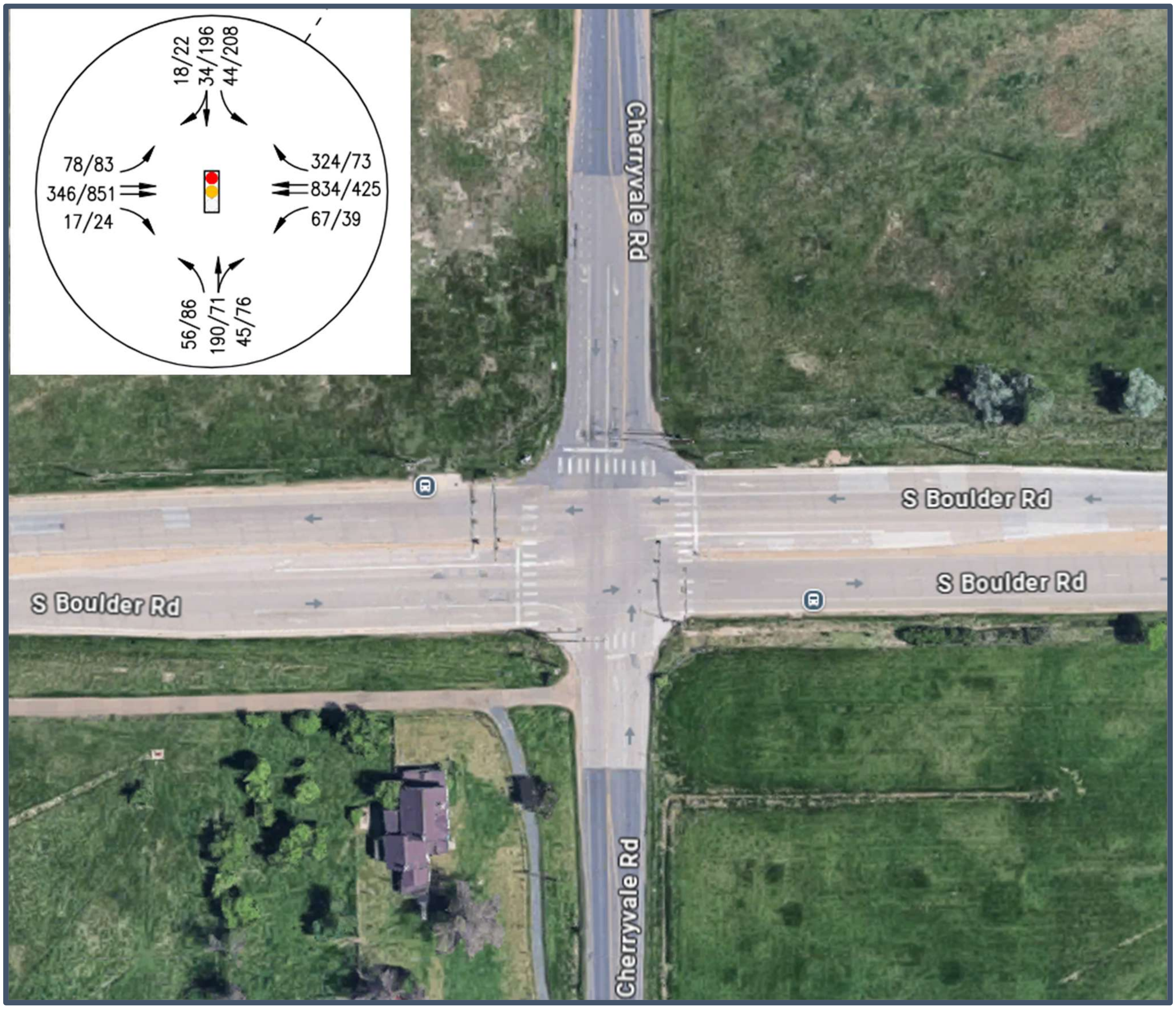

Figure 2. Existing Intersection Layout

Not to scale

C. Traffic Data and Current Volumes

Traffic counts were collected by Fox Tuttle Transportation Group (Fox Tuttle) for this project in late January 2025 with schools in session. The collection included the following:

- 24-hour directional volume, speed, and classification along South Boulder Road just east of 55th Street
- Weekday AM and PM peak hour turning movement, vehicle, bicycle, and pedestrian counts at both the South Boulder Road/55th Street and South Boulder Road/Cherryvale Road intersections

The existing traffic data and lane configurations for South Boulder Road at Cherryvale Road are shown in Figure 2. Traffic count data sheets are included in the appendix.

The traffic data shows that South Boulder Road is servicing approximately 14,100 vehicles per day (vpd) within the study area with less than 1% heavy trucks (FHWA class 7 or greater). Table 1 shows Average Annual Daily Traffic (AADT) data collected by Boulder County in 2022 and 2023 at each leg of the intersection.

Table 1. Daily Traffic Volumes

Roadway	2022 AADT (vpd)
Cherryvale north of S. Boulder Rd.	4,700
Cherryvale south of S. Boulder Rd.	3,500
S. Boulder Rd. east of Cherryvale	10,800*
S. Boulder Rd. west of Cherryvale	9,300

** Indicates 2023 data*

The speed data collected near 55th street (approximately 0.5 miles west) shows that eastbound 85th-percentile speed is approximately 60 mph and westbound 85th-percentile speed is approximately 53 mph.

III. EVALUATION CRITERIA

The evaluation of the existing intersection and proposed intersection alternatives considers multiple factors, including operations, safety, environmental impacts, and costs.

A. Operations

The operational analysis of the traffic volume scenarios and alternatives were performed by Fox Tuttle using the Highway Capacity Manual (HCM) methodology through SYNCHRO (v12) traffic analysis software for signalized conditions. To measure level of service and delay for roundabouts, the design program SIDRA was used.

Measures of effectiveness display quantitative information about the performance of an intersection or network of intersections. The primary measures that are used in this study are level of service and delay.

Delay and Level of Service
The Level of Service (LOS) at an intersection, as described in the HCM, is a qualitative measure that reflects the operational conditions within a traffic stream and the perception of those conditions by motorists and passengers. LOS is categorized from A to F, with A representing the best operating conditions and F the worst.

Here's how LOS is determined:

1. **Control Delay**: This is the primary measure used to determine LOS at intersections. Control delay includes the time vehicles spend slowing down as they approach the intersection, the wait time at the intersection, and the time it takes for vehicles to speed up after passing through the intersection.

2. **Average Intersection Control Delay**: For signalized and roundabout intersections, the average intersection control delay is calculated as a volume-weighted average of the delay experienced by all motorists entering the intersection from all approaches.

3. **LOS Criteria**: The HCM provides specific delay thresholds for each LOS category. For example, a signalized intersection might have different delay thresholds compared to an unsignalized intersection. Generally, the delay thresholds for unsignalized intersections are lower because people expect a higher level of service at stop-controlled intersections.

4. **Design Year LOS**: Level of Service D is commonly taken as an acceptable design year LOS. This means that while LOS A, B, and C represent better operating conditions, LOS D is often considered acceptable for planning and design purposes.

5. **Roundabout Intersections**: These are evaluated as unsignalized intersections, meaning they follow the same delay thresholds and criteria as other unsignalized intersections.

LOS is a comprehensive measure that considers various factors affecting the delay experienced by vehicles at intersections, and it helps in assessing and improving traffic flow and intersection performance.

Table 2. Level of Service Criteria

Level of Service	Signalized Intersection	Unsignalized Intersection
A	≤10	≤10
B	>10 and ≤20	>10 and ≤15
C	>20 and ≤35	>15 and ≤25
D	>35 and ≤55	>25 and ≤35
E	>55 and ≤80	>35 and ≤50
F	>80	>50

B. Safety

Safety is an essential consideration when evaluating an intersection and its traffic control measures. The geometry and control type of an intersection—such as the number of approach lanes, lane width, turning radii, and signal phasing—fundamentally shape how road users interact and respond to potential conflicts. These design elements play a significant role in determining the likelihood and severity of vehicle crashes, as intersections with complex layouts or ambiguous markings may foster confusion and increase the risk of collisions. Crash rates are the key measure for intersection safety, with particular attention to fatal and injury crashes. Identifying crash types and opportunities for reduction plays a central role in evaluating intersection improvements.

Intersection Collision Assessment

Crashes are inherently random and can fluctuate year to year at a specific location. To assess trends, it is common practice to analyze three or more years of crash data. Crash frequency prediction using the Highway Capacity Manual (HCM) Safety Performance Functions (SPFs) and the Empirical Bayes (EB) is the method recommended by the Federal Highway Administration (FHWA) for the purposes of Benefit Cost Analysis and involves a two-step process. First, SPFs provide a baseline estimate of expected crash frequency based on roadway characteristics such as traffic volume, segment length, and facility type. The HCM uses empirical models that draw from historical crash data, considering elements like intersection type (signalized or unsignalized), approach and turning movements, and the daily vehicular flow, to predict expected crash rates. These functions are derived from national or regional crash data and serve as a predictive model for typical conditions. Second, the EB method refines this estimate by incorporating observed crash data from the specific site. It adjusts the SPF prediction using a weighted average of the expected crashes (from SPFs) and the actual crash history, accounting for site-specific variability and regression-to-the-mean effects. This combined approach yields a more accurate and statistically robust estimate of crash frequency, which is essential for identifying safety concerns and prioritizing improvements

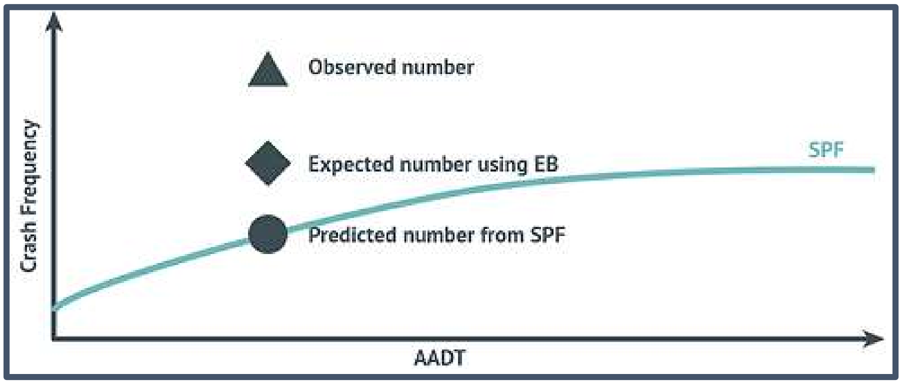

Figure 3. Empirical Bayes Method Schematic for Crash Prediction

(Source: FHWA)

The Federal Highway Administration (FHWA) classifies crash severity using a standardized scale known as the KABCO system, which helps agencies consistently report and analyze traffic crash outcomes. This system includes five categories:

- Killed (Type K)
- Incapacitating Injury (Type A)
- Non-Incapacitating Injury (Type B)
- Possible Injury (Type C)
- Property Damage Only (O or PDO)

These categories are essential for evaluating roadway safety performance, prioritizing safety improvements, and conducting benefit-cost analyses.

Pedestrian and Bicycle Safety

Pedestrian safety is paramount at all intersections, but it is equally important to consider the safety of cyclists. Pedestrian collisions and bicycle crashes can be sporadic, making it challenging to discern clear trends. To address this, engineers and planners often evaluate intersections using additional measures such as vehicle travel speed and exposure time, which apply to both pedestrians and cyclists.
Lower vehicle speeds not only minimize the severity of injuries for pedestrians but also offer greater protection for cyclists in the event of a crash. Furthermore, exposure time—defined as the distance and duration a road user spends crossing an intersection—plays a critical role in safety. The less time a pedestrian or cyclist is exposed to moving traffic, the lower the risk of a collision. For cyclists, intersection design can significantly affect safety outcomes. Dedicated bike lanes, clear signage, and improved visibility at crossings help reduce conflict points and exposure time.

The following information is provided by the Insurance Institute for Highway Safety (IIHS) for pedestrian safety and its relationship to vehicular speeds.

Table 3. Pedestrian Crash Severity and Vehicle Speed

Vehicle Speed	Chance of Fatal Crash
40 mph	80%
30 mph	40%
20 mph	5%

C. Right-of-Way

Right-of-way (ROW) refers to a parcel of land that can be owned by either private individuals or public entities, and is set aside for transportation needs such as roads, trails, or highways. In addition to enabling maintenance and expansion of these transportation corridors, ROW is often utilized for utility infrastructure, including power lines, water mains, and telecommunications. Furthermore, easements may exist within the ROW, granting private entities permission to access and use specific portions for their own utility or service purposes, even if the underlying land is publicly owned. In situations where additional space is required, right-of-way may be acquired from adjacent private or public properties to facilitate construction or improvement of intersections and related infrastructure.

ROW through the South Boulder Road corridor can be characterized as varying in width and can be considered difficult to confirm due to the history of the area and past prescriptive uses. The existing ROW and much of the adjacent parcels are unplatted according to current research. The intersection at Cherryvale Rd. and South Boulder Rd. is surrounded by City of Boulder Open Space property on all four corners, which is operated and maintained by the City's Open Space and Mountain Parks (OSMP) division. The ROW on Cherryvale is approximately 60 feet wide, and the S. Boulder Rd. ROW near the intersection varies from 115-feet to 135-feet in width. Figure 4 below illustrates the existing ROW mapping at the intersection, as currently defined by the design and analysis team.

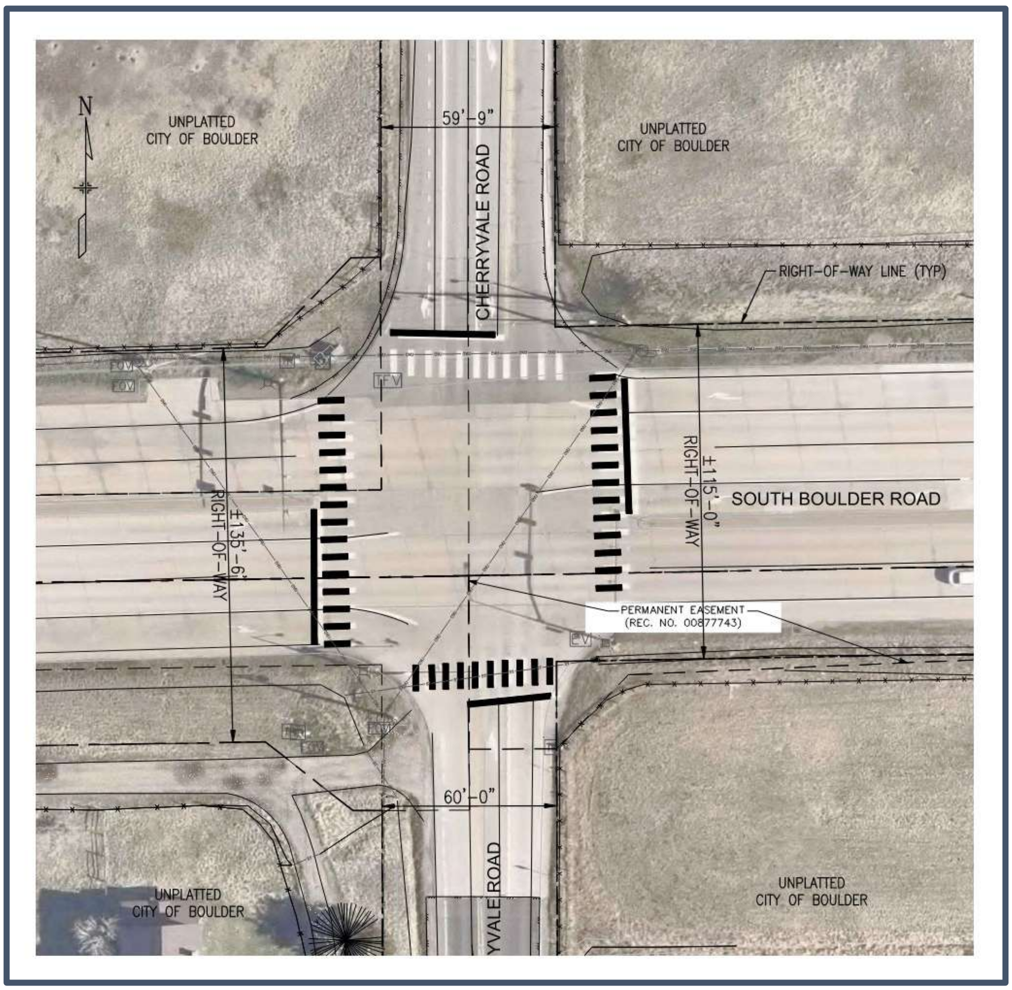

Figure 4. Existing Intersection ROW Map

(Source: Topographic Exhibit dated February 11, 2025, by Flatirons, Inc.)

D. Financial Impacts

The cost of roadway improvements is a key factor when evaluating intersection alternatives. Beyond initial capital and maintenance expenses, several other considerations can significantly influence the overall cost of an intersection project. These include land acquisition costs—since changes in geometry or size may require purchasing additional property from adjacent owners—as well as expenses related to utility relocation, environmental mitigation, and drainage improvements. Factors such as traffic signal equipment upgrades, landscaping, pedestrian and cyclist infrastructure, and long-term operational costs should also be weighed. Further discussion on the estimated capital investment costs, and annual maintenance and operations costs, is included in the Alternatives Analysis Section (IV) of this report.

Discount Rate and Adjustments for Inflation
The Discount Rate refers to the concept that a dollar received today has greater value than a dollar received five years from now, even without considering inflation. This is because today's dollar can be invested or used over five years, potentially resulting in increased value. As a result, benefit and cost projections are discounted to account for this time difference.

Benefit-cost analyses commonly exclude inflation since forecasting future prices can increase uncertainty. Discount rates are usually determined using interest rates or borrowing rates with the inflation element excluded, which produces the "real" interest rate. The real interest rate is often calculated by subtracting the inflation rate (such as that shown by the consumer price index) from the interest rate of an investment, for example, a 10-year U.S. Treasury bill. The Federal Highway Administration (FHWA) recommends a 7% real discount rate for benefit-cost analysis, particularly when benefits accrue to the public. This rate represents the average before-tax rate of return on private capital in the U.S. economy, and it frequently serves as the base-case for regulatory analysis. For the purposes of this study, the FHWA recommended discount rate of 7.0% has been used.

User Operational Cost Benefits
An alternative may yield cost savings through a reduction in travel distance or travel time. Decreasing travel distance lowers fuel consumption, while decreasing travel time not only reduces fuel usage but also increases the time available for other activities.

For the purposes of this analysis, the intersection alternatives, including the base condition meet acceptable LOS in the future 20-year (2045) design condition, with the exception of the Operational and Geometric Improvements Alternative; therefore, the user operational cost savings are considered to be negligible, and have been ignored as a quantitative analysis factor in favor of a safety-based approach to the analysis. The LOS data may still be considered in a quantitative manner during decision making. Table 4 provides the overall intersection LOS for the current and anticipated 2045 design volume for both alternatives and the base condition.

Table 4. Intersection Alternatives Peak Traffic Volume Level of Service

Improvement Alternative	Current Intersection LOS (AM / PM)	2045 Intersection LOS (AM / PM)
Base Condition	B / C	C / C
Operational Signal & Layout Improvements	NA	C / E
Multi-Lane Roundabout	NA	B / C

(Source: South Boulder Road Reconstruction -Traffic Analysis, March 2025, by Fox Tuttle Transportation Group)

Safety Cost Benefits
A safety-based approach allows user operational costs to be measured by anticipated time savings from reduced crash frequency and severity, which can then be discounted for benefit-cost analysis. Both alternatives are expected to lower crashes and save delay time compared to the baseline, so time saving and environmental benefits associated with delays due to crashes can be calculated accordingly. Costs associated with crashes are determined by the FHWA for various categories, as shown in Table 5.

Table 5. Recommended Value of Reduced Fatalities, Injuries, and Crashes

KABCO Level	Monetized Value
O / PDO – No Injury / Property Damage Only	$9,500
C – Possible Injury	$118,000
B – Non-incapacitating	$246,900
A - Incapacitating	$1,254,700
K - Killed	$13,200,000

(Source: U.S. Department of Transportation, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, May 2025)

Further discussion and the results of user safety-based cost benefits for each alternative are discussed later in the Alternative Analysis section of this report.

Additional Cost and Time Factors
Other factors, identified in Table 6 below, are critical for determining the value of time as it relates to vehicle fuel usage, personal and fright value of time due to delays on an annual basis. These values have been obtained from AAA, and the current value of gas, as well as recommendations by the FHWA.

Table 6. Values Used for Cost of Fuel and Time

Cost or Time Metric	Value
Fuel Cost ($ / Gallon)	$3.05
Value of Time ($ / Hour) Personal	$21.10
Value of Time ($ / Hour) Freight	$35.70
Combined Value of Time ($ / Hour)	$21.25
Days of Analysis per Year	260
Hours of Peak Traffic per Day	2

(Sources: AAA Average Fuel Prices for Boulder County, Colorado; and U.S. Department of Transportation, Benefit-Cost Analysis Guidance for Discretionary Grant Programs, May 2025)

Delay time associated with crashes also has an impact on fuel consumption, either due to idling or alternative routes to avoid delays. The NHTSA also provides data, based on roadway and crash type, that estimates the net increase and costs of fuel consumption due to crashes on roadways.

Table 7. Net Increase in and Cost of Fuel Consumption per Crash

Crash Type	Gallons/ Fuel
Fatal (K)	$294.00
All Injuries (A,B,C)	$ 54.00
Property Damage Only (O)	$ 55.00

(Source: National Highway Traffic Safety Administration, The Economic and Societal Impact of Motor Vehicle Crashes, 210)

E. Environmental Impacts

Intersection safety improvements—such as converting a signalized intersection to a roundabout—can offer environmental benefits but may also introduce potential impacts that must be carefully considered in a benefit-cost analysis. While roundabouts reduce vehicle idling and improve traffic flow, thereby lowering emissions and noise pollution, they often require additional space and right-of-way to accommodate their circular geometry and approach curvature. This expansion can disturb adjacent properties and environmentally sensitive areas, including dedicated open space, wetlands, and active cattle grazing lands. Such disturbances may affect habitat continuity, water quality, and agricultural operations, necessitating thorough environmental review and mitigation planning. Balancing these trade-offs is essential to ensure that safety and operational gains do not come at the expense of ecological integrity.

Environmentally sensitive areas adjacent to the ROW near this intersection have not been identified and are capable of taking on intersection expansion through the proposed improvement alternatives. The costs associated with adjacent land impacts have been included in the ROW impacts portion of the analysis. Emissions reductions though, will be factored in the study based on the anticipated reduction in travel and idle time associated with the expected reduction in crashes through the implementation of the proposed improvement alternatives. The National Highway Traffic Safety Administration (NHTSA) provides monetary data for key emissions values to be used in the BCA, as shown in Table 8.

Table 8. Estimated Value of Net Emissions per Crash

Crash Type	CO^2	CO	NOx	PM^{10}	$PM^{2.5}$	SO^2	VOC
Fatal (K)	$124.60	$ -	$ 59.72	$ -	$178.65	$ 10.38	$ 2.44
All Injuries (A,B,C)	$ 22.98	$ -	$ 11.02	$ -	$ 33.05	$ 1.94	$ 0.45
Property Damage Only (O)	$ 23.38	$ -	$ 11.21	$ -	$ 33.38	$ 1.91	$ 0.46

(Source: National Highway Traffic Safety Administration, The Economic and Societal Impact of Motor Vehicle Crashes, 210)

CO2 or PM10 emission reductions per crash are not estimated by the NHTSA. CO reduction benefits are included in vehicle operation calculations, per the FHWA.

Overall, the environmental benefits of many transportation improvement projects may vary depending on the facility type, project size, and level of estimated safety improvements or crash reductions. For a singular intersection project, they likely do not have enough impact to outweigh safety or right-of-way benefits or costs but are included nonetheless.

IV. ALTERNATIVES ANALYSIS

Two intersection alternatives have been reviewed to improve the safety and operations of the existing condition at the intersection of South Boulder Rd. and Cherryvale Rd. These alternatives prioritize vehicle, pedestrian, and cyclist safety by providing signal operations and timing modifications and/or geometric improvements. The elements described in Section II of this report were evaluated for each alternative, and input into benefit-cost analysis methodology against the Base Condition, as recommended by FHWA for determination of the anticipated ratio of benefits to cost of the public and Boulder County.

A. Base Condition

The intersection is considered a “4SG” type based on the existing number of through lanes, signalized traffic control, and number of legs. This information is useful in a BCA analysis, particularly in determining the expected crash frequency at the intersection. Other factors that may affect the operation and safety at an intersection include:

- Lighting Present (Yes)
- Red-light cameras present (No)
- Daily Pedestrian Volume (Minimal)
- Number of bus stops within 1,000 feet (2)
- School(s) present within 1,000 feet (None)
- Alcohol sales establishments within 1,000 feet (None)

Average Annual Daily Traffic (AADT) through the intersection, signal phasing type, turn lane movements, and other factors also contribute to the operation of the intersection, and is used in calculations for determining intersection safety. This data is presented in Table 9 below.

Table 9. Intersection Configuration and Traffic Data

Street Data	Major (SBR)	Minor (Cherryvale)
Street configuration	Two-way	Two-way
Annual average daily traffic (AADT), veh/day	14,000	8,200
Number of through lanes	4	2
Number of approaches with left-turn lanes	2	2
Number of left-turn movements with protected phasing	2	2
Number of right-turn movements prohibited on red	0	0
Number of U-turn movements prohibited	0	2
Number of approaches with right-turn channelization	2	1

Expected Crash Frequency

In a safety-based approach to the BCA analysis, the existing crash data must be determined in the base condition to calculate costs associated with safety improvements and reduction in crashes.

The National Cooperative Highway Research Program (NCHRP) developed a tool for estimating crashes based on the HCM and the SPF factors discussed in Section II of this report, and develops a distribution for types of crashes, including utilization of the EB method, as recommended by the FHWA. The results of the expected crash frequency at the intersection of South Boulder Rd. and Cherryvale Rd. can be found in Table 10 below.

Table 10. Expected Crash Frequency for Base Condition

Predicted Crash Frequency (crashes / year)				Site-Specific Observed Crash Totals*			Expected Crash Frequency (crashes / year)			
Total- vehicle		Vehicle-pedestrian	Vehicle-bicycle	Total- vehicle		Vehicle-pedestrian	**Total- vehicle**		**Vehicle-pedestrian**	**Vehicle-bicycle**
F+I	PDO	F+I	F+I	F+I	PDO	F+I	**F+I**	**PDO**	**F+I**	**F+I**
1.954	1.956	0.038	0.074	0.478	0.522	0.043	**1.180**	**1.010**	**0.038**	**0.042**

**Note: Site-Specific Observed Crash Totals are utilized in the EB method and have been provided from the best available CDOT data and supplemented with a known fatality crash that occurred in the Spring of 2025.*

The HCM further provides an estimated distribution of KABC crashes, which can be applied to the Fatality or Injury (F+I) expected crash frequency from Table 8 to determine the expected number of annual crashes at the intersection. O/PDO crashes are not distributed. Table 11 outlines the distribution of KABCO crashes for use in the BCA.

Table 11. Base Condition Crash Frequency Distribution for Crash Types

Crash Type	A: Expected Crash Frequency	B: Severity Distribution Factor	Distributed Annual Crash Totals (A x B)	% of Crash by Type
O - Property Damage Only	1.01	1.00	**1.01**	**28.1%**
C - Possible Injury	1.26	1.39	**1.75**	**48.7%**
B - Non-incapacitating		0.54	**0.68**	**19.0%**
A - Incapacitating		0.11	**0.14**	**3.8%**
K - Killed		0.01	**0.01**	**0.4%**
Totals			**3.60**	**100.0%**

For the purposes of the BCA analysis, F+I crashes did not differentiate between vehicular and pedestrian or bicycle injury crashes, and the analysis included both types under the frequency distribution, totaling 1.26 F+I crashes per year.

It should be noted that the Distributed Annual Crash Totals in Table 9 from the HCM predictions, based on the EB adjustment, equal to approximately 3.6 crashes per year. This closely corresponds to the observed number of crashes for the last 5 years of approximately 4.6 crashes per year.

B. Alternative 1: Lane Configuration and Operation Improvements

The first alternative considered for the intersection improvements consist of revising lane geometry and the signal operations for left turning vehicles. The following summarizes the key elements for the improvement alternative:

- **Geometry Improvements**
  - Conversion of paved shoulders to buffered bikeable shoulders approaching the intersection
  - Dedicated space for cyclists through right-turn lanes
  - 11-foot lane widths for traffic calming
  - Improved ADA ramps at intersection corners
  - Paved sidewalk connections to adjacent transit stops Addition of a dedicated right turn lane on the north and south legs of the intersection
  - Dedicated space for cyclists in the through movements on north and south legs
  - Inclusion of bikeable shoulders through the intersection reconstruction limits
  - 11-foot lane widths for traffic calming
  - Improved ADA ramps at intersection corners

- **Signal Operation Improvements**
  - New signal equipment, including ADA compliant pedestrian crossing push buttons
  - Convert protected-permissive left turn signals to protected-only on all legs of the intersection

Figure 5 provides graphical detail of the proposed improvements associated with the lane reconfigurations at the intersection. A full exhibit is also included in Appendix A of this report.

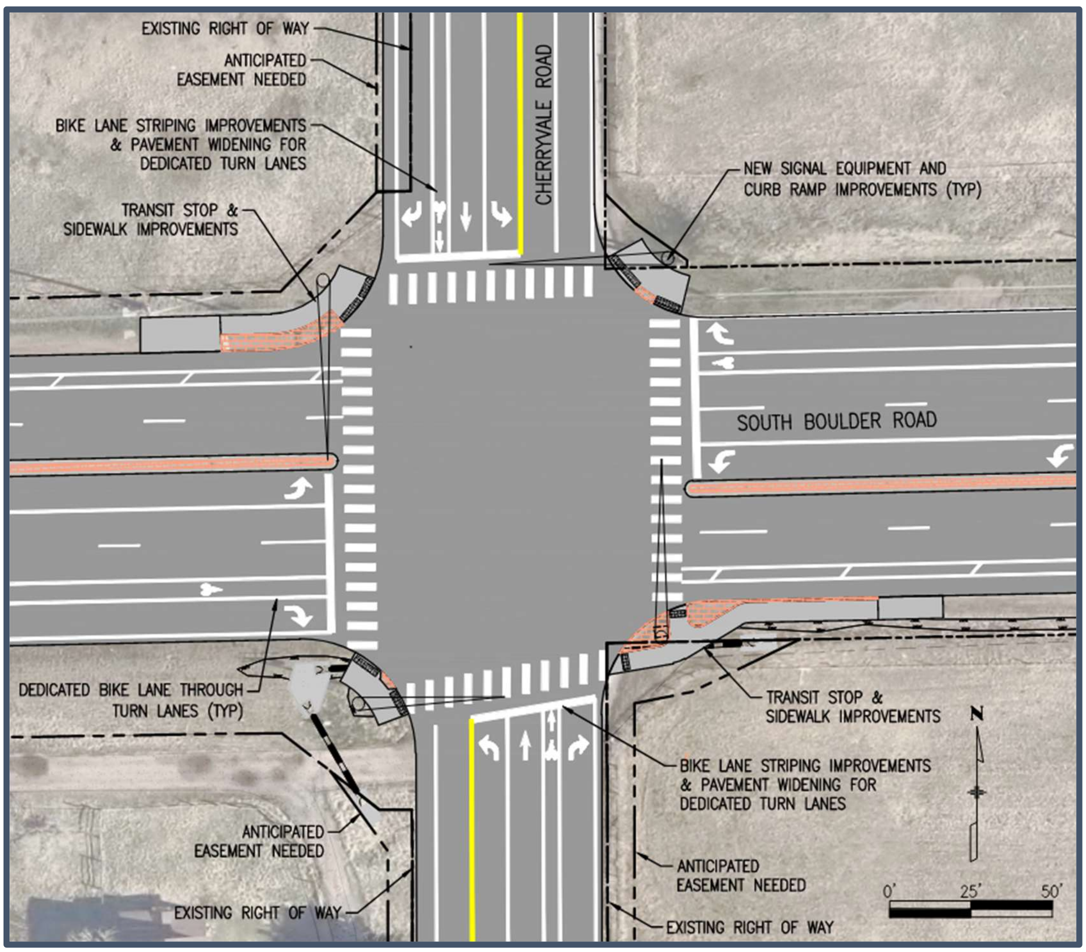

Figure 5. Alternative 1: Signal & Geometry Improvements Concept Plan

Signal Operation Safety Improvements
Fox Tuttle Transportation Group has performed an initial analysis of the existing traffic volumes, revisions to the signal for a protected left-turns on all legs of the intersection for the projected 2045 traffic volumes. Under this scenario, with all-protected left-turn operation, the overall intersection LOS is anticipated to be LOS E in PM peak hour, with several movements of LOS E/F and exceeding existing storage lengths during the busiest periods of the peak hours. The full analysis of the intersection LOS and operation can be found in Appendix B of this report.

While the LOS of the intersection may be reduced to grades that are not acceptable from a planning perspective, the protected-only left-turn signal modifications are expected to reduce injury and bike/pedestrian crashes, based on historic data. The dedicated turn lanes also provide for a safer interaction between cyclists, pedestrians, and vehicles, as no facilities exist today that provide cyclists with space to maneuver through the intersection without utilizing the vehicle lanes.

Lane Configuration and Geometry Improvements
In addition to enhancements focused on signal operation safety, this alternative also includes proposed modifications to lane configuration and roadway geometry designed to better accommodate public needs and enhance intersection safety. Currently, the existing lane geometry and configuration at Cherryvale and S. Boulder Rd. lack dedicated facilities for cyclists, which results in shared use of turn lanes by both vehicles and bicycles for those making turning movements on to S. Boulder Rd from Cherryvale. The approaches on both the north and south legs of Cherryvale Rd. provide minimal shoulders for cyclists, and as a result, only highly experienced cyclists tend to utilize this route given the necessity of mixing with vehicular traffic.

The proposed alternative intends to establish dedicated bicycle space throughout the intersection, while narrowing vehicular lane widths to introduce a traffic-calming effect. A dedicated right-turn lane is planned for the south leg, allowing right-turning vehicles to bypass through traffic, thereby reducing queueing. Dedicated bike lanes will be provided for through movements; however, cyclists making turning maneuvers onto South Boulder Rd. will still need to share turn lanes with vehicles. Additionally, the lengths of the turn lanes have been revised to more accurately reflect projected future traffic volumes. Nonetheless, some queuing may exceed available turn lane capacity during peak hours in the 2045 forecast period due to right-of-way constraints and project limitations related to grading and drainage.

Other Proposed Improvements and Right-of-Way Needs
The intersection alternative will also provide for upgraded ADA compliant curb ramps, with sidewalk connections to the transit stops on the east and west far-side legs of the intersection. The transit stops will be improved to include a concrete waiting area, and potentially other amenities, such as bike tracks. Drainage will also be improved at the intersection, with existing pipes being properly sized and replaced to reduce standing water that exists today, creating low wetland-like areas.

The ROW needs for this intersection alternative consist of requiring additional portions of land on all four corners of the intersection. This land is owned and maintained by City of Boulder OSMP, and it is assumed that the land is capable of being converted to ROW due to the current use, and benefits to OSMP users from the intersection improvements. The total required ROW and/or easement needs associated with the work is currently estimated at 6,634 square feet (0.15 acres).

All pavements will also be replaced at the intersection for full reconstruction.

C. Alternative 2: Multi-lane Roundabout

The second alternative that is being considered for the intersection improvements consists of the design and installation of a multilane roundabout. Roundabouts have been proven to reduce severe crashes by eliminating conflict points associated with right-angle and head-on collisions, typically found in four-leg intersections. Signalized intersections are associated with a high number of vehicle and pedestrian conflict points, contributing to elevated crash risk.

A standard four-leg signalized intersection typically contains 32 vehicle-vehicle conflict points and 24 vehicle-pedestrian conflict points, totaling 56 conflict points. In contrast, a roundabout configuration reduces these to 16 vehicle-vehicle and 8 vehicle-pedestrian conflict points, for a total of 24. This reduction, combined with the geometric design that forces vehicles to slow down, significantly decreases the likelihood of high-speed, high-energy collisions. According to the FHWA, converting a signalized intersection to a roundabout can reduce serious injury and fatal crashes by up to 78%.

The following list summarizes the key considerations for the proposed multilane roundabout alternative at Soth Boulder Rd. and Cherryvale Rd.:

- **Geometry Considerations**
  - Inscribed Circle Diameter
    - Ensures sufficient diameter to accommodate design vehicles and maintain appropriate deflection for speed control.
  - Entry and Exit Lane Configuration
    - Uses tangent exits to support natural vehicle paths and reduce curb damage.
    - Avoids entry and exit path overlap to minimize conflict points and confusion.
  - Approach Geometry and Speed Management
    - Implements reverse curvature on high-speed approaches to reduce entry speeds
    - Integrate super-elevation and deflection geometry to guide vehicles into the roundabout safely.
  - Design Vehicle Accommodation
    - WB-67 vehicles can navigate the roundabout without excessive widening.
    - Dual-lane entries for approaches.
  - Sight Distance Requirements
    - Provides adequate stopping and intersection sight distances for all approaches and circulatory paths.
  - Splitter Islands
    - Design includes splitter islands to channelize traffic, provide pedestrian refuge, and enhance visibility.

- **Pedestrian and Bicycle Facilities**
  - Includes bike ramps and transitions to and from street facilities
  - Design includes pedestrian crossings with refuge islands, clear markings, and pedestrian-actuated RRFB illumination and signage.
  - ADA-compliant features such as ramps and truncated domes.

- **Non-Geometric Design Elements**
  - Consider signage, lighting, and landscaping to support driver recognition and safe navigation.

Figure 6 below depicts the multilane concept at South Boulder Rd. and Cherryvale Rd used in this report.

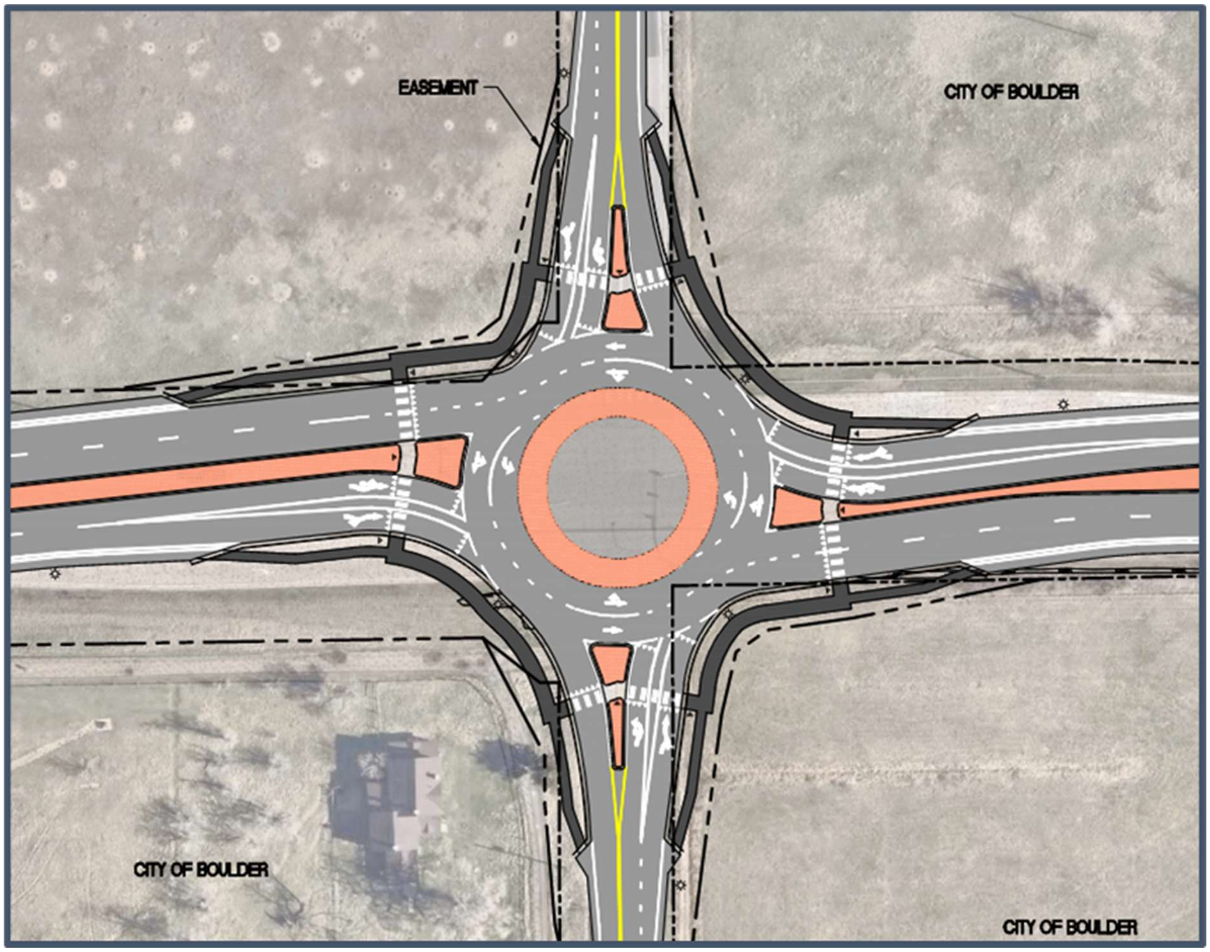

Figure 6. Alternative 2: Multilane Roundabout Concept Plan

Cost Impacts of Roundabouts

Although roundabouts may involve higher initial construction costs, they eliminate the need for traffic signal equipment, ongoing maintenance, and power consumption, resulting in reduced long-term operational expenses. Roundabouts also support continuous traffic flow, which minimizes congestion and lowers vehicle emissions associated with idling. However, the need for additional street lighting and its associated costs and environmental impacts should be evaluated during design.

Bicycle and Pedestrian Safety in Roundabouts

From a multimodal perspective, multilane roundabouts present both advantages and challenges. Benefits include lower vehicle speeds that reduce crash severity, shorter pedestrian crossing distances with staged crossings and refuge islands, and the elimination of left-turn conflicts. Bicycle accommodations can be provided through ramps that allow cyclists to exit the roadway and cross as pedestrians, while also permitting on-street navigation through the roundabout. Challenges include the absence of dedicated pedestrian signals, requiring users to judge gaps in traffic and relying on driver yielding. Multilane approaches may also create “multi-threat” scenarios where a yielding vehicle in one lane obscures the pedestrian from drivers in adjacent lanes. Additionally, drivers may be focused on navigating the roundabout geometry and less attentive to crossing pedestrians.

ROW Needs for Roundabouts
Similarly to Alternative 1, ROW needs for this roundabout intersection alternative consist of requiring additional portions of land on all four corners of the intersection. This land is owned and maintained by the City of Boulder OSMP, and it is assumed that the land is capable of being converted to ROW due to the current use, and benefits OSMP users from the intersection improvements. The total required ROW and/or easement needs associated with the roundabout alternative is currently estimated at 16,153 square feet (0.37 acres), which is more than double than the traditional signal improvements alternative.

D. Alternatives Capital and Annual Maintenance Costs

The information and tables shown below show the change in key analysis metrics and benefits for each intersection alternative. These metrics are based on the FHWA recommendations for a safety-based approach to public decisions and cost-benefit analysis.

Project Implementation Costs
Project costs consider the physical construction, ROW acquisition, and construction management costs of an alternative. These are expressed in terms of current (2025) dollars. Design costs are assumed to be equal and not included in the analysis. The capital cost of traffic signal improvements includes all of the improvements as designated in the concept layout for the project. The alternatives capital costs include the initial investment of the construction and other costs as described above. ROW costs are estimated based on the Colorado Department of Transportation (CDOT) recommended value of $90,000 per acre of land. Project Support costs (such as construction management and materials testing) have been estimated at 7% of the construction value of the alternatives. The intersection improvement alternatives capital costs are included in Appendix B of this report and summarized in Table 12 below.

Table 12. Alternatives Design Year Estimated Capital Costs

Improvement Alternative	Project Support	Right-of-Way	Construction	Total Capital Cost (2025)
Operational Signal & Layout Improvements	$208,752	$13,500	$2,982,165	**$3,204,417**
Multi-Lane Roundabout	$185,543	$33,300	$2,650,609	**$2,872,370**

Roundabouts are traditionally considered more costly to construct, compared to signalized intersections, however in this case, the signalized intersection has a high value to the anticipated widening, and longer turn lane requirements on Cherryvale Rd, due to queue length needs in the future traffic conditions.

Annual Maintenance Costs
In addition to initial construction expenses, it is essential to consider the recurring annual operations and maintenance costs associated with both signalized intersections and roundabouts, as these ongoing expenditures can impact the long-term affordability and sustainability of each alternative.

The maintenance costs of the alternatives are approximately equal based on the data developed by the Crash Modification Clearinghouse from 20 different states. The average annual maintenance and operating costs for a traffic signal intersection developed from this data is approximately $5,800 per year. The annual maintenance and operating costs for a roundabout intersection range from $2,500 to $5,000 per intersection, depending on the improvements provided, such as landscaping, striping, and lighting.

For the purposes of this study, we assume that landscaping and irrigation will be minimal in any roundabout installation, but lighting and a Rapid Rectangular Flashing Beacon (RRFB) will be installed on the roundabout. The average annual costs to maintain a RRFB are approximately $2,500 each, and lighting and signage are estimated at $2,200 per year, per the Crash Modification Clearinghouse. So, the total annual operations and maintenance costs assumed for this study are $2,700 for a roundabout.

Table 13. Assumptions for Annual Maintenance Costs of Intersection Alternatives

Improvement Alternative	Annual Maintenance & Operations	Striping & Signing Update (every 4th year)	Pavement Rehabilitation (at year 20)	20-Year Total (discounted at 7%)
Operational Signal & Layout Improvements	$5,800	$9,000	$157,800	**$3,307,089**
Multi-Lane Roundabout	$2,700	$18,000	$350,000	**$3,014,055**

Overall, the difference in operating and maintenance costs of the alternatives is minimal over the 20-year time frame but have been included in the BCA. It should also be noted that pavement rehabilitation costs have been estimated and included for each intersection at the 20-year mark for the purposes of this BCA analysis.

E. Expected Crash Reductions

Crash reduction expectations for each design alternative must be carefully considered and based on accepted data for similar improvements. The FHWA's *Highway Safety Benefit-Cost Analysis Guide* outlines a step-by-step approach that includes identifying the safety issue, selecting appropriate countermeasures, estimating crash reductions using Crash Modification Factors (CMFs), and calculating benefits based on crash severity and frequency reductions.

Crash Modification Factors for Each Alternative

The following CMFs were obtained from the Crash Modification Factors Clearinghouse, which provides several data sources for determining CMFs for use in BCAs:

- **Alternative 1: Signal and Geometric Improvements**
  - **CMF = 0.58 (All Crashes)**
    (Clearinghouse ID No. 340; 4-Star Rated; *Safety Effects of Left-Turn Phasing Schemes at High-Speed Intersections*, Davis and Aul, 2007)

- **Alternative 2: Multilane Roundabout**
  - **CMF = 0.34 (K, A, B, C Crashes)**
    (Clearinghouse ID No. 4185; 4-Star Rated; *Safety Effectiveness of Converting Signalized Intersections to Roundabouts*, Gross Et al. 2012)

  - **CMF = 3.33 (PDO Crashes)**
    (Clearinghouse ID No. 9887; 4-Star Rated; *Whether Conversion and Weather Matter to Roundabout Safety*, 2018)

The CMFs for Alternative 2 were broken into two crash categories for the analysis, due to the nature of roundabouts and the differing reaction of drivers to the geometric changes, and the known high reduction in injury crashes after roundabout installations. This more granular approach to CMFs predicts better modifications from more data and additional studies, painting a more accurate picture of the expected crashes from the improvements.

Annual Crash Reduction Benefits

Expected crash reductions have been annualized and monetized, based on the values presented in previous sections of this report. Table 14 provides the annual crash reduction expected for each alternative, and the annual value of the reduction

Table 14. Annual Crash Reductions and Monetization After Improvements

Injury Severity Scale	Comprehensive Crash Unit Cost	Alternative 1		Alternative 2	
		Annual Reduction in Crashes	Annual Reduction Benefit	Annual Reduction in Crashes	Annual Reduction Benefit
K	$ 13,200,000	0.010	$ 125,993	0.015	$ 197,989
A	$ 1,254,700	0.094	$ 117,583	0.147	$ 184,773
B	$ 246,900	0.471	$ 116,332	0.740	$ 182,808
C	$ 118,000	1.207	$ 142,426	1.897	$ 223,812
O	$ 5,300	0.822	$ 4,354	-4.557	$ (24,155)
Total Annual Benefit			**$ 506,688**		**$ 765,227**
Total 20-Year Benefit (Discounted at 7%)			**$ 7,318,675**		**$ 11,053,054**

F. Expected Travel Time Benefits

Travel time reductions for each alternative were calculated using the NHSTA recommended monetary values for user time, as discussed in Section III of this report. Table 15 provides the calculated annual monetary value of travel time saved, due to reduction in crashes for each alternative.

Table 15. Calculation for the Monetization of Annual Travel Time Benefits

	Alternative 1	Alternative 2
Total Annual Reductions in Delay (Hours)	505.13	-61.57
Unit Value of Time (Dollars)	$ 21.25	$ 21.25
Total Annual Benefit	**$ 10,733.99**	**$ (1,308.28)**
Total 20-Year Benefit (Discounted at 7%)	**$ 155,042.00**	**$ (4,225.00)**

Alternative 1 provides a greater travel time benefit due to the decreased number of PDO crashes, whereas Alternative 2 increases the number of PDO crashes (the most common crash type), and therefore offsets the benefits to travel time expected from injury related crashes. As discussed in Section III of this report, travel times associated with operational changes were not evaluated in this BCA.

G. Expected Environmental Benefits

Environmental benefits for both alternatives were included in the analysis but proved to be negligible in the overall BCA. Over the 20-year analysis period, the emissions and fuel cost savings were calculated as follows:

- **Alternative 1: 20-Year Emissions and Fuel Cost Savings (Discounted at 7%) = $7,532**
- **Alternative 2: 20-Year Emissions and Fuel Cost Savings (Discounted at 7%) = -$2,335**

As was shown with travel time benefits for Alternative 2, there is an anticipated increase in both emissions and fuel consumption due to an increase in expected PDO crashes.

V. BENEFIT-COST ANALYSIS

The FHWA recommends a structured BCA framework to evaluate the economic efficiency of intersection safety improvements. This method involves comparing the monetized benefits of a proposed countermeasure, such as those described in earlier sections of this report, against its implementation and lifecycle costs. The FHWA BCA tool was utilized to perform these calculations, with modifications to factors for updated monetary values, as recommended in their BCA guidance documents. The following summarizes the results of the BCA, based on the data presented in previous sections of this report, and

A. Summary of Benefits and Costs

A summary of each alternative's 20-year total monetized benefits and annual maintenance costs (each discounted at 7%) and the upfront capital costs are shown in in Table 16.

Table 16. Summary of Alternatives Present Value Benefits and Costs

South Boulder Rd. at Cherryvale Rd. Intersection Improvements		
Benefit	**Cost (2025)**	
	Alternative 1: Signal and Lane Configuration Improvements	**Alternative 2: Multilane Roundabout**
Economic		
Travel Time Savings	$155,042	($18,897)
Environmental		
Reduced Emissions	$1,203	$1,890
Fuel & Operation Savings	$6,329	($4,225)
Safety		
Reduced Crashes	$7,318,675	$11,053,054
Total Benefits	**$7,481,249**	**$11,031,822**
Capital Costs		
Project Support	$208,752	$185,543
Right-of-Way	$13,500	$33,300
Construction	$2,982,165	$2,650,609
Operations and Maintenance Costs		
20-Year O&M Costs	$102,672	$141,686
Total Costs	**$3,307,089**	**$3,011,138**
Benefit-Cost Analysis		
Net Present Value	**$4,174,160**	**$8,020,684**
Benefit-Cost Ratio	**2.3**	**3.7**

The largest components of the benefits that can be expected from the project are concentrated is the monetary value of crash reductions, with additional significant benefits from travel time savings in Alternative 1. Environmental benefits are only modest, and capital costs are relatively equal.

B. Results

Over the 20-year assessment period, the South Boulder Rd. at Cherryvale Rd. improvement may provide a range of $7.5M to $11.0M in benefits, with benefit-cost ratios ranging from 2.3 to 3.7 depending on the potential alternative implemented. While both alternatives would be suitable and could alleviate safety issues while providing acceptable levels of service, the best alternative will provide minimal delays to traffic with a lower fatal or injury crash rate potential at a low cost and fits within the constraints of the available space at the intersection.

The following are key differences and improvement study conclusions:

- The level of service is better with the roundabout during all hours of the day.
- While traffic does slow down in a roundabout, traffic may be stopped at a traffic signal, resulting in similar corridor travel times.
- Predicted fatal and injury crashes are lower for the roundabout, but minor crashes are expected to increase.
- Signal and lane configuration improvements provide a larger overall benefit to travel times but are expected to produce a higher frequency of fatal or injury crashes.
- The roundabout provides safety benefits where crashes tend to be less severe due to the lower vehicle speeds and the angle of incidence.
- Pedestrian safety is increased with the roundabout alternative due to shorter exposure to traffic and the lower vehicle speeds at pedestrian crossing locations.
- Based on the planning level cost estimates, both alternatives have approximately equal capital costs.
- Considering the delay to the users of the system and the safety benefits of both alternatives, the roundabout has a higher benefit for the cost.

C. Recommendation

The multilane roundabout alternative (Alternative 2) is the preferred intersection alternative to maintain mobility and increase safety at the intersection of South Boulder Rd. and Cherryvale Rd. Based on the considerations of operations (technically feasible), safety and right-of-way (environmentally compatible), financial impacts (economically viable), and the higher benefit-cost ratio of 3.7, implementing the double-lane roundabout is recommended for this intersection to effectively and safely address present and future traffic demands.

APPENDIX A:

INTERSECTION ALTERNATIVES CONCEPT PLAN EXHIBITS

APPENDIX B:

INTERSECTION ALTERNATIVES CONCEPTUAL COST ESTIMATES

APPENDIX C:

SOUTH BOULDER ROAD TRAFFIC ANALYSIS MEMO

Prepared by Fox Tuttle Transportation Group

(Note: Select Memo Appendices Removed)