Proposed Action Development

I-270 Corridor Improvements

September 2022

Prepared For:
CDOT Region 1
2829 West Howard Place
Denver, CO 80204

CDOT Project No.
STU 2706-043

CDOT Project Code
23198

Contents

Figures

Tables

Acronyms and Abbreviations

Acronym	Definition
CDOT	Colorado Department of Transportation
CHPTE	Colorado High Performance Transportation Enterprise
DRCOG	Denver Regional Council of Governments
EA	Environmental Assessment
EIS	environmental impact statement
FHWA	Federal Highway Administration
I-25	Interstate 25
I-70	Interstate 70
I-270	Interstate 270
MOE	measure of effectiveness
MP	mile post
mph	mile(s) per hour
PCCP	Portland cement concrete pavement
PEL	Planning and Environmental Linkages
RTP	regional transportation plan
US-36	U.S. Highway 36
V/C	volume-to-capacity ratio
VHT	vehicle hours traveled
VMT	vehicle miles traveled

1.0 Introduction

The Colorado Department of Transportation (CDOT) and the Federal Highway Administration (FHWA), in conjunction with local partners Adams County and Commerce City, are proposing improvements to 6 miles of Interstate 270 (I-270) in Adams County, Commerce City, and the City and County of Denver, Colorado, primarily between Interstate 25 (I-25) and Interstate 70 (I-70) (Figure 1-1). CDOT and FHWA are preparing an Environmental Assessment (EA) for the project, referred to as the I-270 Corridor Improvements Project (project).

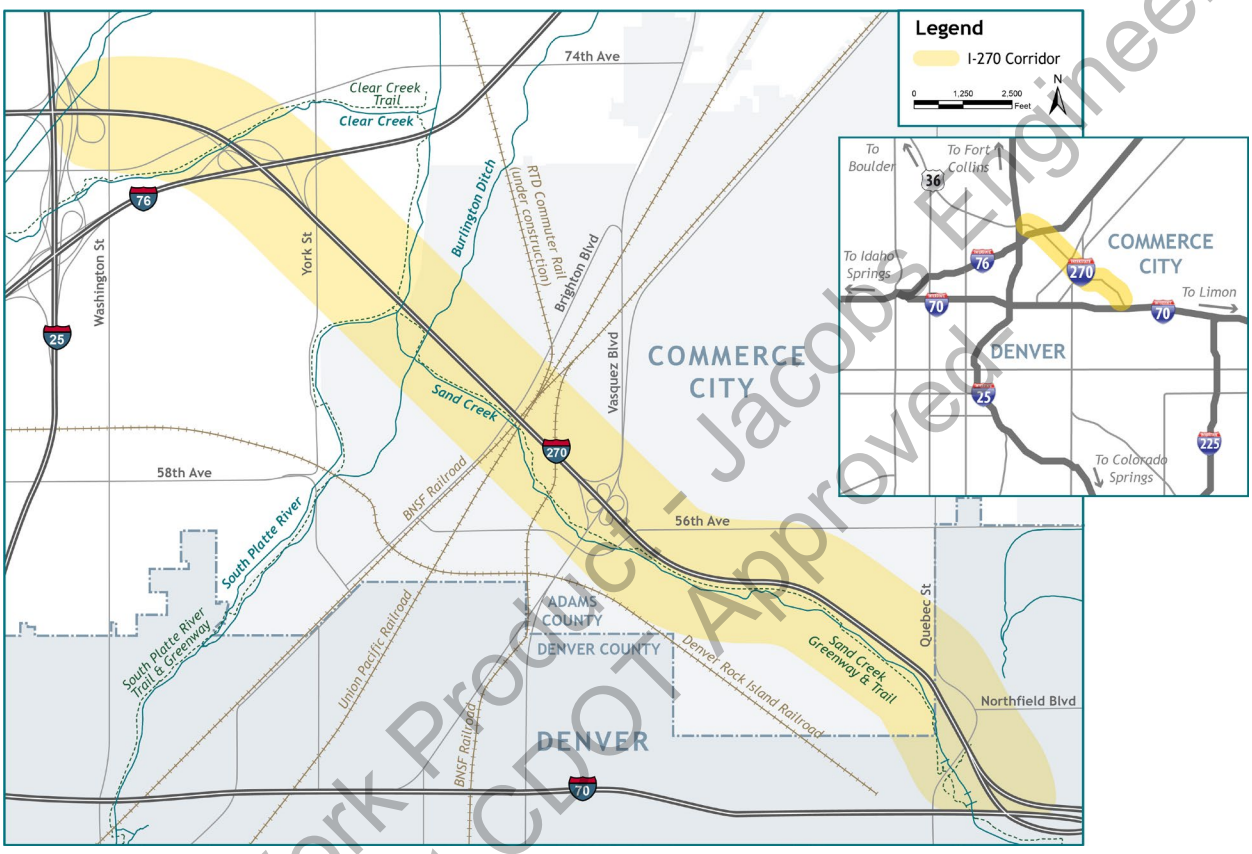

Figure 1-1. Project Location
Source: Jacobs

The purpose of this report is to summarize the process and decision making used in developing and identifying the Proposed Action for the project. The alternatives development for the EA relied heavily on previous work conducted, specifically the following:

- *Vasquez Boulevard Planning and Environmental Linkages (PEL) Study* (CDOT 2018a)
- *I-270 Traffic Study* (Atkins 2019)
- *Colorado Express Lane Master Plan* (CHPTE 2020)

These previous efforts were building blocks for developing the Proposed Action evaluated in the EA. During the EA, the Proposed Action was refined to meet the project purpose and need (refer to Section 2 of the EA) based on traffic, engineering, environmental, and stakeholder and public considerations (Figure 1-2).

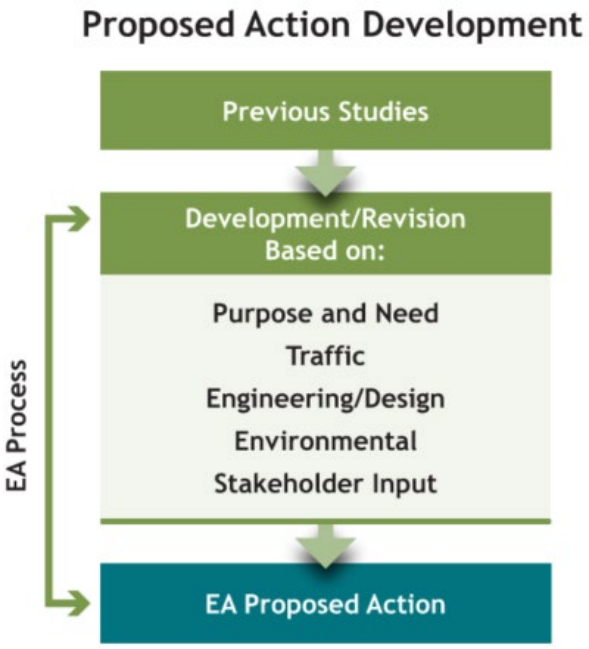

Figure 1-2. Development of the Proposed Action
Source: Jacobs

2.0 Previous Studies

2.1 Vasquez Boulevard Planning and Environmental Linkages Study

In 2018, CDOT in cooperation with FHWA and local agencies conducted a PEL study for Vasquez Boulevard, including the interchange of I-270 and Vasquez Boulevard. Driven by identified needs within the PEL study area, the purpose of the PEL study was to identify transportation improvements that would "improve operations, mobility and safety for vehicles and freight at the I-270/Vasquez Boulevard interchange; improve its connection to the Vasquez Boulevard/56th Avenue and Vasquez Boulevard/60th Avenue intersections, on Vasquez Boulevard and the surrounding local road system; and improve transportation connectivity for all modes." (CDOT 2018a)

2.1.1 I-270/Vasquez Interchange Alternatives Evaluated

More than 20 alternatives were evaluated and screened against the PEL study's purpose and need (CDOT 2018a) for the I-270/Vasquez interchange. These alternatives were developed by the PEL study team in consultation with the Technical Working Group, stakeholders, and technical CDOT and consultant team staff. Four alternatives for the I-270 interchange were advanced through the screening process, which included a partial cloverleaf, a diverging diamond, splits pairs, and viaduct alternatives. These alternatives were identified to best address safety and operational issues at the interchange and improved travel times on I-270.

Partial Cloverleaf

The partial cloverleaf at-grade interchange solution would remove the existing I-270 exit loop ramps identified to pose safety and operational concerns and create two new signalized intersections along Vasquez Boulevard at proposed I-270 exit ramps (eastbound and westbound).

Diverging Diamond

The diverging diamond at-grade solution would convert the cloverleaf interchange into a diamond interchange, featuring two new traffic signals along Vasquez Boulevard at proposed I-270 ramp intersections. In between the two new traffic signals, Vasquez Boulevard thru traffic would be shifted to

the opposite side of the roadway in effort to creatively increase interchange capacity and reduce intersection conflict points.

One-way Pairs

The one-way pairs elevated solution would split existing Vasquez Boulevard (between East 56th Street and Highway 2) into one-way streets—northbound to remain along existing Vasquez Boulevard and southbound to use existing Clermont Street. The I-270/Vasquez interchange is within these limits and would be re-designed entirely.

Viaduct

The viaduct elevated solution would elevate bypass lanes along existing Vasquez Boulevard (between Colorado Boulevard and Highway 2), effectively widening North Vasquez Boulevard. The I-270/Vasquez interchange is within these limits and would be re-designed entirely.

2.1.2 Conclusions Relevant to the EA Proposed Action

The study identified near-term improvements that "address critical issues with reasonable costs using available funds" and would integrate with any of the alternatives identified for Vasquez Boulevard in the study (CDOT 2018a). The near-term improvement identified at the I-270 and Vasquez Boulevard interchange was the partial cloverleaf concept. CDOT is advancing some of the other near-term improvements on North Vasquez Boulevard identified in the study. The partial cloverleaf concept addresses the I-270 Corridor Improvements Project purpose and need, mainly by removing the two loop exit ramps that contribute to I-270 congestion and crashes.

2.2 I-270 Traffic Study

In 2019, CDOT commissioned Atkins to complete the *I-270 Traffic Study* (Atkins 2019) in advance of initiating the EA. The purpose of the *I-270 Traffic Study* (Traffic Study) was to document existing traffic conditions, develop a calibrated traffic model to use for alternatives analysis, forecast design year (2040) traffic, and analyze the operational performance of potential I-270 alternatives. As discussed in Section 2.2.4, the Traffic Study helped inform decisions on the Proposed Action to be evaluated in the EA.

2.2.1 Alternatives Considered in I-270 Traffic Study

To address I-270's transportation needs, CDOT identified several potential I-270 mainline alternatives to analyze in the Traffic Study. These build alternatives were developed from a combination of improvements—specifically, adding general purpose or managed lanes, upgrading the Vasquez Boulevard interchange, and providing a direct connection between I-270 and I-70 managed lanes. A No Action Alternative also was analyzed. Table 2-1 summarizes the alternatives modeled and analyzed in the Traffic Study.

Table 2-1. I-270 Traffic Study—Alternatives Modeled and Analyzed

Alternative	Description	I-270 Lanes (each direction)	Other Improvements
1	No Action	2 general purpose lanes	None
2	Vasquez Boulevard interchange improvements	2 general purpose lanes	Full-access interchange at Vasquez Boulevard
3	3 general purpose lanes	3 general purpose lanes	Full-access interchange at Vasquez Boulevard
4a	2 general purpose lanes plus 1 managed lane without direct connection to I-70 managed lanes	2 general purpose lanes + 1 managed lane	Full-access interchange at Vasquez Boulevard

Alternative	Description	I-270 Lanes (each direction)	Other Improvements
4b	2 general purpose lanes plus 1 managed lane with direct connection to I-70 managed lanes	2 general purpose lanes + 1 managed lane	• Full-access interchange at Vasquez Boulevard • Direct connections for managed lanes per I-70 East FEIS
5a	3 general purpose lanes plus 1 managed lane without direct connection to I-70 managed lanes	3 general purpose lanes + 1 managed lane	Full-access interchange at Vasquez Boulevard
5b	3 general purpose lanes plus 1 managed lane with direct connection to I-70 managed lanes	3 general purpose lanes + 1 managed lane	• Full-access interchange at Vasquez Boulevard • Direct connections for managed lanes per I-70 East FEIS

FEIS = final environmental impact statement (CDOT 2016)

2.2.2 Measures of Effectiveness Analysis from I-270 Traffic Study

The Traffic Study evaluated the alternatives against measures of effectiveness (MOEs) to quantify and compare the operational performance of the I-270 alternatives described in Table 2-1. Each MOE was analyzed based on the a.m. peak period (7 a.m. to 9 a.m.) and p.m. peak period (4 p.m. to 7 p.m.). The Traffic Study analyzed the following six MOEs:

- Volumes: average of the 15-minute volumes of throughput on the I-270 corridor and ramps during the a.m. and p.m. peak periods
- Travel times: minimum and maximum travel time through the study corridor during the peak periods
- Speed: minimum speed through the study corridor during the peak periods
- Travel demand volume-to-capacity ratio (V/C)
- Vehicle miles traveled (VMT) for eastbound and westbound lanes of I-270
- Vehicle hours traveled (VHT) for eastbound and westbound lanes of I-270

2.2.3 Summary of Results from I-270 Traffic Study

Table 2-2 summarizes the Traffic Study results of analyzing the MOEs for the six alternatives compared. The speeds from the Traffic Study are not shown because it reported speeds for each segment on the corridor and not the average speed for the entire length of the corridor, which is a parameter that should be used for alternatives' comparison. Similarly, the V/C values from the Traffic Study are not shown because they were estimated using TransCAD[1] capacities. The travel demand models developed in TransCAD assume higher capacities because they do not account for any friction from intersection operations, which can lead to imprecise V/C estimations.

Results for Improving Vasquez Boulevard Interchange Only

Table 2-2 shows that Alternative 2 (Vasquez Boulevard interchange improvements) does not notably improve the MOEs as compared with existing conditions or the No Action Alternative. The VMT and VHT values as well as the average peak 15-minute volumes are similar for the No Action Alternative and Alternative 2. Alternative 2 would reduce travel times slightly compared with the No Action Alternative, but improvements are modest.

[1] TransCAD is a traffic modeling platform that does not account for the finer details of traffic operations).

Table 2-2. I-270 Traffic Study—Peak Period MOEs for Existing Conditions and Alternatives

MOEs[a]	Time Period	Existing Conditions		Alternative 1: No Action		Alternative 2: Vasquez Boulevard Improvements		Alternative 3: 3 General Purpose Lanes		Alternative 4a: 2 General Purpose + 1 managed Lane without DC		Alternative 4b: 2 General Purpose + 1 managed Lane with Direct Connection		Alternative 5a: 3 General Purpose+ 1 managed Lane without Direction Connection		Alternative 5b: 3 General Purpose+ 1 managed Lane with Direct Connection	
		EB	WB	EB	WB	EB	WB	EB	WB	EB	WB	EB	WB	EB	WB	EB	WB
Average Peak 15-minute Volumes	a.m.	800	700	800	600	800	600	1,200	1,000	1,200	900	1,200	1,000	1,300	1,200	1,300	1,200
	p.m.	800	600	800	600	800	600	1,100	1,000	1,100	900	1,100	1,000	1,200	1,200	1,200	1,100
Travel Times (minimum/maximum in minutes)	a.m.	15/23	15/17	18/21	19/22	16/19	20/26	10/12	14/17	9/10	13/19	10/11	11/15	8/10	10/14	8/11	10/14
	p.m.	16/20	12/19	17/20	14/25	15/17	12/23	9/10	11/27	9/10	10/25	9/10	10/19	8/10	9/27	8/9	9/30
VMT	a.m.	89,000		158,000		158,000		188,000		183,000		183,000		200,000		204,000	
	p.m.	148,300		217,000		238,000		260,000		254,000		258,000		292,000		296,000	
VHT[a]	a.m.	1,400		6,700		6,700		6,300		6,100		6,300		5,900		6,000	
	p.m.	2,400		10,000		10,000		9,300		9,100		9,700		8,600		8,700	

Source: Atkins 2019

[a] The volumes, VMT, and VHT are averages rounded to the nearest 100. Travel times are rounded to the nearest 1.

EB = eastbound
WB = westbound

Results for Three-lane Alternatives

As shown in Table 2-2, the three-lane capacity in Alternatives 3, 4a, and 4b would increase the traffic volume served compared with the No Action Alternative while reducing travel times during both a.m. and p.m. peak periods. VMT results were similar for Alternatives 3, 4a, and 4b, and higher than the No Action Alternative because of the increased traffic volumes. VHT results were similar for Alternatives 3, 4a, and 4b. Even though all three would increase traffic volumes, these alternatives would reduce travel delay and therefore lower VHT compared with the No Action Alternative.

Results for Four-lane Alternatives

Alternatives 5a and 5b, with four lanes in each direction, would serve a higher traffic volume compared with other alternatives. Because of the increased vehicles served and despite the additional capacity, Alternatives 5a and 5b showed increased traffic friction at the merge and diverge sections between the York Street/I-76 off-ramp and I-25 off-ramp on I-270 in the westbound direction during the p.m. peak period. This contributes to higher travel times in the range of 5 to 10 minutes for westbound traffic, when compared with the three-lane alternatives during the p.m. peak period. Westbound travel times during the a.m. peak period and eastbound traffic during a.m. and p.m. peak periods are better compared with the three-lane alternatives, but the differences are minor. With the increase in traffic volume served, the VMTs for these alternatives are higher than the three-lane alternatives. Even though Alternatives 5a and 5b would increase traffic volumes, these alternatives would use an extra lane that would alleviate congestion and reduce travel delay and therefore lower VHT compared with the No Action Alternative and the three-lane alternatives.

2.2.4 Conclusions Relevant to the EA Proposed Action

This section summarizes conclusions made from the Traffic Study (Atkins 2019) results that informed the development of the EA Proposed Action.

- Alternative 2 (the Vasquez Boulevard interchange improvements) would not fully meet the project purpose and need. Alternative 2 would not accommodate future transportation demands because the average peak 15-minute volumes served would remain the same as existing conditions. Also, Alternative 2 does not address corridor-wide needs including deficient bridges, substandard shoulder widths, and deteriorating pavement and subgrade infrastructure.
- The three-lane and four-lane alternatives would meet the project purpose of accommodating future transportation demands because they both serve higher peak-hour volumes than existing conditions. Additionally, these alternatives could include corridor-wide improvements, thereby addressing project needs for improving safety, replacing deficient bridges, widening shoulders, and addressing deteriorating pavement and subgrade throughout the corridor.

  The three-lane alternatives (Alternatives 3, 4a, and 4b) provide varying levels of improvements as compared with existing conditions and the No Action Alternative. These alternatives would serve higher traffic volume, provide notable reductions in travel delay, and therefore lower VHT compared with the No Action Alternative. These alternatives would also be similar in lane-carrying capacity to the connecting interstate and highway systems.

  The four-lane alternatives (Alternatives 5a and 5b) would add lane capacity that would serve slightly higher traffic volumes when compared with three-lane alternatives. However, the higher traffic volume served would result in increased traffic friction at the merge and diverge sections on I-270. The impacts of increased traffic friction are more visible on westbound I-270 in the p.m. peak period, where travel time through the study corridor could be up to 30 minutes.

  The additional capacity provided in the four-lane alternatives would exceed the lane capacity of the receiving systems (U.S. Highway 36 [US-36] and I-70) on each end of the project. At its western

terminus, I-270 links to US-36, with traffic flowing in the east–west direction. US-36, which was reconstructed between 2012 and 2016, has one express lane in each direction and two general purpose lanes, totaling three lanes in each direction (CDOT 2020). With this configuration, US-36 would not be able to receive additional capacity from I-270 if I-270 were widened to more than three lanes in the westbound direction. At its eastern end, I-270 connects with I-70 via ramps. The ramps in both the eastbound and westbound directions are limited to two lanes entering and exiting I-70. In the three-lane alternatives, the eastbound third lane drops at the Quebec Street off-ramp, leaving two lanes continuing to the I-70 ramp. With the four-lane alternatives, there is an additional lane that creates a lane balance issue approaching the I-70 ramp. Similar to US-36, I-70 is unable to handle additional capacity from I-270 in excess of two general purpose lanes from the eastbound direction. Overall, the benefits of the four-lane alternatives versus the three-lane alternatives were modest for traffic volumes, VMT, and VHT, considering the negative impact on westbound p.m. peak period travel times.

- Alternatives with and without managed lane direct connections to I-70 managed lanes performed similarly. A direct connect ramp for managed lanes between I-270 and I-70 was part of the Preferred Alternative in the I-70 East FEIS (CDOT 2016), although it was not included in the *I-70 East Record of Decision (ROD) 1: Phase 1* (Central 70 Project) (CDOT 2017). The three-lane alternative with managed lane direct connections (Alternative 4b) and the three-lane alternative without managed lane direct connections (Alternative 4a) serve similar traffic volumes. The travel times, VMT, and VHT are also in similar ranges for both the alternatives. Similarly, the four-lane alternatives with and without managed lane direct connections (Alternatives 5a and 5b) show similar performance for different MOEs, traffic volumes served, travel times, VMT, and VHT.

2.3 Express Lane Master Plan

The Colorado High Performance Transportation Enterprise (CHPTE) conducted a study to create a statewide express lane master plan in conjunction with other regional partners. The study found a systematic need for express lanes throughout the Denver metropolitan area. The *Colorado Express Lane Master Plan* (CHPTE 2020) establishes a three-tier system that prioritizes the plan for express lane roadway segments. Tier 1 is the highest priority and Tier 3 is a lower priority. Within the tiers, a ranking score was averaged between the sum of the corridor mobility and financial scores for each priority segment. The entirety of I-270 was included in the master plan as a Tier 1 priority, with an overall ranking of 4. Three other Tier 1 projects ranked ahead of I-270 (green segments on Figure 2-1). I-270 between I-25 and I-70 is a critical link to provide users more reliable travel times system-wide as travel demand continues to grow throughout the Denver area (CHPTE 2020).

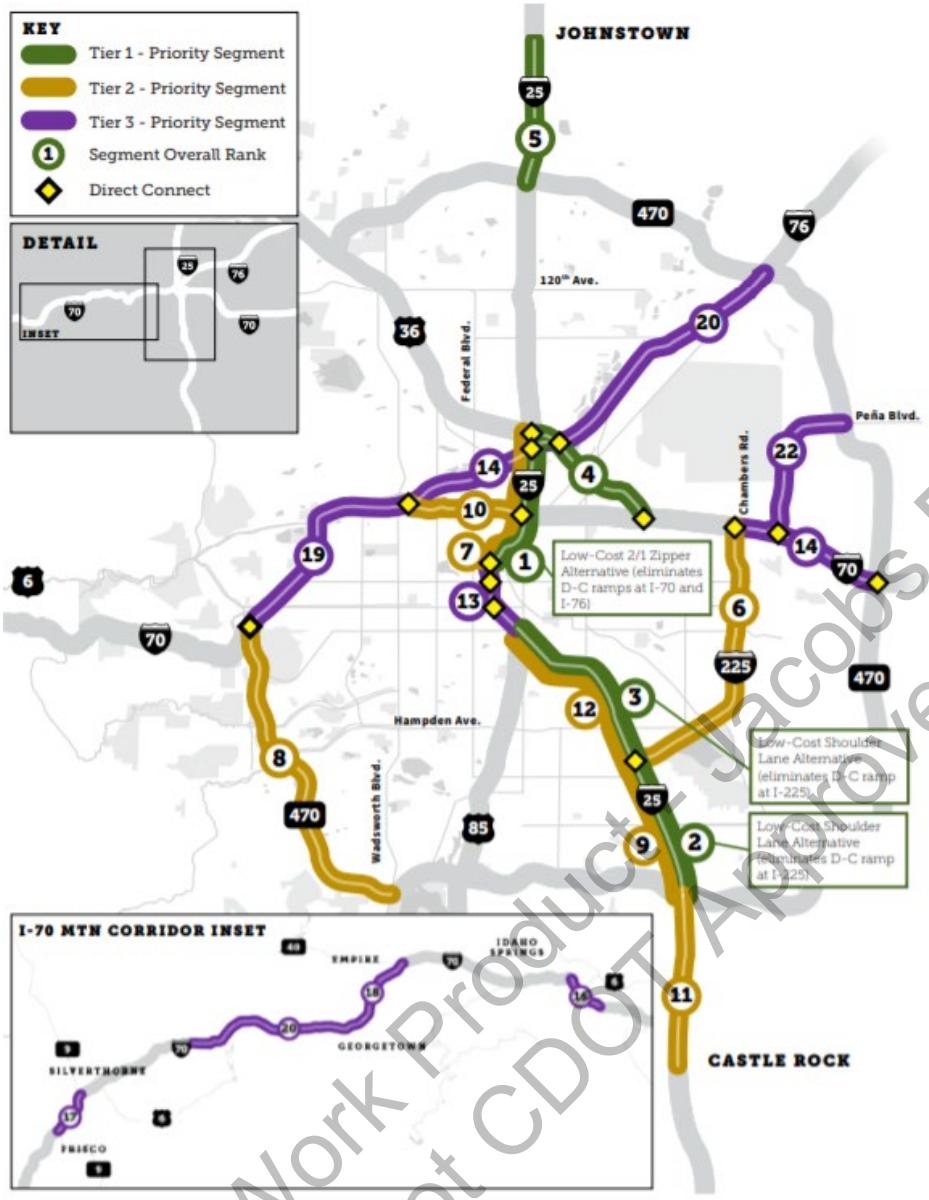

Figure 2-1. Express Lane Segment Prioritization within the Denver Metropolitan Area
Source: CHPTE 2020

3.0 Proposed Action Development

Based on the results from the previous studies, public/stakeholder input, and by considering the project purpose and need, CDOT and FHWA developed the EA Proposed Action by generally addressing these questions:

- What should the I-270 typical section be? That is, how many additional travel lanes are warranted?
- How should CDOT manage or operate these new lanes?
- What other improvements are needed along the I-270 mainline?
- What other improvements are needed at the I-270 interchanges?
- What bicycle and pedestrian improvements are needed?
- What design elements are needed to address public and stakeholder concerns?

Section 3 discusses how these questions were addressed during the EA process and how the Proposed Action evolved based on traffic analyses, design, and stakeholder considerations.

3.1 I-270 Travel Lanes

As discussed in Section 2.2.4, the results of *I-270 Traffic Study* (Atkins 2019) informed the decision making on the number of lanes or typical section to be included in the EA Proposed Action. Overall, the study found that the benefits of the four-lane alternatives versus the three-lane alternatives were modest for traffic volumes, VMT, and VHT when considering the negative impact on westbound travel times in the p.m. peak period.

When the EA was initiated, the *2040 Fiscally Constrained Regional Transportation Plan* (RTP) (DRCOG 2015) served as Denver Regional Council of Governments' (DRCOG's) adopted plan. The plan included I-270 being widened to three lanes in each direction. Because the three-lane alternatives have similar performance to four-lane alternatives, and consistency with adjoining interstate facilities and the 2040 RTP, CDOT and FHWA opted to carry forward a three-lane Proposed Action Alternative in the EA, to be analyzed against the No Action Alternative. In April 2021, DCROG adopted the 2050 Metro Vision RTP. This plan also includes I-270 as a six-lane facility, with two general purpose lanes and an express lane in each direction. A sensitivity analysis was performed to check how the three-lane alternative would perform during the 2050 horizon year. The analysis showed that the Proposed Action (three-lane section with select auxiliary lanes in each direction) would have acceptable performance even when traffic increases into 2050.

3.2 Operational Options

Two operational options for the additional travel lane on the I-270 mainline were considered by FHWA and CDOT: a general purpose lane option and an express lane option.

The general purpose lane option would provide a third travel lane (one additional lane) in each direction along I-270. There would be no lane use restrictions under the general purpose option. The general purpose lane option would offer some near-term improvement for travel time reliability by addressing the causes of crashes, one of which is stop-and-go traffic conditions. However, these benefits would erode over time as traffic volumes increase.

The express lane option would provide one express lane in each direction that would be price-managed to continuously provide reliable travel times. The express lane option would feature a 4-foot painted buffer to separate the express lane from the two adjacent general purpose (non-tolled) lanes. Motorists would be able to travel in the express lane if they pay a toll or ride the bus or carpool with three or more people toll-free (with a switchable transponder). All emergency and transit vehicles would be allowed to use the express lane toll-free. To help with travel reliability, heavy trucks would be discouraged from using the express lane via hefty surcharges.

Direct connections between express lanes on I-70 and I-270, as evaluated in the Traffic Study (Atkins 2019), is not part of the I-270 EA Proposed Action; CDOT is advancing this improvement separately from the I-270 EA.

3.2.1 Comparison of Operating Options

This section compares the operating options based on their ability to meet the project needs and environmental impacts.

Project Needs

Both operating options add one lane of capacity in each direction, which in turn, improves safety and operations, updates obsolete and deficient infrastructure, and improves truck freight movement efficiency. The primary focuses for comparison were how well each operating option addressed the project need to improve travel time reliability and reduce travel delay.

Based on current conditions, reliability of travel times through the corridor during a.m. and p.m. peak travel periods were rated a combined fair or poor between 80 and 87 percent of the time

(*Traffic Technical Report,* EA Appendix A2). Over time, increased traffic volumes associated with projected regional population increases will further impact the predictability of travel times.

The traffic analysis completed for the EA (*Traffic Technical Report*, EA Appendix A2) found that general purpose lanes under both operating options would experience similar design year (2040) peak period travel delays with average speeds below 45 miles per hour (mph) on certain segments. However, the analysis reveals differences in travel time between the express and general purpose lanes. In 2040, average peak period travel times through the 6-mile corridor would vary between 8 and 12 minutes for travelers using the general purpose lanes (under either operating option), compared to a travel time range of 7 to 7.5 minutes for travelers in express lanes.[2] Therefore, express lanes offer travelers a faster travel option that can be managed to provide reliable and predictable travel times through the project corridor.

Express lanes provide I-270 users a travel option with little or no travel delay, even during weekday peak periods, compared to the general purpose option which experience a degree of noticeable delay (*Traffic Technical Report*, EA Appendix A2). Active management strategies of express lane operations provide CDOT flexibility to adapt highway operations for changing travel behaviors, such as increased use of rideshares or longer commutes between housing and employment centers.

The general purpose option also induces more traffic along I-270 than the express lane option as indicated by its higher VMT (*Traffic Technical Report,* EA Appendix A2). This suggests the general purpose lane option may alleviate congestion on roadways outside of the study network more so than the express lane option, but at the expense of slower speeds and more congestion along I-270. [3]

Environmental Impacts

The evaluation completed for the EA demonstrates that environmental impacts of the general purpose lane and express lane options are very similar, with minor differences identified for corridor aesthetics and environmental justice; all of which can be mitigated. This section summarizes these minor differences; Section 3.7 summarizes how environmental considerations influenced the design of the Proposed Action.

For environmental justice, CDOT is keenly aware of the equity impacts on low-income populations that result from tolling the I-270 express lanes. CDOT desires that the I-270 project increase transportation options for all commuters, including low-income commuters, to achieve relatively congestion-free travel. CDOT is proactively developing a program to measure the potential impacts of toll fees, which will ultimately lead to designing a program that is equitable to all the I-270 transportation users.

For corridor aesthetics, the tolling infrastructure for the express lane option would add new vertical features that could potentially block distant views, particularly of mountains for westbound travelers. This impact is minor because the sensitivity of that viewer group (auto travelers) is low and could be mitigated through sign placement that avoids blocking views.

[2] This analysis assumes express lanes are managed to maintain free-flow travel conditions with reliable travel times and little to no travel delay during peak periods.

[3] The observation that three general purpose lanes operate at similar travel speeds as two general purpose lanes with an express lane may seem counterintuitive when considering that express lanes would be underutilized lanes during off-peak periods. However, research shows that reserving a lane for carpools/tolled-vehicles on congested freeways induces a smoothing effect that is characterized by higher capacities in adjacent general purpose lanes through bottleneck areas. The effect occurs because disruptive vehicle lane changing diminishes in the presence of an express lane. The benefit is reproducible across days and freeway sites; it was observed, without exception, in all cases tested (Cassidy et al. 2008). This phenomenon suggests that the two general purpose lanes in the express lane option are, on average, able to service more vehicles than three general purpose lanes on a per-lane basis at bottleneck locations.

Conclusion

While both operational options have similar impacts and similar benefits for safety, infrastructure, and truck freight movement, the express lane operational option is preferred over the general purpose lane option because of the project need identified for reliable travel times through the I-270 corridor. Therefore, the express lane operational option is carried forward as part of the Proposed Action.

Adding express lanes on I-270 also provides an opportunity to connect the Colorado express lane system currently in place on I-25, US-36, and I-70, providing a regional network of managed lanes consistent with the *Colorado Express Lane Master Plan* (CHPTE 2020). Express lanes are effective for regional corridors like I-270 that serve a high percentage of through trips whose users can remain in the express lane to arrive at destinations within a more predictable time. For example, travel time predictability would be particularly beneficial for trips originating from the northwest Denver metropolitan area destined for Denver International Airport via I-270.

3.3 Other Mainline Improvements

In addition to adding travel lanes along I-270, other improvements were identified to modernize I-270 and address the identified project needs. The improvements include replacing deficient bridges and pavement; correcting subgrade settlement; adding longer acceleration, deceleration and merge lanes; and addressing the lack of breakdown lanes for commercial vehicles.

3.3.1 Deficient Bridges

Some of the bridges on I-270, constructed between 1968 and 1970, are considered obsolete by modern interstate standards, which contribute to safety and impaired travel conditions. Bridges in disrepair require continual maintenance, and it is more cost effective in the long run to replace them.

CDOT routinely monitors and rates its bridge structures for maintenance and replacement, applying both Bridge Sufficiency Ratings and the CDOT Structure Ratings (which determines structural deficiency). Under FHWA guidelines, highway bridges are prioritized for replacement or rehabilitation projects when they meet both the primary criteria of being rated as structurally deficient, combined with the secondary criteria of a sufficiency rating of 80 or less. Bridges are prioritized for replacement when they are rated as structurally deficient. A bridge is considered structurally deficient if the condition of different parts of the structure (deck, superstructure, substructure) score less than or equal to 4. A rating of 4 out of 10 is considered poor condition. Of the 11 bridges from York Street to East 56th Avenue, 7 of them are rated structurally deficient.

For the Proposed Action, all bridges except I-270 over Vasquez Boulevard are planned for replacement. Additionally, the Vasquez Boulevard bridge, constructed over Sand Creek in 1940, is also a bridge rated structurally deficient and planned for replacement

3.3.2 Retaining Walls

I-270 has generous amounts of CDOT right-of-way along most of the corridor. However, there are areas along the project where slopes would extend outside of the existing right-of-way. In some of those instances, the design has implemented the use of retaining walls to contain the slopes and minimize impacts to adjacent properties.

3.3.3 Pavement Settling over Old Landfill

Within the corridor exists flexible (asphaltic pavement) and rigid (Portland cement concrete pavement [PCCP]) pavement sections. The rigid pavement sections on I-270 have remaining serviceable life. However, the existing flexible pavement material on I-270 is distressed and deteriorating, thereby causing long-term maintenance issues (Rocksol 2012). Pavement distress refers to unfavorable pavement conditions showing signs of upcoming failure, including uneven road surfaces that can affect driver comfort and safety. Known pavement distress occurs along eastbound and

westbound I-270 between the South Platte River and Brighton Boulevard, where I-270 travels atop an old landfill. This segment of I-270 displays visible differential settlement (for example, heaving and settling). Numerous asphalt pavement overlays since I-270's original construction in 1968 have attempted to address these settlement issues. The original pavement section was constructed of 8 inches of PCCP per the as-built constructed plans. The maintenance overlays were intended to mitigate for the heaving and sinking roadway, which has only progressively worsened (Rocksol 2012).

To address these settlement issues and uneven road surfaces in this area, more advanced technologies in ground improvement and subgrade compaction and stabilization would be implemented as part of the Proposed Action. Other solutions would likely involve using high-tech geo-grids or light-weight fill materials that distribute and minimize loads across the roadbed subgrade.

3.3.4 Shoulders and Auxiliary Lanes

Between I-25 and I-70, the inside shoulders would be widened to between 10 and 12 feet and the outside shoulders would be widened to between 10 and 12 feet to accommodate vehicle breakdowns and facilitate more efficient emergency response through the corridor. Auxiliary lanes would be added between the York Street and Vasquez Boulevard interchanges in both directions, providing more distance for vehicles to accelerate, decelerate, and merge safely. The auxiliary lanes would also better facilitate truck climbing between Vasquez Boulevard and York Street. Another auxiliary lane is planned for westbound I-270 from Quebec Street to Vasquez Boulevard, which would serve the highest on-ramp volumes in the corridor. Further analysis of auxiliary lane locations between interchanges are detailed in Section 3.4.6.

3.4 Interchange Improvement Options

The study team reviewed previous studies provided in Section 2 of this report as a starting point in developing interchange improvements. As part of the EA, further design, traffic, and safety analyses were used to develop interchange design. Public and stakeholder concerns also were considered, as discussed in Section 3.6. Within the corridor, critical existing geometric deficiencies include the following:

- Lack of auxiliary lanes along I-270.
- Short weaving segments in both directions on I-270 caused by cloverleaf ramps at the Vasquez Boulevard interchange. American Association of State Highway and Transportation Officials recommends 1,500-foot minimum weaving distance (2018), but the weaving distance is currently 550 feet in both directions on I-270.
- Consecutive eastbound I-270 on-ramps (spaced 900 feet apart) coming from northbound and southbound I-76, both individually merging into the right lane on I-270.
- Limited uphill acceleration distance for heavy vehicles using the westbound I-270 on-ramp from southbound Vasquez Boulevard.

3.4.1 Corridor-Wide Interchange Improvements

To address the deficiencies noted above, the study team took a comprehensive, corridor-wide look at interchange improvements in close coordination with the traffic operations analysis. The I-270 Traffic Study (Atkins 2019) found that a 2040 alternative featuring a three-lane mainline and Vasquez Boulevard interchange improvements still had operational deficiencies along I-270, often located at interchange weaving sections and ramp junctions.

To optimize the traffic operations, the traffic modeling considered different geometric improvements for both the general purpose and express lane operating options, summarized in Table 3-1. These improvements, or configuration scenarios—identified from workshops involving design and traffic staff—considered several factors, including how the geometric improvements would enhance traffic

operations and safety in the corridor and at the ramp junctions. The improvement scenarios formed versions of traffic modeling runs to study operations. Other factors considered the project need to move freight more efficiently by providing auxiliary lanes to allow heavy trucks more distance for navigating grades to merge and diverge between interchanges.

Table 3-1. Summary of Geometry Improvements Analyzed Across Three Traffic Model Versions.

Corridor and Ramp Geometry Changes for both General Purpose and Express Lane	Version 1	Version 2	Version 3
Westbound Off-ramp to Quebec Street	X	X	
Westbound Auxiliary Lane from Quebec Street to Vasquez Boulevard	X		X
Westbound Auxiliary Lane from Vasquez Boulevard to York Street	X	X	X
Splitting of York Street and I-76 Westbound Off-ramps			X
Eastbound Collector Ramp for I-76 On-ramps	X	X	X
Eastbound Auxiliary Lane from York Street to Vasquez Boulevard	X	X	X
Eastbound Dual-exit-lane Off-ramp for Vasquez Boulevard			X
Eastbound Auxiliary Lane East of Vasquez Boulevard	X	X	X
Eastbound On-Ramp from Northbound Vasquez Boulevard	X	X	X
Reconfigure Interchange Ramps at Vasquez Boulevard for Partial Cloverleaf	X	X	X
Corridor Geometry Changes Specific to Express Lane	**Version 1**	**Version 2**	**Version 3**
Express Lanes in Each Direction Between I-25 and I-70	X	X	X
Start of Eastbound Express Lane Furthest from Southbound I-25 On-ramp			X

Source: Jacobs

The traffic analysis evaluated the MOEs for each version depicted in Table 3-1 to determine which version provided the best operational benefits. MOEs comprised average speed, average travel time, vehicle hours of delay, average vehicle delay (minutes), average vehicle density, VMT, VHT, truck miles traveled, and travel time reliability (*Traffic Technical Report*, EA Appendix A2).

When comparing the performance measures, version 3 provided the best operational and safety benefits. These improvements[4] were included in the Proposed Action.

Between I-25 and I-70, I-270 contains the following four partial interchanges (listed from west to east):

1. I-76
2. York Street
3. Vasquez Boulevard
4. Quebec Street

All existing I-270 interchanges are considered partial because all traffic flow movements do not have direct access between I-270 and the respective crossroad. With the exception of Vasquez Boulevard, close spacing between interchanges imposes operational and geometric concerns associated with providing full interchanges along I-270. As part of the alternatives development, the project team assessed the tradeoffs associated with providing full connectivity and movements at the partial

[4] Version 3 includes all of the geometric improvements tabulated in Table 3-1 except the westbound off-ramp to Quebec Street. This was excluded from version 3 because of the operational, safety, and environmental impacts associated with adding this ramp as documented in the partial interchange memo (Appendix A).

interchanges. Refer to Appendix A of this report (*Partial Interchange Technical Memorandum*) for details.

The study team reviewed each interchange to identify other improvements needed to meet the project purpose and need. Specific interchange improvements are summarized below; multimodal improvements near interchanges are addressed in Section 3.5.

3.4.2 I-25 Interchange Improvements

Traffic modeling showed that no improvements are needed at this interchange except increasing the exit lane capacity for the northbound I-25 ramp. To improve operations, the westbound I-270 ramp to northbound I-25 would be restriped to provide dual-exit-lane capacity for traffic destined for northbound I-25. An extra auxiliary lane would be striped along westbound I-270 approaching this exit.

3.4.3 I-76 Interchange Improvements

A new eastbound collector ramp (Figure 3-1) is proposed that would consolidate incoming movements from the I-76 entrance ramps. The collector ramp would be barrier-separated from the I-270 mainline to reduce traffic operational issues and accidents from merging traffic identified on eastbound I-270 near the dual I-76 entrance ramps(*I-270 Existing Safety Conditions Report*, EA Appendix A1).

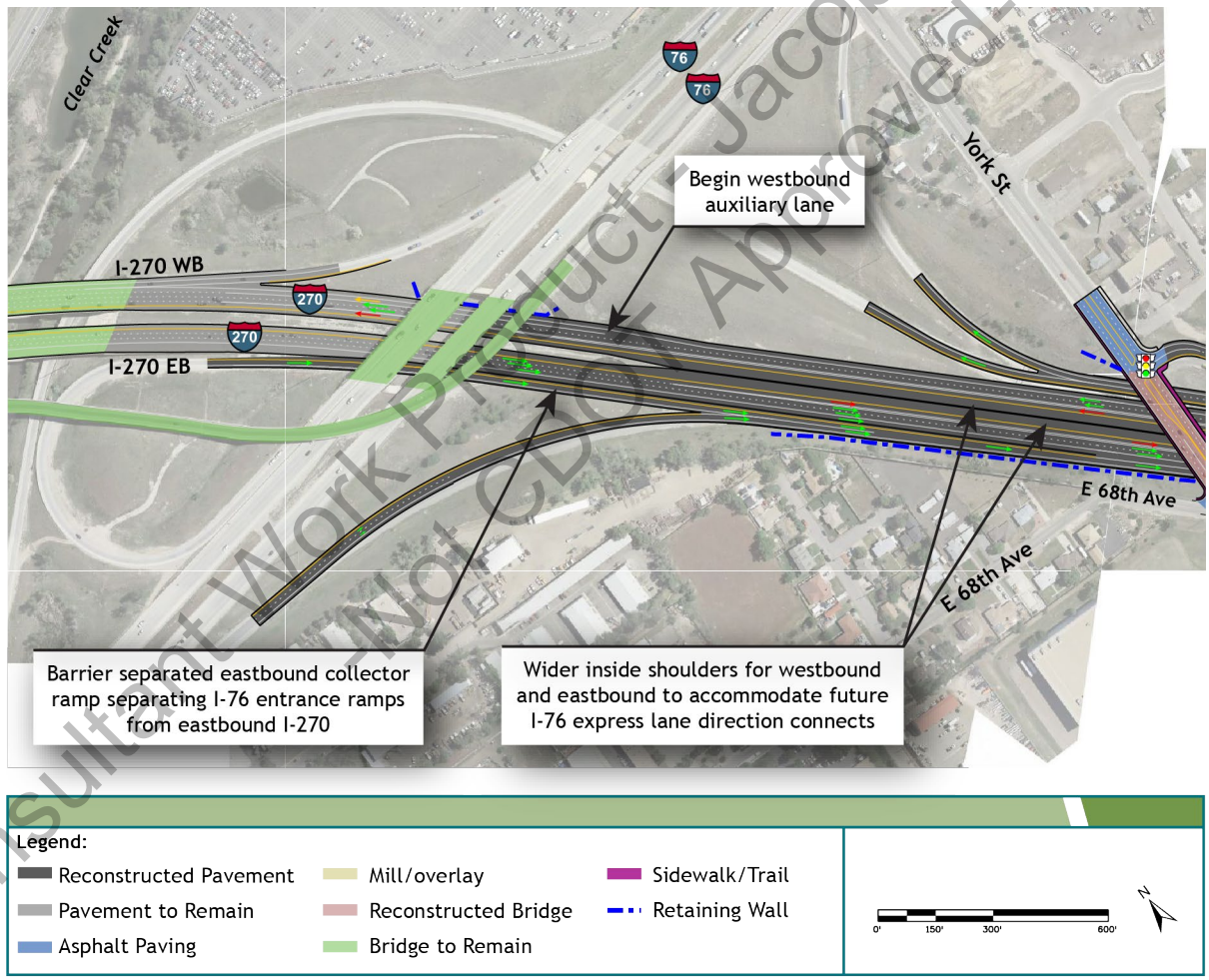

Figure 3-1. Eastbound Collector Ramp for I-76 Entrance Ramps
Source: Jacobs

The collector ramp system would feed directly into an auxiliary lane that continues eastbound to Vasquez Boulevard. As noted in Appendix A, the I-76 and I-270 interchange would not add the two missing ramps because of operational and safety challenges.

3.4.4 York Street Interchange Improvements

Adams County is improving York Street in the study area as part of a separate project. Therefore, proposed improvements were identified to tie into and supplement this project. The I-270 Proposed Action includes the following:

- Widening York Street to two through lanes in the northbound and southbound directions with a center-turn lane to match the planned improvements by Adams County.
- Modifying ramps for the westbound York Street service exit ramp, which would be split and separated from the I-76 system exit ramps by more than 1,500 feet. Separating the ramps would meet driver expectations and lessen driver confusion thereby improving ramp operations and capacity. To regulate traffic flow on I-270, the eastbound entrance ramp from Quebec Street would also have a ramp meter operating in the a.m. and p.m. peak periods.
- Lengthening the York Street bridge to accommodate widening for the eastbound and westbound inside shoulders on I-270 to not preclude future direct connections with I-76.
- Adding and widening sidewalks for improved multimodal access. Along the west side of York Street, a 5-foot-wide sidewalk would be provided, and along the east side a 10-foot-wide multi-use path would be constructed. These sidewalks and paths match the proposed improvements that Adams County is advancing on York Street north and south of the interchange.

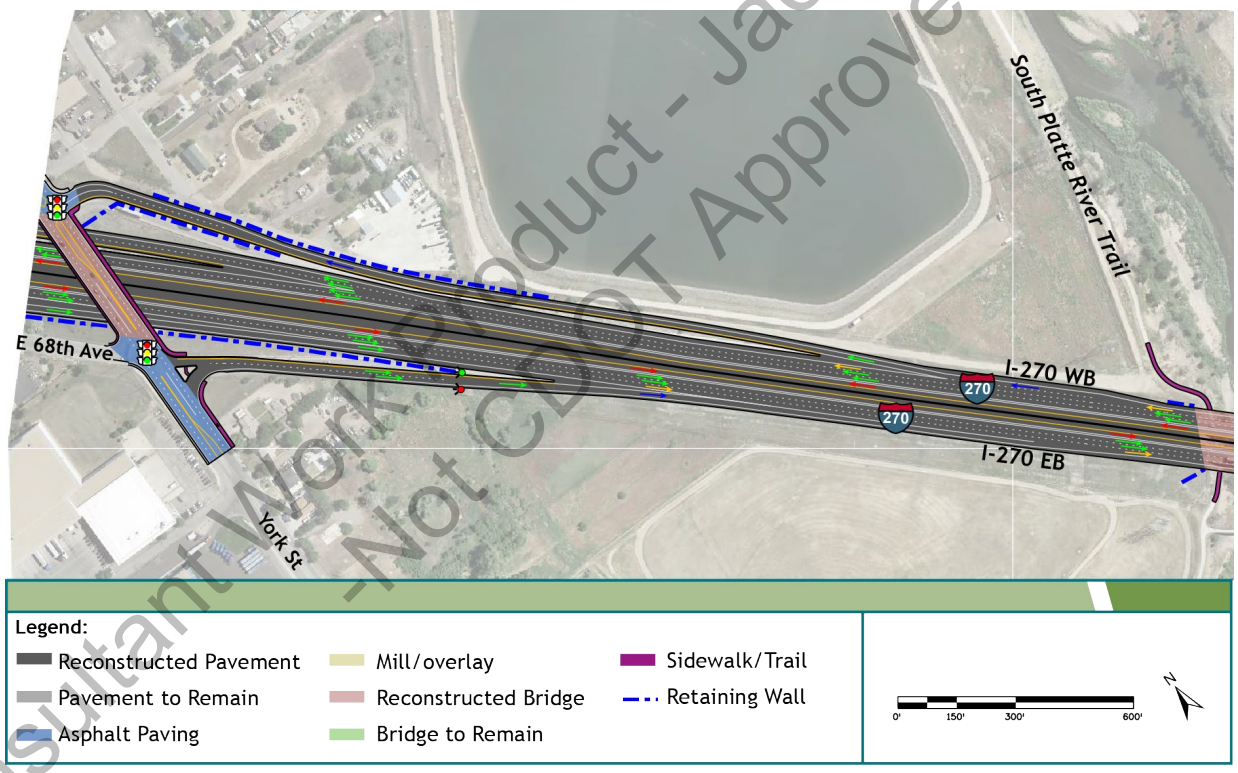

Figure 3-2. I-270/York Street Interchange
Source: Jacobs

As noted in Appendix A, the York Street and I-270 interchange would not add the two missing ramps for this partial interchange because of operational and safety challenges. However, additional signage and pavement striping would be included in the Proposed Action to aid drivers in navigating to and from the interstates.

3.4.5 Vasquez Boulevard Interchange Improvements

The only isolated interchange along I-270 is the Vasquez Boulevard interchange because there are no I-270 ramps located within a mile of the interchange. CDOT, in coordination with FHWA, determined this to be the only interchange that was recommended to be converted into a full interchange.

Existing cloverleaf ramps at this interchange are posted with 25-mph advisory speeds directly onto or off of the 55-mph posted speed on the I-270 mainline. CDOT safety studies show that vehicles and especially trucks, often run off the road when speeding through horizontal curves with small radiuses in combination with short deceleration lengths (CDOT 1999). In general, because of the wide speed deferential between ramp and highway running speeds, exit loop ramps have more safety issues if traffic is not properly slowed down. Cloverleafs have the largest speed changes in the shortest distance, in additional to imposing dangerous weaving maneuvers. For this reason, all the Vasquez Boulevard interchange re-design alternatives proposed in the PEL study for Vasquez Boulevard (CDOT 2018a) remove the existing cloverleaf exit ramps from I-270.

As described in Section 2.1, the PEL study (CDOT 2018a) included detailed traffic analysis for the following full interchange alternatives, all of which were considered for the Proposed Action:

- At-grade alternatives
  - Partial cloverleaf
  - Diverging diamond
- Grade-separated alternatives
  - One-way pairs
  - Viaduct

When CDOT considered the interchange options, a key requirement was to use the exiting I-270 bridge over Vasquez Boulevard (bridge no. E-17-WZ). Some of the I-270 bridges are in poor condition, but this bridge was constructed in the year 2000 and should be useful still in the year 2050. This bridge also has the necessary width to carry an additional lane in each direction of I-270. The one-way pairs alternative, described in Section 2.1.1, could use E-17-WZ, but it would split the interchange and underutilize bridge E-17-WZ while also requiring four new bridge structures in addition to the current bridges. The viaduct alternative would require replacing bridge E-17-WZ.

Both at-grade alternatives would use bridge E-17-WZ and both alternatives would implement new signals on Vasquez Boulevard. Between the two at-grade alternatives, the partial cloverleaf would operate at a higher level of service and introduce less vehicle delay when compared to the diverging diamond (CDOT 2018a).

Additionally, a citizen-submitted alternative interchange design was considered by the project team (Figure 3-3). This alternative proposes grade separation for one direction (southbound or northbound) of Vasquez Boulevard, which would reduce interchange delay compared to the partial cloverleaf interchange. One advantage of the citizen-submitted alternative, compared to the grade-separation alternatives assessed in the PEL study, is that a smaller funding commitment would be needed. This alternative would avoid adding new signals to Vasquez Boulevard but would have larger impacts than the partial clover leaf design. The grade separation would be constrained between the Vasquez Boulevard intersections neighboring the I-270 interchange: East 60th Avenue and East 56th Avenue. However, with the intent to reuse bridge no E-17-WZ (newer I-270 bridge discussed previously), analysis of the vertical profile determined that there is insufficient spacing along Vasquez Boulevard between East 56th Avenue and I-270 to carry one direction of Vasquez Boulevard over the I-270 mainline. This issue precludes the construction of an elevated structure above the I-270 mainline. The citizen-submitted alternative, while innovative, was determined to not be practicable for construction reasons.

Figure 3-3. I-270/Vasquez Boulevard Citizen Submitted Alternative
Source: Jacobs

CDOT and FHWA determined the partial cloverleaf interchange concept to be most favorable primarily because of the following findings:

- Grade-separated solutions exceeded project funding identified for the North Vasquez Improvements project, which ties-in to the I-270 project limits.
- Of the at-grade solutions, the partial cloverleaf alternative would operate with minor peak delays for the design year, while the diverging diamond alternative would impose severe delays on Southbound Vasquez Boulevard traffic during the weekday p.m. peak (CDOT 2018a).
- The partial cloverleaf design would use the existing I-270 bridge over Vasquez Boulevard.

The partial cloverleaf interchange was selected to move forward in the Proposed Action (Figure 3-4).

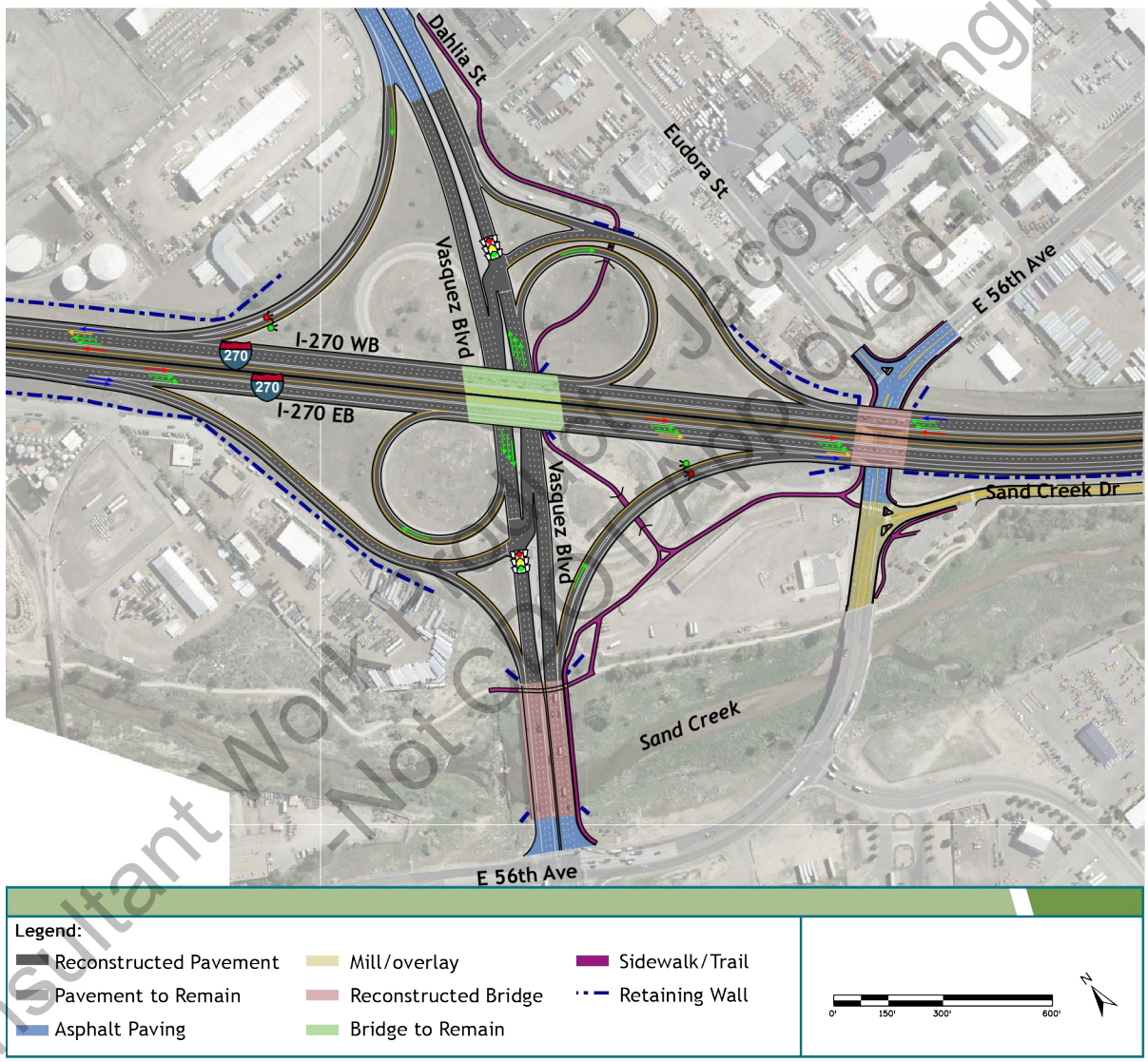

Figure 3-4. I-270/Vasquez Boulevard Interchange
Source: Jacobs

A ramp from northbound Vasquez Boulevard to eastbound I-270 would be constructed as part of the Proposed Action and as detailed in the partial interchange memo (Appendix A). To regulate flow on I-270, ramp metering for the a.m. and p.m. peak periods is planned for this new entrance ramp as well as the reciprocal entrance ramp in the northwest quadrant with access to westbound I-270. Project analysis and discussions with the trucking industry determined that idling trucks on these metered

ramps are a hinderance to peak period operations and improving air quality. So, ramp widening would be provided along these two ramps to prioritize a designated class of heavy trucks and transit vehicles during peak periods. This would provide a queue jump bypass that would allow heavy vehicles to avoid idling on the ramp while waiting for a green light, thereby reducing emissions and moving freight and people using transit more efficiently.

During the course of the project, information was gathered about sidewalk connectivity through the interchange. It was apparent that the corridor has a well-developed system of regional trails and public transit facilities along Vasquez Boulevard. However, the existing cloverleaf and lack of sidewalk connections present challenges for reaching those trails and transit options for citizens who choose not to own or operate a motor vehicle. Navigating the interchange on foot or bicycle has its own barriers. During the public and stakeholder outreach, numerous comments were made about the inability to get through the interchange along Vasquez Boulevard. The obstacles include a narrow 5-foot bridge sidewalk over Sand Creek, missing sidewalks along Vasquez Boulevard, Dahlia Street, and East 56th Avenue, three at-grade interchange ramps to cross, missing connections to trails and sidewalks in disrepair or not compliant with the Americans with Disabilities Act (ADA) (Figure 3-5).

Figure 3-5. Vasquez Boulevard Interchange with ADA obstacles
Source: Jacobs

The Vasquez Boulevard interchange reconstruction will include sidewalk widening, on street bike lanes, reconstruction of the aging Vasquez Boulevard bridge over Sand Creek, grade separated pedestrian tunnels (Figure 3-6), and a new sidewalk network connecting the Sand Creek Greenway Trail to the sidewalk along northbound Vasquez Boulevard (Figure 3-3). It will also include a missing sidewalk connection along East 56th Avenue and additional access points to the Sand Creek Greenway Dahlia trailhead. All new sidewalk and trail construction will adhere to ADA requirements. These improvements will increase safety for pedestrians and cyclists as well as break down existing barriers to opportunity. The mobility improvements will also align with the goals of the statewide Bicycle and Pedestrian Plan (CDOT 2012), which aims to improve environment, air quality, and fossil fuel independence, as well as provide transportation equity.

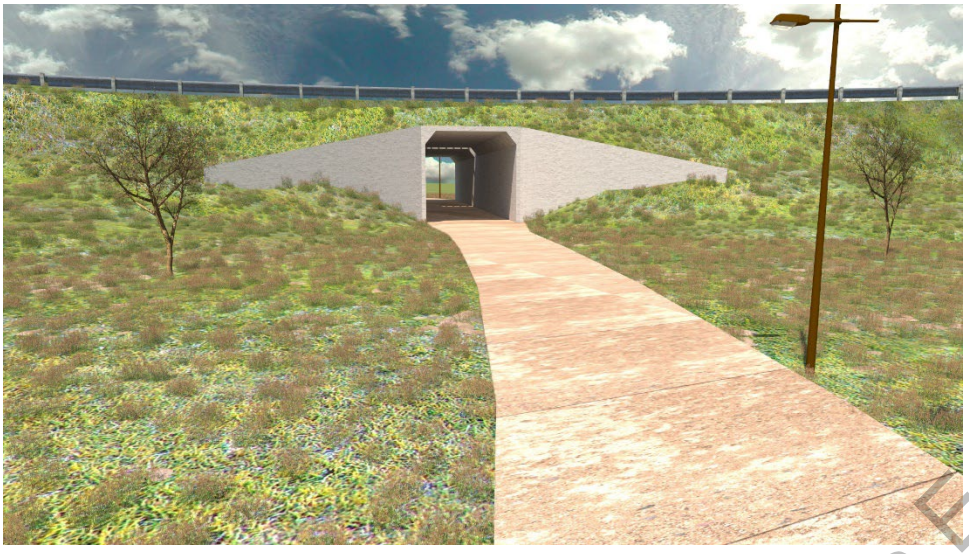

Figure 3-6. Pedestrian Tunnel rendering improving pedestrian and bicycle mobility
Source: Jacobs

3.4.6 Quebec Street Interchange Improvements

The Proposed Action at this interchange involves ramp changes for the eastbound direction (Figure 3-7).

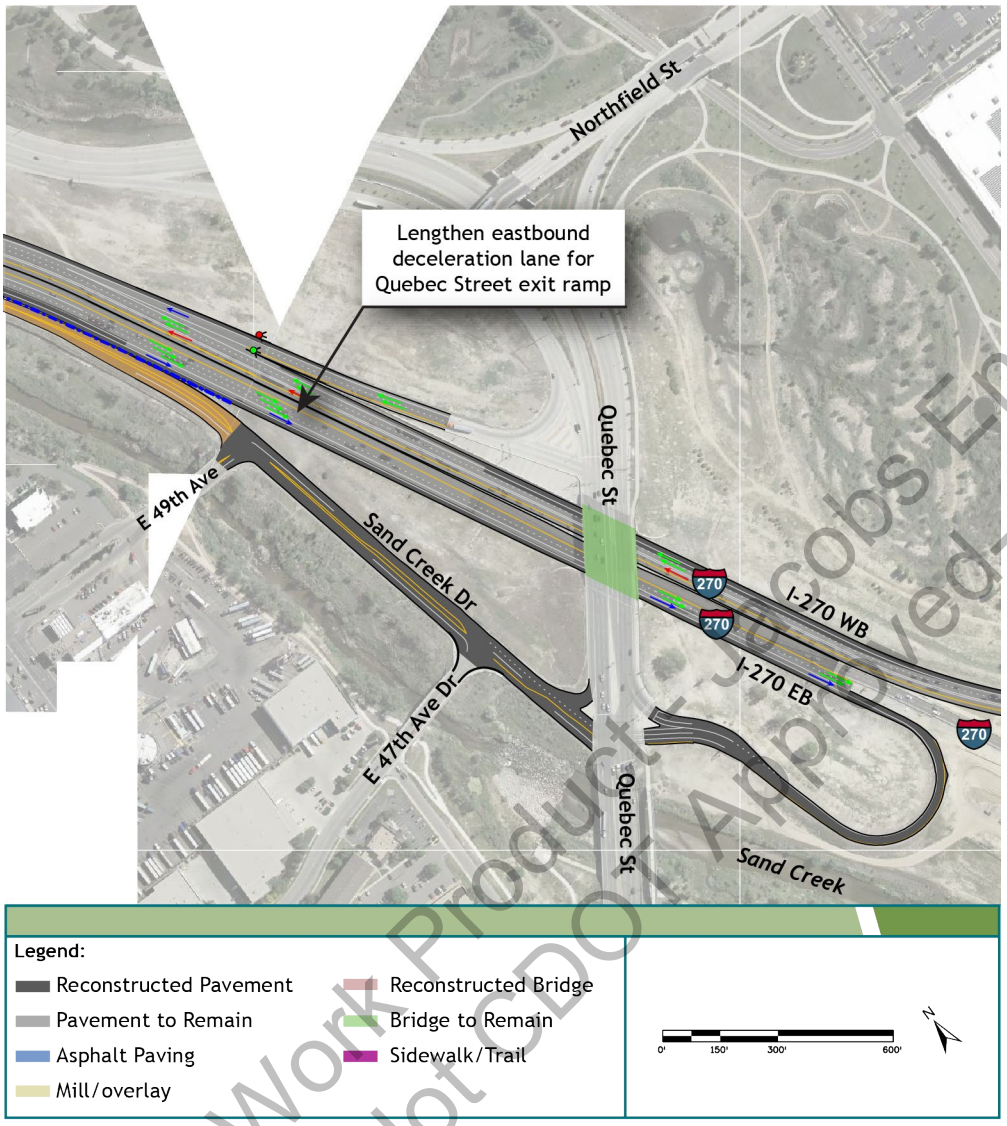

Figure 3-7. I-270/Quebec Street Interchange

Source: Jacobs

Because of the close proximity of Sand Creek Drive and Sand Creek, the existing eastbound I-270 exit ramp is designed as a far-side loop ramp terminating on the southern side of the Quebec Street crossroad instead of a typical exit ramp terminating on the northern side. Instead of exiting before the Quebec Street bridge, eastbound traffic currently passes below the interchange bridge and makes a U-turn or fishhook back to the Quebec Street intersection. The existing far-side loop exit ramp would remain with minimal impact to the ramp; however, the eastbound deceleration lane for the far-side loop exit ramp would be lengthened an additional 2,500 feet from the existing exit ramp. The lengthening of the deceleration lane would aid in the operation and safety of eastbound I-270 in this area. Lengthening the deceleration gives drivers an earlier point to break out of the mainline travel and make their deceleration time longer and safer than existing conditions. To regulate traffic flow on I-270, the westbound entrance ramp from Quebec Street would also have a ramp meter operating in the a.m. and p.m. peak periods.

As noted in Appendix A, the proposed Quebec Street and I-270 interchange would not include the two missing ramps because of operational, safety, and environmental challenges. However, additional signage and pavement markings would be included in the Proposed Action to help drivers navigate to and from the neighboring interstates.

No arterial improvements are planned for Quebec Street.

3.5 Bicycle and Pedestrian Improvements

Bicycle and pedestrian improvements were identified based on a review of existing conditions, multimodal plans, and public and stakeholder comments. Ideas for improvements were garnered from workshops involving Adams County, City of Commerce City, Greenways Foundation, Sand Creek Regional Greenway, Cultivando, and Bicycle Colorado. These Proposed Action improvements, some of which are noted in Section 3.4.3, are detailed in the *Operating Multimodal Technical Report* (Appendix A8 to the EA). All new sidewalk and trail construction would adhere to Americans with Disabilities Act requirements. These improvements would increase safety for pedestrians and cyclists as well as increase route connectivity that breaks down existing physical barriers to opportunity for those who do not own, or opt not to use, a vehicle. The mobility improvements will also align with the goals of Colorado's *Statewide Bicycle and Pedestrian Plan* (CDOT 2012), which aims to improve environment, air quality, and fossil fuel independence, as well as provide transportation equity.

During the course of the EA, numerous comments were made about the lack of pedestrian connectivity through the Vasquez Boulevard interchange and to the Sand Creek Greenway Trail. Therefore, the interchange reconstruction would include sidewalk widening, reconstruction of the aging Vasquez Boulevard bridge over Sand Creek (including a wider sidewalk along the bridge), grade-separated pedestrian tunnels, and a new sidewalk network connecting the Sand Creek Greenway Trail to the sidewalk along northbound Vasquez Boulevard. The Proposed Action would also include adding a missing sidewalk connection and on-street bike lanes along East 56th Avenue and additional access points to the Sand Creek Greenway Dahlia trailhead.

3.6 Stakeholder and Public Influence in Proposed Action Development

Input received from stakeholders and the public throughout the study supported the major elements included in the Proposed Action. Section 13.3 and the *Public and Agency Outreach Report* (Appendix A18 of the EA) summarizes the ways in which the Proposed Action addresses the top priorities voiced by the public.

Several design elements also reflect specific stakeholder and public input received. They include design elements of the Vasquez Boulevard interchange, bicycle and pedestrian facilities, I-76/York Street exits, I-76/I-270 traffic merging, and water quality. Table 3-2 summarizes specific input received and the design elements included in the Proposed Action that addresses those issues.

Table 3-2. How Proposed Action Design Addresses Stakeholder and Public Input

Stakeholder and Public Input	Proposed Action Design
Vasquez Interchange Improvements	
Trucks exiting eastbound I-270 at Vasquez Boulevard experience difficulty in maneuvering into the left-turn lane on southbound Vasquez to proceed east on East 56th Avenue, south of I-270.	The design of the Vasquez interchange improvements was modified to also provide a perpendicular connection to Vasquez Boulevard from the eastbound off-ramp via a new traffic-signal-controlled intersection, thus allowing a right turn directly into Vasquez Boulevard southbound lanes and providing more distance for trucks to maneuver to the left-turn lane on southbound Vasquez at 56th Avenue.
56th Avenue is a bottleneck under the I-270 bridge where 56th Avenue narrows to two lanes.	The geometry of 56th Avenue in that area would be widened and improved.

Table 3-2. How Proposed Action Design Addresses Stakeholder and Public Input

Stakeholder and Public Input	Proposed Action Design
The Vasquez interchange area has low visual quality.	Landscaping would be included to improve the visual quality of this area.
Bicycle and Pedestrian Facilities	
Pedestrian connections need to be improved, including through the I-270 and Vasquez Boulevard interchange and area trails.	• Bicycle and pedestrian facilities would be improved in the vicinity of the interchange to improve connectivity north and south of I-270 and to eliminate pedestrian/traffic conflicts. This includes widening sidewalks along Vasquez Boulevard from 4 feet to 10 feet, providing grade-separated bicycle and pedestrian crossings under I-270 and the on/off-ramps, and improving access from the south side of I-270 to the Walmart and other destinations north of the highway. • In addition, two new connections would be provided to the Sand Creek Trail. • The existing sidewalk from the East 56th Avenue bridge to the Sand Creek Greenway Dahlia trailhead would be extended to improve access to and from the Sand Creek Trail. • A 10-foot-wide sidewalk is also planned along the west side of East 56th Avenue as it crosses under I-270 to tie into the existing sidewalk along the west side of Eudora Street, providing an additional north-south connection. • The study team also coordinated with Commerce City on the City's plans to complete the missing sidewalk connection along the south side of East 56th Avenue (under a separate city project), which could be used as a temporary bicycle/pedestrian detour to maintain connectivity during construction of the Proposed Action.
Concern was voiced about temporary impacts to trails during construction of the project.	For trails that would be impacted during construction, a trail detour would be provided that is convenient and as direct as practicable to maintain trail connectivity during construction. Signage would be used to direct users to the trail detour.
Increased Distance Between I-76/York Street Exits	
The existing combined I-76 and York Street exits for westbound I-270 are inadequately signed to provide sufficient notice of the exits, resulting in driver confusion.	The westbound I-76 and York Street exits would be separated by approximately 1,500 feet to provide clear exit points for the system (I-76) and service (York Street) interchanges. Updated signage would accompany the planned design.
New Collector Ramp for I-76 traffic Merging to Eastbound I-270	
The safety analysis conducted under this study indicated that the area where northbound and southbound I-76 traffic merges into eastbound I-270 experiences high crash rates; this issue was confirmed by stakeholder and public input.	A new collector ramp would be provided for I-76 traffic to merge within a barrier-separated auxiliary lane before merging into mainline eastbound I-270.
Water Quality	
To manage stormwater runoff, construction of a pipe outfall approximately 2,000 feet west of Brighton Boulevard was proposed that would run directly south into Sand Creek from the south side of I-270. However, the Colorado Department of Public Health and Environment indicated that the area proposed for the pipe outfall is a covered landfill area with prohibitive covenants.	The pipe outfall was moved farther west to curve around and avoid the landfill

3.7 Environmental Considerations in Proposed Action Development

Environmental considerations influenced the development and design of the Proposed Action. Examples include the following:

- Designing water quality and drainage features to avoid former landfill areas
- Designing bridge structures to minimize wetland impacts
- Designing bridge structures and trails to avoid permanent impacts to historic resources

4.0 Conclusion

The *Project Setting and Description of Alternatives* (Appendix B2 of the EA) provides a detailed description of the Proposed Action considering all geometry updates and improvements outlined in Section 3. The Proposed Action includes mainline, interchange, bridge, wall, drainage, multimodal, and intelligent transportation system improvements that modernize the I-270 corridor and directly address the corridor's needs. These improvements would improve safety, travel time reliability, and freight movements while updating the aging infrastructure nearing the end of its service life.

5.0 References

Adams County. 2012. *Adams County Transportation Plan*. https://www.adcogov.org/sites/default/files/2776.pdf

American Association of State Highway and Transportation Officials (AASHTO). 2018. *A Policy on Geometric Design of Highways and Streets*. 7th Edition.

Atkins. 2019. *I-270 Traffic Study*. Final. November.

Cassidy, Michael J., Kitae Jang, and Carlos F. Daganzo. 2008. *The Smoothing Effect of Carpool Lanes on Freeway Bottlenecks.* University of California at Berkley. UCB-ITS-VWP-2008-9.

Colorado Department of Transportation (CDOT). 1999. *Effects of Geometric Characteristics of Interchanges on Truck Safety*. January. https://www.codot.gov/programs/research/pdfs/1999/trucksafety.pdf

Colorado Department of Transportation (CDOT). 2012. *Statewide Bicycle and Pedestrian Plan*. October. Amended 2015. https://www.codot.gov/programs/bikeped/building-a-bike-ped-friendly-community/Bike_Ped_Plan/BikePedStatePlan

Colorado Department of Transportation (CDOT). 2016. *I-70 East Final Environmental Impact Statement (FEIS) and Section 4(f) Evaluation*. January.

Colorado Department of Transportation (CDOT). 2017. *I-70 East Record of Decision (ROD) 1: Phase 1 (Central 70 Project)*. January.

Colorado Department of Transportation (CDOT). 2018a. *Vasquez Boulevard Planning and Environmental Linkages (PEL) Study*. August.

Colorado Department of Transportation (CDOT). 2018b. *Structure Inventory and Appraisals*.

Colorado Department of Transportation (CDOT). 2020. "US 36 Express Lanes." Accessed December 2020.https://www.codot.gov/projects/archived-project-sites/US36ExpressLanes/project-overview.

Colorado High Performance Transportation Enterprise (CHPTE). 2020. *Colorado Express Lane Master Plan*. February.

Denver Regional Council of Governments (DRCOG). 2015. *2040 Fiscally Constrained Regional Transportation Plan*. Adopted February 15. https://www.codot.gov/programs/planning/transportation-plans-and-studies/assets/denver-regional-transportation-plan.

Denver Regional Council of Governments (DRCOG). 2021. *2050 Metro Vision Regional Transportation Plan*. Adopted April 21. Regional Transportation Plan | DRCOG.

Rocksol. 2012. *Geotechnical Investigation I-270 Pavement Distress Evaluation Between Brighton Boulevard and South Platte River Commerce City, Colorado*. May 25.

Appendix A
Partial Interchange Technical Memorandum

I-270 Partial Interchanges at I-76, York Street, Vasquez Boulevard, and Quebec Street

PREPARED FOR:	CDOT Region 1
COPY TO:	**FHWA CO Division**
PREPARED BY:	EA Team
DATE:	April 1, 2021

1.0 Introduction

The history of Interstate 270 (I-270) construction spans several decades. I-270 was constructed in multiple stages beginning in 1965 with the eastern end of the corridor and then working west towards Interstate 76 (I-76). Construction between I-76 and Interstate 25 (I-25) began in 1978 but was not finished until 1993. On the western end, U.S. Highway 36 (US-36) transitions into I-270 as it crosses over I-25 while on the eastern end, I-270 originates and terminates with Interstate 70 (I-70) via system ramps (Figure 1).

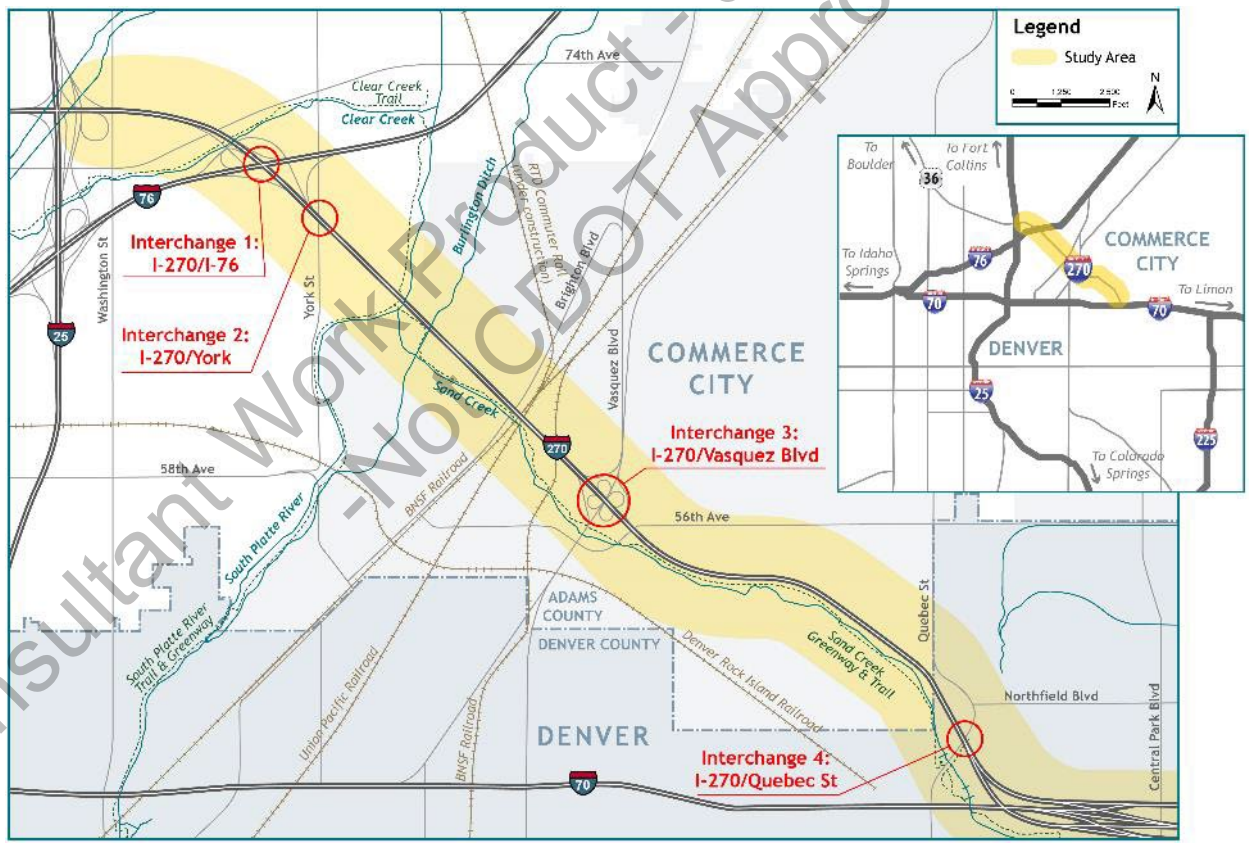

Figure 1. Project Location Showing I-270 Limits and Partial Interchanges 1, 2, 3 and 4 along I-270
Source: Jacobs

This technical report documents (1) the four existing partial interchanges along I-270—at I-76, York Street, Vasquez Boulevard, and Quebec Street, (2) the missing movements at the interchanges and

(3) the evaluation performed under the I-270 Corridor Improvement Project. Three of these interchanges are in close proximity to system-to-system interchanges while I-270/Vasquez Boulevard is not.

It is a policy of AASHTO that "each interchange shall provide for all traffic movements" (2016), however when an interchange is less than a full interchange each interchange needs to be studied on a case-by-case basis per Federal Highway Administration (FHWA) policy. This report evaluates the additional movements for these four interchanges from traffic operations, safety, and environmental aspects of adding the missing ramps to the partial interchanges.

2.0 Project Setting

I-270 is a 6.5-mile-long controlled-access interstate highway with two through lanes in each direction, providing a diagonal connection between I-25 and I-70, serving the northern and eastern Denver metropolitan region and traveling through a primarily industrial setting (Figure 1). I-270 is a key link to Denver International Airport; large energy, manufacturing, and freight distribution centers; and adjacent industrial areas. Between I-25 and I-70, partial interchanges occur on I-270 at I-76, York Street, Vasquez Boulevard, and Quebec Street. The posted speed limit on I-270 is 55 miles per hour (mph). The highway crosses over both the Union Pacific Railroad and BNSF Railway, as well as the South Platte River, Clear Creek, and Burlington Ditch. The corridor alignment parallels Sand Creek to the east of the South Platte River.

Even-numbered two-digit interstates are designated westbound and eastbound travel; however, for this document, the I-76 direction of travel is referred to as northbound (for existing eastbound travel) and southbound (for existing westbound travel) to avoid confusion with the I-270 direction of travel (westbound and eastbound).

3.0 Proposed Action

The Proposed Action for the I-270 Corridor Improvements project proposes construction of three lanes (one additional lane proposed) in each direction along the I-270 corridor from the corridor's western terminus at the I-25/US-36/I-270 interchange to the eastern terminus at I-70 (approximately 6.5 miles). Auxiliary lanes are proposed between some of the interchanges.

In the westbound direction, new auxiliary lanes are proposed from the Quebec Street entrance ramp to the Vasquez Boulevard exit ramp, and then from the Vasquez Boulevard entrance ramp to the I-76 system exit ramp. In the eastbound direction, the new auxiliary lane would begin at the I-76 collector ramp entrance and terminate at the Vasquez Boulevard exit ramp.

Other improvements would include ramp improvements at I-270 and Vasquez Boulevard and slight geometry shifts planned at the I-76 and York Street on-ramps and off-ramps as well as at the Quebec Street entrance ramp to accommodate the widened I-270 mainline.

4.0 Level of Service of Safety

The American Association of State Highway and Transportation Officials (AASHTO) *Highway Safety Manual* (2014) offers several performance measures to quantify the safety performance of a roadway facility, including level of service of safety (LOSS). The LOSS method (Federal Highway Administration 2011) compares a roadway segment's observed crash frequency and severity to the crash frequencies and severities predicted by safety performance functions. The safety performance functions consider parameters such as the traffic volume, functional classification of the road, number of lanes, and terrain. The higher the deviation of the field data from the predicted data, the higher the opportunity for the improvement. Figure 2 shows the gradation of LOSS and the potential for crash reduction.

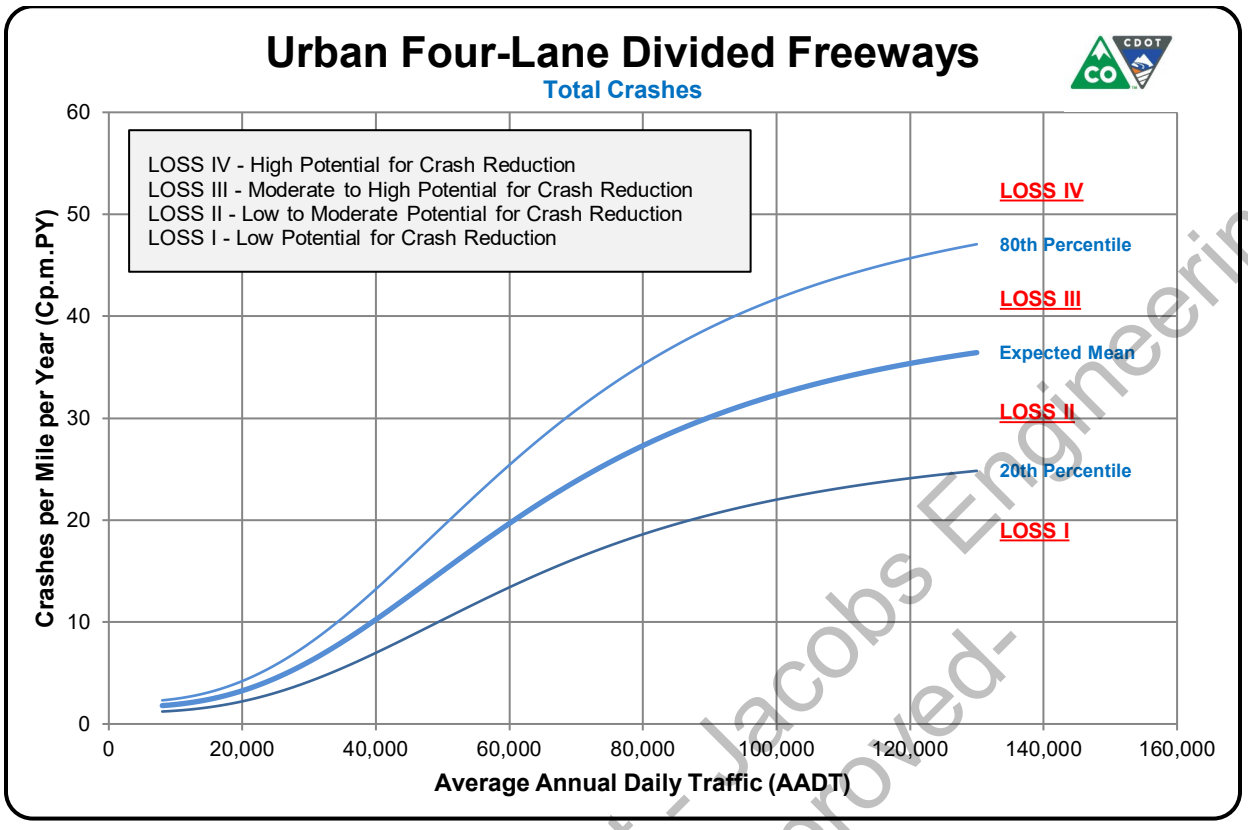

Figure 2. The Urban Four-lane Divided Freeway Safety Performance Functions and Level of Service of Safety Mean and Boundary Curves
Source: CDOT 2016

5.0 Interchange 1: I-270/I-76

This interchange is part of a group of system interchanges informally referred to as the Turnpike Triangle. This area is further defined as a conglomerate of partial interchanges that are connected by I-270, I-25, and I-76 to form a triangle, depicted on Figure 3. This group of three system interchanges is unique to both the Denver area and the United States. It is an aggregation in what could be considered a "mega interchange." The two interchanges, I-25/I-270 and I-25/I-76, conflict with the interchange spacing of 1 mile. The substandard spacing between interchanges "create[s] shorter distances in which to inform [the] driver of the course to follow when exiting [the] freeway" (AASHTO 2018). The proximity of the mega interchange with its web of overlapping ramps makes the system of interchanges confusing for the driver. AASHTO cautions against looking at each interchange as independent entities and encourages considering the entire system as a single entity to ease the way-finding for its users (AASHTO 2018).

The I-76 system interchange with I-270 is considered a partial interchange because it is missing the ramps between northbound I-76 to westbound I-270/US-36 and eastbound US-36/I-270 to southbound I-76 (dashed red lines on Figure 3).

The missing northbound I-76 exit ramp to I-270 would provide a direct connection for northbound I-76 travelers intending to go west while eastbound traffic on I-270 could potentially benefit from an exit ramp to southbound I-76. Both of these ramps would complete the I-76/I-270 interchange. The following sub-sections evaluate the safety, traffic operations, and environmental impact of providing the missing ramps to make it a full interchange.

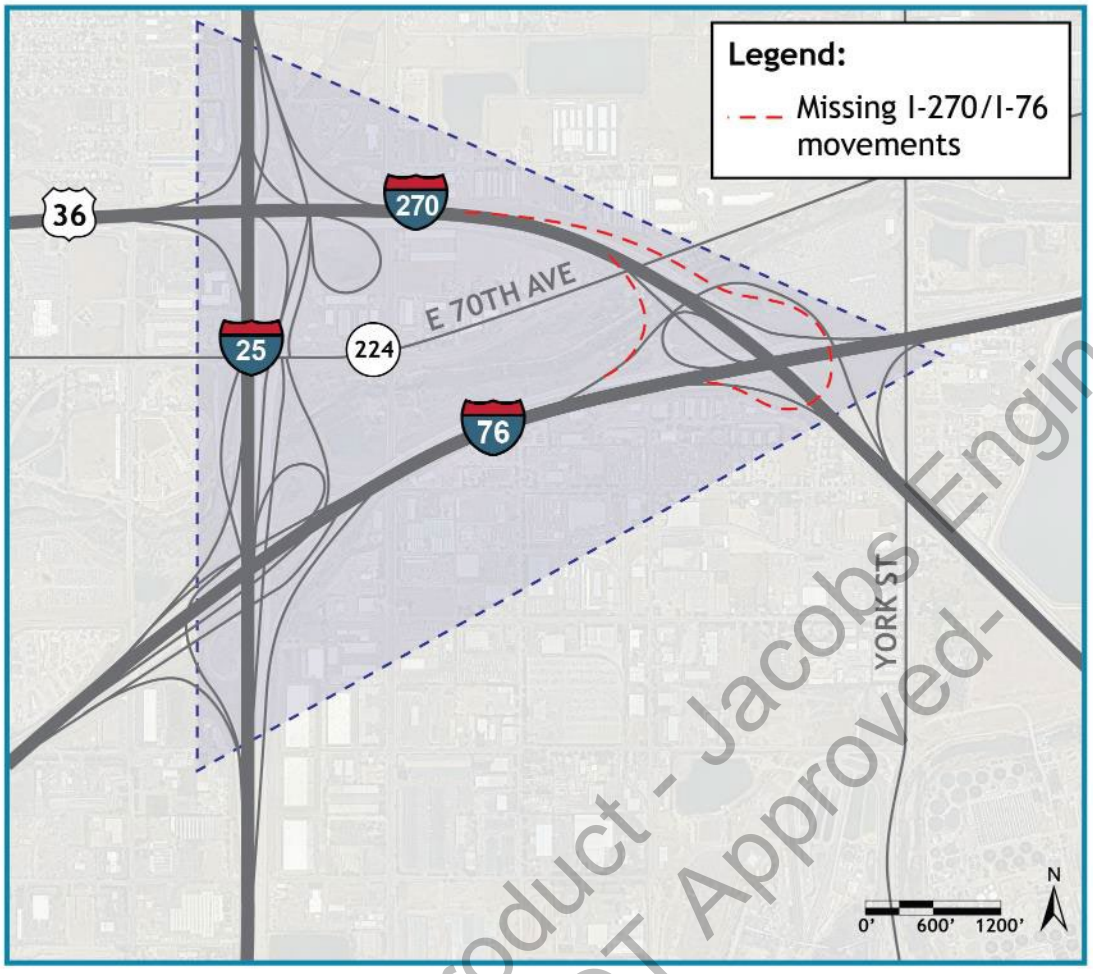

Figure 3. Turnpike Triangle of System-to-System Interchanges with Missing I-270/I-76 Movements
Source: Jacobs

5.1 Missing Ramp from Eastbound I-270 to Southbound I-76

Figure 4 shows a missing ramp that connects eastbound I-270 to southbound I-76. The ramp initially appears to be making a U-turn-type movement with vehicles backtracking in the direction they originally came to go south. The U-turn-like visual presentation of the ramp is unusual and can be attributed to the acute angle at which freeway I-76 and I-270 cross each other. The sharper angles make the ramp geometry more complicated, as the horizontal curve's radius and the length of the ramp has to be decreased because the physical separation of the freeways is less than 90 degrees. The system-to-system ramp running speed must be reduced to correspond with the smaller radius and shorter ramp length, which warrants longer deceleration and acceleration lengths on both I-270 and I-76. The distance from the I-270/I-25 interchange to the I-270/I-76 interchanges is approximately 5,150 feet and the distance from I-270/I-76 interchange to the I-76/I-25 interchange is 5,500 feet, however, when you factor in the system ramps the distances between them are even less than that.

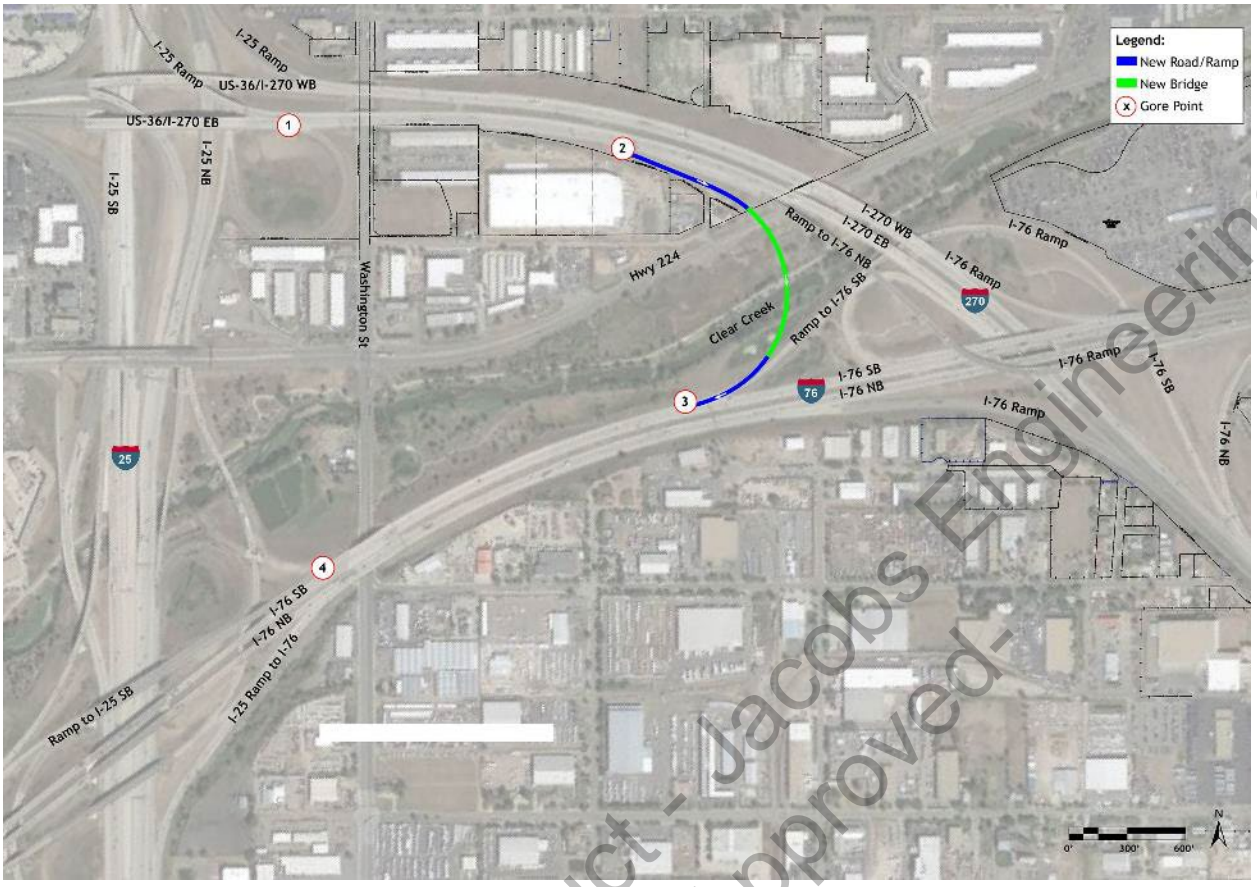

Figure 4. I-270 to I-76 Missing Movement
Source: Jacobs

Currently, traffic traveling eastbound on US-36/I-270 could exit onto I-25 to proceed south on I-25. The traffic that needs to proceed southbound on I-76 could exit US-36 at Federal Boulevard (U.S. Highway 287 [US-287]) or even Pecos Street (Figure 5). Exiting west of I-25 instead of proceeding farther east and making a U-turn seems to be a more logical travel option. The ramp is a longer alternative to the existing north-south routes, accommodated at I-25, Pecos Street, and Federal Boulevard (Figure 5). The travel distance along Pecos Street is 1.5 miles between US-36 and I-76 whereas this ramp would instead make the same trip a distance of 4.3 miles. Local trips that originate or end in-between the two interstates will travel directly to the interstate they need instead of travelling the longer route U-turn. The use of the north-south routes is validated by the demand for the ramp. The projected 2040 traffic forecasts indicate a low demand for the ramp: less than 200 annual average daily traffic (AADT) and less than 50 vehicles in both the a.m. and p.m. peak hours.

The configuration for this ramp conflicts with the principle of route continuity outlined in AASHTO (2018), that "simplifies the driving task in that it reduces lane changes, simplifies signing, delineates the through route, and reduces the driver's search for directional signing."

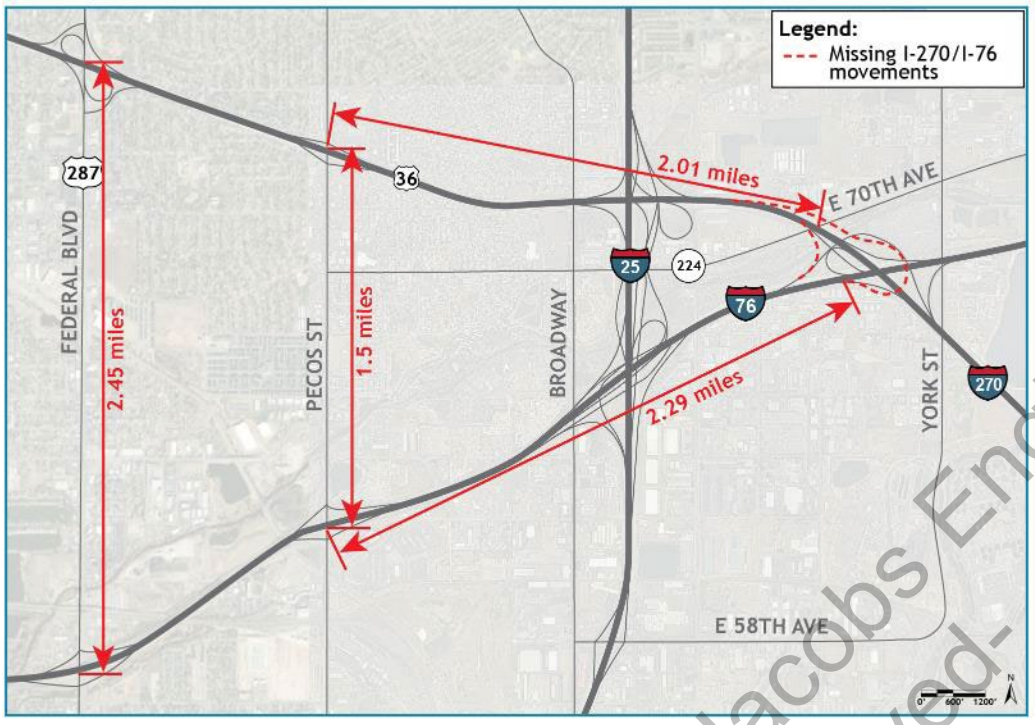

Figure 5. Alternate North-South Connections between US-36 and I-76
Source: Jacobs

5.1.1 Safety

The segment of I-270 between the eastbound entrance from I-25 (mile post [MP] 0.18) and the southbound I-76 (MP 0.76) on-ramp has a LOSS IV, based on crashes in both directions of travel for the past 5 years, with approximately 75 percent of the crashes occurring in the eastbound direction (Jacobs 2021a). Further, the area between gore point (GP) 1 and GP 2 (1,900 feet) is considered a high frequency crash area (Figure 4). GP 1 is the entrance gore from southbound I-25 onto eastbound I-270 (left-hand entrance), and GP 2 is the right-hand exit ramp gore for eastbound I-270 to northbound I-76. Through this section of I-270, there is also a 1,500-foot deceleration lane for the eastbound exit ramp to northbound I-76; merging, diverging, and weaving maneuvers are continuous within this 1,900 foot space of I-270.

Currently, sideswipe crashes in this section are overrepresented, likely because of weaving caused by the southbound I-25 system traffic entering I-270 from the left-hand entrance ramp, through traffic from US-36 and the diverging traffic for I-76 northbound. Sideswipes comprise 41 percent of all crashes in the eastbound direction. The two lanes of I-25 traffic have 800 feet to merge into one lane and another 1,200 feet to merge again in order to exit onto I-76. The left-side merging traffic thus pressures the I-270 through traffic. The heavy congestion on I-270 through lanes, in turn, then blocks access to the deceleration lane or, in the worst case, through traffic uses auxiliary space as a through lane before merging back to eastbound lanes. The driver's reaction time in the highly congested weaving section is slower than in non-congested segments of roadway. The lower reaction time of a single driver has a cascading effect on everybody driving in this section of the freeway.

The new off-ramp for southbound I-76 would exit at the same location as the current exit ramp for northbound I-76, making the ramp a dual exit ramp (GP 2 on Figure 4). Thus, providing an additional off-ramp from eastbound I-270 to southbound I-76 is not feasible without decreasing the level of safety of the existing facility and negatively influencing weaving operations on this segment of I-270 (TRB 2016). Providing access to southbound I-76 via I-270 will increase merging traffic on eastbound I-270 and add weaving and diverging traffic bound for the I-76 exit ramps at GP 2 for a location that currently does not

have enough weaving distance, noted as 1,900 feet (AASHTO [2018] recommends 2,000 feet), and as reflected in the accident data.

Adding this ramp would also impact the safety along southbound I-76. I-76 has a LOSS III between the southbound I-25 (MP 6.01) exit ramp and westbound I-270 (MP 6.43) entrance ramp, based on crash data in both directions for the past 5 years. Sideswipe same-direction accidents account for 45.5 percent of the crashes in the southbound direction. The addition of the ramp would create another weaving movement that would contend with I-76 traffic diverging for the southbound I-25 exit ramp (16,000 AADT) near GP 4 and the traffic from westbound I-270 entering I-76 southbound (5,300 AADT) near GP 3 (Figure 4). The distance between GP 3 and GP 4 is 1,750 feet.

One safety concern with partial interchanges is they conflict with drivers' expectations and might contribute to the wrong-way entrances when no provisions have been made for all movements (AASHTO 2018). However, for a system-to-system interchange wrong-way ramp entrances are highly unlikely since traffic is continually moving with no stopping and getting back onto the system.

5.1.2 Traffic Operations

The traffic operations is the second most critical concern after safety, when considering the new ramp connecting from eastbound I-270 to the southbound I-76. There are many system-to-system ramps in this area already accommodating high traffic volumes. The addition of another system-to-system ramp in such a close proximity to existing facilities will cause problems with lane balancing and lane densities that could overload the outer lanes of the interstates. This ramp affects two facilities, I-270 and I-76.

First, I-270 between GP 1 and GP 2 (1,900 feet in length) has a high amount of traffic entering the facility from I-25 into the two inside acceleration lanes of eastbound I-270. After accelerating, this traffic then has to look over their shoulder and safely merge into mainline I-270 traffic, then cross two lanes of I-270 traffic to align for the I-76 system ramp. The new ramp would add more traffic volume to a 1,900-foot weave along eastbound I-270. The insufficient weaving length does not meet the design standard (AASHTO [2018] recommends 2,000 feet) and is further complicated by the high concentration of traffic on the eastbound I-270 through lanes. The additional exiting volume caused by the new ramp would increase the friction on those through lanes, thus exacerbating the existing bottlenecks during peak hours and reducing speeds.

A new ramp to southbound I-76 would parallel and merge with an existing entrance ramp near GP 3. On Figure 4, there is only 1,750 feet between the ramp gores of two interchanges, where eastbound I-270 connects to southbound I-76 (GP 3), and where southbound I-76 exits onto the southbound I-25 exit ramp (GP 4). AASHTO recommends that an auxiliary lane be carried 2,500 feet beyond the "interchange influence of the last interchange" (2018). This requirement cannot be met because of proximity of the two system interchanges. Further, the outer lane would have a slower running speed and would have to merge over to the existing auxiliary lane before merging into a southbound through lane. As mentioned in the safety section, the outside lane already has high traffic density caused by southbound I-76 traffic exiting on the southbound I-25 exit ramp while also handling merging traffic from the southbound I-76 entrance ramp (from the westbound I-270 exit ramp). The additional new ramp traffic, while low volume, would add more travel delay to the network and complicate the merge and weaving along I-76 southbound.

The balance in the number of traffic lanes on the freeway and ramps is important for efficient traffic operations. AASHTO states that "at entrances, the number of lanes beyond the merging of two traffic streams should not be less than the sum of all traffic lanes on the merging roadway minus one" (2018). For southbound I-76 between GP 3 and GP 4 (Figure 4), there should be four lanes to receive the three southbound I-76 lanes and the two southbound I-76 entrance ramps. There are only three lanes on southbound I-76, so adding an extra through lane to the existing facility to achieve lane balance can be accommodated between GP 3 and GP 4. However, the

mainline would wind up imbalanced for the approach to southbound I-25 exit ramps near GP 4 (four lanes approaching three lanes).

5.1.3 Environmental

The ramp would cross sensitive environmental resources, including Clear Creek, its associated wetlands, and the Clear Creek Trail, which is a Section 4(f) resource. Assuming the ramp design would span the trail and Clear Creek, environmental impacts could include permanent wetlands impacts from pier placement and temporary impacts to wetlands and the 4(f) trail.

5.1.4 Conclusion

The missing ramp from eastbound I-270 to southbound I-76 would provide a direct connection between the system interchanges but should not be constructed because of safety and traffic operations reasons. As discussed in previous sections, the direct connection has low demand in the future, so the construction of the ramp is not reasonable because the function of the missing ramp is already served by the existing network of ramps at the adjacent I-76/I-25 interchange. The eastbound traffic also can connect to southbound I-76 via US-287 before the I-25/I-270 interchange. Since this is a system-to-system interchange, wrong-way ramp entrances are highly unlikely since traffic is continually moving with no stopping and getting back onto the system.

The construction of this ramp is also not feasible because this section of eastbound I-270 is highly congested, and running speeds observed are single digits during morning and afternoon peak hours. The missing ramp also does not meet the requirements for the weaving length, lane reduction and lane balance. Because of the close proximity to nearby system-to-system interchanges the missing ramp would overlap with sections of I-270 and I-76 that experience high crash rates even with current traffic volumes. The projected increased traffic volumes, while low, would not improve safety or lessen congestion. There would also be some environmental impact to the area, because of the ramp bridge pier impacts relative to proximity of wetlands and the Clear Creek floodplain. The proposed project construction does not preclude this missing ramp from being re-evaluated in the future and possibly constructed if conditions change.

5.1.5 Mitigation

Because of the low volume demand, there are no proposed mitigation measures for this missing ramp.

5.2 Missing Ramp from Northbound I-76 to Westbound I-270/US-36 (Option A)

Figure 6 shows two ramp options (Option A and B) for providing access from northbound I-76 to westbound I-270/US-36. Both ramp options provide a U-turn-type movement, with vehicles backtracking in the direction they came to go slightly north or west. The 2040 traffic forecast supports these findings. It shows a projected low demand for the ramp: approximately 400 AADT, with 70 vehicles in the a.m. peak hour and 50 vehicles in the p.m. peak hour.

The I-76/I-25 system-to-system interchange already accounts for the majority of movements. Figure 6 shows I-76 traffic that needs to travel north can currently exit onto north I-25 (shown by a red dashed line). Traffic that needs to go west on US-36 can take either the Federal Boulevard (US-287) or Pecos Street north-south arterials between I-76 and US-36 (Figure 5).

Option A would provide a successive right-hand exit from an existing right-hand exit ramp spaced at a minimum of 800 feet, then raising grade and looping over the I-76 ramp, I-270 mainline, I-76 ramp, and I-76 mainline. Option A would then fly over another I-76 ramp, Clear Creek, and State Highway 224 (SH-224) before merging with westbound I-270 (depicted as Ramp Option A on Figure 6). The configuration of this Option A conflicts with the principle of route continuity outlined in AASHTO (2018), that "simplifies the driving task in that it reduces lane changes, simplifies signing, delineates the through route, and reduces the driver's search for directional signing."

The Option A configuration of the missing ramp, illustrated on Figure 6, might be considered a long detour as it is out of direction by one mile. There is already a northbound I-76 ramp to northbound I-25 (dashed red line on Figure 6) so then the primary function of Option A (and Option B) would be to serve northbound I-76 traffic continuing west onto US-36.

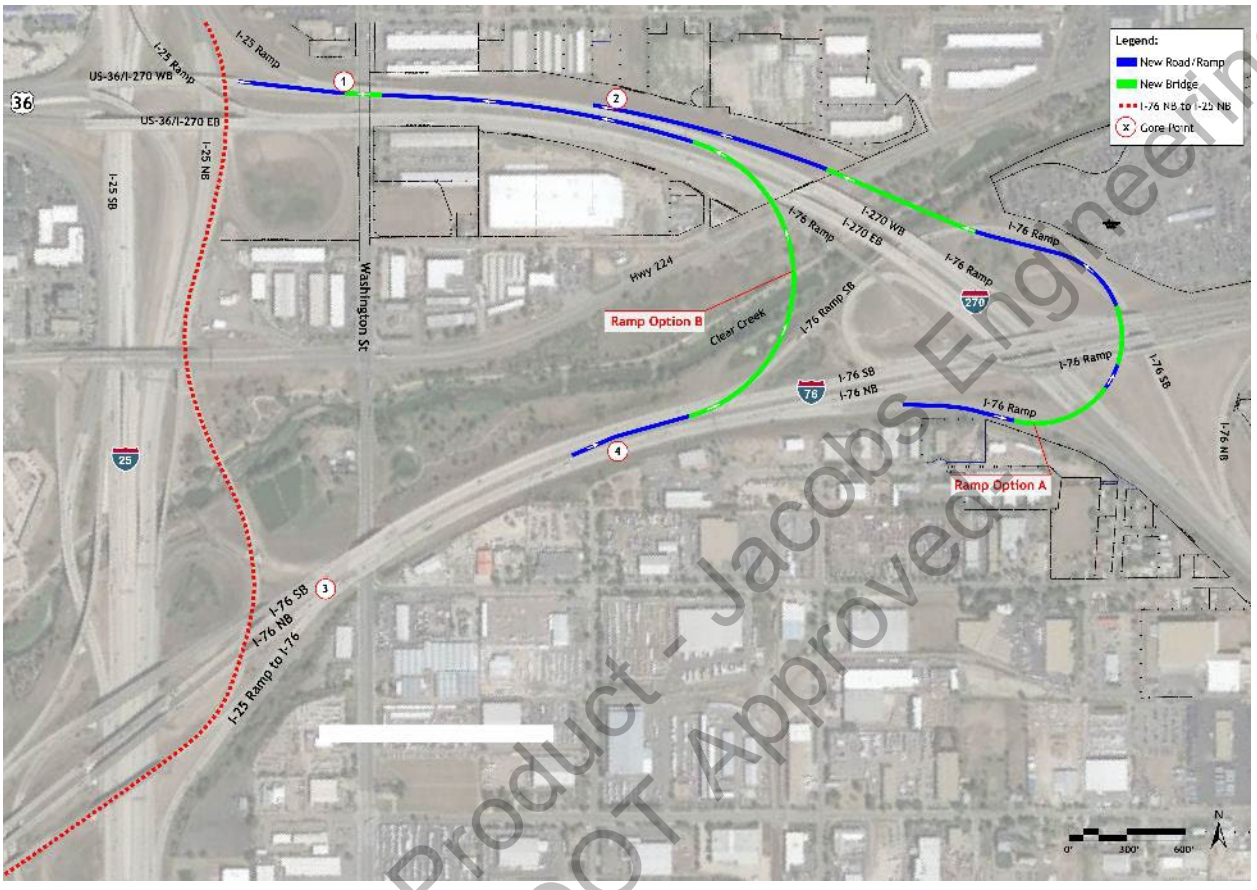

Figure 6. I-76 to I-270 Missing Movements (Ramp Options A and B)
Source: Jacobs

5.2.1 Safety

This section of I-270 has the same LOSS as noted in Section 5.1.1. Most of these crashes are happening in the eastbound direction of I-270 and not the westbound direction. 24 percent of the crashes going eastbound are sideswipe crashes. The new ramp would create an additional weaving section between GP 1 and GP 2 (Figure 6) since the vehicles on the ramp are likely destined for US-36. Traffic would need to look over their shoulders and weave across two lanes of northbound I-25 exit ramp and the southbound I-76 entrance ramp traffic within a space of 1,500 feet where AASHTO recommends 2,000 feet for weaving (2018). In 2040, the mainline volume for this westbound section of I-270 is projected to be 4,190 vehicles in the a.m. peak hour and 3,910 vehicles in the p.m. peak hour. Even though there would be a small amount of traffic utilizing this ramp, it would create safety issues because of the unexpected high-speed weave movement within 1,500 feet.

One safety concern with partial interchanges is they conflict with drivers' expectations and might contribute to wrong-way entrances when no provisions have been made for all movements (AASHTO 2018). However, for a system-to-system interchange wrong-way ramp entrances are highly unlikely since traffic is continually moving with no stopping and getting back onto the system.

5.2.2 Traffic Operations

As mentioned in Section 5.2.1, westbound I-270 has a high volume of traffic for mainline and the adjacent auxiliary lane (between GP 1 and GP 2, Figure 6). Providing another system-to-system ramp would cause problems with lane balancing and lane densities that would create friction along the two interstates (I-270 and I-76). This option for providing a system-to-system ramp would merge on the northern side of heavy westbound I-270 traffic, leaving about 1,500 feet of space for a traveler to look over their shoulder to merge and then weave across two lanes to align with westbound I-270/US-36, creating impacts to speeds and increasing congestion for westbound travelers. The 1,500 feet of weaving distance is less than the desirable 2,000 feet (AASHTO 2018). This layout creates lane imbalance approaching an exit as there will be 5-lanes approaching 5 receiving lanes (3 mainline + 2 ramp lanes) when only 4 lanes should approach.

In the eastbound direction, speeds are reduced to crawling single digits during peak hours because of successive system entrance ramps. The data shows that a driver's acceleration-deceleration behavior during weaving maneuvers is affected by heavy congestion. Adding this system-to-system ramp to the westbound would create a similar situation as eastbound, slowing speeds and impairing system operations. System-to-system ramps are intended to move traffic efficiently while not impeding the system, but because of the ultimate destination (westbound US-36) this ramp would affect westbound I-270 and traffic destined for northbound I-25.

5.2.3 Environmental

The ramp would cross sensitive environmental resources, including Clear Creek, its associated wetlands, and the Clear Creek Trail, a Section 4(f) resource. Assuming the ramp design would span the trail and Clear Creek, environmental impacts could include permanent wetlands from pier placement and temporary impacts to wetlands and the 4(f) trail.

5.2.4 Conclusions

The missing ramp from northbound I-76 to westbound I-270 would provide a direct connection between the system interchanges but should not be constructed due to safety and traffic operations concerns. As discussed in previous sections the direct connection has low demand in the future, so the construction of the ramp is not reasonable because the function of the missing ramp is already served by the existing network of ramps at the adjacent I-76/I-25 interchange. The northbound traffic can also connect to westbound US-36 via US-287 or Pecos Street arterials well in advance of the I-76/I-270 interchange.

The construction of the system-to-system ramp is also not feasible because this section of westbound I-270 is highly congested with two other system ramps converging in the same area. The missing ramp also does not meet the requirements for the weaving length, lane reduction and lane balance. The projected increased traffic volumes, while low, would not improve safety nor ease congestion. There would also be minor environmental impact to the area because of the ramp bridge pier impacts in proximity to wetlands and the Clear Creek floodplain. The proposed project construction does not preclude this missing ramp from being re-evaluated in the future and possibly constructed if conditions change.

5.2.5 Mitigation

Because of the low volume demand, there are no proposed mitigation measures for this missing ramp.

5.3 Missing Ramp from Northbound I-76 to Westbound I-270/US-36 (Option B)

To overcome the weaving movement and ultimate destination of westbound US-36 outlined in Option A, Option B proposes a left-side exit into the I-76 median that raises grade and spans over the southbound I-76 ramp, Clear Creek, SH-224, northbound I-76 ramp, and eastbound I-270 before touching down in the I-270 median and then crossing Washington Street just before a left-side merge with westbound I-270/US-36 (depicted as Ramp Option B on Figure 7).

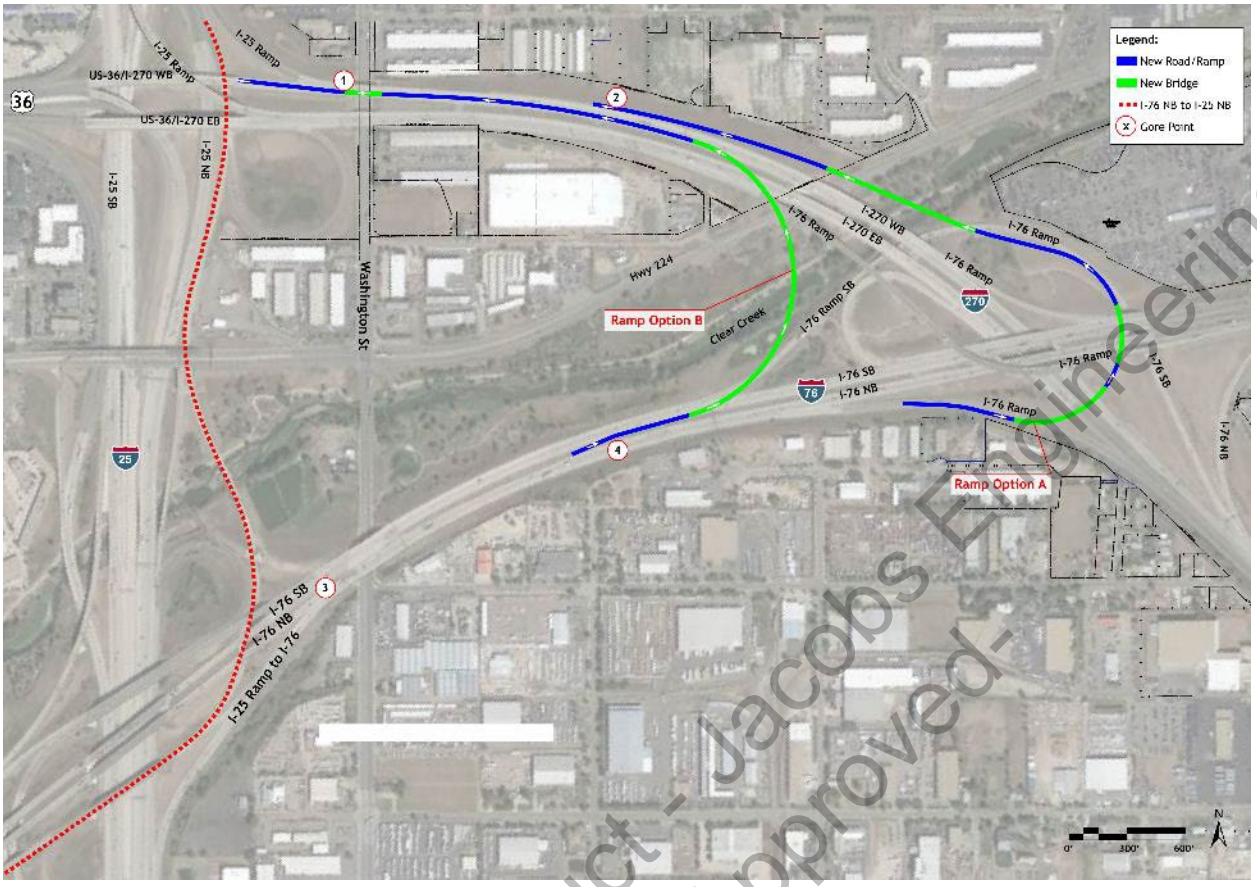

Figure 7. I-76 to I-270 Missing Movements (Ramp Options A and B)
Source: Jacobs

5.3.1 Safety

The atypical geometric layout of the ramp would require additional lane changes on northbound I-76, as traffic would have to move to the inside travel lane before exiting, which consequently would require additional advance warning signage for this left-hand exit. AASHTO stresses "the difficulty of left-entrance merging with high-speed through traffic" and considers these ramps undesirable and recommends using them only in highly special cases (AASHTO 2018).

The left-hand exit ramp (GP 4 Figure 7) for Option B would be approximately 1,400 feet downstream from a right-side entrance ramp entering northbound I-76 from I-25 (GP 3 Figure 7). This distance between GP 3 and GP 4 (1,400 feet) is too short for providing safe distances for merging, weaving, and diverging (AASHTO [2018] recommends 2,000 feet). Left-hand exit and entrance ramps are atypical and counterintuitive to drivers. The driver who is especially not familiar with the layout of the interchange system most likely would have to search for the signage. Providing a left-hand exit will be similarly confusing to not having the exit.

Colorado High Performance Transportation Enterprise developed an Express Lanes Master Plan (HPTE 2020) that anticipates I-76 express lanes through the I-76/I-270 interchange. The express lanes would be located on the interior of the mainline, thereby requiring a weaving area to accommodate the Option B ramp diverging from the left side of eastbound I-76. The ramp volume, although projected at a low volume, creates safety and operational concerns given that the new ramp traffic must weave through high-speed express lanes.

As noted previously, a safety concern with partial interchanges is they conflict with drivers' expectations and might contribute to the wrong-way entrances when no provisions have been

made for all movements (AASHTO 2018). However, a system-to-system interchange such as Option B, wrong-way ramp entrances are not likely since traffic is continually moving with no stopping and getting back onto the system. The bigger safety issue will be drivers exiting northbound I-25 (near GP 3 Figure 7) and looking over their shoulder to weave across two lanes of traffic and stay focused on the road ahead. Anticipated ramp demand may be low, but consider an incident or heavy congestion on northbound I-25 influencing the I-25 traffic destined for westbound US-36 and diverting them to northbound I-76 to catch this ramp; this would be a much higher volume, increasing the safety risks along northbound I-76.

5.3.2 Traffic Operations

The construction of an access ramp from northbound I-76 to westbound I-270/US-36 introduces an additional weaving maneuver on northbound I-76 between GP 3 and GP 4. At the westbound merge slower ramp traffic will be merging onto I-270 west of GP 1 and ahead of the high-speed express lane traffic. Due to high traffic congestion on both I-76 and I-270 this ramp would further disrupt both systems traffic flow as more traffic movements are added. Especially true if an incident on northbound I-25 shifts traffic to catch this ramp to westbound US-36 as noted above. The inside lane is for faster traffic, and having vehicles slow down for a left-hand exit from or entrance onto the freeway would cause reduced speeds at these diverge and merge locations.

The median ramp design, along I-270 and I-76, precludes the ability for connecting the future I-270 to the US-36 express lanes and providing future direct-connect express lanes from I-270 to I-25 and from I-270 to I-76. The configuration of a left-hand ramp (Option B) is geometrically unexpected and does not mirror any other ramp at this interchange. Interchange uniformity alleviates drivers' confusion in relation to patterns of ramp exits and entrance points (AASHTO 2018). This ramp does not provide uniformity and would add confusion to the system-to-system interchange.

5.3.3 Environmental

Option B would have similar affects as discussed with Option A. The ramp would cross sensitive environmental resources, including Clear Creek, its associated wetlands, and the Clear Creek Trail, a Section 4(f) resource. Assuming the ramp design would span the trail and Clear Creek, environmental impacts could include permanent wetlands from pier placement and temporary impacts to wetlands and the 4(f) trail.

5.3.4 Conclusions

The missing ramp from northbound I-76 to westbound I-270 via Option B would provide a direct connection between the system interchanges but should not be constructed due to safety and traffic operations concerns. As discussed in previous sections the direct connection has low demand in the future, so the construction of the ramp is not reasonable because the function of the missing ramp is already served by the existing network of ramps at the adjacent I-76/I-25 interchange. The northbound traffic can also connect to westbound US-36 via the US-287 or Pecos Street arterials well in advance of the I-76/I-270 interchange (Figure 5).

The construction of the system-to-system ramp is not feasible because this section of westbound I-270 is highly congested with two other system ramps converging in the same area as well as a high-speed express lane on westbound I-270. The missing ramp does not meet the requirements for the weaving length and would be an atypical left-hand exit to left-hand entrance ramp that is not desirable. The projected increased traffic volumes, while low, would not improve safety nor ease congestion, especially during an incident on northbound I-25. There would also be minor environmental impact to the area, because of the ramp bridge pier impacts relative to proximity of wetlands and the Clear Creek floodplain.

5.3.5 Mitigation

Because of the low volume demand, there are no proposed mitigation measures for this missing ramp.

6.0 Interchange 2: I-270/York Street

The existing York Street and I-270 interchange is considered a partial diamond interchange; it is currently missing the westbound entrance ramp and the eastbound exit ramp (west-half of the diamond interchange). The west-half of the diamond was not constructed originally because of its close proximity (1,930 feet) to the I-76/I-270 system-to-system interchange, the east half of the diamond has less conflicts. On the west side of York Street, the existing I-76 system entrance and exit ramps physically occupy the space that would have otherwise been allocated for the missing York Street service ramps (Figure 8). Adding to this complexity is the I-25/I-270 system-to-system interchange located approximately 1 mile west of the I-76 system interchange with I-270.

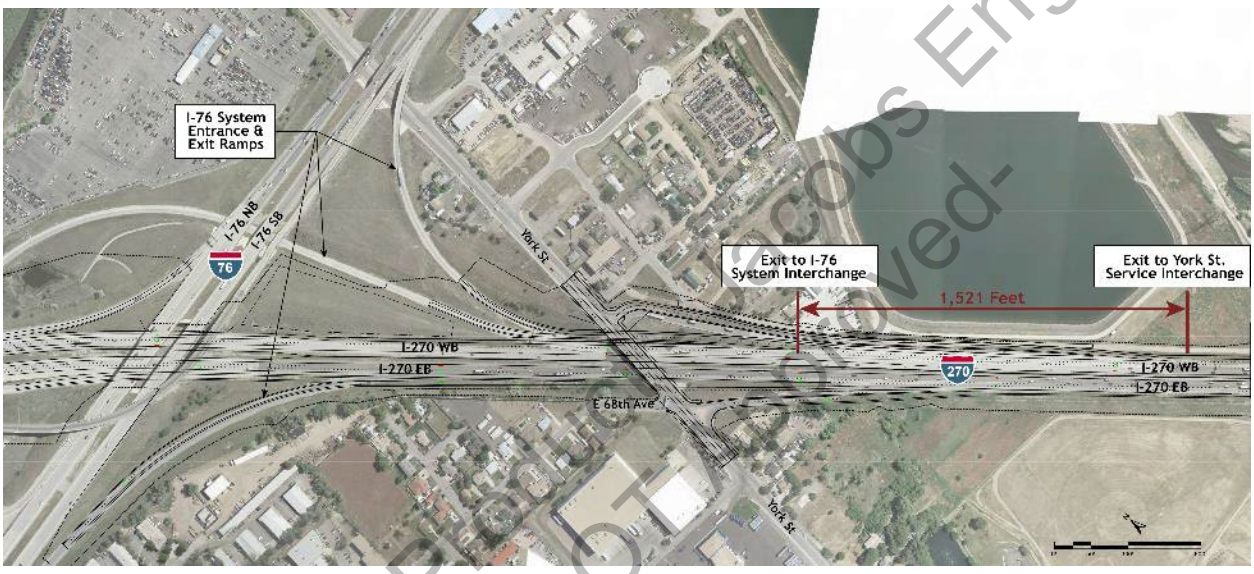

Figure 8. I-270/York Street Partial Interchange with Split Westbound System and Service Exit Ramps
Source: Jacobs

On the east side of the interchange the westbound system ramp to I-76 and the service ramp to York Street share a common exit and has been documented as confusing for drivers. The layout of I-270, York Street and I-76 forms a triangle to the north side of I-270 while the two legs of that triangle I-76 and York Street converge together at the apex with no access from York Street to I-76.

The Proposed Action in the I-270 Environmental Assessment is arterial widening, as well as ramp changes for the westbound York Street service exit ramp, which would be split and separated from the I-76 system exit ramps by more than 1,500 feet (Figure 8). Separating the ramps would meet driver expectations and lessen driver confusion thereby improving ramp operations and capacity. York Street also would be widened to two through lanes in the northbound and southbound directions with a center-turn lane to match other planned improvements by Adams County.

A new collector ramp is proposed that consolidates incoming movements from the I-76 entrance ramps. The collector ramp (shown in orange on Figure 10) would be barrier-separated from the I-270 mainline to reduce traffic friction and accidents identified on eastbound I-270 near the dual I-76 entrance ramps. The collector ramp system would feed directly into an auxiliary lane that continues eastbound.

The project explored adding a new westbound entrance ramp from I-270 and an eastbound exit ramp from I-270 to determine if the ramps would be feasible and safe. The following sub-sections evaluates the safety, traffic operations, and environmental impact of adding the missing ramps at this location.

6.1 Missing Ramp from York Street to Westbound I-270

Currently there is no access ramp from the York Street to westbound I-270 and signage on York Street for returning to the interstate system is non-existent and therefore lacking direction. To access westbound I-270/US-36, vehicles must travel north on York Street and turn right onto SH-224, follow the on-ramp to southbound I-76, then proceed south before exiting onto the I-270 westbound (blue route shown on Figure 9).

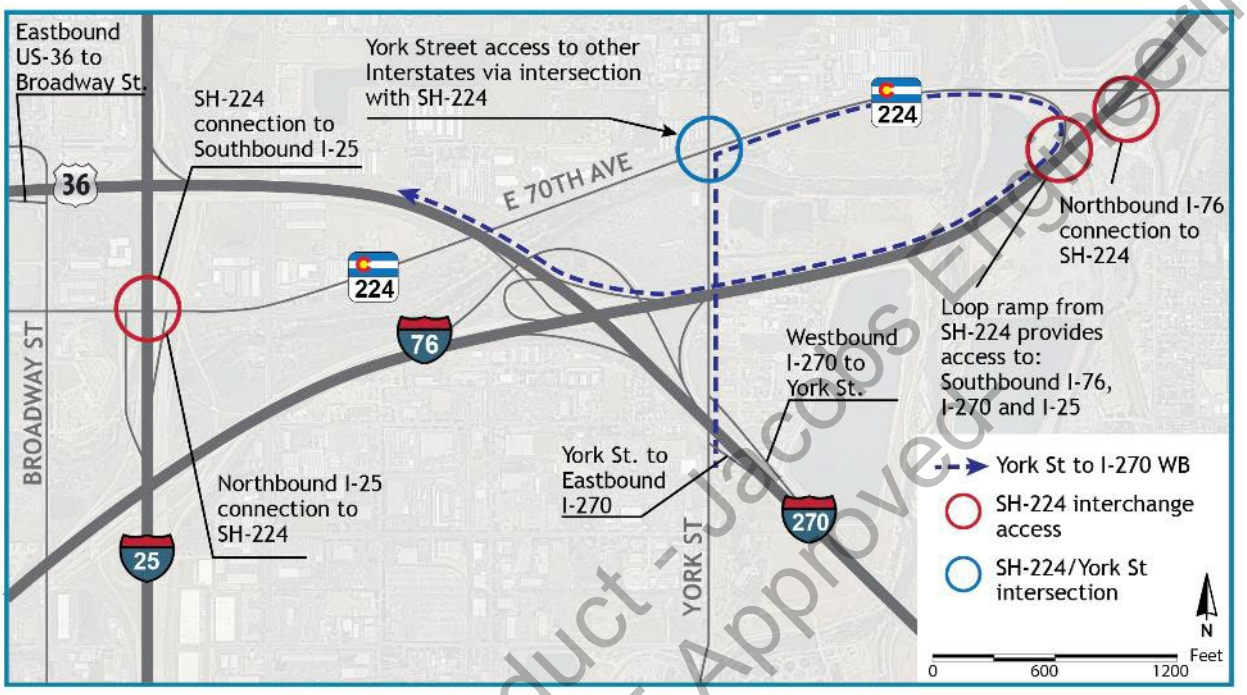

Figure 9. Access to Interstates via SH-224
Source: Jacobs

This route is counterintuitive because drivers need to proceed north, then east, then south before finally heading in the intended western direction. Replacing this out-of-direction travel could be achieved with a westbound ramp from York Street.

To provide a westbound I-270 entrance ramp from York Street, a new braided ramp bridge approximately 500 feet long would need to be constructed over the I-76 Y-split ramps (new ramp shown in blue and green on Figure 10). Traffic forecasts for 2040 indicate a demand for the westbound entrance ramp from York Street. The 2040 AADT is estimated to be 5,600, with 270 vehicles in the a.m. peak hour and 880 vehicles in the p.m. peak hour.

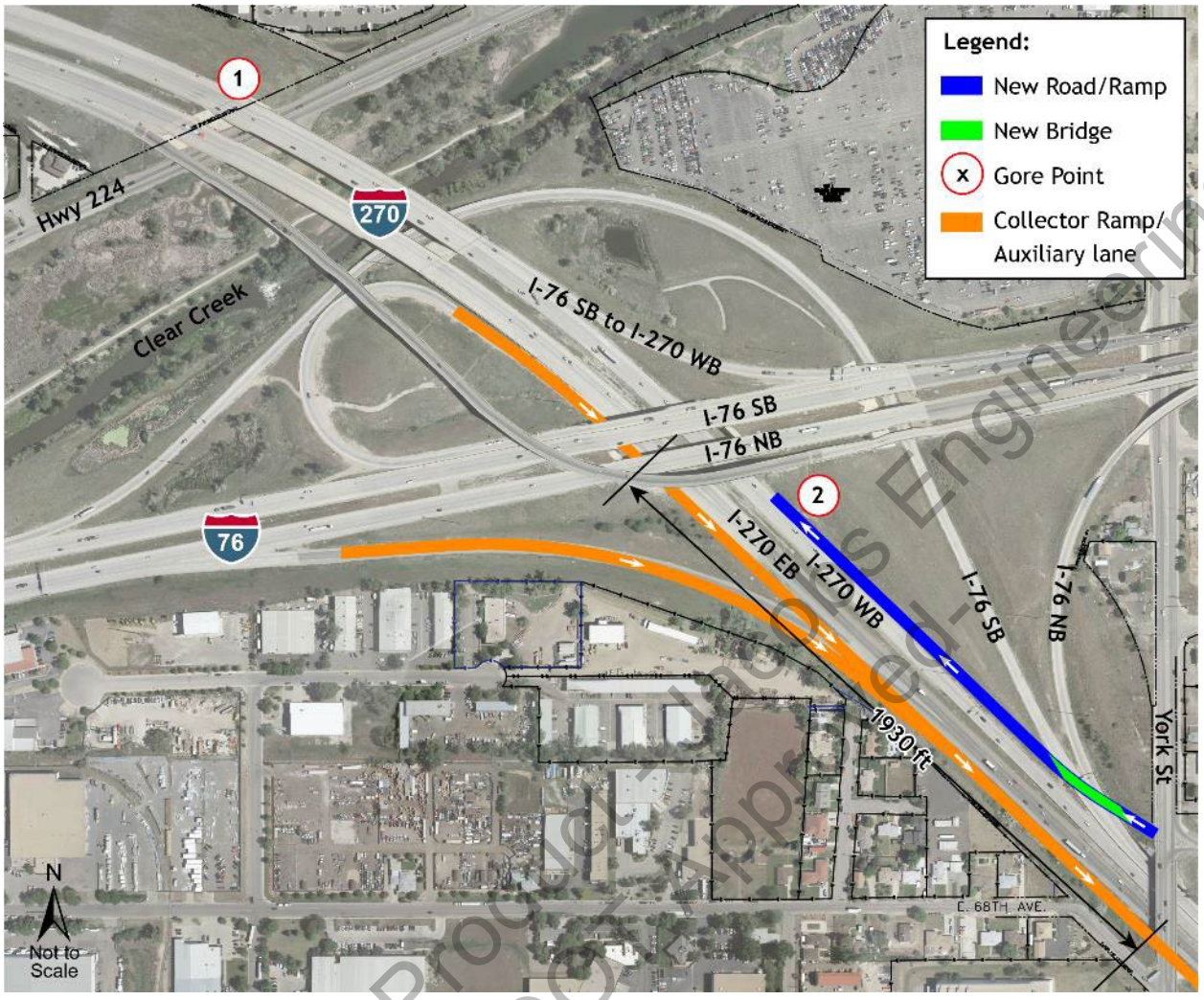

Figure 10. York Street Westbound Braided Entrance Ramp with Bridge (Shown in Green) over I-76 Y-Split Ramps
Source: Jacobs

6.1.1 Safety

Partial interchanges such as I-270/York Street are not desirable because of safety reasons. Specifically, partial interchanges conflicts with the drivers' expectations and might contribute to the wrong-way entrances when no provisions have been made for all movements (AASHTO 2018). Based on previous 5-year crash analyses, there are no documented wrong-way ramp entrance crashes at this interchange; however, the stretch of I-270 between I-76 (MP 0.0) and York Street (MP 0.39) has a LOSS IV in both directions of travel. Most crashes happen in the eastbound direction, while the westbound crashes only represent approximately 17 percent of the crashes in this section. Crashes in this area are likely attributable to the two successive, high-speed, system-to-system interchanges (I-76/I-270 and I-25/I-270).

The service entrance ramp would connect York Street to the westbound I-270 system-to-system auxiliary lane (GP 2) approximately 1,900 feet before another system-level entrance ramp from southbound I-76 (GP 1). This design would exceed the recommended 1,000 feet guidance for successive entrance ramps (AASHTO 2018). However, meeting the minimum length requirement for ramp spacing does not guarantee smooth or safe traffic operations.

A new westbound service on-ramp could introduce speed differentials along I-270 because the ramp entrance would be at the start of the system-to-system auxiliary lane (near GP 2 on Figure 10) at the

same point where westbound I-270 traffic is diverging for the northbound I-25 system exit ramp 4,700 feet ahead. Downstream of GP 2, westbound I-270 traffic from York Street would create additional merging and diverging between the lower speed service ramp entering onto a higher speed system ramp, which would create speed differentials on I-270. A westbound I-270 commuter destined for Boulder via US-36 would not be expecting the slower merging traffic from the new entrance ramp. This new merge would be abnormal and would contribute to crashes in this segment. The combined service and system ramp conflicts with driver's expectations because I-270 traffic should not be decelerating for lower speed service ramp traffic entering the system.

Adding this ramp would impact the safety of the I-25 system-to-system ramp, I-76 system-to-system ramp, I-270 mainline, and, likely, I-76 mainline. Service ramps do not impact one system-to-system ramp, but this westbound service ramp would impact two interchange systems.

6.1.2 Traffic Operations

Along this section of I-270, the traffic congestion is equally distributed in the westbound and eastbound directions. In the westbound direction, heavier traffic accumulates in the outer I-270 lanes, because there are more vehicles preparing to exit onto northbound I-25 than vehicles continuing west on US-36. The system-to-system connection (I-270 to I-25) creates a higher demand for the outside exit lane. The traffic distribution on westbound I-270 is not balanced, and traffic preparing to exit I-270 shifts into the far-right lane far in advance of the southbound I-76 entrance ramp entering at GP 1 (Figure 10). Downstream of GP 1, a weave is created by the traffic accelerating onto I-270 from southbound I-76 and traffic preparing to exit I-270 onto northbound I-25. Hence, both traffic movements attempt to occupy the same 2,400-foot space in the right lane between the gore of the westbound I-270 exit ramp and the end of the I-76 exit ramp acceleration lane. The addition of a new ramp at GP 2 (shown in blue on Figure 10) adds additional traffic volume that would compete for the same outer right lane.

The York Street entrance ramp would also introduce another weave and force the I-270 westbound exiting traffic to queue in the right lane farther east from the existing location, possibly before the York Street bridge. The early shift to the right lane would increase congestion and traffic density in the outer lanes, thus convoluting the traffic merge from the I-76 entrance ramp (GP 1) and York Street entrance ramp (GP 2), creating a ripple effect of congestion on those ramps and mainline.

As noted previously, service ramps generally do not impact one system-to-system ramp, but this westbound ramp would impact the traffic operations of two interchange systems. To avoid these impacts, the proper design would need to involve building a barrier-separated collector ramp to carry the service ramp traffic and get them up to speed before merging, but there is not enough distance to develop this collector ramp because of proximity of the successive system interchanges to York Street.

6.1.3 Environmental

There are no environmental concerns or resource impacts for adding this westbound entrance ramp. For noise and air quality impacts, the majority of the traffic using this ramp would already be traveling on York Street.

6.1.4 Conclusions

Typical minimum interchange spacing for developing safe full-movement interchange ramps in an urban setting is 1 mile (5,280 feet) (AASHTO 2018), but these two interchanges are only separated by 1,930 feet (Figure 10). Braided ramps like the one shown are often needed to accommodate ramp movements with less spacing between interchanges. However, even when ramps can be made to work geometrically, they can introduce additional friction to system operations or even increase safety risks, particularly when mixing service-level traffic with system-to-system traffic.

This ramp should not be added because of the negative safety and traffic operational impacts documented previously. These impacts are related to the unique location of York Street and its

proximity to the I-76 and I-25 system interchanges. Providing a westbound service entrance ramp from York Street in this limited area along I-270 would be unsafe because of the speed differentials and driver expectations of connecting the system-to-system interchanges while merging a service ramp. The proposed project construction does not preclude this missing ramp from being re-evaluated in the future and possibly constructed if conditions change.

The missing movement is accommodated by the I-76 interstate connection to SH-224. The current route (blue dashed line on Figure 9) is safer because the SH-224 traffic (collected from York Street) merges with interstate traffic before reaching any system-to-system interchange ramps.

6.1.5 Mitigation

As a mitigation measure to the missing ramp, additional signage and interstate marking badges for exits would be provided along York Street, SH-224, and I-76 to more easily direct traffic to the interstates (Figure 11).

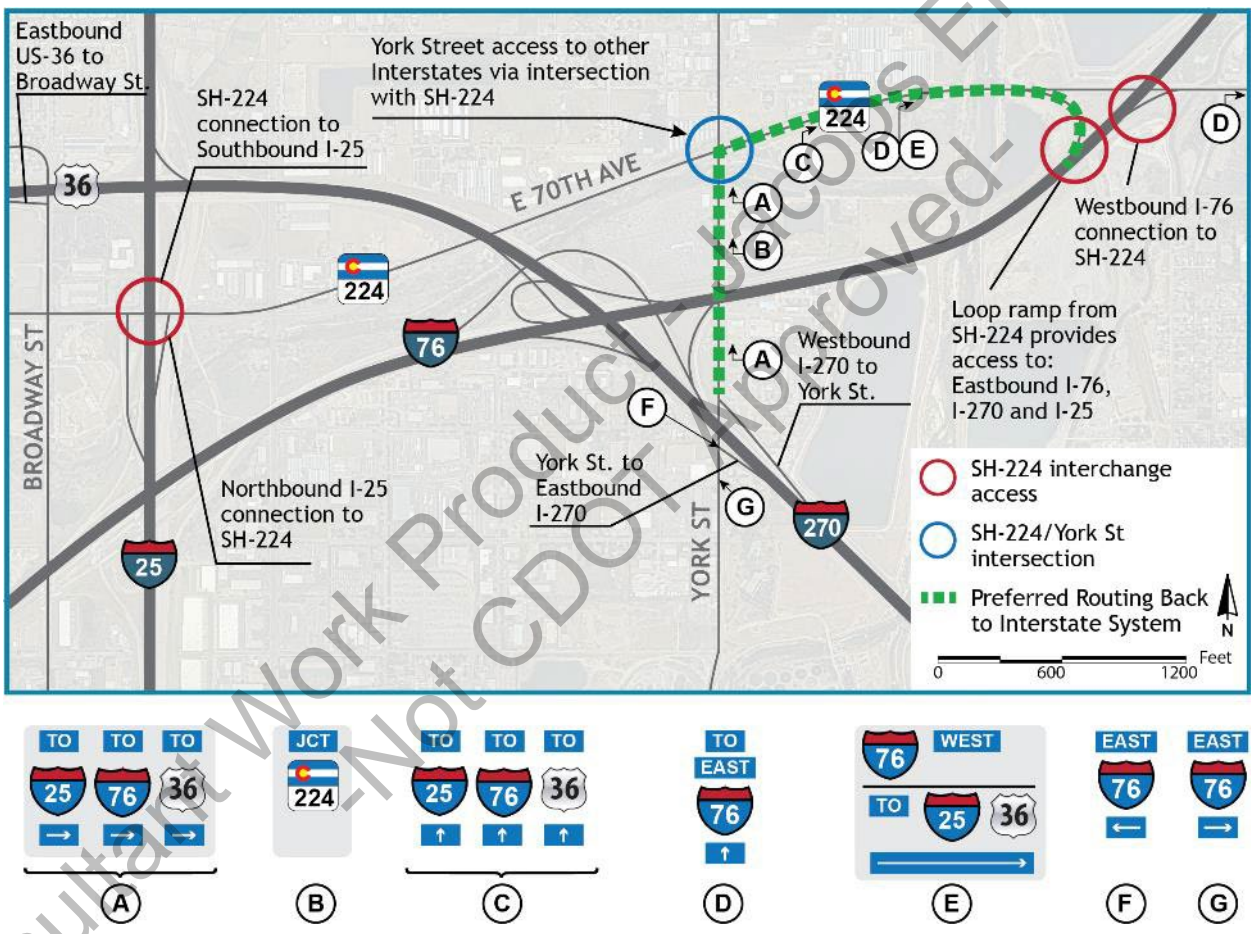

Figure 11. Signage Plan for Access to Interstates and Highways via SH-224
Source: Jacobs

6.2 Missing Ramp from Eastbound I-270 to York Street

The I-270 and York Street interchange is also missing the exit ramp from eastbound I-270 to York Street. Traffic coming from the west on US-36/I-270 must exit the fly-over ramp to northbound I-76 and proceed north to SH-224 then turn west onto SH-224 before turning south onto York Street, which is circuitous (Figure 12). Replacing this indirect pattern of travel could be achieved with an eastbound exit ramp from I-270.

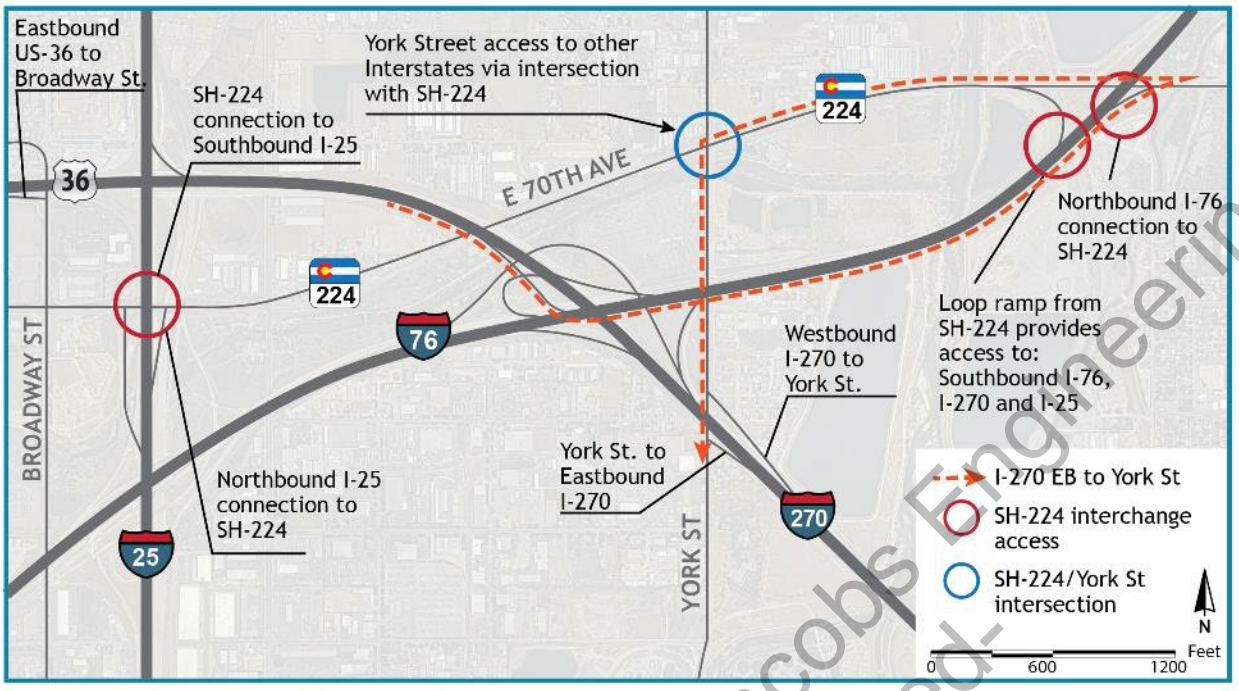

Figure 12. Access to Interstates via SH-224
Source: Jacobs

The 2040 traffic forecasts indicate a demand for an eastbound exit ramp from I-270 to York Street. It is expected that the ramp traffic would grow to 4,500 AADT in 2040, with an equal number of vehicles in the morning and evening rush hour: 670 vehicles in the a.m. peak hour and 670 vehicles in the p.m. peak hour. The additional 670 vehicles in the peak hour would represent a 23 to 29 percent surge to eastbound I-270 peak hour volumes (3,550 a.m. and 2,950 p.m.).

In the eastbound direction, the project is proposing a collector ramp that would improve safety and operations by barrier-separating eastbound I-270 from multiple entrance ramps from I-76. To provide for an eastbound exit ramp, the proposed collector ramp could be shifted to receive a parallel exit ramp from eastbound I-270 traffic destined for York Street (Figure 13). After merging all ramp collector traffic (distance of 450 feet from GP 3 to GP 4), a deceleration lane could then diverge near GP 5 (distance of 950 feet from GP 4 to GP 5) from the eastbound collector ramp, then continue under the reconstructed York Street bridge and allowing for a far-side, jug-handle, exit ramp to York Street that terminates at the intersection of York Street and East 67th Avenue (Figure 14).

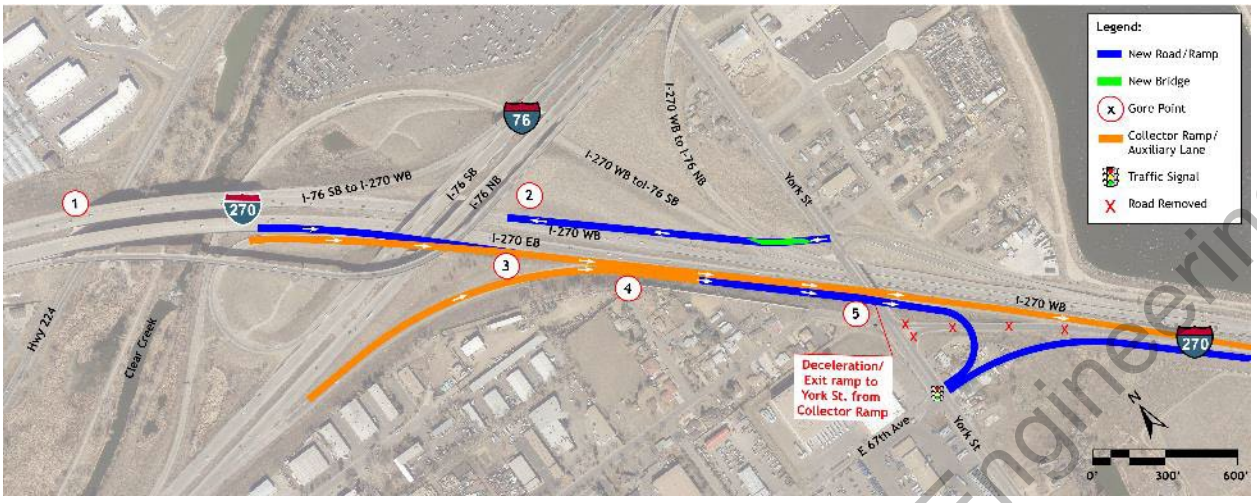

Figure 13. I-270 Eastbound Exit to York Street and Collector Ramp Converted to Collector-distributor Road
Source: Jacobs

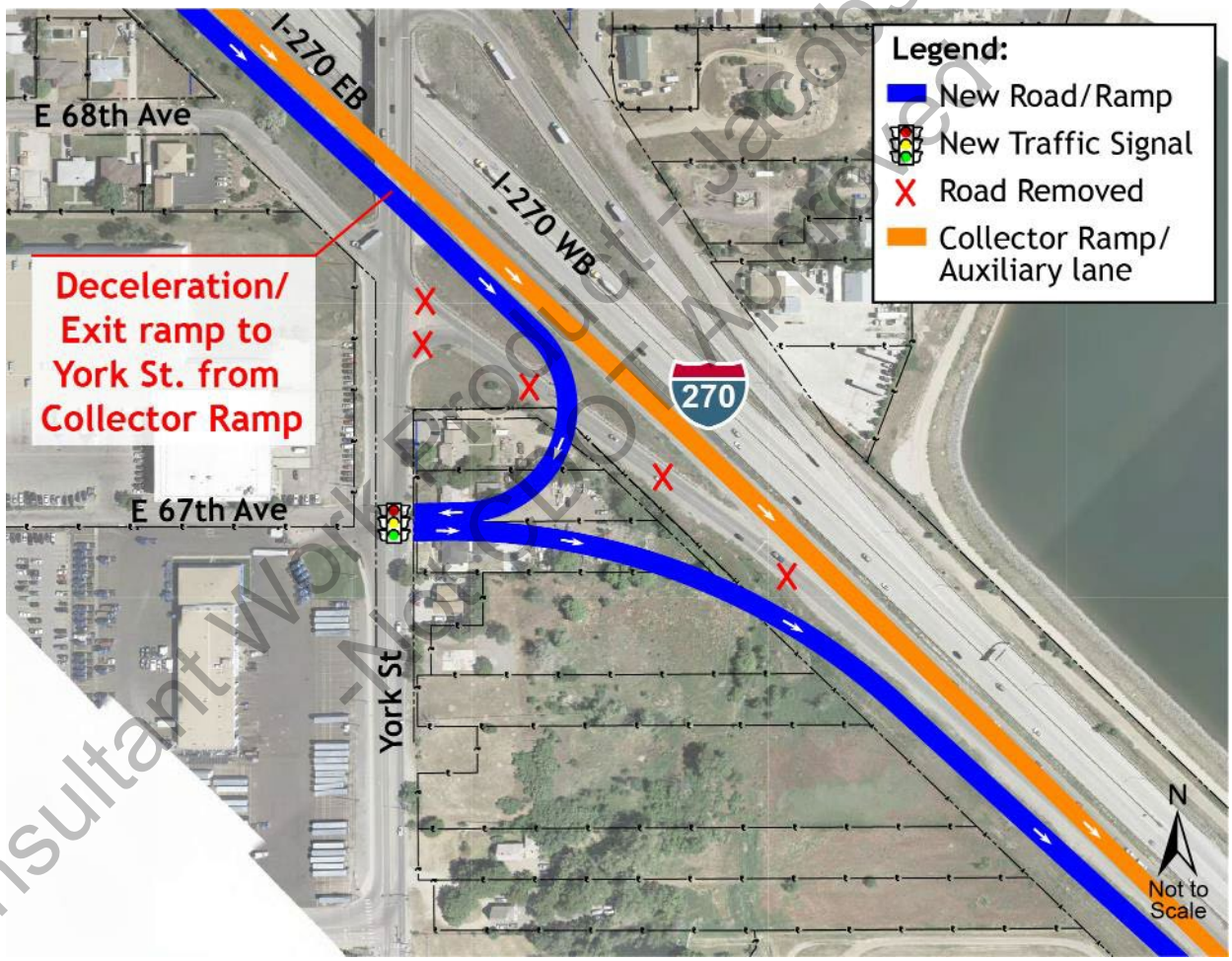

Figure 14. I-270 Eastbound Far-side Exit Ramp to York Street (Jug Handle) and Eastbound Entrance Ramp from York Street
Source: Jacobs

6.2.1 Safety

As mentioned in Section 6.1.1, this section of I-270 is at LOSS IV, and crashes happen primarily in the eastbound direction with the northbound I-76 to eastbound I-270 ramp currently

overrepresented for sideswipe crashes. As a result, the barrier-separated collector ramp discussed previously is provided to improve safety in this segment. This improvement is negated by converting the collector ramp into a collector-distributor road—with eastbound I-270 traffic exiting for York Street adding additional merging and weaving and therefore creating speed differentials that increase the potential for rear-end crashes. The collector-distributor road is still a system-to-system connection that would likely have a speed limit between 50 and 60 mph while the service exit ramps for York Street would have much lower speeds. The combined service and system ramp would conflict with driver's expectations because I-76 system traffic looking to accelerate onto I-270 between GP 4 and GP 5 (950 feet) would likely instead have to slow down mid-route as service traffic begins weaving over and decelerating for the York Street exit.

The small radius jug-handle exit ramp with lower design speed exacerbates this deceleration as traffic needs to slow down approaching the York bridge ahead of tight curve. The segment between GP 4 and GP 5 is where most of the weaving would happen, and unless the ramps' running speeds can be equalized before GP 5, there will likely be a high-speed differential in this area resulting in increased traffic incidents. With the additional exit ramp, it would be difficult to meet the minimum spacing for an entrance-to-exit distance between ramp terminals. The desirable distance for a system-to-service ramp (from GP 4 to GP 5) is 1,600 feet (AASHTO 2018). For this location, the maximum that could be achieved is closer to 1,000 feet.

The jug-handle ramp at this location is needed to provide additional distance for deceleration and then loop service traffic to the eastern side of York Street. This jug-handle design would be similar to a partial clover design with a shared ramp terminus at the York Street crossroad (as shown on Figure 14). Shared ramp terminuses that tee at two-way crossroads can be conducive to wrong-way entry on the exit ramp (AASHTO 2018). Additionally, because of the higher speed system-to-system collector-distributor road leading to this exit ramp, drivers could easily exceed the 20- or 25-mph speed limit of this tight-radius jug-handle leading to run-off-the-road crashes. This observation is confirmed by the crash data collected by CDOT at other far-side exit ramps. Studies show that vehicles often run off the road when speeding through horizontal curves with small radiuses. In general, because of the wide speed deferential between ramp and highway running speeds, many studies suggest that when compared to other types of ramps, exit loop ramps have more safety issues if traffic is not properly slowed down. One of the reasons why cloverleaf ramps have been mostly replaced with other type ramps is that cloverleafs have the largest speed changes in the shortest distance, as well as many weaving maneuvers.

6.2.2 Traffic Operations

Currently during peak hours, the travel speeds drop down to single digits along eastbound I-270 approaching York Street because of extremely high congestion in this section of I-270. As mentioned in Section 5.1.1, the driver's reaction time in the highly congested weaving section is slower than in non-congested segments of roadway. The lower reaction time of a single driver has a cascading effect on everybody driving in a weaving section of a freeway. If the existing collector ramp is replaced by collector-distributor road, it would serve up to 1,360 vehicles in the p.m. peak hour as opposed to 690 vehicles as a collector ramp. The volume to capacity ratio in the heaviest congested section (between GP 4 and GP 5, shown on Figure 13) would be 0.72 in the p.m. peak hour. The 0.72 ratio is not considered a high ratio; however, with extra weaving movements in this section, capacity would be much lower compared to a typical freeway ramp.

When considering traffic operations, the main issue is that the collector-distributor road would essentially serve a dual purpose, it would act as a system and a service ramp simultaneously. System interchanges connect freeways to other freeways while service interchanges connect freeways to arterials with lower speeds and volumes of traffic. In this case, it would connect the northbound and southbound I-76 system ramps to the eastbound York Street service ramp. As a rule, system interchanges operations improve as the number of weaving sections are minimized. The collector-

distributor is primarily a system-to-system connection where weaving is not expected, but by intermingling a service ramp, there would be increased weaving.

Because of the limited space at this specific location, the collector-distributor road does not support the required distance for weaving between successive entrance ramps and exits (only 950 feet between GP 4 and GP 5). The substandard distance would most likely yield a sizable compromise to traffic operations relative to not only the collector-distributor road but also eastbound I-270. To remove the short weave condition, a braided ramp would be needed; however, this cannot be done without further impacts to the I-76 and I-25 system interchanges.

6.2.3 Environmental

This jug-handle ramp plan (Figure 14) would not result in any additional resource impacts but it would lead to four right-of-way takes and involve up to three property relocations that would be counter to the I-270 Environmental Assessment goal of "consideration for the human environment" (property owners). With the addition of these ramps, York Street may need to be widened even more than planned to accommodate the necessary turning volumes (possibly needing dual lefts), thereby increasing right-of-way impacts. Right-of-way impacts are normal for any project and are listed as impacts but would not preclude putting the ramp in. There are no other environmental impacts that would preclude adding this eastbound exit ramp.

6.2.4 Conclusion

This missing ramp should not be constructed because of the adverse safety and traffic operations impacts resulting from a combined system and service collector-distributor road. This is primarily because of the unique location and overlap with the I-76 system interchange as well as the intermingling of higher speed system-level and lower speed service-level traffic. Providing an additional ramp in this limited area along I-270 would be unsafe because of the speed differential and additional weaving created by combining the system-to-system ramp and service ramps. It is also noted that the proposed project construction does not preclude this missing ramp from being further re-evaluated and possibly constructed in the future if conditions change.

The missing York Street connection is already being made from interstates connecting to SH-224. In fact, the current route (orange dashed line on Figure 12) is safer because traffic is transferred from system to system before gradually being stepped down in speed from I-76 to SH-224 then York Street, which meets driver expectations for this area.

6.2.5 Mitigation

As a mitigation measure to the missing ramps, additional signage and interstate pavement badges for exits would be provided along I-270, I-76, and SH-224 to easily direct traffic to and from interstate and highway routes (Figure 15).

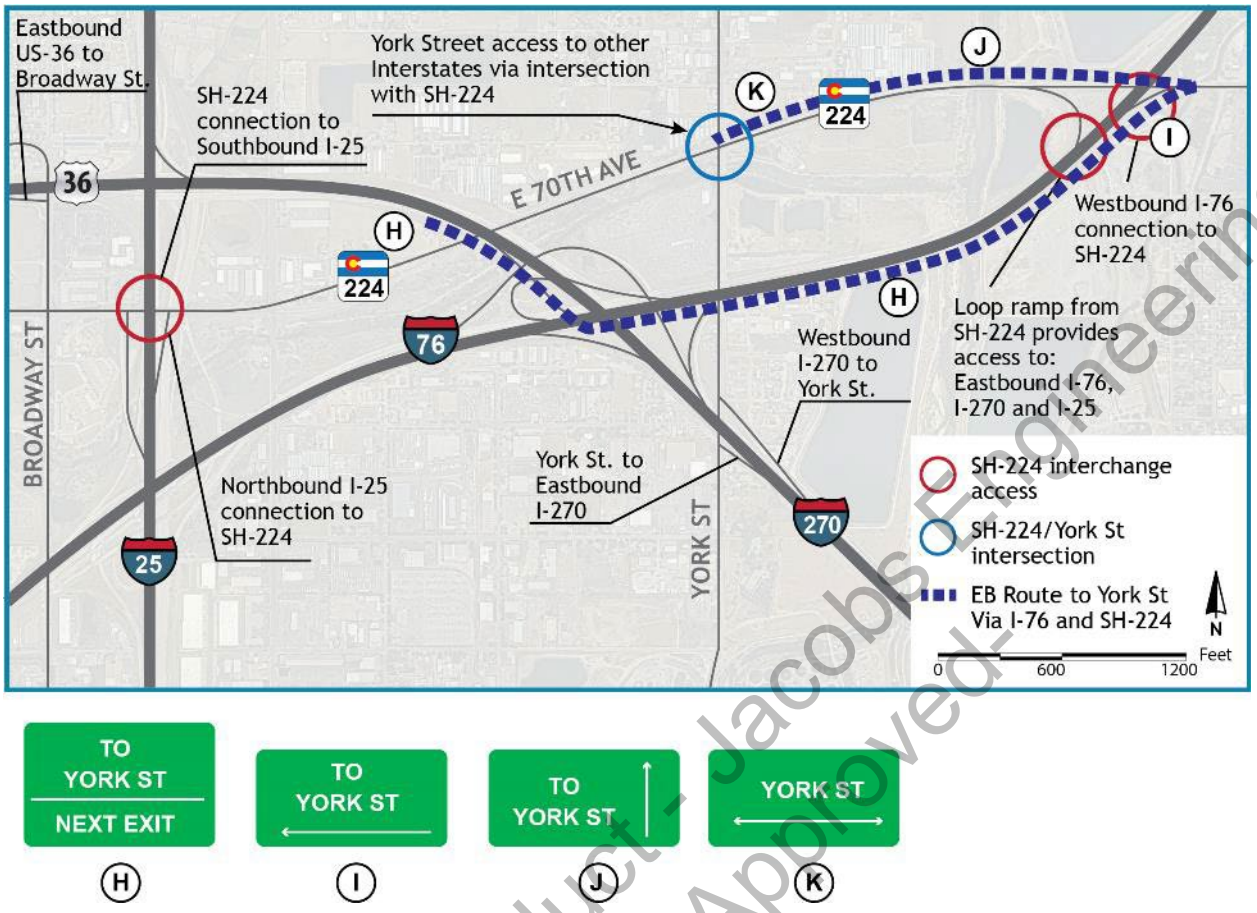

Figure 15. Signage Plan for Access to York Street via I-76 and SH-224
Source: Jacobs

7.0 Interchange 3: I-270/Vasquez Boulevard

The Vasquez Boulevard interchange with I-270 is an outdated four-leaf clover interchange. It is considered a partial interchange because it is missing one entrance ramp, the eastbound I-270 entrance ramp from northbound Vasquez Boulevard in the southeastern corner of the interchange. The interchange is to be reconfigured into a partial clover interchange by eliminating the tight radius exit loop ramps of the clover and reconstructing the exit ramps to tee into Vasquez Boulevard and terminate with signalized intersections. Ramp capacity and acceleration and deceleration improvements are also planned for the interchange.

The following subsections evaluate the safety, traffic operations, and environmental impacts of adding this missing ramp.

7.1 Missing Ramp from Vasquez Boulevard to Eastbound I-270

An eastbound connection at the I-270/Vasquez Boulevard interchange would alleviate travel delays on local networks. Considering that the ultimate destination of eastbound I-270 is eastbound I-70, then this ramp would provide quicker access to eastbound I-270/I-70 as many travelers currently head east on East 56th Avenue (or on Sand Creek Drive) and then proceed south on Quebec Street before eventually turning east onto I-70 (nearly 3 miles of local street). This trip could be shortened by providing an entrance ramp to eastbound I-270 from Vasquez Boulevard. Another way drivers currently make this maneuver is by navigating all three clover loop ramps to then travel to eastbound I-270. This will not be possible when the two exit loop ramps are removed.

Figure 16 shows the reconfigured interchange and a new eastbound I-270 entrance ramp from northbound Vasquez Boulevard (southeastern corner of interchange). The ramp would mirror the opposite ramp in the northwestern quadrant of the interchange except a new bridge would need to be constructed over East 56th Avenue to facilitate acceleration onto the mainline. The ramp would then merge into a parallel auxiliary lane that continues east of the merge for another 1,000 feet. The 2040 traffic forecasts demonstrate that adding the missing ramp from Vasquez Boulevard would generate a moderate demand for the ramp: 1,420 AADT, with 230 vehicles in the a.m. peak hour and 400 vehicles in the p.m. peak hour.

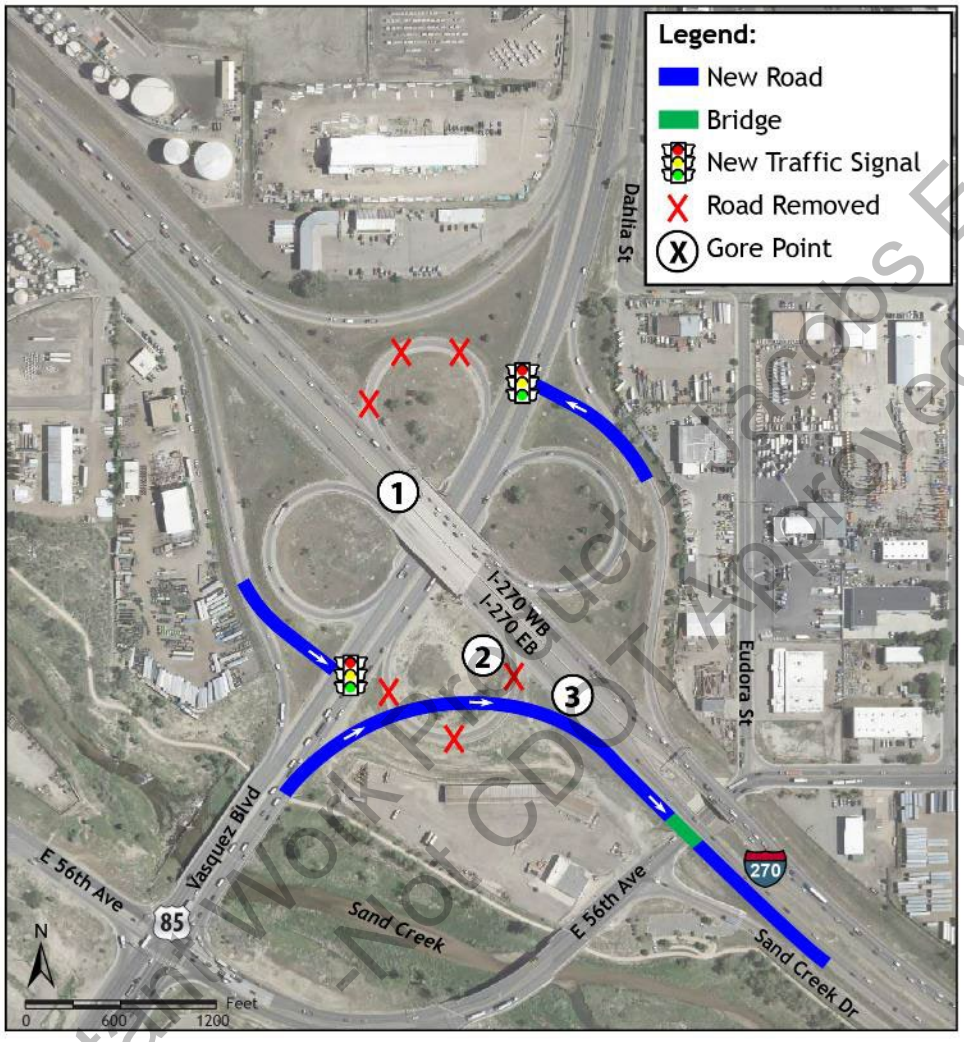

Figure 16. I-270/Vasquez Boulevard Interchange Reconfiguration
Source: Jacobs

7.1.1 Safety

The LOSS III for the eastbound section of I-270 is ranked fifth highest in the corridor when compared to other areas, and the westbound side of I-270 is ranked highest in the corridor with a LOSS of IV. The majority of the accidents in this section of the roadway are attributable to the short weave distance between entrance (GP 1) and exit (GP 2) loop ramps in the cloverleaf (GP 1 to GP 2 is 545 feet, Figure 16). This is substantiated by the overrepresentation of sideswipe same direction crashes over a period between 2014 and 2019 (*I-270 Existing Safety Conditions Report*, provided under separate cover for this project). Removing the exit ramps would improve safety for both directions of I-270. AASHTO does not provide a recommended distance for weave distance between clover-leaf loop ramps.

Adding the new entrance ramp in conjunction with proper acceleration and merge length would not create any safety concerns. The distance between GP 1 entrance ramp and the new GP 3 entrance ramp is more than 1,000 feet which meets the minimum length (AASHTO 2018). There are no obstacles to prevent design of the required acceleration and merge lengths onto eastbound I-270 and the nearest interchange (I-270/Quebec Street) is 2 miles away.

7.1.2 Traffic Operations

For this section of eastbound I-270, AADT is expected to be in excess of 54,000 vehicles while the peak traffic hours would carry 3,050 vehicles in the a.m. and 2,680 vehicles in the p.m. The 2040 traffic forecasts for adding the missing ramp from Vasquez Boulevard would increase mainline AADT by about 3 percent. Because the ramp would also be a metered entrance ramp during the heavier peak hours, traffic operations on the mainline would not be impacted by the addition of this ramp. This was verified when comparing the speed maps that showed negligible differences between the Build Alternative (with the ramp) with the No Action Alternative (without the ramp).

Currently bottlenecks are created on eastbound and westbound I-270 because of the short weaves between the clover-leaf ramps. Partial clover-leaf designs with entrance loops in opposite corners eliminate weaving sections and have been found by some states to be superior in traffic operations to other interchange types (AASHTO 2018).

7.1.3 Environmental

There are no environmental impacts with adding this missing ramp.

7.1.4 Conclusion

The missing ramp was evaluated and there were no constraints at this location to preclude adding the ramp. The ramp has minimal safety, traffic operations impacts and no environmental impacts. The missing ramp will mirror the other ramp in the northwest quadrant which helps with driver expectancy for the interchange. The ramp will provide additional interstate access for drivers heading east. Adding the ramp will meet the FHWA policy directive. This ramp is recommended to be installed.

Converting the interchange from a full clover-leaf to a partial clover-leaf design is preferred from a traffic operations and safety stand point. The reconfiguration does not impact the environment.

7.1.5 Mitigation

This ramp requires no mitigation.

8.0 Interchange 4: I-270/Quebec Street

The Quebec Street interchange with I-270 is considered a partial interchange because it is missing a westbound exit ramp and an eastbound entrance ramp.

The I-270/Quebec Street partial interchange is located roughly 6,000 feet from the I-70/I-270 interchange (that is, a merge/diverge location), which meets the criterion of 1-mile separation between urban interchanges (AASHTO 2018). The I-270/Quebec Street partial interchange is also located 1,900 feet from a full-service diamond interchange at I-70 and Quebec Street and does not meet the criterion of 1 mile separation between urban interchanges.

The geometric configuration of Quebec Street and I-270 freeway is not ideal; the roadways cross each other at about a 45-degree angle which complicates the geometry of the interchange, making the configuration of the ramps difficult. The topography, adjacent roadway facilities and the system-to-system connection between I-270 and I-70 impact the geometry and location of the ramps. The Sand Creek Drive frontage road and Sand Creek both parallel along the western side of I-270 where an eastbound exit ramp would normally belong. Because of the close proximity of Sand Creek Drive and Sand Creek, the existing eastbound I-270 exit ramp is designed as a far-side loop ramp terminating on the southern side of the

Quebec Street crossroad instead of a typical exit ramp terminating on the northern side. Instead of exiting before the Quebec Street bridge, eastbound traffic currently pass below the interchange bridge and make a U-turn or fishhook back to the Quebec Street intersection (Figure 17).

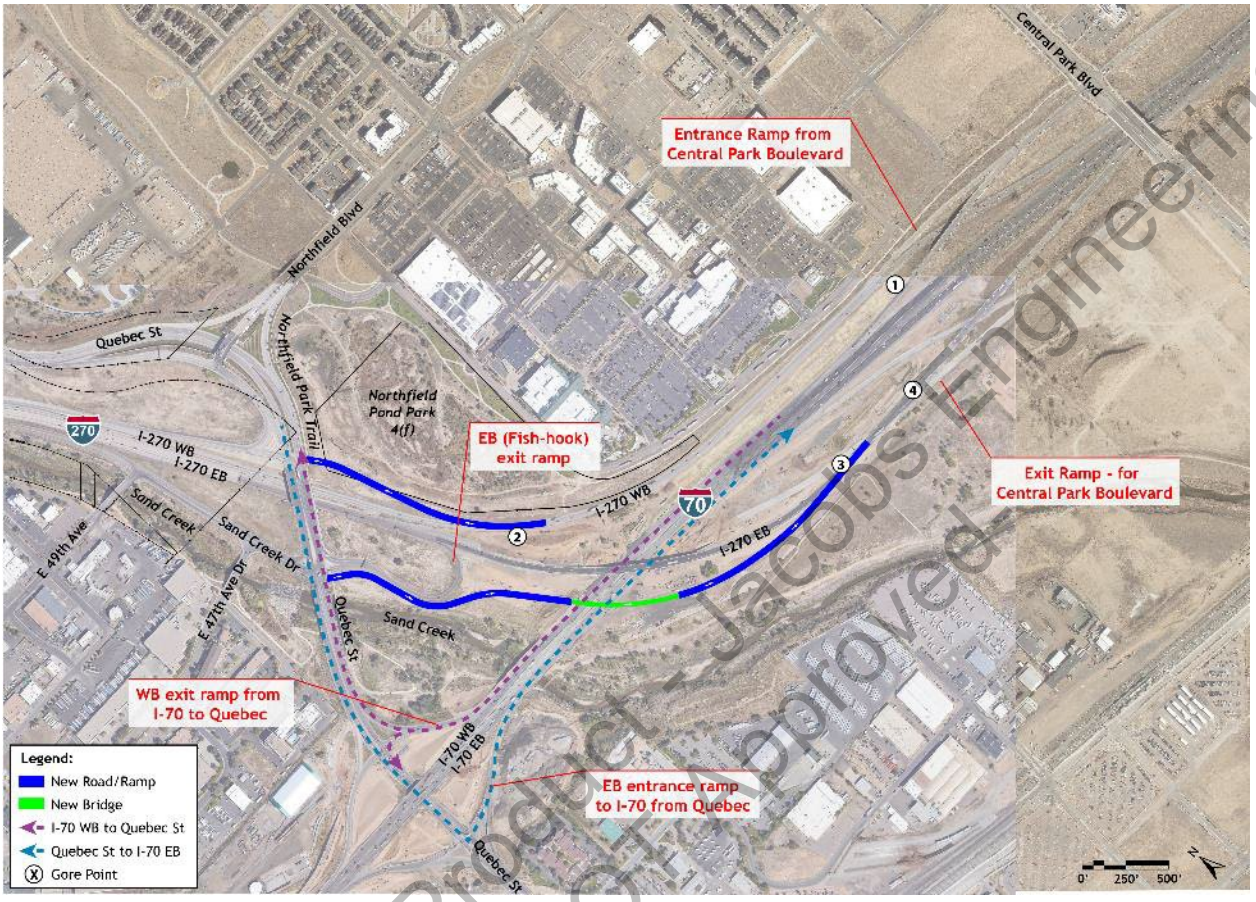

Figure 17. Westbound I-270 Exit Ramp to Quebec Street Relative to I-70/Quebec Street Interchange
Source: Jacobs

The Proposed Action for the I-270 Environmental Assessment involves ramp changes for the eastbound direction. The existing fishhook exit ramp would remain with minimal impact to the ramp; however, the eastbound deceleration lane for the far-side loop exit ramp would be lengthened an additional 2,500 feet from the existing exit ramp. The following sub-sections evaluate the safety, traffic operations, and environmental impact of adding the missing ramps.

8.1 Missing Ramp from Westbound I-270 to Quebec Street

Figure 17 shows the configuration and approximate location of a westbound I-270 exit ramp to Quebec Street (top-middle of figure). The 2040 traffic forecasts demonstrate that adding the westbound exit ramp to Quebec Street would generate modest demand for the ramp: 2,000 AADT, with 150 vehicles in the a.m. peak hour and 130 vehicles in the p.m. peak hour. The projected demand for the ramp is modest because there is currently a more intuitive alternative route. Traffic traveling on westbound I-70 currently exits Quebec Street at the I-70/Quebec Street interchange (dashed purple line on Figure 17). The I-70/Quebec Street ramps and I-270/I-70 ramps, where I-270 ends with I-70 (east of Central Park Boulevard bridge), are approximately a mile apart along I-70. Building a westbound I-270 exit ramp to Quebec Street would require traffic to exit I-70 for westbound I-270 and then proceed west and exit to Quebec Street across the Northfield Pond Park, creating a service ramp off a system ramp.

This double exit plan conflicts with the route continuity discussed in Section 5, and is difficult to sign and adequately guide the traveling public. The existing route is more logical and is achieved through one exit

ramp instead of two consecutive exit ramps. The current Quebec Street and I-70 interchange provides for the Quebec Street exit at a more intuitive location. Drivers that are unfamiliar with the area will have seen the signage for Quebec Street on I-70 ahead of the I-270 exit and will plan to use this existing signed route.

8.1.1 Safety

The section of I-270 where the new ramp would diverge functions as a system-to-system exit ramp from I-70 to I-270. In this same section is the Central Park Boulevard (CPB) service entrance ramp that merges on the northern side of westbound I-270 (GP 1 on Figure 17) approximately 2,400 feet before this new exit ramp (GP 2 on Figure 17). From 2014 through 2019, there is a documented overrepresentation of night-time and run-off-the-road crashes in the area. The high rate of accidents is hard to pinpoint because there is little evidence of sight distance issues or inadequate lighting. It could be related to unexpected westbound I-270 congestion (peak hour speeds range from 20 to 40 mph) encountered by high-speed traffic existing from I-70. Another potential cause of accidents is possibly related to the existing ramp braid; the CPB entrance ramp to westbound I-270 has a large elevation difference and lateral separation from I-270 and is not visible to the system-level I-270 traffic until the service level merges with the westbound through movements, which might cause the speed differentials within this section. Adding additional vehicles at this location is not advised due to this crash history.

The ramp spacing between GP 1 and GP 2 (shown on Figure 17) is more than adequate for AASHTO; however, the additional diverging maneuver from westbound I-270 and the exit ramp within a horizontal curve likely would contribute to additional speed differentials in this heavily congested section and increase safety risks.

8.1.2 Traffic Operations

The 2040 traffic projection on westbound I-270 in this section is approximately 44,000 AADT, with the CPB entrance ramp contributing 1,650 AADT; if the ramp were to be constructed, there would be nearly 2,000 AADT exiting the freeway at Quebec Street. There would be some degradations to peak hour speeds on westbound I-270 with the consecutive merging movement from the CPB entrance ramp and then a diverging movement for the new ramp. For 2040, running speeds on westbound I-270 range from 20 mph to 40 mph for the morning and afternoon peak hours, while farther west of Quebec Street where the Quebec Street entrance ramp merges onto westbound I-270, running speeds drop to as low as 10 mph. This is already a high area of traffic congestion and unexpected bottlenecks. Adding the missing ramp will slightly diminish the traffic operations with traffic slowing for the diverge to the exit.

This new ramp would be difficult to sign because I-70 is already advanced signed for the Quebec Street exit via I-70. Additional signage in this area for the new exit ramp could lead to driver confusion and create unexpected lane changes.

The I-70/Quebec Street interchange has recently been reconstructed and widened to handle the future traffic demands for Quebec Street. Adding this missing ramp is just providing redundant access.

8.1.3 Environmental

A new westbound exit ramp from I-270 to Quebec Street could be provided, but it would result in use of the 4(f)-designated Northfield Pond Park (Park and Wildlife) property owned by the City and County of Denver. Constructing this ramp at Quebec Street would also interrupt the Northfield Park trail system (Figure 17), an integral multimodal link to the Sand Creek Regional Trail.

8.1.4 Conclusion

The construction of the westbound I-270 to Quebec Street is geometrically feasible but should not be constructed based on the fact this access will be confusing and redundant as well as concerns for the safety and environmental effects. The geometric layout of the ramp is not complex and would not

drastically impact the existing traffic movements on I-270; it would have an effect on the existing high-crash accident rate in the section. However, the ramp necessitates using the adjacent 4(f) recreational area, which is highly undesirable. If the movement is accommodated at the adjacent I-70 and Quebec Street, it does not seem reasonable to construct a redundant route through a 4(f) recreational property that would also be difficult to sign on I-70 and prevent confusion.

The proposed project construction does not preclude this missing ramp from being further re-evaluated and possibly constructed in the future if conditions change.

8.1.5 Mitigation

Because the exit ramp at I-70 and Quebec Street has been upgraded, there are no proposed mitigation measures for this missing ramp.

8.2 Missing Ramp from Quebec Street to Eastbound I-270

The other missing movement at this interchange is the eastbound entrance ramp from Quebec Street to I-270. This on-ramp would parallel the southern limits of the existing fishhook ramp before raising grade and bridging over I-70 to tie into eastbound I-270 before CPB (Figure 18).

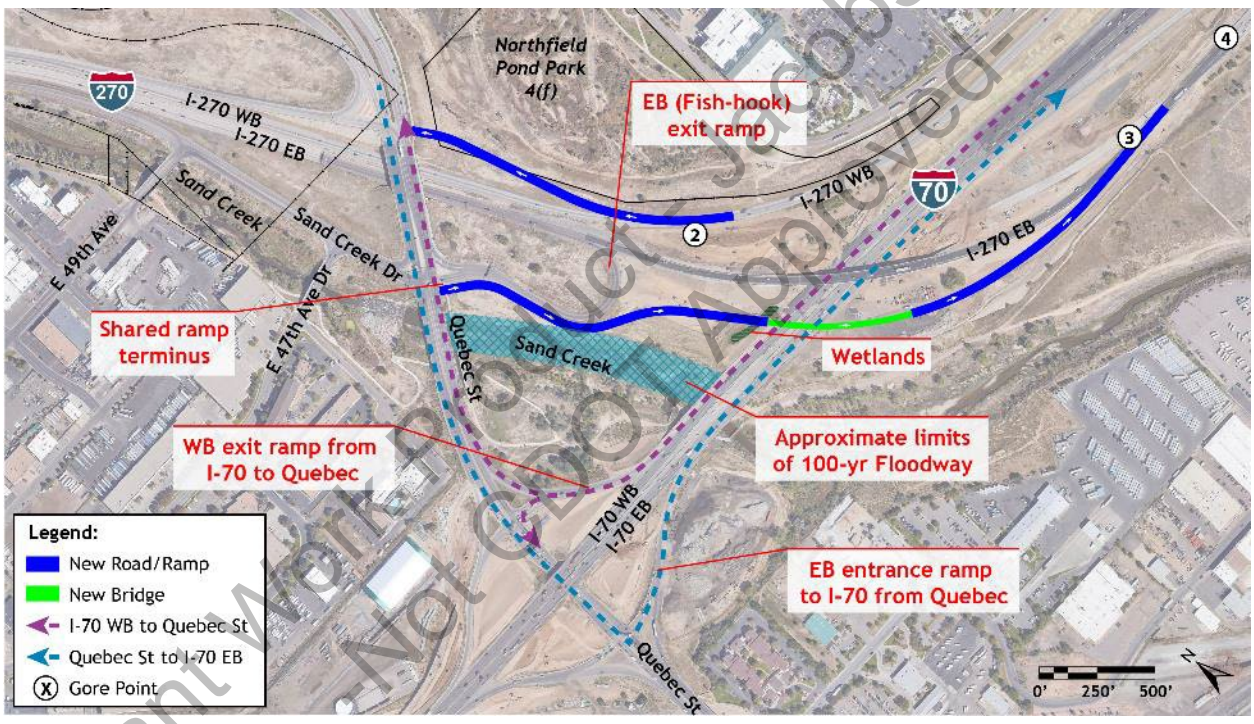

Figure 18. Eastbound Entrance Ramp to I-270/I-70 Relative to I-70/Quebec Street Interchange
Source: Jacobs

Because of the terrain, conflict with I-70, and the need for a new bridge, the new ramp would be almost 3,000 feet long. Traffic would cross over the interstate and then come down to the existing ground elevation before it merges with I-270 eastbound (near GP 3 on Figure 17). The point of merge is at the fork location, where I-270 splits into two ramps (near GP 4 on Figure 17)—one system-level ramp that connects I-270 with eastbound I-70 (where I-270 ends) and a service-level ramp that connects I-270 with CPB. A new 650-foot-long ramp bridge would need to be constructed over I-70 to span existing and future widening of I-70, because the existing bridge (over I-70) cannot be widened. The new bridge would run parallel to the existing eastbound I-270 bridge over I-70. This design would create a quick merge and diverge with eastbound I-270.

Traffic forecasts demonstrate that adding the eastbound entrance ramp from Quebec Street showed strong demand for the ramp in 2040: 4,800 AADT with 530 vehicles in the a.m. peak hour and 590

vehicles in the p.m. peak hour. However, this strong demand is just being moved from the existing I-70/Quebec Street on-ramp (1,900 feet away) to this ramp.

The ramp would be a redundant addition to the overall system of interchanges in this area. Traffic coming from south Quebec Street that needs to proceed eastbound on I-70 would still use the I-70 and Quebec Street interchange and is unlikely to travel farther north to the Quebec Street and eastbound I-270 entrance ramp. Any traffic coming from north Quebec Street and adjacent neighborhoods can also use the existing I-70 and Quebec Street interchange (dashed cyan line on Figure 18), which is the current access route. This ramp would serve the same function as the recently upgraded Quebec Street to eastbound I-70 on-ramp. Upgrades involved adding storage lane capacity and signal upgrades on Quebec street.

Because of the complex geometry of the ramp, traffic would likely favor the existing facility.

8.2.1 Safety

The ramp design would be similar to a partial clover design, with a shared ramp terminus at the Quebec Street crossroad. Studies show that shared ramp terminuses that tee at two-way crossroads (as shown on Figure 18) pose a safety hazard because they are conducive to wrong-way entry on the exit ramp (AASHTO 2018). To facilitate the new eastbound entrance ramp, changes would be needed along Quebec Street, and a new southbound left-turn lane pocket would need to be added on Quebec Street at the intersection to provide access to the new entrance ramp, thereby introducing a new signal phase and another intersection conflict point in an area with many other conflict points.

Because the I-270 splits into eastbound and westbound roadway east of the Quebec Street interchange and merges with I-70, it is not clear where the freeway ends and the system-to-system ramp begins. It can be argued that the segment east of the fishhook ramp gore on eastbound I-270 no longer functions as a freeway, but as a system-to-system ramp. There might be some driver confusion associated with a quick transition from freeway to a system-level ramp, and introducing the new service level ramp. The previous sections discussed the disadvantages of overlapping routes in urban interchanges setting. The combining of the higher speed system-to-system and slower speed service ramps would lead to increased speed differentials that could contribute to increased crashes between GP 3 and GP 4, a distance of 500 feet (Figure 18). Further, the ramp would merge with through traffic near GP 3 and add another weave in this section of roadway and increase the potential for sideswipe collisions. Because of the proximity of the CPB crossroad relative to this new ramp merge (GP 3), there is not enough distance to safely merge and diverge traffic.

8.2.2 Traffic

Traffic forecasts demonstrate a strong demand for the ramp; however, this demand mostly reflects shifting a portion of traffic from the existing eastbound I-70/Quebec Street entrance ramp (1,900 feet away) to this new ramp. The new ramp will serve most existing eastbound I-70/Quebec Street entrance ramp traffic, which originates to the north of the existing ramp; existing entrance ramp traffic that originates from the south of the existing ramp is anticipated to maintain the same route.

AASHTO recommends 1,600 feet minimum separation between successive interchange ramp terminals (AASHTO 2018). Figure 18 shows a distance of about 500 feet between the new ramp entrance (GP 3 on Figure 18) and the exit ramp to CPB (GP 4 on Figure 18). The ramp would then merge with eastbound I-270 just before a right-side service exit ramp for CPB. Geometrically, there is not enough room to develop a proper entrance-to-exit weave distance between these ramps, thereby creating an unsafe and highly congested weaving condition that will bottleneck both the system-to-system and service ramps. The lack of adequate spacing between entrance and exit ramps also directly affects decision sight distance, as drivers need time and space to switch lanes.

The Quebec Street entrance ramp to eastbound I-70 is a metered ramp that helps control the traffic flow onto I-70 while the I-270 to I-70 system-to-system ramp is free-flow. Because Quebec Street traffic would shift to this new ramp, there would be a redistribution of uncontrolled traffic that negatively affects I-70 traffic operations.

The intersection for the I-270 exit ramp, Quebec Street, and Sand Creek Drive currently is operating at level of service (LOS) D in the a.m. peak hour and LOS E in the p.m. peak hour (Jacobs 2021b). As noted previously, a new southbound left-turn lane pocket on Quebec Street would need to be added at the intersection to provide access to the new entrance ramp, thereby introducing a new signal phase and additional delay on Quebec Street travelers. In addition to creating a southbound left-turn pocket on Quebec Street, the outside northbound lane approaching the reconfigured intersection would need to be converted to a right-turn/through lane or a new dedicated right-turn lane would need to be added, resulting in the widening of the Quebec Street bridge over Sand Creek.

Although southbound traffic will be removed from the I-70/Quebec Street interchange, the addition of this ramp will impose higher delays on northbound traffic at the intersection of the I-270 exit ramp, Quebec Street, and Sand Creek Drive. Higher delays result in higher likelihood of queue spillbacks to the south, which would adversely impact the I-70/Quebec Street interchange. Although the primary appeal of this ramp is to alleviate congestion at I-70/Quebec Street interchange, additional changes associated with this rerouting may have an overall negative effect on local traffic.

8.2.3 Environmental

The proximity of the eastbound entrance ramp from Quebec Street relative to Sand Creek as well as Quebec Street bridge widening means there would be impacts to both the floodway and floodplain. Placing additional embankment within a floodway can only be done if it does not cause a rise to the 100-year base flood elevation. Otherwise, a Conditional Letter of Map Revision (CLOMR) would be needed to analyze the effects of building this ramp and widening the bridge. There are also expected to be wetland impacts within this area as depicted on Figure 18.

8.2.4 Conclusion

The eastbound entrance ramp from Quebec Street to I-270 should not be constructed because of the impacts to I-70 and Quebec Street operations, environmental impacts, and the inability to construct a safe merge at the end of the ramp. The topography combined with the current geometry of the existing ramps and interstates results in a winding unorthodox geometric layout for the ramp.

The Quebec Street/I-70 interchange and the I-270/I-70 interchange are spaced approximately 6,000 feet apart along I-270, and the layout for the I-270/I-70 interchange is designed to facilitate westbound and eastbound movements between the two interstates. Because the ultimate destination for eastbound I-270 is eastbound I-70, an eastbound entrance ramp from Quebec Street to I-270 is not necessary because that movement is already provided at the full-movement interchange at I-70 and Quebec Street. The I-70/Quebec Street interchange has been reconstructed with the Central I-70 project and will continue to serve increased volumes in the future and also improve safety at the interchange. The interchange added increased lane capacity and improved signage and pavement markings as well as installed new traffic signals with protected left-turn-only phases for southbound Quebec Street traffic turning onto eastbound I-70.

The proposed project construction does not preclude this missing ramp from being further re-evaluated and possibly constructed in the future if conditions change.

8.2.5 Mitigation

The way finding and upgraded sign plan for the I-70 project will drastically improve traffic operations for the area. As a mitigation measure to the missing ramp, supplemental signage for exit ramps and along Quebec Street will be provided to easily direct traffic to the nearby interstate routes (Figure 19).

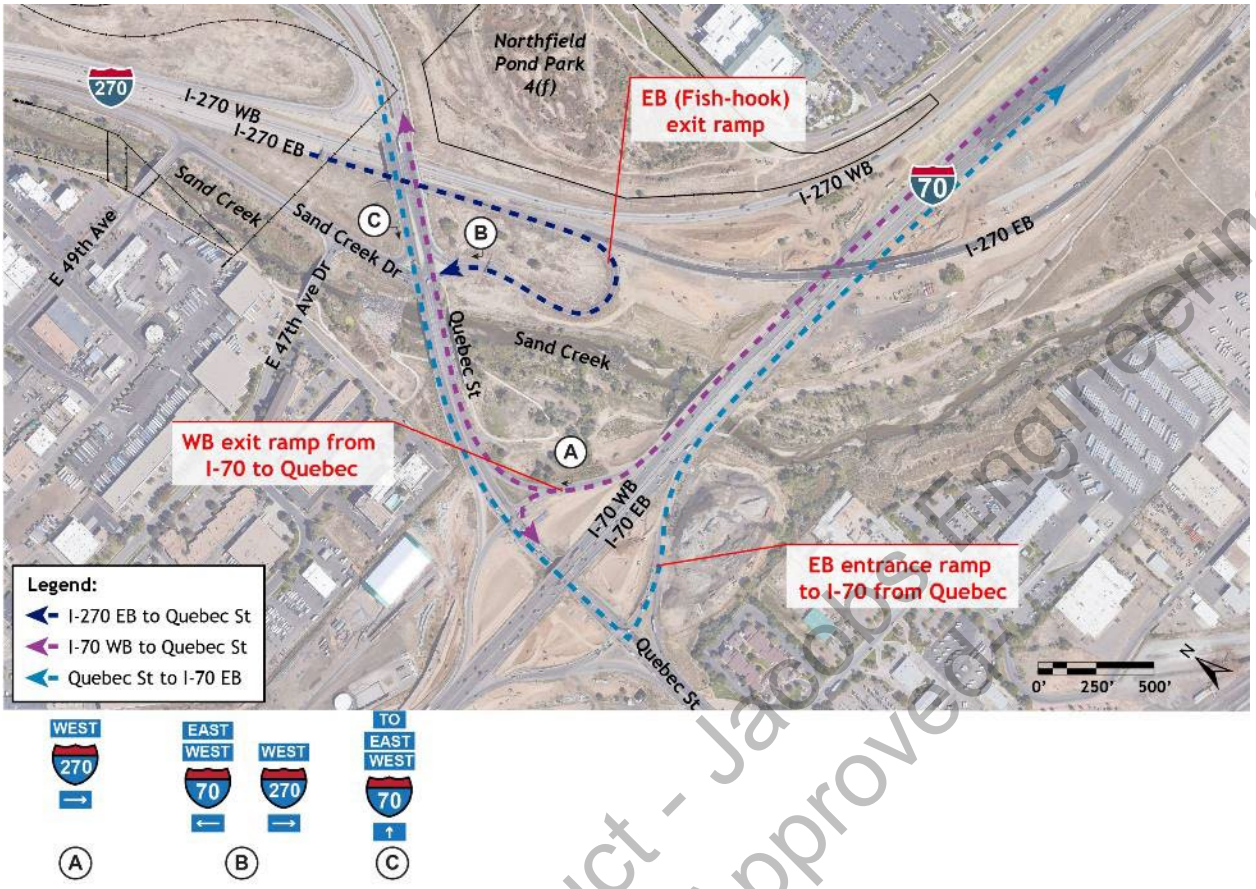

Figure 19. Signage Plan for Access to Interstates near Quebec Street
Source: Jacobs

9.0 Summary

Adding additional ramps can be justified by compelling demand in combination with no adverse impacts to the existing roadway system.

The I-76, I-270, and I-25 interchange has many system-to-system ramps in a busy location, and providing the two missing ramps for I-270/I-76 would overcomplicate the system by providing a redundant connection that would only benefit those needing to make a U-turn.

With the proximity and geometry of the York Street crossroad to I-76, adding the currently missing entrance and exit ramps into the middle of a system-to-system interchange would cause safety and traffic issues.

The Quebec Street location is near the southern limit of I-270, and all movements are coming from or going to I-70, which has full-interchange access ramps at I-70 and Quebec Street. Where appropriate, mitigation measures are offered in lieu of the missing ramp.

At the I-270 and Vasquez Boulevard interchange, there is a demand for and no real obstacles to adding the missing eastbound ramp. Notably, it does not overlap any other interchanges and thereby has no adverse effects on traffic, safety, or the environment. The missing movement at this location is recommended.

10.0 References

American Association of State Highway and Transportation Officials (AASHTO). 2014. *Highway Safety Manual*. Washington DC. Supplement (includes Chapters 18-19 and Appendix B to Part C).

American Association of State Highway and Transportation Officials (AASHTO). 2016. *A Policy on Design Standards - Interstate System*. 6th Edition. May.

American Association of State Highway and Transportation Officials (AASHTO). 2018. *A Policy on Geometric Design of Highways and Streets*. 7th Edition. January.

Colorado Department of Transportation (CDOT). 2016. *Urban Four-Lane Divided Freeway SPF*. https://www.codot.gov/safety/traffic-safety/programs-and-analysis/analysis.

Colorado High Performance Transportation Enterprise (HPTE). 2020. *Express Lanes Master Plan*. February.

Federal Highway Administration. 2011. *Level of Service of Safety and Diagnostic Analysis, HSIP Noteworthy Practices Series*. Federal Highway Administration, Washington, DC.

Jacobs. 2021a. *I-270 Existing Safety Conditions Report*. Prepared for CDOT Region 1. May.

Jacobs. 2021b. *Traffic Technical Report*. Prepared for CDOT Region 1. June.

Transportation Research Board (TRB). 2016. *Highway Capacity Manual: A Guide for Multimodal Mobility Analysis.* 6th Edition. Vol. 2.