May 14, 2024

I-25/Happy Canyon Road

Interchange Alternatives Analysis

I-25/Happy Canyon Road Pre-NEPA Traffic Study
Castle Pines, CO
211027901

I-25/Happy Canyon Road Interchange Alternatives Analysis

I-25/Happy Canyon Road Pre-NEPA Traffic Study
Castle Pines, CO
2110027901

May 14, 2024

Prepared by

WILSON & COMPANY

5755 Mark Dabling Boulevard, Suite 100
Colorado Springs, Colorado 80919
719-302-6752

Table of Contents

List of Tables

List of Figures

List of Acronyms and Definitions

Acronym/ Term	Definition
AM	Refers to the morning weekday peak traffic period, which includes primarily work and school trips.
ADT	**Average Daily Traffic:** The amount of vehicular traffic that crosses an imaginary line across a roadway in a 24-hour period. ADT information typically includes both directions of vehicle travel (if on a two-way street).).
AWDT	**Average Weekday Daily Traffic:** When the term ADT is used specifically to mean typical weekday traffic, it is often called AWDT.
AWSC	**All-Way Stop Controlled:** All intersection approaches are controlled by STOP signs.
C	**Calibration Factor**
CDOT	**Colorado Department of Transportation:** CDOT has jurisdiction over Colorado's State Highway System, including facilities within the project study area.
CMF	**Crash Modification Factor**
CRF	**Crash Reduction Factor**
DDI	**Diverging Diamond Interchange**
DRCOG	**Denver Regional Council of Governments:** The Denver Regional Council of Governments is a voluntary organization of municipal and county governments serving as the federally mandated Metropolitan Planning Organization serving Adams, Arapahoe, Boulder, Clear Creek, Douglas, Gilpin and Jefferson counties, the City and County of Denver, the City and County of Broomfield and southwest Weld County.
DU	**Dwelling Unit**
Gap in Traffic	A gap in traffic is the space between vehicles approaching the pedestrian crossing. Gaps are typically measured in seconds, not distance, as it is the length of the gap in time in which a pedestrian must be able to cross the street. A directional gap is the gap between vehicles approaching in a single direction. A directional gap can be measured between vehicles in a single lane, or between vehicles approaching in the same direction but in different lanes on a multi-lane approach. If there is no median refuge at the crossing, a pedestrian will need to find an acceptable gap in traffic approaching from two directions at once. This is much more challenging than finding a gap in each approach direction separately.
EB	**Eastbound:** Refers to one-way traffic flowing from the east to the west (e.g., from Castle Rock towards Parker), and the lanes that carry such traffic.
FHWA	**Federal Highway Administration**
Hazmat	Hazardous material
HCM	**Highway Capacity Manual:** A publication of the U.S. Transportation Research Board of the National Academies of Science. It contains concepts, guidelines, and computational procedures for computing the capacity and quality of service of various highway facilities, including freeways, highways, arterial roads, roundabouts, signalized and unsignalized intersections, rural highways, and the effects of mass transit, pedestrians, and bicycles on the performance of these systems. The *Highway Capacity Manual, Sixth Edition: A Guide for Multimodal Mobility Analysis* (HCM6) was used as part of this study.

IAR	**Interchange Access Request:** Demonstration that a project is needed and advisable based on safety, operational and engineering criteria.
IHSDM	Interactive Highway Safety Design Model
INRIX	Private Company that provides location-based data and software-as-a-service analytics
ISA	**Initial Site Assessment**
KSF	**Thousand Square Feet**
Lane	A portion of the roadway surface designated for motor vehicle travel, typically in a single direction, which is delineated by pavement marking stripes. Types of lanes include: "through lanes" for travel along the length of the roadway, often through intersections; "turn lanes," which are typically on intersection approaches and provide space for left- or right-turning motorists; "bike lanes," which are designated for bicycle travel in the same direction as the automobile travel, are typically narrower than vehicle lanes, and are usually located along the outside edges of the roadway.
LT	**Left Turn:** Refers to traffic that turns left at an intersection, often using a designated left-turn lane and sometimes afforded a dedicated left-turn phase in traffic signal timing.
LOS	**Level of Service:** A qualitative measure used to relate the quality of traffic service. LOS is used to analyze highways by categorizing traffic flow and assigning quality levels of traffic based on performance measure like speed, density, etc.
MPO	**Metropolitan Planning Organization:** A federally mandated and federally funded transportation policy-making organization that is composed of representatives from local government and governmental transportation authorities. MPOs were introduced by the Federal-Aid Highway Act of 1962, which required the formation of an MPO for any urbanized area with more than 50,000 residents.
MSF	**Million Square Feet**
NCRHP	**National Cooperative Highway Research Program:** A forum for coordinated and collaborative research, addressing issues integral to the state Departments of Transportation and transportation professionals at all levels of government and the private sector.
NB	**Northbound:** Refers to traffic flowing from the south toward the north, and the lanes that carry such traffic.
NEPA	**National Environmental Policy Act**
NCRHP	**National Cooperative Highway Research Program:** A forum for coordinated and collaborative research, addressing issues integral to the state Departments of Transportation and transportation professionals at all levels of government and the private sector.
OTIS	**Online Transportation Information System:** A publicly available website maintained by the Colorado Department of Transportation, providing information on current and projected traffic volumes, state highway attributes, summary roadway statistics, demographics, and geographic data. It was used in this study as a data source for historical trends-based annual and 20-year traffic growth factors.
PD	Planned Development
PDO	Property Damage Only
PM	Refers to the afternoon/evening weekday peak traffic period, which includes work trips plus other trip types.

RBT	**Roundabout:** A type of circular intersection or junction in which road traffic is permitted to flow in one direction around a central island, and priority is typically given to traffic already in the junction
RIRO	**Right-In/Right-Out:** Refers to a condition in which only partial access to land adjacent to a roadway is allowed only by right turns to/from the roadway.
ROW	**Right-of Way:** Public Road right-of-way refers to an area of land, the right to possession of which is secured or reserved by the state or a governmental subdivision for roadway purposes.
RT	**Right Turn:** Refers to traffic that turns right at an intersection, sometimes using a designated right-turn lane.
RTD	**Denver Regional Transportation District**
RTP	**Regional Transportation Plan:** The long-range (20-year) multimodal transportation plan completed by the MPO and updated on a 4 to 5-year cycle as part of the federally mandated and federally funded regional transportation planning.
SB	**Southbound:** Refers to traffic flowing from the north toward the south, and the lanes that carry such traffic.
SPF	**Safety Performance Factor**
SPUI	**Single Point Urban Interchange**
TDM	**Travel Demand Management:** Refers to strategies to reduce single occupant vehicle travel, including telecommuting, public transit options, micromobility options, congestion pricing, mixed use development, etc.
Through/Right Turn	Refers to traffic (and the lane that carries it) at an intersection that is continuing forward straight through without turning, together with traffic that turns right at the intersection.
TIS	T**raffic Impact Study:** an analysis conducted in support of access permit and/or development entitlement approvals.
TWSC	**Two-Way Stop Controlled:** Cross street minor approaches are controlled by STOP signs.
Turning-Movement Counts (TMC)	Traffic counts for a given time interval that specify how many vehicles turn left or right, as well as counting vehicles that proceed straight forward through the intersection.
V/C Ratio	**Volume-to-Capacity Ratio:** Measures roadway level of congestion, or degree of saturation, by dividing the existing or future volume of traffic by the capacity of roadway.
VISSIM	Microscopic multi-modal traffic flow simulation software.
VPD	**Vehicles Per Day**
VPH	**Vehicles Per Hour**
Vehicle Queue	A line of stopped vehicles in a single travel lane, commonly caused by traffic control at an intersection.
WB	**Westbound:** Refers to one-way traffic flowing from the east to the west (e.g., from Parker towards Castle Rock), and the lanes that carry such traffic.

Executive Summary

Purpose

This technical memorandum describes the supporting data, methodology and assumptions used and the results of traffic operations analysis for proposed improvements to the I-25/Happy Canyon Road interchange. Traffic operations were evaluated for existing conditions, 2050 conditions without improvements to the interchange, and 2050 conditions for three alternative interchange configurations. A diverging diamond interchange configuration was selected as the recommended alternative to be advanced for NEPA clearance and the 1601/Interchange Access Request approvals.

This technical memorandum also addresses cost sharing for construction of the improvements. The cost sharing analysis incorporates development agreement obligations and is supported by analysis of traffic shares that will use and benefit from the improved interchange.

Alternatives Analysis

No Action Alternative

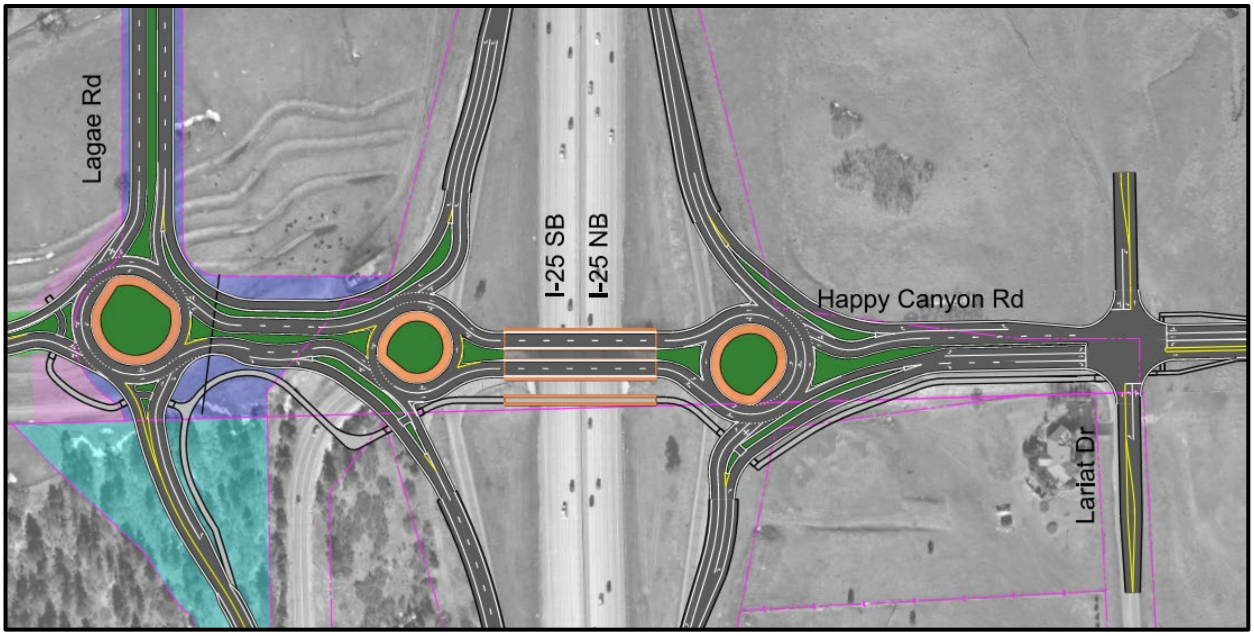
The 2050 No Action alternative levels of service for the intersections within the study area are summarized below. The delay and level of service values shown in the table are based on the average of 15 runs of the VISSIM 2050 No Action models. These analysis results show that, with increased 2050 traffic flows and without significant improvement to the I-25/Happy Canyon interchange, multiple intersections within the study area would operate at LOS E or F during the peak hours.

No Action Alternative Traffic Operations Analysis Summary

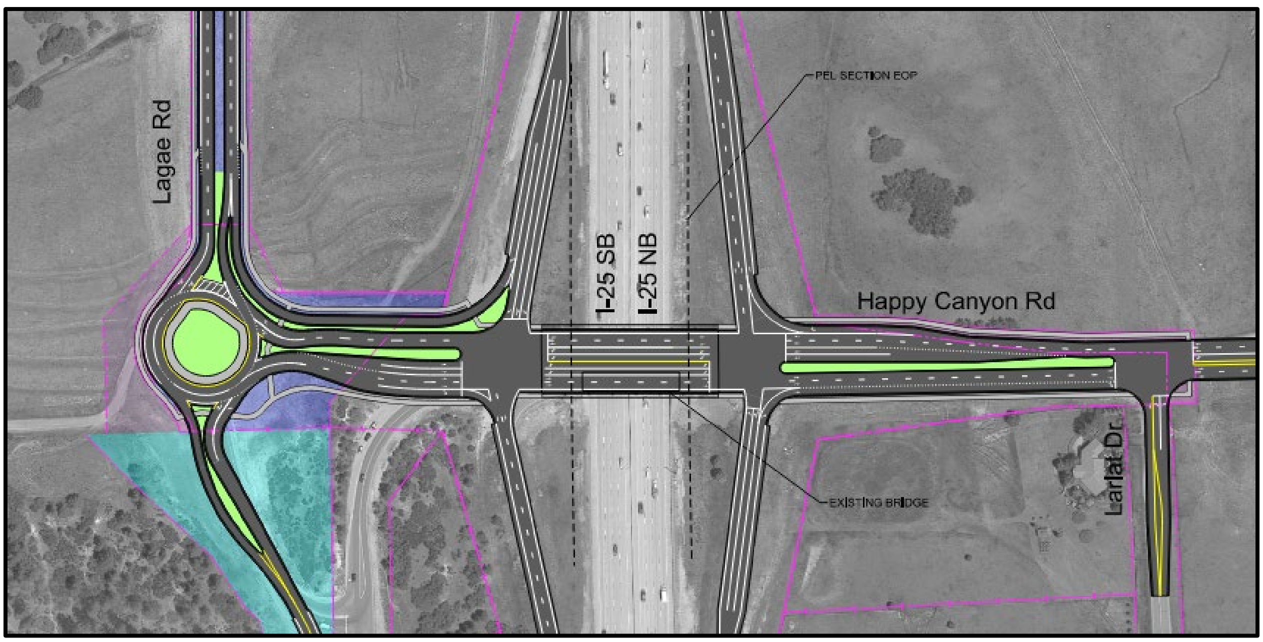
Control	Intersection	LOS/Delay [in seconds/vehicle] (Critical Movement)	
		AM Peak Hour	**PM Peak Hour**
Roundabout	Castle Rock Pkwy & I-25 SB	**B** / 14.0	**A** / 6.5
Roundabout	Happy Canyon Rd & Lagae Rd	**D** / 32.3	**F** / 53.9
Signal	Happy Canyon Rd & I-25 SB	**D** / 41.9	**D** / 52.7
Signal	Happy Canyon Rd & I-25 NB	**F** / 86.7	**F** / 107.6
Signal	Castle Pines Pkwy & I-25 SB	**E** / 60.0	**D** / 44.8
Signal	Castle Pines Pkwy & I-25 NB	**B** / 12.1	**B** / 15.1

Build Alternatives

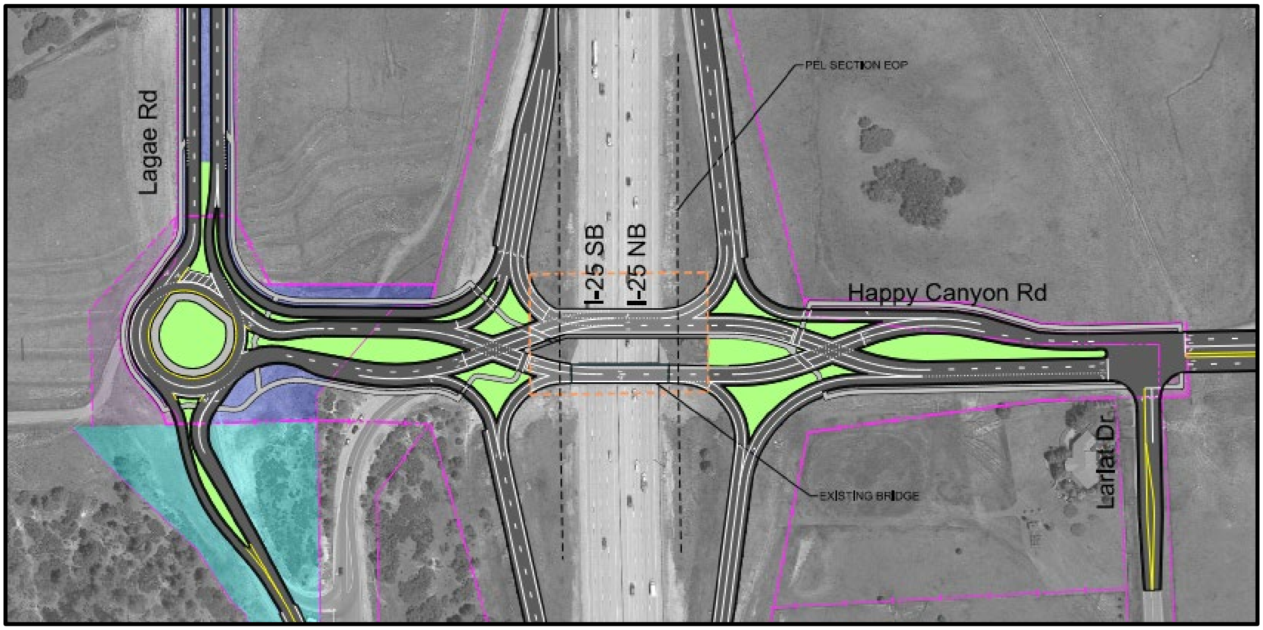
Initially two alternatives were evaluated, a roundabout interchange and a signalized diamond interchange. The roundabout interchange alternative failed to accommodate the heavy traffic volumes at the ramp termini which led to extremely long delays and queues. As a result of the poor performance of the roundabout diamond interchange, a diverging diamond interchange was proposed to replace the roundabout diamond interchange alternative for full traffic analysis. Conceptual layouts of all three build alternatives are shown on the following pages.



Roundabout Interchange Alternative – Conceptual Layout



Signalized Diamond Interchange Alternative – Conceptual Layout



Diverging Diamond Interchange Alternative – Conceptual Layout

Analysis results for all three build alternatives are summarized below. The results show long delays and failing LOS for the roundabout interchange alternative and more efficient operation of the diverging diamond interchange alternative compared to the signalized diamond interchange as demonstrated by the better LOS and less delay at the I-25/Happy Canyon Road ramp intersections.

Build Alternatives Traffic Operations Analysis Summary

Control	Intersection	LOS/Delay [in seconds/vehicle] (Critical Movement)			
		Signalized Diamond Interchange		Diverging Diamond Interchange	
		AM Peak	PM Peak	AM Peak	PM Peak
RBT	Castle Rock Pkwy/I-25 SB	A / 9.9	A / 6.6	A / 9.7	A / 6.5
RBT	Happy Canyon/Lagae	A / 8.2	A / 9.8	A / 7.3	A / 8.7
Signal	Happy Canyon/I-25 SB	C / 21.9	C / 22.4	A / 9.6	B / 10.2
Signal	Happy Canyon/I-25 NB	B / 17.1	B / 12.4	A / 8.5	A / 6.1
Signal	Castle Pines Pkwy/I-25 SB	D / 40.6	C / 25.9	D / 41.2	C / 25.8
Signal	Castle Pines Pkwy/I-25 NB	A / 9.3	A / 8.4	A / 9.4	A / 8.4
Approach	**Intersection**	**LOS/Delay [in seconds/vehicle] (Critical Movement)**			
		Roundabout Interchange			
		Rodel Analysis		**HCS 8.1 Analysis**	
		AM Peak	**PM Peak**	**AM Peak**	**PM Peak**
Eastbound	Happy Canyon/I-25 SB	A / 8.8	C / 19.4	F / 82.5	F / 374.2
Westbound	Happy Canyon/I-25 SB	A / 9.2	A / 8.0	A / 7.2	A / 6.8
Southbound	Happy Canyon/I-25 SB	C / 17.9	E / 48.6	F / 422.9	F / 776.7
Eastbound	Happy Canyon/I-25 NB	A / 8.5	B / 12.1	A / 8.2	B / 10.5
Westbound	Happy Canyon/I-25 NB	A / 6.5	A / 6.0	F / 1046.3	F / 906.9
Northbound	Happy Canyon/I-25 NB	A / 6.6	B / 11.0	F / 77.8	F / 364.8

Recommended Alternative

The No Action alternative is unable to accommodate the forecasted 2050 traffic volumes without significant delays and failing LOS due to the failing operations at the I-25/Happy Canyon Road interchange. However, both the signalized diamond interchange alternative and diverging diamond interchange alternative are shown to fully accommodate the forecasted 2050 traffic volumes without significant vehicle queues or delays. The analysis showed that the diverging diamond interchange is expected to operate more efficiently than the signalized diamond interchange demonstrated by the better LOS and less delay at the I-25/Happy Canyon Road ramp termini intersections.

Traffic Distribution Analysis

Large-scale development project entitlements have been approved within the study area that will use the I-25/Happy Canyon Road interchange as a primary or secondary access to I-25. As shown in Table 17, at buildout, these developments will add approximately 6,540 residential units and 2.7 million square feet of commercial uses to the study area. Together these developments will generate 125,890 daily trips and will play a significant role in triggering the need for improvements to the I-25 interchanges as well as other elements of the regional roadway network.

Development agreements for The Canyons and Castle Pines Town Center development agreements include cost sharing responsibilities for improvements to the I-25/Happy Canyon interchange. Selected requirements of the development agreements include responsibility for improvements such as ramp metering and ramp terminal intersection signalization. Other development agreement funding responsibilities are predicated on cost sharing for larger improvement costs based on estimated shares of traffic that will use the interchange, including shares of regional traffic and shares of site-generated development traffic attributed to either The Canyons or Castle Pines Town Center.

An analysis of the distribution of background regional traffic and site-generated traffic demonstrated that 47% of the 2050 design year traffic can be expected to consist of regional background traffic, and that of the remaining 53% of the traffic using the interchange, 34% and 19% is expected to be generated by The Canyons development and the Castle Pines Town Center development, respectively.

Purpose

This technical memorandum describes the supporting data, methodology and assumptions used and the results of traffic operations analysis for proposed improvements to the I-25/Happy Canyon Road interchange. Traffic operations were evaluated for existing conditions, 2050 conditions without improvements to the interchange, and 2050 conditions for three alternative interchange configurations.

This technical memorandum also addresses cost sharing for construction of the improvements. The cost sharing analysis incorporates development agreement obligations and is supported by analysis of traffic shares that will use and benefit from the improved interchange.

Analysis Area

The extents of the area to be included in the microsimulation models were selected to include the adjacent interchanges and freeway mainline between those interchanges as well as all arterial intersections and freeway elements with potential to be impacted by or impact the interchanges and interchange ramp terminal intersections and I-25/Happy Canyon Road interchange. Consistent with these criteria, the extents of the area included in this study extend from the I-25 mainline north of the Castle Pines Parkway interchange to south of the Castle Rock Parkway interchange and all ramp terminal intersections associated with these areas of freeway. The included ramp terminal intersections are included in **Figure 1** and are identified as:

1. Castle Pines Pkwy / I-25 SB ramps
2. Castle Pines Pkwy / I-25 NB on-ramps
3. Castle Pines Pkwy / I-25 NB off-ramp
4. Happy Canyon Rd / I-25 SB ramps
5. Happy Canyon Rd / I-25 NB ramps
6. Castle Rock Pkwy / I-25 SB ramps / Promenade Pkwy

Additionally, the microsimulation models include three intersections on Happy Canyon Road that are near the ramp terminal intersections. These intersections are:

7. Happy Canyon Road / Lagae Road
8. Happy Canyon Road / Lariat Drive
9. Happy Canyon Road / Canyonside Boulevard

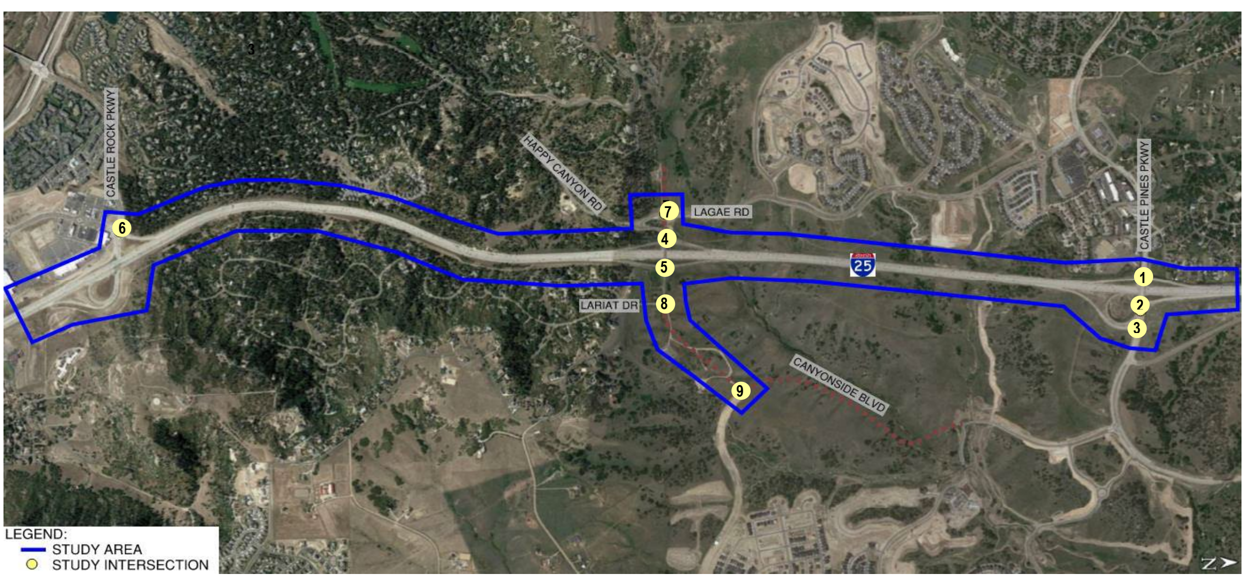


Figure 1. Happy Canyon Rd Study Area

Traffic Data Collection

Table 1 outlines the data that were used to code and calibrate the VISSIM Existing Conditions models and to support validation of the Denver Regional Council of Governments (DRCOG) regional travel demand model as modified to enhance traffic assignment fidelity within the study area subarea of the regional model during the pre-NEPA process. The data collected and the traffic analysis methodology and assumptions that were used for per-NEPA traffic analysis are documented in the *I-25/Happy Canyon Interchange Traffic Analysis and Assumptions Technical Memorandum* (2/2022). The traffic volumes and forecasts developed using this data were used as input to the VISSIM microsimulation and Synchro analysis conducted for the pre-NEPA process and will be used for the VISSIM microsimulation and Synchro analysis for the Systems Level Study.

Table 1. Existing Conditions Data Summary

Data Category	Data Source
ADT Traffic Volumes	• ADT coverage counts were assembled for validation of the DRCOG regional TDM as modified to include enhanced network coding within the subarea including the area of influence of the proposed improvements.
Freeway Traffic	• IDAX collected ramp counts. • The CDOT Automatic Count Recorder at MP 191.25 was used for mainline traffic volumes and vehicle classification. • INRIX data was used for mainline traffic speeds.
Freeway Travel Times	• Wilson & Company collected field data to determine freeway travel times.
Intersection Turning Movement Counts	• IDAX collected Tuesday – Thursday intersection turning movement counts at all study intersections for the AM & PM peak periods. Bicycle and pedestrian counts were included in all counts.
Queue Length Observations	• Wilson & Company performed field work to document observed queue lengths at all the study intersections during the AM & PM peak periods.
Signal Timings	• Existing traffic signal and ramp meter timing was provided by CDOT for coding in the Existing Conditions Models.

2022 Traffic Volumes

The VISSIM models included both AM and PM peak period scenarios. The AM peak period was determined to be 6:00 – 9:00 AM and the PM peak period was determined to be 3:00 – 6:00 PM. Existing traffic count data was collected in March 2022. The existing traffic volumes for each of the six hours are shown in **Figures 2-7**. The raw count data is included as **Appendix A**.

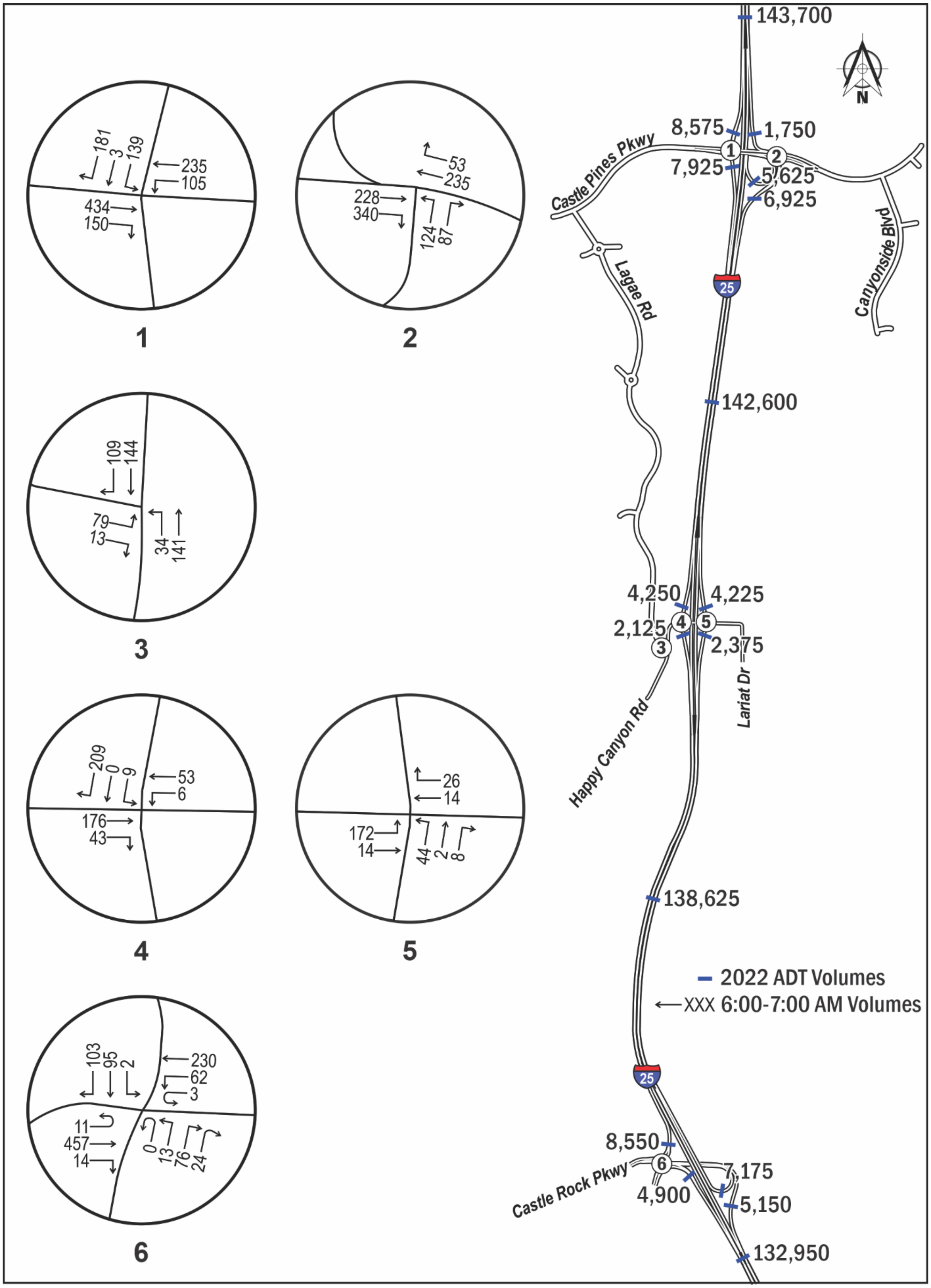


Figure 2. 6:00 – 7:00 AM Peak Hour Turning Movement Counts (2022)

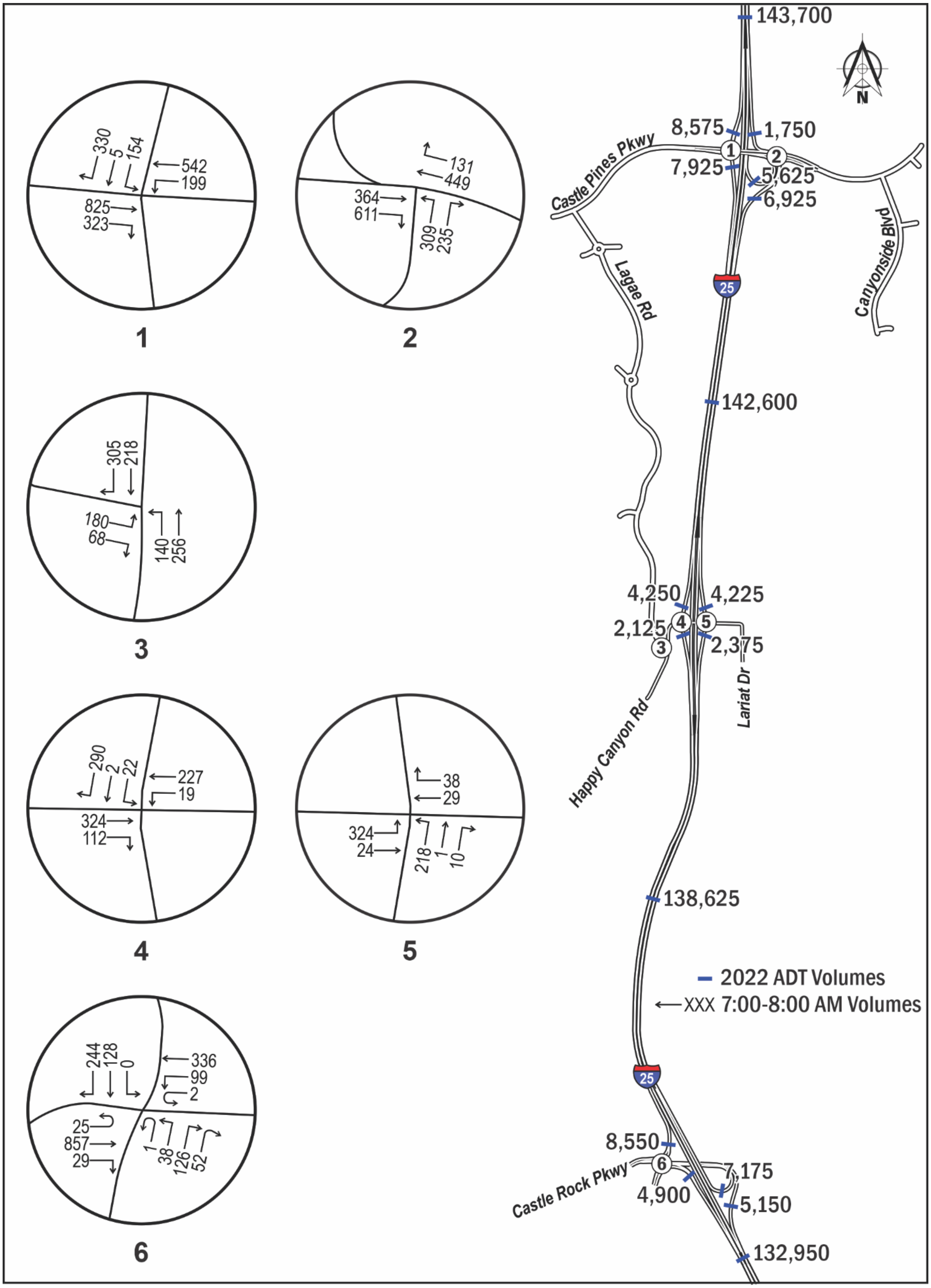


Figure 3. 7:00 – 8:00 AM Peak Hour Turning Movement Counts (2022)

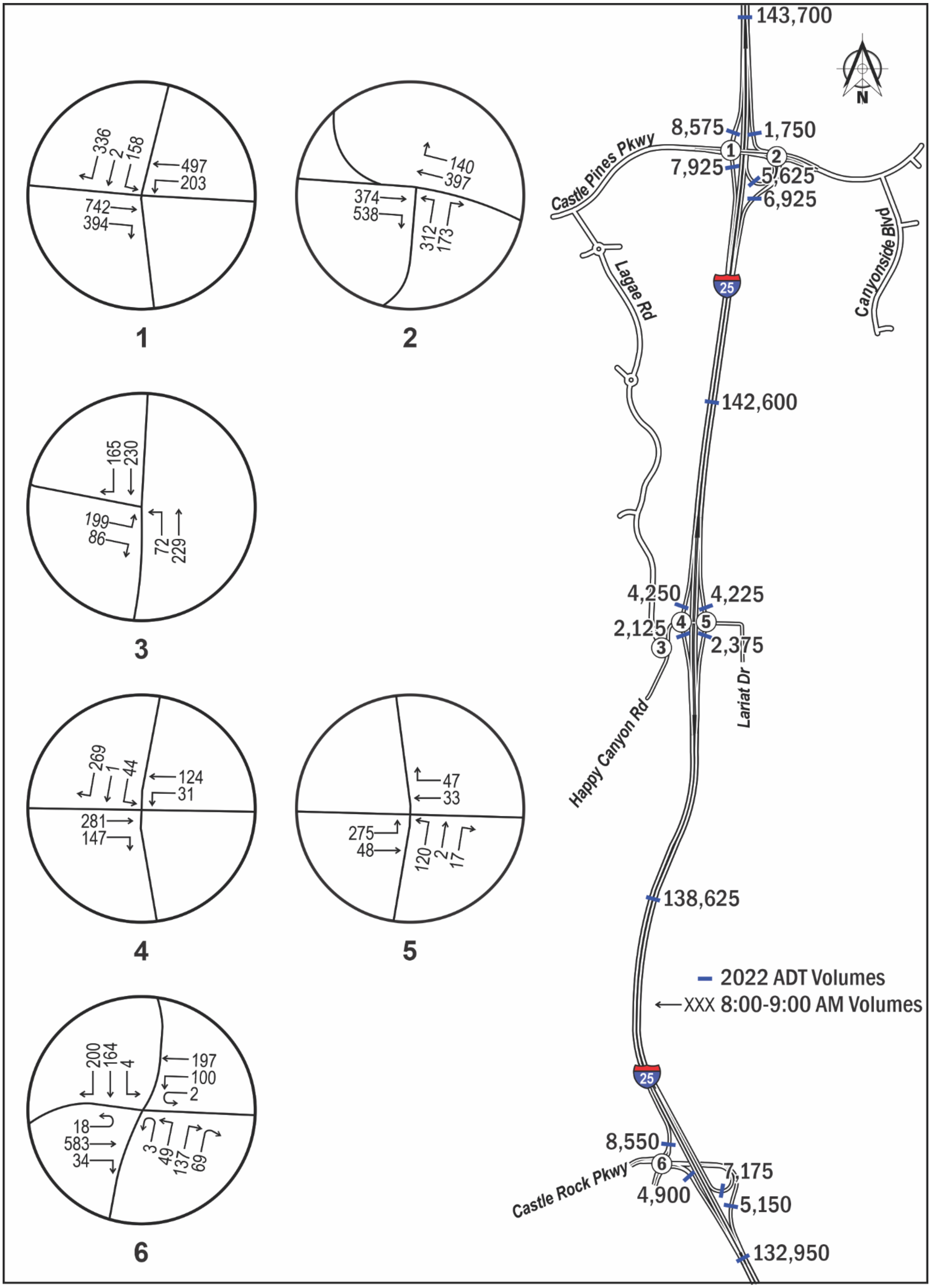


Figure 4. 8:00 – 9:00 AM Peak Hour Turning Movement Counts (2022)

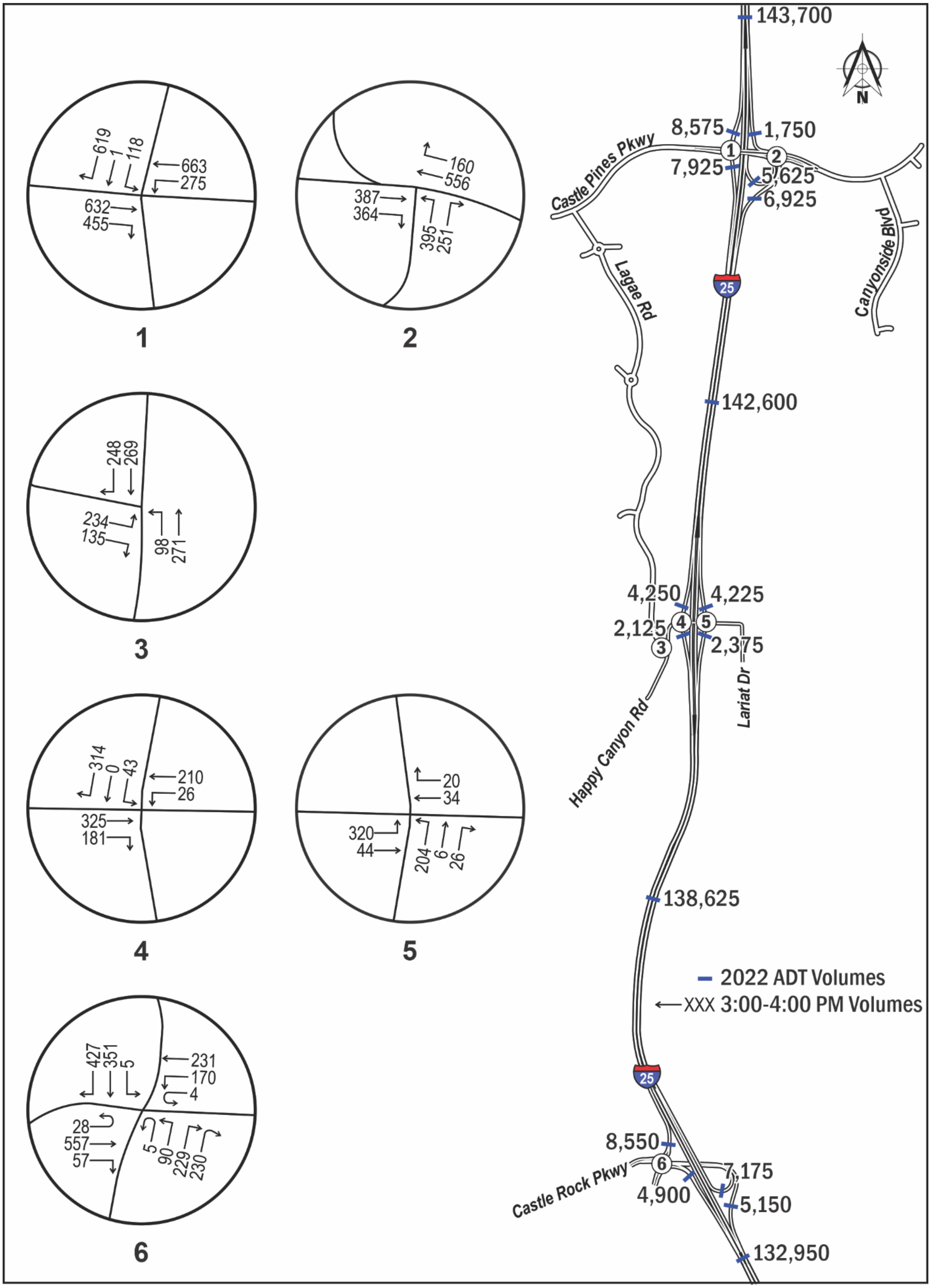


Figure 5. 3:00 – 4:00 PM Peak Hour Turning Movement Counts (2022)

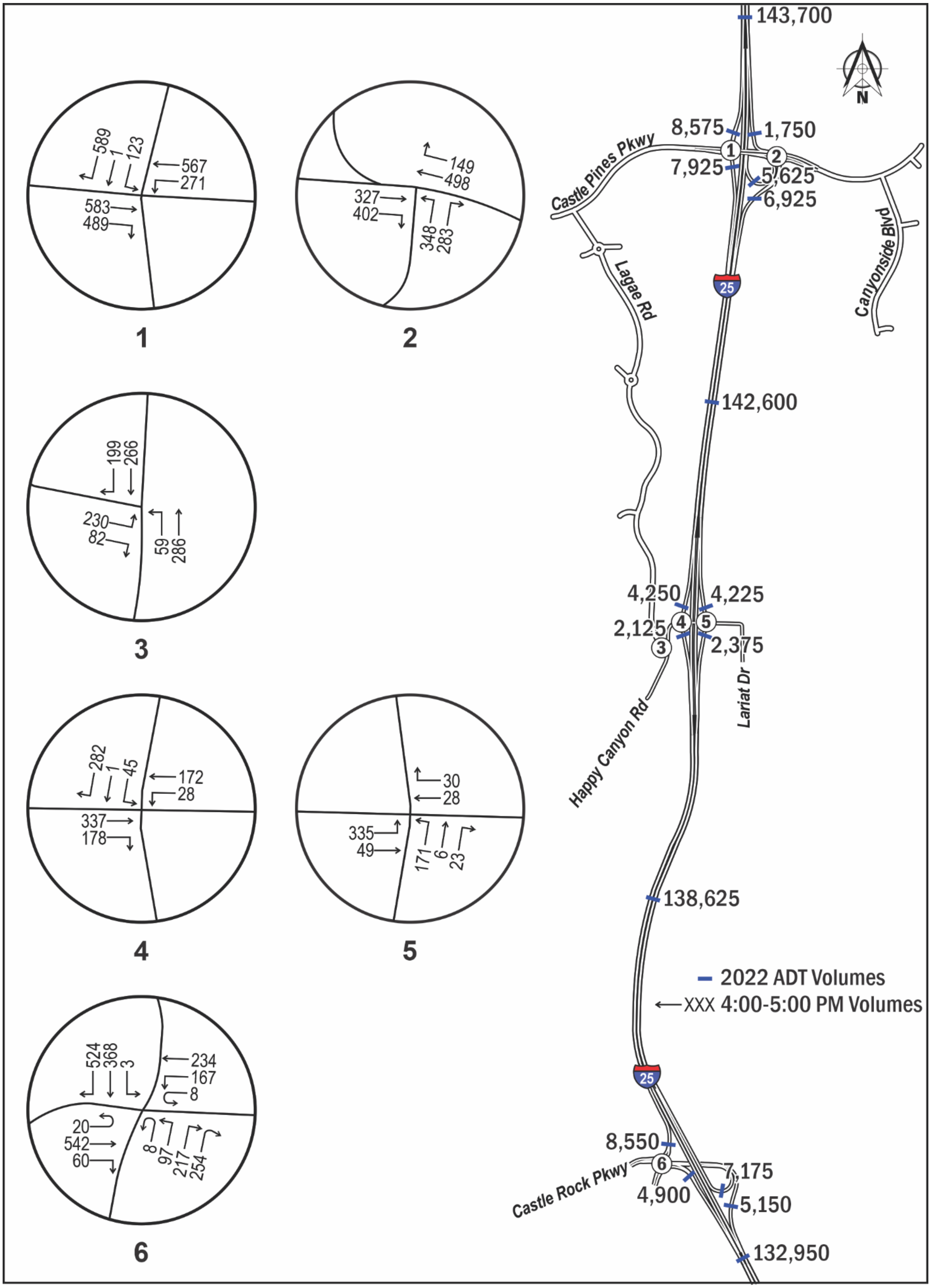


Figure 6. 4:00 – 5:00 PM Peak Hour Turning Movement Counts (2022)

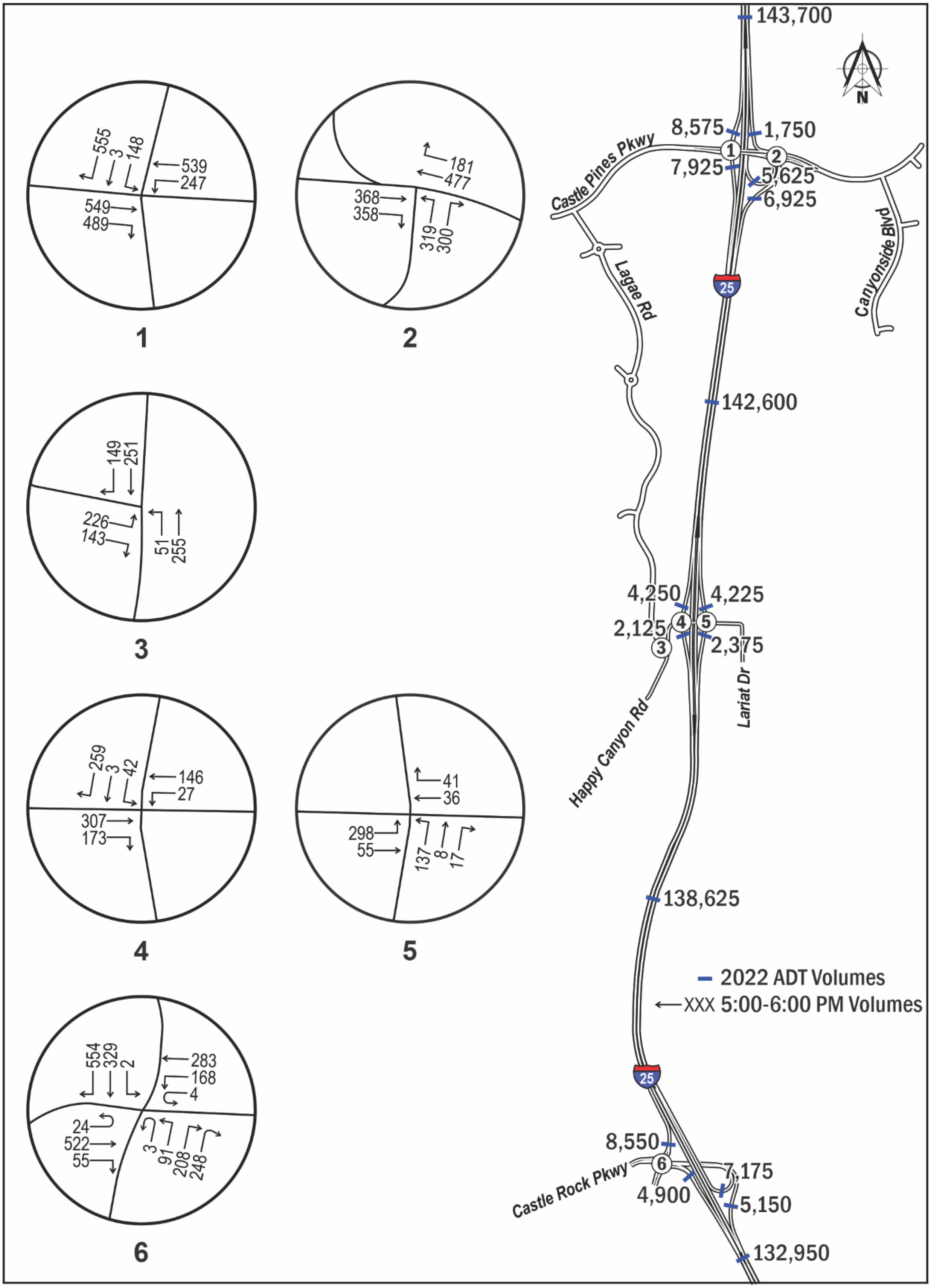


Figure 7. 5:00 – 6:00 PM Peak Hour Turning Movement Counts (2022)

Analysis Tools and Methodology

Traffic Operations Analysis

VISSIM (v21) microsimulation was chosen as the primary traffic operations analysis tool for traffic operations analysis, alternatives screening and selection of a recommended alternative for upgrade to the I-25/ Happy Canyon Road interchange. Microsimulation supports accurate modeling of vehicular operations and interactions within an entire network, including cross-street arterials, mainline freeway segments, ramps, weave sections and ramp terminal intersections. This was deemed particularly important for analysis of arterial elements of the study network, including the closely spaced intersections adjacent to interchange ramp terminal intersections. Synchro (v11) traffic analysis software was used to supplement the arterial network microsimulation analysis. The roles of Synchro analysis included supporting adjustments to traffic signal timing for future conditions and high-level screening analysis of build alternatives. This approach is consistent with Colorado Department of Transportation (CDOT) guidance that stipulates that microsimulation is the preferred tool to be used to evaluate both arterial elements and freeway segment operations, including evaluation of merge/diverge operations, and weaving segment operations.

Intersection Analysis Methodology

The traffic operations analysis addressed signalized and unsignalized intersection operations using the procedures and methodologies contained in the Transportation Research Board's Highway Capacity Manual Sixth Edition (HCM6, Transportation Research Board 2016) for weekday AM (7:00-8:00 AM) and PM (4:00-5:00 PM) peak hour traffic operations. Study intersection operations were evaluated using level of service (LOS) calculations as analyzed in the VISSIM (v21) microsimulation software.

To measure and describe the operational status of the local roadway network and corresponding intersections, transportation engineers and planners commonly use the LOS grading system. LOS is a description of an intersection's operation, ranging from a LOS A (indicating free-flow traffic conditions with little or no delay) to a LOS F (representing oversaturated conditions where traffic flows exceed design capacity, resulting in long vehicle queues and delays).

Signalized Intersections

At signalized intersections, the operational analysis uses intersection characteristics (such as traffic volumes, lane geometry, and signal phasing) to calculate vehicle delay. For signalized intersections, the HCM6 defines the LOS as the average delay per vehicle for the overall intersection. **Table 2** summarizes the relationship between delay and LOS for signalized intersections.

Unsignalized Intersections

For unsignalized intersections, operations are defined by the average control delay per vehicle (measured in seconds) for each stop-controlled movement. The method incorporates delay associated with deceleration, acceleration, stopping, and moving up in the queue. For side street stop-controlled intersections, LOS is reported for the approach with the highest average delay/vehicle. **Table 3** summarizes the relationship between delay and LOS for unsignalized intersections.

Table 2. LOS Criteria for Signalized Intersections

Level of Service	Intersection	Control Delay (seconds/vehicle)
A	Progression is extremely favorable. Most vehicles arrive during the green phase and do not stop at all. Short cycle lengths may contribute to low delay.	≤10
B	Good progression, short cycle lengths, or both. More vehicles stop than with LOS A.	>10–20
C	Fair progression, longer cycle lengths, or both. The number of vehicles stopping is significant, though many still pass through without stopping.	>20–35
D	Longer delays result from some combination of unfavorable progression, long cycle lengths, and high v/c ratios. Many vehicles stop.	>35–55
E	High delay values generally indicate poor progression, long cycle lengths, and high v/c ratios. Individual cycle failures are frequent occurrences.	>55–80
F	This level often occurs with oversaturation when arrival flow rates exceed the capacity of the intersection. Poor progression and long cycle lengths may be major contributing factors to such delays.	>80

Source: Transportation Research Board, Highway Capacity Manual.

Table 3. LOS Criteria for Unsignalized Intersections

Level of Service	Intersection	Control Delay (seconds/vehicle)
A	Little or no delay	0–10
B	Short traffic delays	>10–15
C	Average traffic delays	>15–25
D	Long traffic delays	>25–35
E	Very long traffic delays	>35–50
F	When demand volume exceeds the capacity of the lane, extreme delays will be encountered with queuing that may cause severe congestion that affects other traffic movements in the intersection. This condition usually warrants improving the intersection.	>50

Note: For two-way stop-controlled intersections, level of service is determined by the control delay for each minor movement, LOS is not defined for the overall intersection, but as the critical movement LOS/delay (worst LOS/highest delay movement) of the minor approaches.
Source: Transportation Research Board, Highway Capacity Manual.

Travel Demand Modeling

Travel demand forecasts were completed using the current DRCOG Focus 2.3 travel model as a foundation, supplemented by detailed trip generation and phasing information obtained from traffic impact analysis reports for approved study area development. Full and partial runs of Focus 2.3 and analysis of model inputs and outputs were performed using the TransCAD v7 software platform per DRCOG model use guidance.

Modeling Approach and Methodology

The current Focus 2.3 travel model installation files were obtained from DRCOG and were used to develop travel demand forecasts for the I-25/Happy Canyon interchange study area. Full model scenarios for a 2020 base year and 2050 planning horizon were obtained as well as model outputs produced by DRCOG in-house model runs for each of these scenarios. The 2030 dataset was also obtained, anticipating its use for the Opening Year scenario for the Systems Level Study. Full scenarios for Focus 2.3 and the DRCOG-produced model results (output files) for the three scenarios were obtained to preserve flexibility to apply the model either fully or partially to address a variety of potential demand forecasting and analysis needs.

Model Installation and Testing

The DRCOG Focus 2.3 Model obtained from DRCOG was installed in accordance DRCOG policy for external user model use.[1] Test runs were completed to confirm model function for the study area. These tests included full runs for the provided scenarios and comparison to provided DRCOG outputs to ensure consistency of traffic assignment results. Regional model performance within the interchange study area will be reviewed for the 2020 model scenario consistent with industry standard "goodness of fit" criteria.

Network Modifications

The DRCOG 2020 regional travel demand model network within the study area subarea was enhanced to provide greater detail within the subarea to improve interchange study area traffic assignment fidelity, see **Figure 8**. To build modified networks, the Focus 2.3 Tripod network processing utilities were applied to the enhanced DRCOG network(s) for 2020, 2030 and 2050 scenarios. Network modifications were reviewed and accepted by a traffic technical advisory group for the project including local agency traffic staff, and traffic/modeling staff from DRCOG, CDOT and the Federal Highway Administration (FHWA). The study area is outside the RTD service area. All final network modifications, and particularly those that represent updates to the DRCOG network scenarios, will be shared with DRCOG as potential updates to the MPO network models.

The assignment results were compared to DRCOG-provided in-house model run results as well as to 2020 ADT traffic ground counts and/or other recent counts that have been adjusted to represent 2020 traffic *average weekday daily traffic (AWDT) traffic flows. Additional adjustments were made as required to meet industry standard "goodness of fit" criteria.[2]

---

[1] (*Denver Regional Council of Governments Focus Regional Travel Model Release Agreement Form,*
Focus_2.3_Release_Agreement.pdf (drcog.org).

[2] Travel Model Improvement Project (TMIP) – Travel Model Validation and Reasonability Checking Manual, 2010.

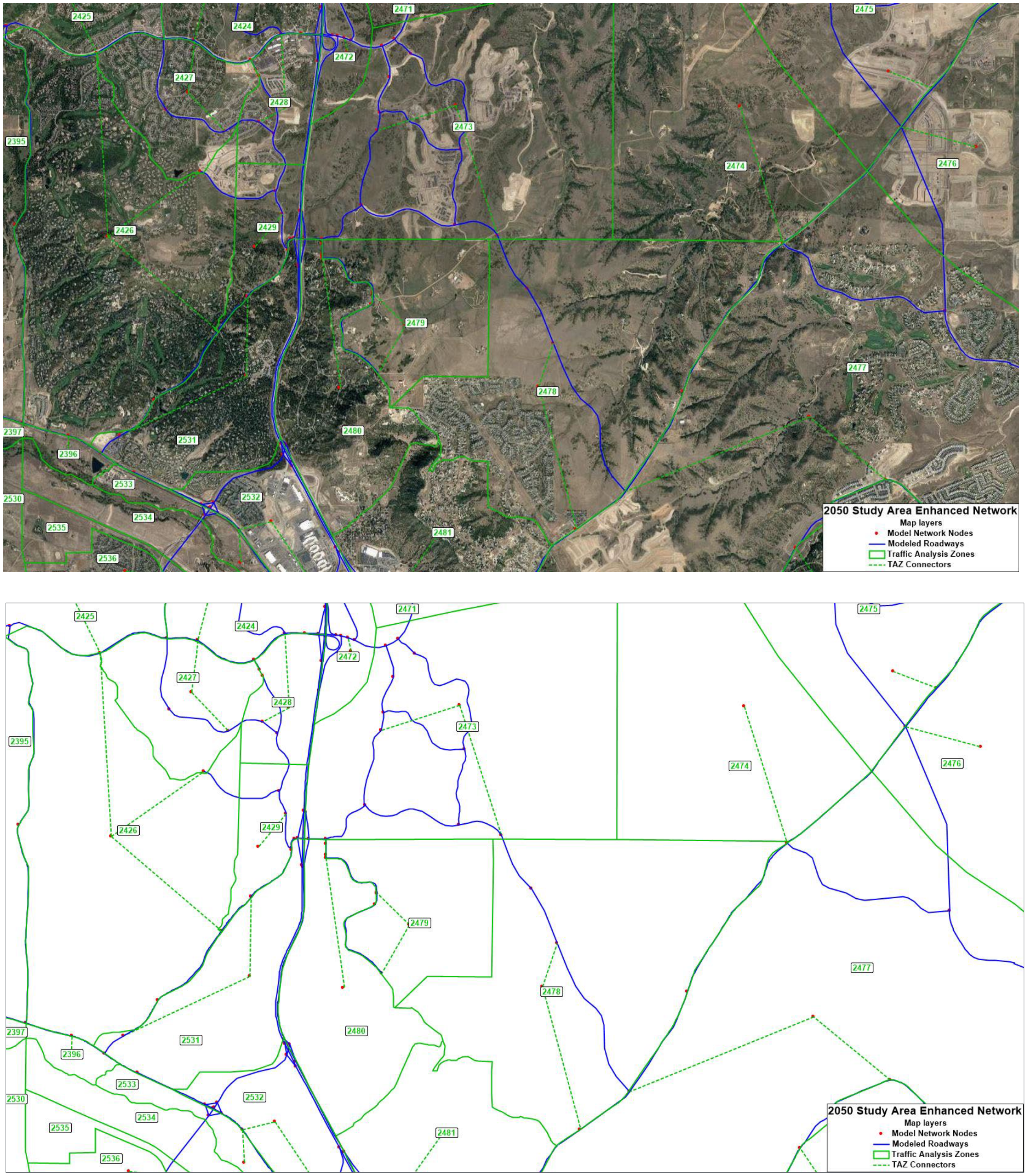


Figure 8. DRCOG Model Network – Happy Canyon / I-25 Interchange Study Area

Land Use Review

DRCOG model land use assumptions were reviewed together with land use mix and entitlement densities for the Lagae Ranch, Castle Pines Town Center, and The Canyons developments. DRCOG model land use data for study area traffic analysis zones is shown in **Table 4.** The selected large development entitlements within the immediate study area amount to roughly 46% of residential plus commercial growth (48% of the residential and 38% of the commercial) forecast by DRCOG for the broader area (including TAZs 2426-2429, 2471-2474, 2478 and 2479). Thus, the Canyons and Castle Pines Town Center are not fully included in the DRCOG model. Use of the DRCOG model alone to develop traffic forecasts would both risk underestimating development traffic and/or not capturing trip generation rates for residential, public, and commercial land use types that may be higher than rates used for the DRCOG model.

To produce accurate forecasts of total traffic for the 2030 and 2040 analysis scenarios, the DRCOG model was used to estimate background, regional traffic. Detailed entitlement land uses and densities were used together with Institute of Transportation Engineers (ITE) trip generation rates to calculate site-generated traffic associated with the entitlements. Total traffic for each scenario was calculated as background traffic plus site-generated development traffic and distribution. For consistency, site-generated development traffic and distribution from approved traffic studies for the developments and individual development phases were used. Full detail regarding development trip generation is included in the 2050 Buildout Site-Generated Development Traffic Volumes section and is summarized in **Table 19** and **Table 20**.

Table 4. DRCOG Model Land Use Review

Zone ID	DRCOG 2020 Data		DRCOG 2050 Data		2020-2050 Change		2020-2050 Entitlements	
	DUs	Employees	DUs	Employees	DUs	Employees	DUs	Employees
2426	1,311	311	4,227	1,751	2,916	1,440		
2427	952	360	3,043	1,186	2,091	826		
2428	507	1,156	2,416	1,058	1,909	-98		
2429	**33**	**121**	**933**	**368**	**900**	**247**	**1,541**	**212**
2471	129	82	366	170	237	88		
2472	**8**	**21**	**279**	**126**	**271**	**105**		**1,148**
2473	**8**	**177**	**4,151**	**1,699**	**4,143**	**1,522**	**5,000**	
2474	20	35	761	298	741	263		
2478	960	510	4,165	1,615	3,205	1,105		
2479	40	92	182	77	142	-15		
Totals	**2,460**	**2,324**	**14,708**	**5,926**	**12,248**	**3,602**	**5,978**	**1,360**
% DRCOG Change 2020-2050 Change							**48%**	**38%**

Notes: 1) Castle Pines Town Center is located fully within TAZ 2429.
2) The Canyons is located within TAZs 2472 and 2473, with a small intrusion into TAZ 2478. The Canyons commercial development is primarily in TAZ 2472.

Model Assignment Adjustments

Raw traffic assignment volumes produced by the model for the 2020 base year and 2050 planning horizon scenarios were adjusted using modeled percent growth and absolute growth in traffic flows between the 2020 and the Year 2030 and Year 2050 DRCOG model scenarios, together with observed traffic count data for 2020 as validation. Adjustments to base, raw assignment volumes were made in accordance with industry standard guidance.[3] Adjusted assignment results for 2050 were post-processed to generate balanced peak period intersection turning movements and/or origin-destination volumes as input to VISSIM traffic operations microsimulation, to include 6 hours of data, 3 hours in the AM and 3 hours in the PM.

[3] NCHRP Report 255 – Highway Traffic Data for Urbanized Area Project Planning and Design, 1982; NCHRP Report 765 – Analytical Travel Forecasting Approaches for Project-Level Planning and Design, 2014.

Other Modeling Applications

The TransCAD embedded procedure for select link analysis was used to evaluate local and regional traffic shares using the future connection to Crowfoot Valley Road and using Happy Canyon Road and Castle Pines Parkway. Supplemental O-D data was collected to validate modeling for Happy Canyon Road and Castle Pines Parkway.

Traffic Operations Modeling

Existing Conditions (2022) Model Calibration

The first two key steps in the VISSIM modeling methodology involved coding and then calibrating the Existing Conditions Models. For this study, the Existing Conditions Models reflected the current lane geometry within the study area. The VISSIM Existing Conditions Models include both AM and PM peak period model. The AM peak period was determined to be 6:00 – 9:00 AM and the PM peak period was determined to be 3:00 – 6:00 PM. Existing traffic count data was collected in March 2022.

Once the initial coding of the base models was complete, measures of effectiveness (MOEs) were extracted and compared to the available existing field data to determine if they were within acceptable levels. The MOEs that were reviewed during the calibration process include throughput, travel times, and average speeds along the freeway mainline as well as turning-movement volumes and queue lengths at intersections. To account for variability in the model and obtain more statistically accurate results, a total of 15 runs were performed for each simulation model and averaged. Modeling for each scenario was conducted iteratively until confidence levels and tolerances stipulated by CDOT and FHWA guidance were met. The *CDOT Traffic Analysis and Forecasting Guidelines* (CDOT 2018)[4] informed acceptable thresholds for model calibration. If large discrepancies were found, the model parameters were adjusted through an iterative process to obtain acceptable results. This calibration step is critical to ensure that the VISSIM models reflect field conditions in the study area and provide accurate results of the proposed changes.

Based on the Guidelines, the simulated model was calibrated relative to traffic volume served. The model was adjusted until 85% of the simulated traffic volume served was within the model calibration targets for network links and turning movement counts. The following are the model calibration targets, as outlined by CDOT:

- Within +/- 100 vph of the observed traffic volumes of <700 vph
- Within +/- 15% of the observed traffic volumes of 700 to 2,700 vph
- Within +/- 400 vph of the observed traffic volumes of > 2,700 vph

Table 5 and **Table 6** show the number of data points that were reviewed for both intersection volumes and mainline volumes, respectively, and the percentage of the data points that met the calibration targets.

Appendix B provides additional detail regarding specific simulated values for the intersection turning movement counts compared to the target values, and **Appendix C** provides additional detail regarding specific simulated values for the freeway volumes compared to the target values.

[4] CDOT, Traffic Analysis and Forecasting Guidelines, 2018. traffic_analysis_forecasting_guidelines (codot.gov).

Table 5. Intersection Volume Calibration

Peak Period	Total Movements	# Target Met	% Target Met
AM	46	46	100%
PM	46	46	100%

Table 6. Freeway Volume Calibration

Peak Period	Total Data Points	# Target Met	% Target Met
AM	24	24	100%
PM	24	24	100%

Additionally, the simulated model was calibrated relative to travel time. The model was adjusted until 85% of the simulated travel times were within the model calibration targets. The following are these model calibration targets, as outlined by CDOT:

- Within +/- 1 minute of the observed travel times for routes less than 7 minutes.
- Within 15% of the observed travel times for routes more than 7 minutes.

Table 7 shows the number of travel time routes that were reviewed within the model and the percentage of those routes that met the calibration targets. **Appendix D** provides additional detail regarding specific simulated values compared to the target values.

Table 7. Travel Time Calibration

Peak Period	Total Routes	# Target Met	% Target Met
AM	2	2	100%
PM	2	2	100%

Simulated travel speeds were also reviewed and calibrated relative to existing travel speeds. The model was adjusted until 85% of the simulated travel speeds were within calibration targets. The following are the model calibration targets, as outlined by CDOT:

- Within +/- 10 miles per hour (mph) of average observed speeds

Table 8 shows the number of travel speeds locations that were reviewed within the model and the percentage of those locations that met the calibration targets. **Appendix E** provides additional detail regarding specific simulated values compared to the target values.

Table 8. Vehicle Speed Calibration

Peak Period	Total Data Points	# Target Met	% Target Met
AM	6	6	100%
PM	6	6	100%

Similarly, simulated queue lengths were compared to existing queues. The following are the model calibration targets, as outlined by CDOT:

- Within +/- 20% on Arterials (+/- 30% for movements < 10 vph)
- Within +/- 35% on Freeways

Table 9 shows the number of queue length locations that were reviewed within the model and the percentage of those locations that met the calibration targets. Although the majority of the queue lengths do not meet the target, nearly all of the discrepancies are minor (all within a difference of only five vehicles and most within a difference of only two vehicles). Because the queue length outputs from the model are given in a unit of feet and the field-observed queues are recorded in a unit of number of vehicles, the discrepancy in queue length may be a result of the assumed average length per queued vehicle (25 feet). Furthermore, field observations may not have occurred at the peak flows of traffic. The queue length discrepancies should have no adverse effects on future year alternatives analysis, particularly at the I-25/Happy Canyon interchange where the traffic control will be changed from the existing two-way stop-control to traffic signals or roundabouts. **Appendix F** provides additional detail regarding specific simulated values compared to the target values.

Table 9. Queue Length Calibration

Peak Period	Total Data Points	# Target Met	% Target Met
AM	15	6	40%
PM	15	4	27%

Table 10 shows the parameters that are allowed to be adjusted as part of the model calibration process by the CDOT Traffic Analysis and Forecasting Guidelines. As shown in the table, the default parameters were not adjusted for the calibration of the existing condition traffic models.

Table 10. Calibration Parameter Adjustments

Parameter		Default Value	Range Used
Freeway Car Following Model (Wiedemann 99)			
CC0	Standstill distance	4.92	4.92
CC1	Headway time	0.9	0.9
CC2	"Following" variation	13.12	13.12
Arterial Car Following Model (Wiedemann 74)			
Average Standstill Distance		6.56	6.56
Additive Part of Safety Distance		2.0	2.0
Multiplicative Part of Safety Distance		3.0	3.0

Baseline Traffic Operations Analysis

2022 Existing Conditions Traffic Volumes

Traffic operations analysis was conducted for AM (7:00-8:00 AM) and PM (4:00-5:00 PM) peak hour conditions, as shown in **Figure 3** and **Figure 6**, respectively. These analysis results show that all study area intersections currently operate at a LOS C or better.

2022 Existing Conditions Traffic Operations Analysis

Table 11 shows the existing levels of service for the intersections within the study area. The delay and level of service values shown in the table are based on the average of 15 runs of the VISSIM existing conditions models. These analysis results show that all study area intersections currently operate at a LOS C or better. **Appendix G** provides additional detail regarding the intersection levels of service.

Table 11. Existing Intersection Levels of Service

Control	Intersection	LOS/Delay [in seconds/vehicle] (Critical Movement)	
		AM Peak Hour	PM Peak Hour
Roundabout	Castle Rock Pkwy & I-25 SB	**A** / 3.2	**A** / 3.2
TWSC	Happy Canyon Rd & Lagae Rd	**c** / 17.3 (EB LT)	**c** / 18.8 (EB LT)
TWSC	Happy Canyon Rd & I-25 SB	**c** / 19.6 (SB LT)	**c** / 19.3 (SB LT)
TWSC	Happy Canyon Rd & I-25 NB	**b** / 14.5 (NB LT)	**b** / 14.4 (NB LT)
Signal	Castle Pines Pkwy & I-25 SB	**B** / 10.3	**B** / 10.3
Signal	Castle Pines Pkwy & I-25 NB	**A** / 5.0	**A** / 7.3

2050 No Action Peak Hour Total Traffic Volumes

The traffic volumes for the 2050 No Action model include 2050 background traffic and full buildout of development entitlements for the Lagae Ranch, Castle Pines Town Center, and The Canyons developments. The assignment of traffic to the study area network reflects the redistribution of planning horizon (2050) traffic that would occur were the planned extension of Happy Canyon Road east from Lariat Drive to Canyonside Boulevard not to be completed.

The distribution of background and development traffic for the 2050 No Action scenario was estimated based on comparisons of AM and PM peak hour 2050 assignment volumes generated by DRCOG Focus 2.3 model runs for network alternatives with and without connection of Happy Canyon Road to Canyonside Boulevard. The 2050 No Action total traffic volumes include redistributed background traffic and redistributed site-generated development traffic from Lagae Ranch, Castle Pines Town Center, and The Canyons. **Figure 9** and **Figure 10** show the estimated 2050 No Action total traffic volumes for the AM peak hour (7:00 – 8:00 AM) and the PM peak hour (4:00 – 5:00 PM), respectively.

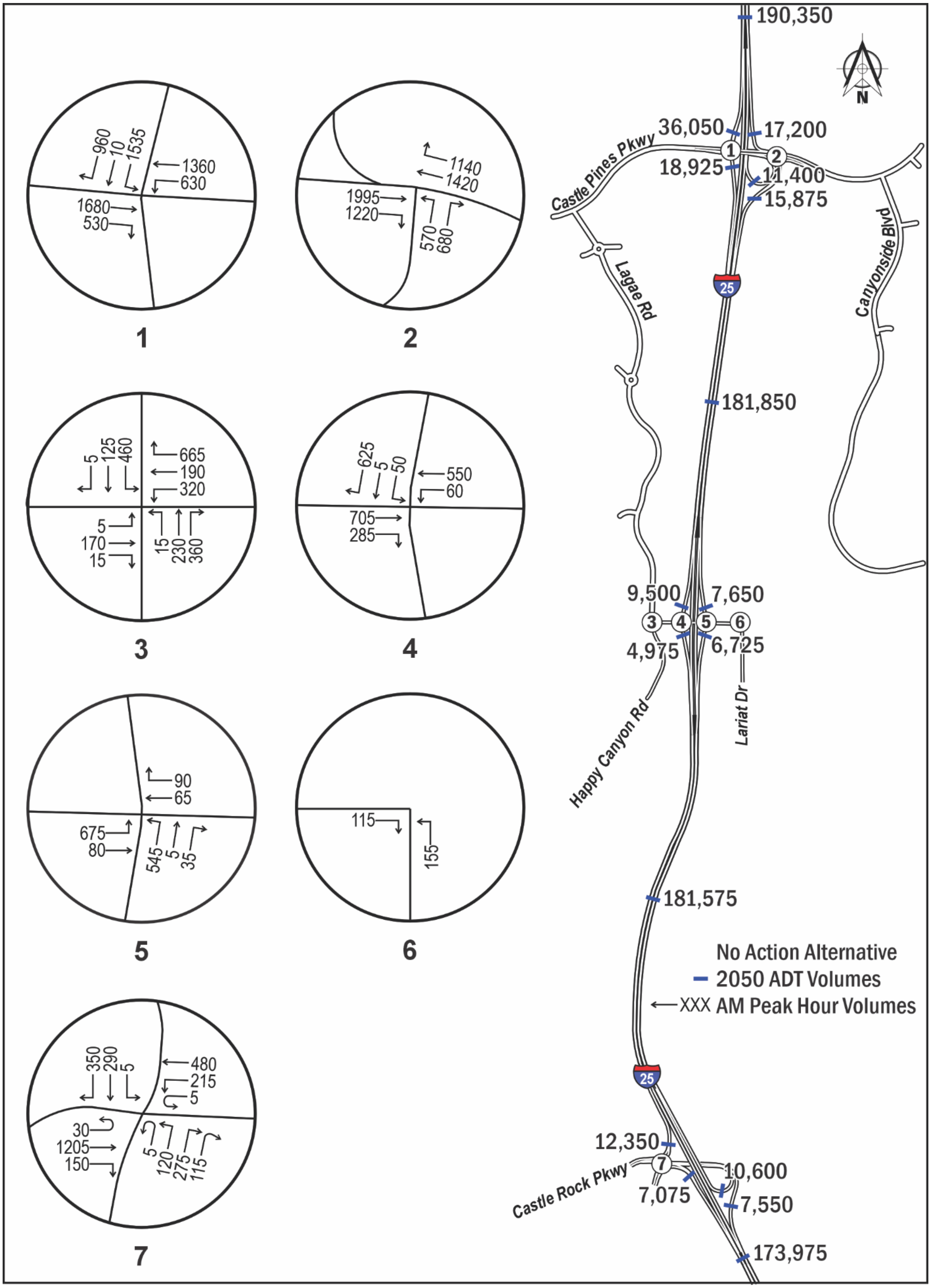


Figure 9. 2050 No Action AM Peak Hour Total Traffic Volumes

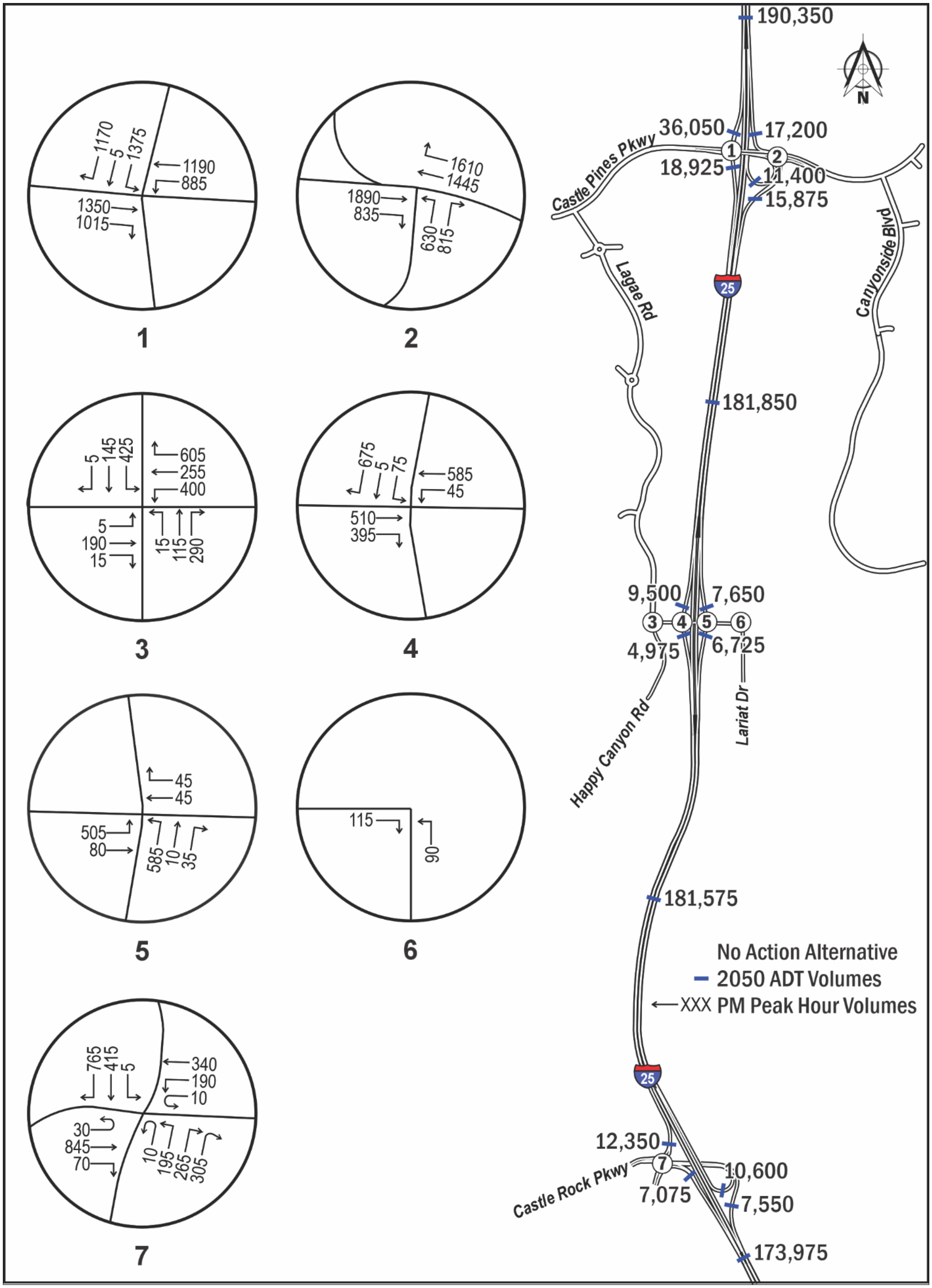


Figure 10. 2050 No Action PM Peak Hour Total Traffic Volumes

2050 No Action Peak Hour Traffic Operations Analysis

The 2050 No Action model includes the planned Lagae Road/Happy Canyon Road intersection improvements shown in **Figure 11** below. These improvements are anticipated to be complete by 2024 and include the construction of a roundabout at the Happy Canyon Road and Lagae Road intersection, realignment of the roadway connection between the roundabout and the west ramp terminal at the I-25/Happy Canyon Road interchange, and the realignment of Lagae Road south of the roundabout which includes the removal of the existing intersection. The existing bridge over I-25 will remain and Happy Canyon Road will remain a two-lane roadway between the I-25 ramp termini intersections. Additionally, it is assumed that both ramp termini at the I-25/Happy Canyon Road interchange would be signalized by the year 2050.

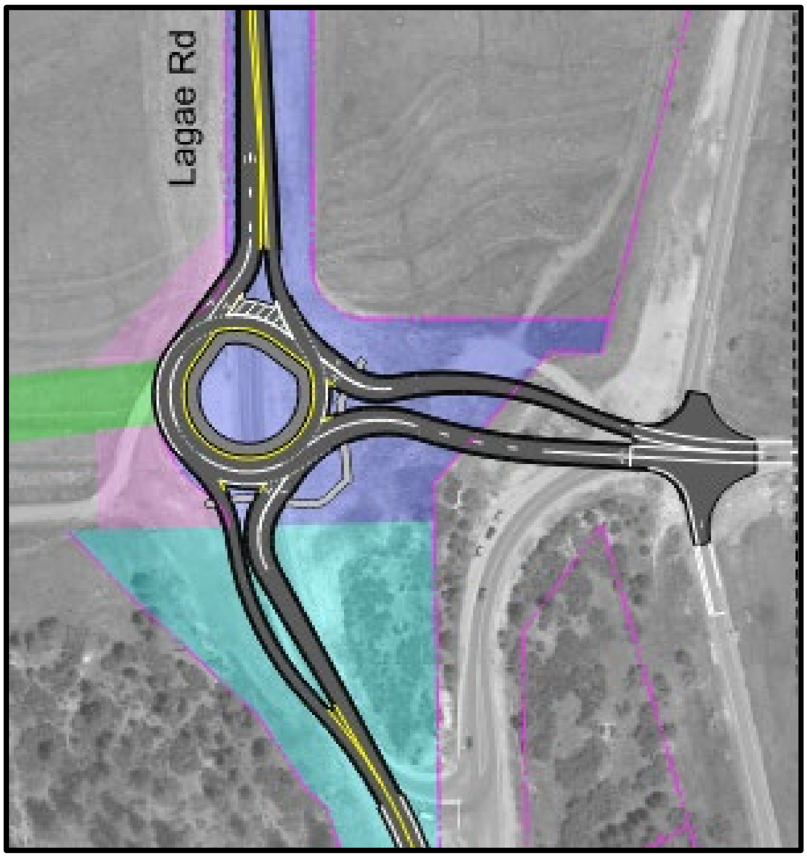


Figure 11. Lagae Road/Happy Canyon Road Intersection Improvements

Additionally, the No Action model does not include the Happy Canyon Road extension from Lariat Drive to Canyonside Boulevard. It is also assumed that a southerly extension of Canyonside Boulevard and connection to Crowfoot Valley Road will be in place for the 2050 No Action models. The former connection is contingent on improvement of the I-25/Happy Canyon Road interchange.

Due to the forecasted heavy exiting volumes, it is assumed the southbound I-25 off-ramp to Castle Pines Parkway will be expanded from a single-lane exit to a two-lane exit. Additionally, it is assumed the southbound left-turn movement from the southbound I-25 off-ramp to Castle Pines Parkway will be expanded to accommodate the triple left-turn as shown in the North Canyons TIA (January 2019) and the North Canyons Traffic Impact Study Addendum – 2nd PD Amendment (October 2019). To account for the triple left, it is also assumed that Castle Pines Parkway will have three receiving eastbound through lanes which will continue to the east end of the model. The VISSIM outputs are included in **Appendix H**.

Table 12 shows the 2050 No Action alternative levels of service for the intersections within the study area. The delay and level of service values shown in the table are based on the average of 15 runs of the VISSIM 2050 No Action models. These analysis results show that, with increased traffic flows and without significant improvement to the I-25/Happy Canyon interchange, multiple intersections within the study area would operate at LOS E or F during the peak hours.

Table 12. 2050 No Action Intersection Levels of Service

Control	Intersection	LOS/Delay [in seconds/vehicle] (Critical Movement)	
		AM Peak Hour	PM Peak Hour
Roundabout	Castle Rock Pkwy & I-25 SB	B / 14.0	A / 6.5
Roundabout	Happy Canyon Rd & Lagae Rd	D / 32.3	F / 53.9
Signal	Happy Canyon Rd & I-25 SB	D / 41.9	D / 52.7
Signal	Happy Canyon Rd & I-25 NB	F / 86.7	F / 107.6
Signal	Castle Pines Pkwy & I-25 SB	E / 60.0	D / 44.8
Signal	Castle Pines Pkwy & I-25 NB	B / 12.1	B / 15.1

2050 Build Traffic Alternatives

2050 Build Total Traffic Volumes

Total traffic volumes for the 2050 Build models include 2050 background traffic (regional and local traffic without site-generated development traffic) and site-generated development traffic for full buildout of the Lagae Ranch, Castle Pines Town Center, and The Canyons developments.

2050 Background Traffic Volumes

The assignment of 2050 background traffic to the study area network reflects the distribution of regional and study area traffic that would occur if both an extension of Happy Canyon Road east from Lariat Drive to Canyonside Boulevard and a connection from Canyonside Boulevard to Crowfoot Valley Road (included in the DRCOG 2050 Regional Transportation Plan (RTP)) were completed. The 2050 background traffic includes the portions of Lagae Ranch and Castle Pines Town Center that were built out at the time when existing conditions traffic count data was collected (March 2022) but does not include additional site-generated traffic associated with full buildout of Castle Pines Town Center and The Canyons. The additional traffic to be generated by Castle Pines Town Center and The Canyons has been accounted for separately from what is referred to as "background traffic" within this report – see the following section for a discussion of the traffic to be generated by those developments, which was added to the background traffic to develop the 2050 traffic volume forecasts used for the Build Alternatives analysis. Traffic assignments produced by the DRCOG Focus 2.3 model for 2020, 2030 and 2050 scenarios with enhanced network coding within the study area were used to estimate 2050 background traffic volumes and the 2050 distribution of traffic within the study area. **Figure 12** and **Figure 13** show the estimated 2050 Build background traffic volumes for the AM peak hour (7:00 – 8:00 AM) and the PM peak hour (4:00 – 5:00 PM), respectively.

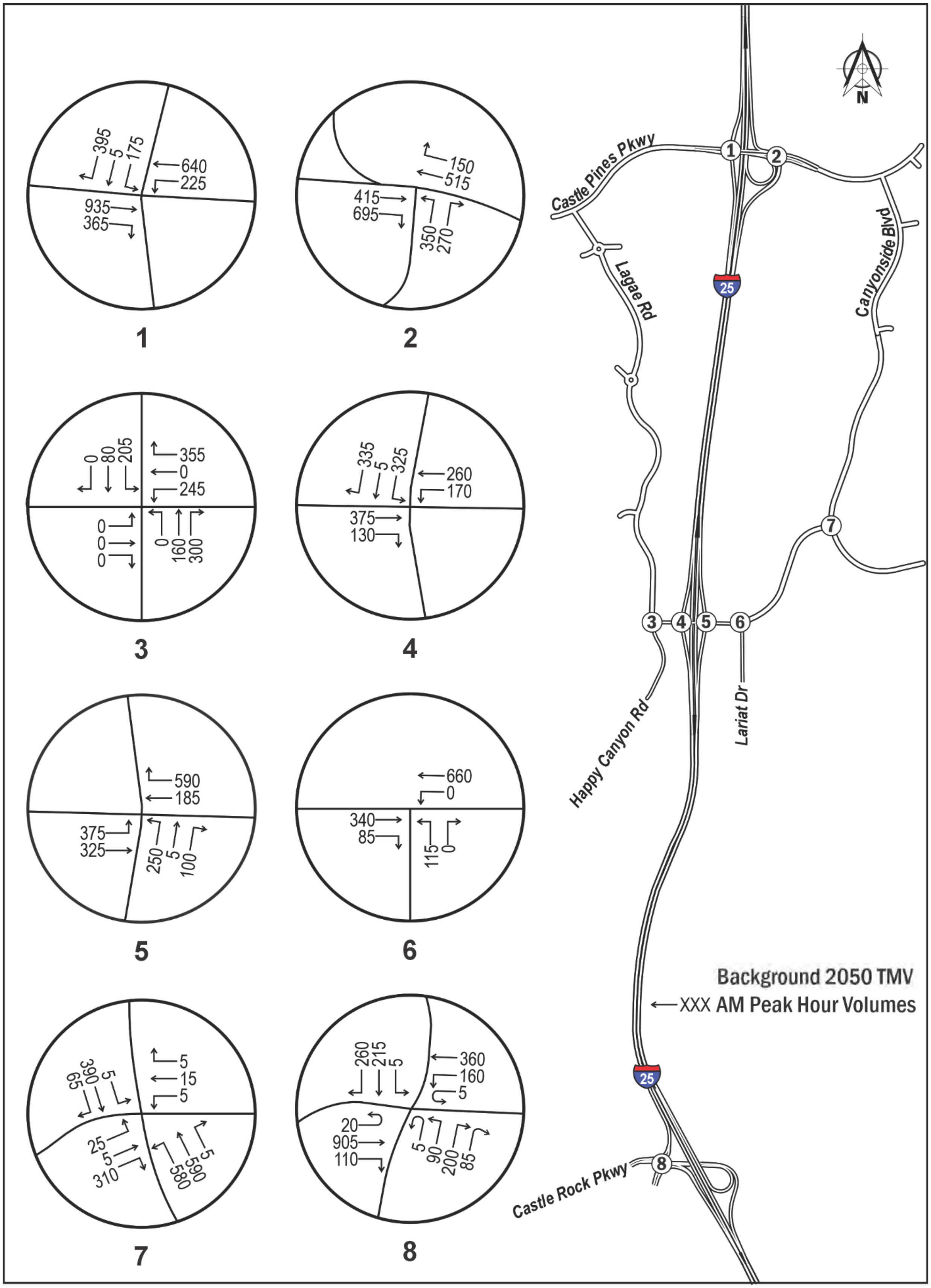


Figure 12. 2050 AM Peak Hour Background Traffic Volumes

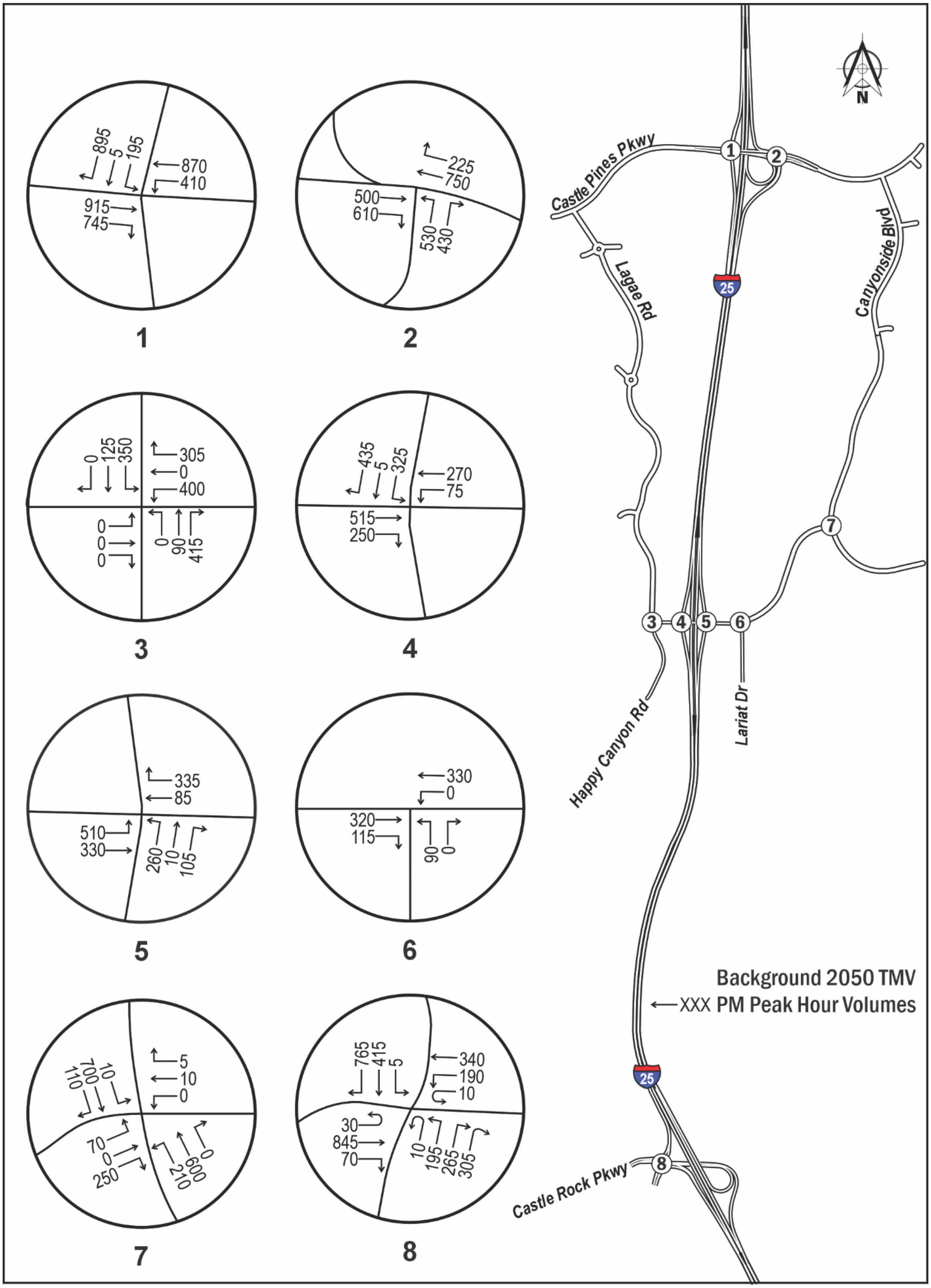


Figure 13. 2050 PM Peak Hour Background Traffic Volumes

Study Area Large Scale Development Entitlements

Two large-scale development project entitlements have been approved within the study area that will use the I-25/Happy Canyon Road interchange as a primary or secondary access to I-25. At buildout, these developments will add approximately 6,540 residential units and 2.7 million square feet (MSF) of commercial uses to the I-25/Happy Canyon Road travel shed. The bulk of this total is made up of entitled land development for seven development plans or PD amendments for The Canyons and Castle Pines Town Center that have been approved or are under review by the Town of Castle Pines. More than half of the planned development was approved as The Canyons PD in 2009. The contributions of each of the approved planned development are detailed below.

The Canyons (2009)

The Canyons Planned Development (Nolte) and *The Canyons Master Transportation Plan* (Fehr & Peers) were completed in May 2009 and June 2009, respectively. The Planned Development (PD) for The Canyons was subsequently approved by the Town of Castle Rock. The approved development levels for Phase 1 and Phase 2 include 2500 residential units, a 450-room hotel and 2158 KSF of other commercials uses (shopping center, general office, and community college). The balance of approved development for The Canyons (thereafter referred to as the North Canyons PD) that was left after transfer of property and development rights to Shea Canyons is 500 residential units and 2,128 KSF of commercial uses.

Shea Canyons (May 2017)

The Shea Canyons development utilizes purchased/transferred development rights for a portion of The Canyons development, including 2000 residential units and 30 KSF of commercial uses. The *Shea Homes Development Transportation Impact Study* for the residential portion of the development was completed in May 2017 (Fehr & Peers) and included a 2025 target date for build-out of Phase 1 (1000 units located to the north of the parcel) without connections to either Happy Canyon Road or Crowfoot Valley Road.

North Canyons 1st PD Amendment (March 2019)

The 1st Amendment to the North Canyons PD includes an additional 1000 residential units.

North Canyons 2nd PD Amendment (July 2019)

The 2nd Amendment to the North Canyons PD included an additional 2500 residential units and a 2,500-student high school. The North Canyons 2nd PD Amendment also includes a "Southern Extension" of the planned development to the area immediately north of Crowfoot Valley Road, as well as additional access to proposed Canyonside Boulevard, Hess Road, and Crowfoot Valley Road.

Castle Pines Town Center PD (2018)

The Castle Pines Town Center PD included 375 residential units as part of a residential PUD development. The development is located to the west of I-25.

Castle Pines Town Center 1st PD Amendment (2019)

An amendment to the Castle Pines Town Center PD added 300 additional residential units, including 200 multi-family units, to approved planned development to the west of I-25. With the amendment, the supporting commercial/mixed use development was increased to a total of 500,865 square feet.

2050 Buildout Site-Generated Development Traffic Volumes

Review of the DRCOG Focus 2.3 model 2050 scenario confirmed that the supporting land use forecasts model did not include the site-generated traffic associated with full buildout of the Lagae Ranch, Castle Pines Town Center, and The Canyons developments.

For accurate representation of 2050 forecasted volumes, build-out site-generated development traffic volumes and the distribution of development traffic within the study area for these developments were obtained from the final TIS reports submitted to the City of Castle Pines and Douglas County.

These traffic impact studies, listed in **Table 13**, were used to estimate I-25/Happy Canyon Road study area development traffic volumes and distribution to routes, intersections, and study area entry/exit portals. Development site-generated traffic was estimated for build-out conditions. The 2050 DRCOG fiscally constrained RTP includes connections from Canyonside Boulevard to Crowfoot Valley Road and to Happy Canyon Road and the I-25/Happy Canyon Road Interchange, consistent with the regional network assumptions used for all the development traffic studies.

Table 13. Traffic Impact Study Reference Documents

Development	Traffic Impact Study Reference
The Canyons	The Canyons Master Transportation Study, Original PD, Fehr & Peers, October 2009.
The Canyons	Shea Homes Development TIS, Original PD, Fehr & Peers, May 2017.
The Canyons	North Canyons TIS, 1st PD Amendment, FHU, January 2019.
The Canyons	North Canyons TIS Addendum - 2nd PD Amendment, FHU, October 2019.
CP Town Center	CP Town Center PA-12, Focused TIA, Rick Engineering Company, December 9, 2019.
CP Town Center	CP Town Center Traffic Impact Analysis Final Report, FHU, December 2011.
CP Town Center	CP Town Center Land Use Revisions memo by FHU, dated October 11, 2013.
Lagae Ranch	Lagae Ranch PA-7, Focused TIA, Rick Engineering Company, August 8, 2019.
Promenade	Promenade at Castle Rock, Traffic Impact Analysis, FHU, January 2015.

Some of the assumptions or findings of the TIS reports listed above are summarized below:

Because both Lagae Ranch and Castle Pines Town Center were partially developed at the time of the traffic counts and had access to Happy Canyon Road, the amount of traffic to be generated by the undeveloped portions of those developments and its assignment to the roadway network was estimated.

Lagae Ranch had just one undeveloped parcel at the time of the traffic counts (PA-7; 190 multifamily units) and its traffic assignment was based on information contained within the *Lagae Ranch PA-7, Focused Traffic Impact Analysis* (Rick Engineering Company, August 8, 2019). **Figure 14** shows the traffic assignment for Lagae Ranch PA-7.

The traffic assignment for Castle Pines Town Center was based on information contained within the following documents: *Castle Pines Town Center Traffic Impact Analysis Final Report* (Felsburg, Holt & Ullevig, December 2011), *Castle Pines Town Center - Land Use Revisions Memo* (Felsburg, Holt & Ullevig, October 11, 2013), and *Castle Pines Town Center PA-12, Focused Traffic Impact Analysis* (Rick Engineering Company, December 9, 2019). The single-family residential portion of Castle Pines Town Center was partially built out at the time of the traffic counts, estimated as 178 homes. The traffic assignment of the 178 homes was estimated and subtracted from the overall buildout volumes for Castle Pines Town Center. **Figure 15** shows the traffic assignment for Castle Pines Town Center (undeveloped portion, as of February 2022).

Although partially developed at the time of the traffic counts (2022), The Canyons does not currently have access to Happy Canyon Road. The traffic assignment for The Canyons after the planned extension of Happy Canyon Road was based on information contained in *Shea Homes Development Transportation Impact Study* (Fehr & Peers, May 2017), *North Canyons Traffic Impact Study* (Felsburg, Holt & Ullevig, January 2019), and *North Canyons Traffic Impact Study Addendum - 2nd PD Amendment* (Felsburg, Holt & Ullevig, October 2019). **Figure 16** shows the traffic assignment for the buildout of The Canyons, with the planned extension of Happy Canyon Road.

Total 2050 Build traffic volumes include 2050 background traffic as well as site-generated traffic associated with full buildout of land use and density entitlements approved for the Lagae Ranch, Castle Pines Town Center, and The Canyons developments. **Figure 17** and **Figure 18** show the estimated 2050 Build total traffic volumes for the AM peak hour (7:00 – 8:00 AM) and the PM peak hour (4:00 – 5:00 PM), respectively.

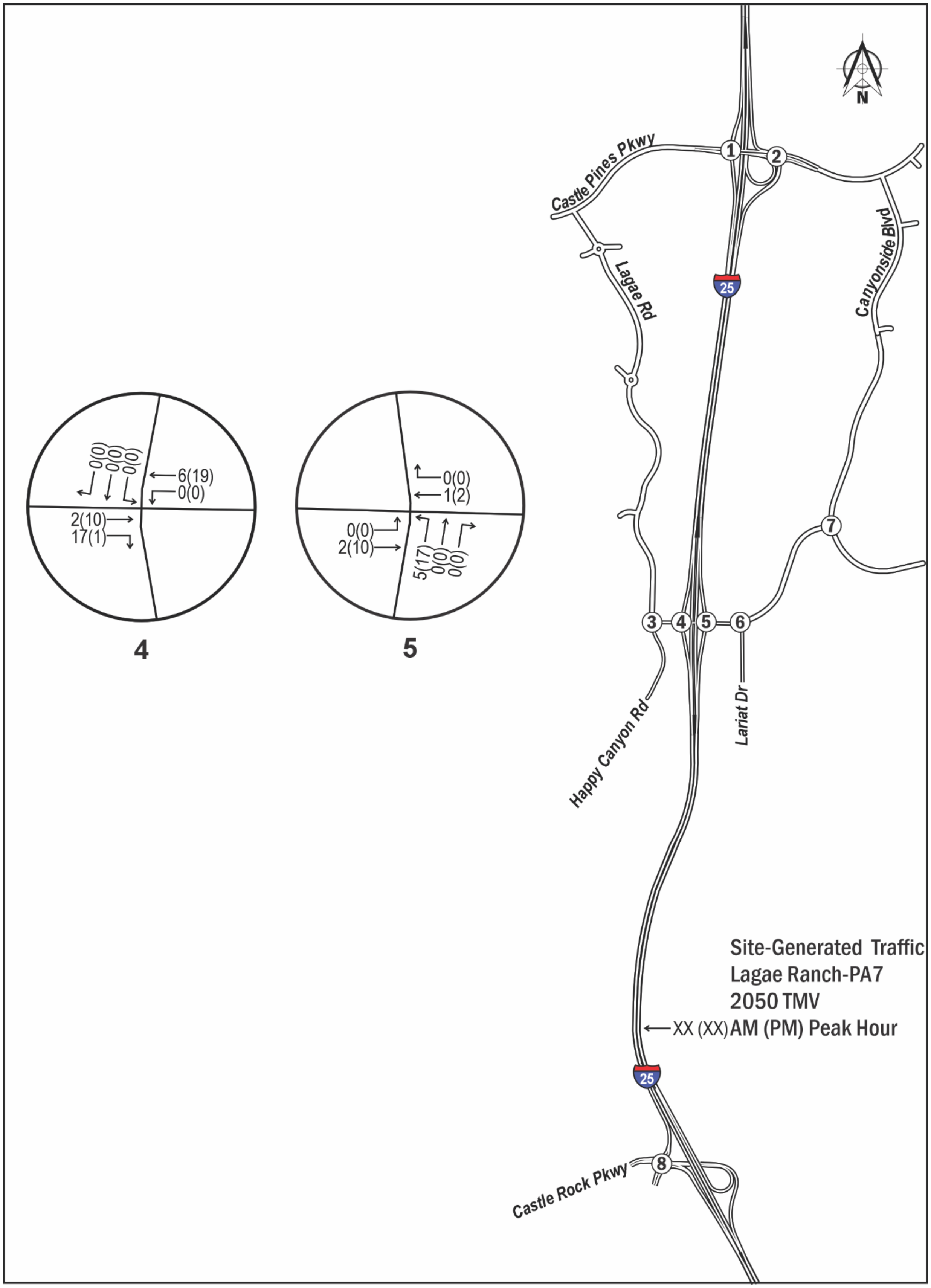


Figure 14. Lagae Ranch PA-7 2050 Peak Hour Traffic Volumes

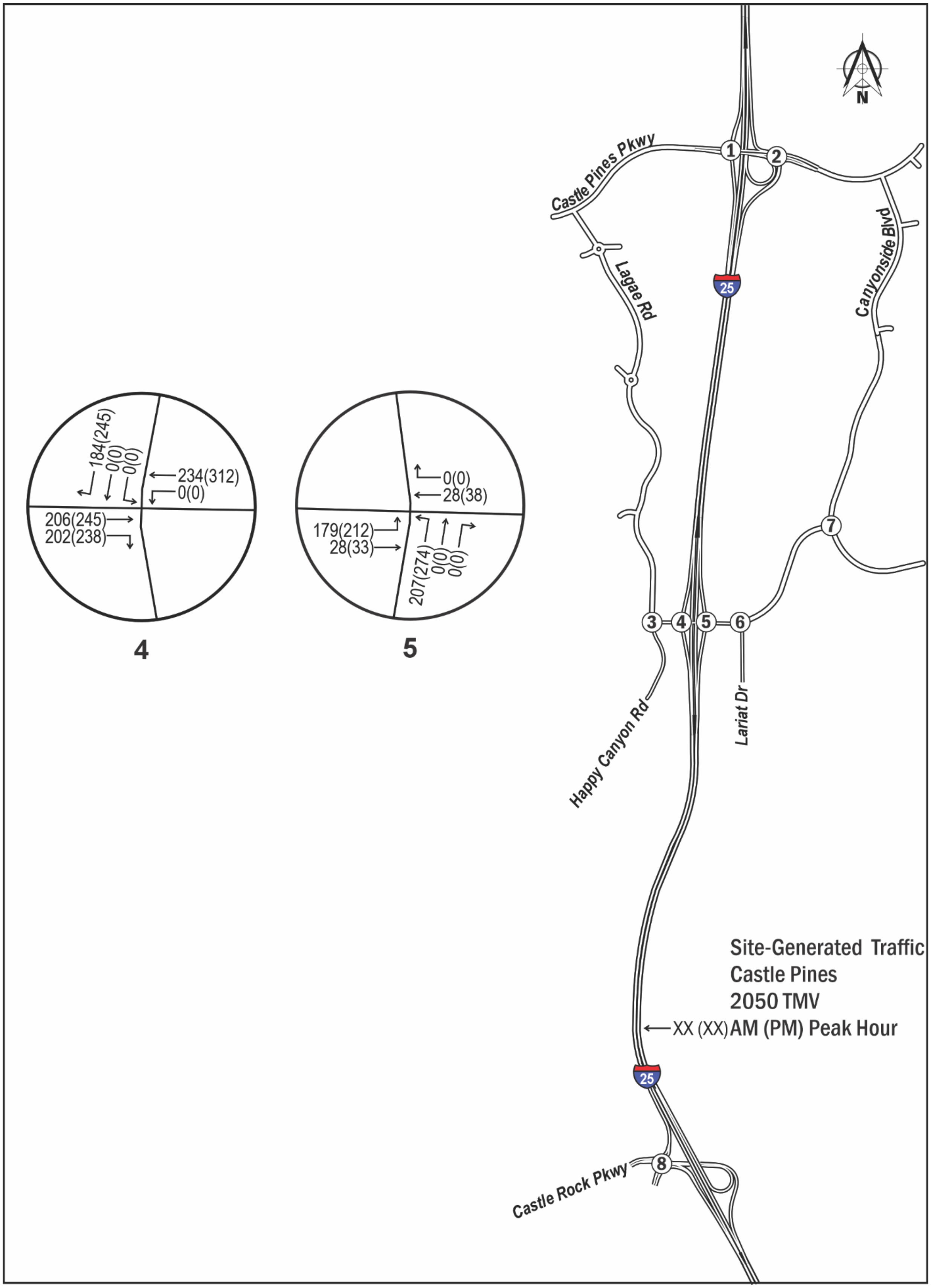


Figure 15. Castle Pines Town Center 2050 Peak Hour Traffic Volumes

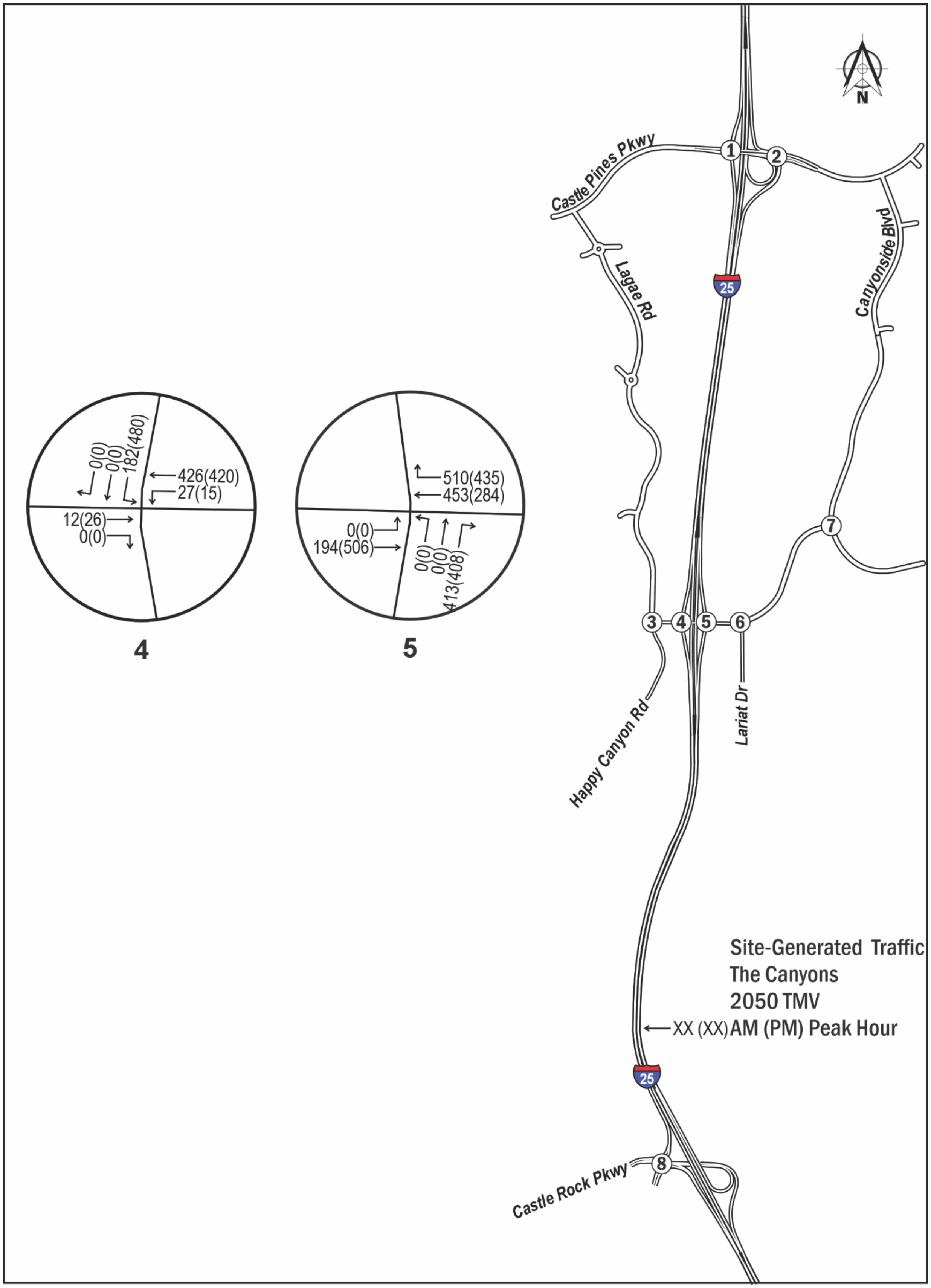


Figure 16. The Canyons Buildout 2050 Peak Hour Traffic Volumes

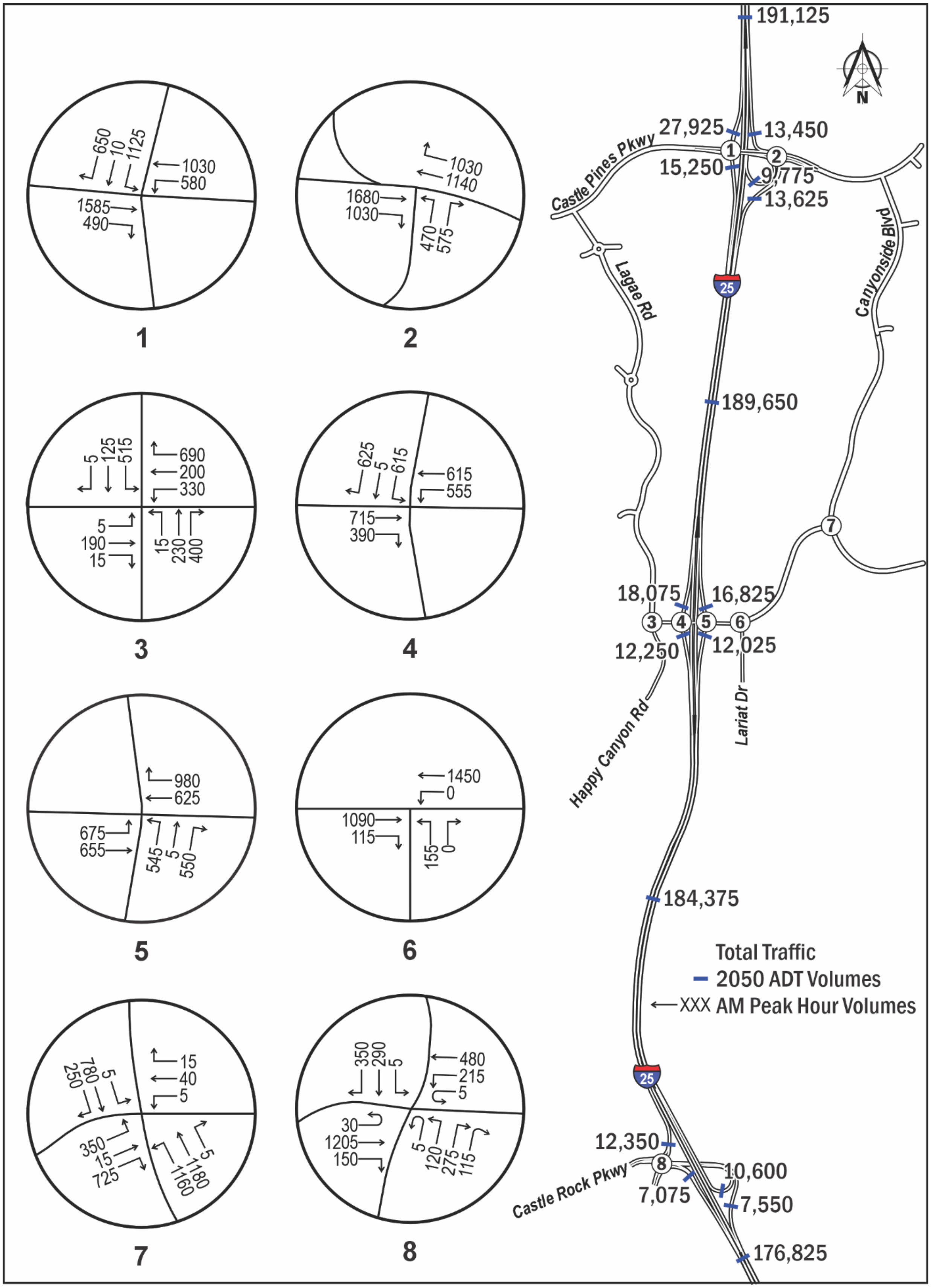


Figure 17. 2050 Build AM Peak Hour Total Traffic Volumes

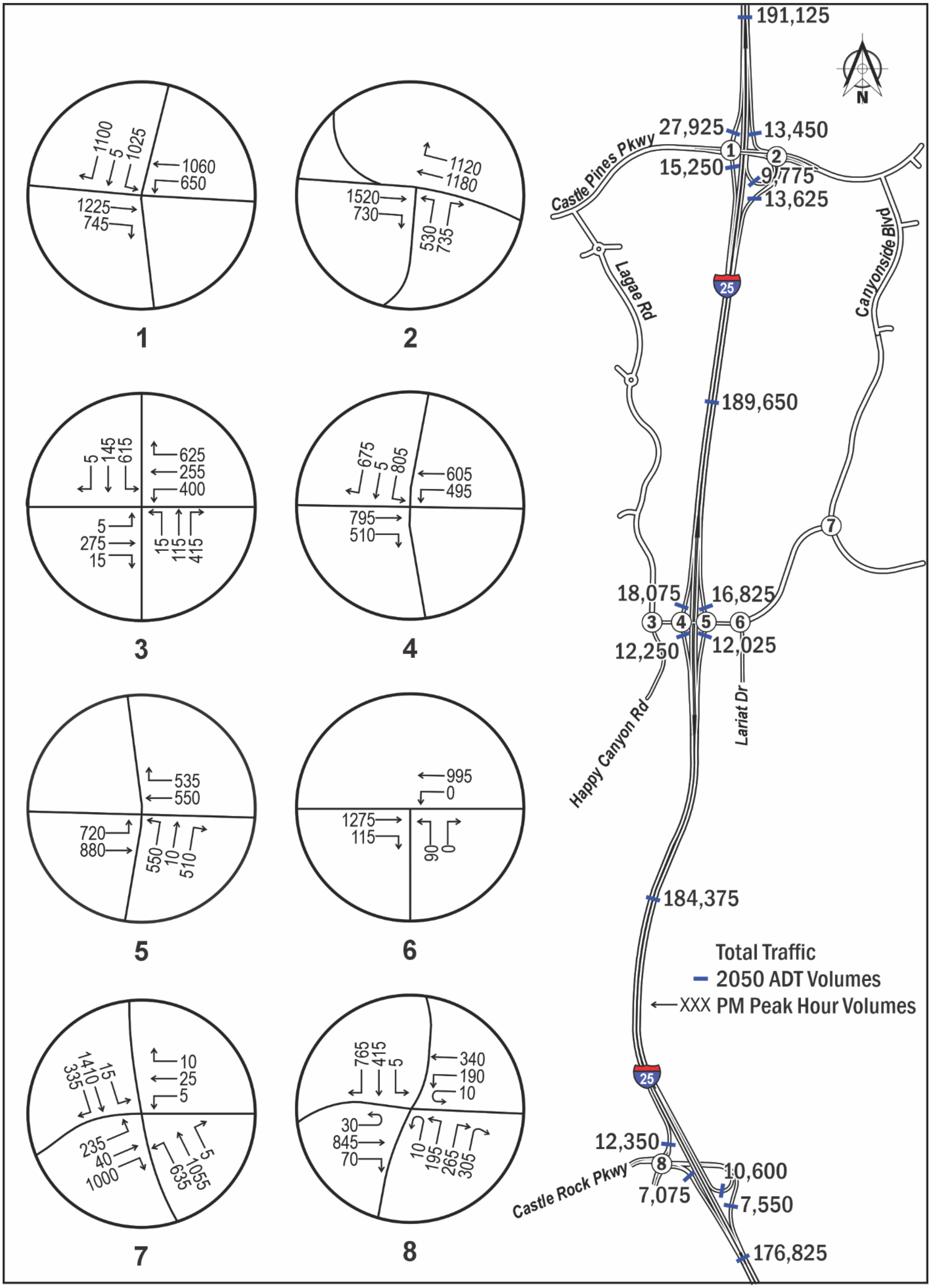


Figure 18. 2050 Build PM Peak Hour Total Traffic Volumes

2050 Build Alternatives Traffic Operations Analysis

Two alternatives were initially proposed to improve future 2050 operations at the I-25/Happy Canyon interchange: a roundabout diamond interchange and signalized diamond interchange. Upon initial analysis of the roundabout diamond interchange, shown in **Figure 19**, it appeared that the alternative failed to accommodate the heavy traffic volumes at the ramp termini which led to extremely long delays and queues (see **Figure 20**). As a result of the poor performance of the roundabout diamond interchange, a diverging diamond interchange was proposed to replace the roundabout diamond interchange alternative for full traffic analysis.

Roundabout Diamond Interchange Alternative

A separate memo analyzing the roundabout interchange was prepared to document the preliminary analysis completed to support the elimination of the roundabout diamond interchange alternative. Multiple software tools were used to analyze the performance of the roundabout diamond interchange including Highway Capacity Software (HCS), Rodel, and VISSIM. Rodel and HCS results (**Table 14** and **Table 15**, respectively) showed failing LOS for at least one movement, and VISSIM modeling showed long queues at the interchange (**Figure 20**). Additionally, the heavy SB left-turn traffic volume at the west ramp terminal and heavy EB left-turn traffic volume at the east ramp terminal would each need to be served by two lanes which would result in the need for a three-lane EB approach at the east ramp terminal. The three-lane EB approach, combined with the two-lane NB approach at the east ramp terminal would ultimately result in four circulating lanes in the SE quadrant of the east ramp terminal which is likely not acceptable to CDOT and/or FHWA. The full Roundabout Interchange Alternative Analysis Memo is included as **Appendix I**.

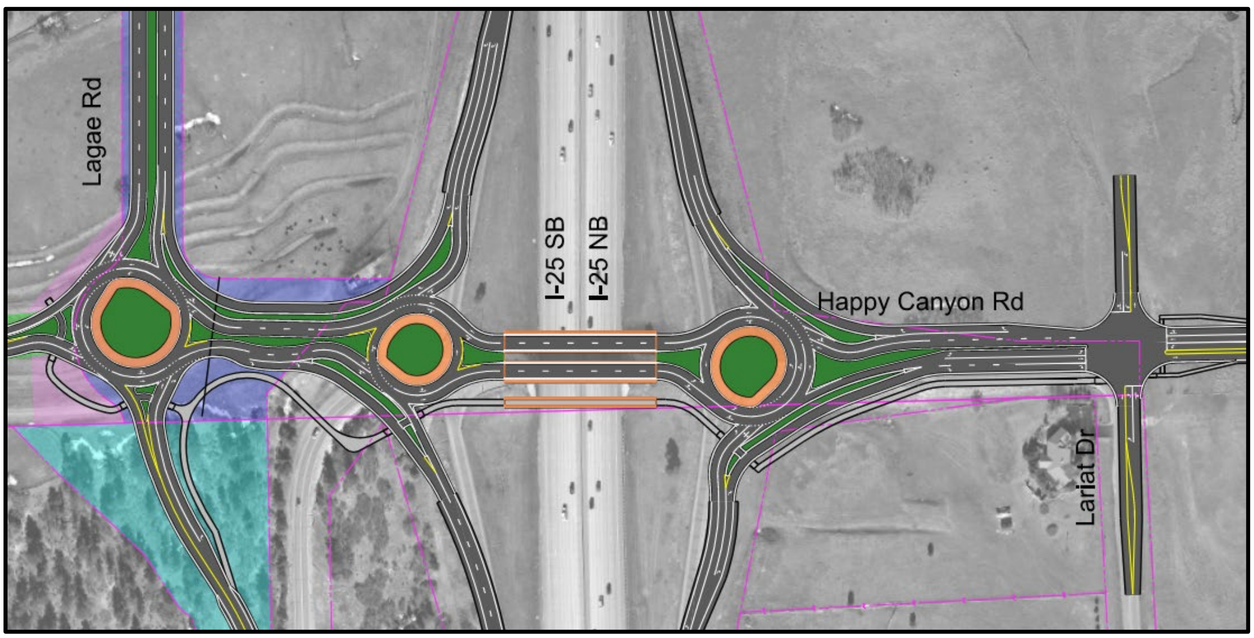


Figure 19. Roundabout Diamond Interchange Alternative

Table 14. Rodel Analysis of Roundabout Interchange Alternative

Roundabout Interchange		LOS/Delay [in seconds/vehicle] (Critical Movement)			
		AM Peak Hour		PM Peak Hour	
		SB Ramps	NB Ramps	SB Ramps	NB Ramps
Approach	Eastbound	A / 8.8	A / 8.5	C / 19.4	B / 12.1
	Westbound	A / 9.2	A / 6.5	A / 8.0	A / 6.0
	Northbound	-	A / 6.6	-	B / 11.0
	Southbound	C / 17.9	-	E / 48.6	-

Table 15. HCS 8.1 Analysis of Roundabout Interchange Alternative

Roundabout Interchange		**LOS/Delay [in seconds/vehicle] (Critical Movement)**			
		AM Peak Hour		**PM Peak Hour**	
		SB Ramps	**NB Ramps**	**SB Ramps**	**NB Ramps**
Approach	Eastbound	**F** / 82.5	**A** / 8.2	**F** / 374.2	**B** / 10.5
	Westbound	**A** / 7.2	**F** / 1046.3	**A** / 6.8	**F** / 906.9
	Northbound	-	**F** / 77.8	-	**F** / 364.8
	Southbound	**F** / 422.9	-	**F** / 776.7	-
Overall Intersection		**F** / 161.9	**F** / 282.5	**F** / 394.1	F / 265.7

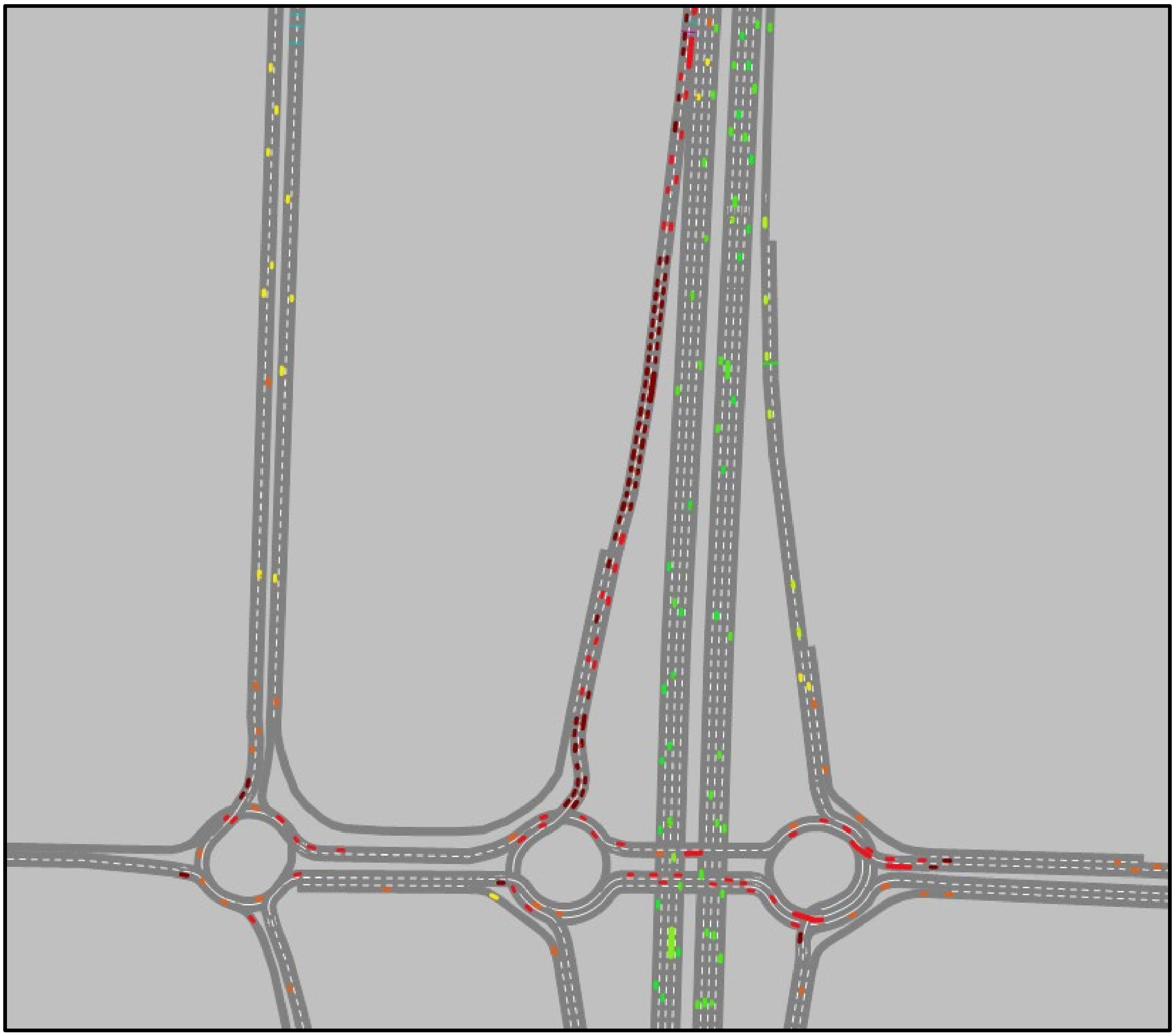


Figure 20. Roundabout Interchange Alternative Queueing (VISSIM)

Signalized Diamond Interchange Alternative

The signalized diamond interchange alternative that was fully analyzed is shown in **Figure 21.**

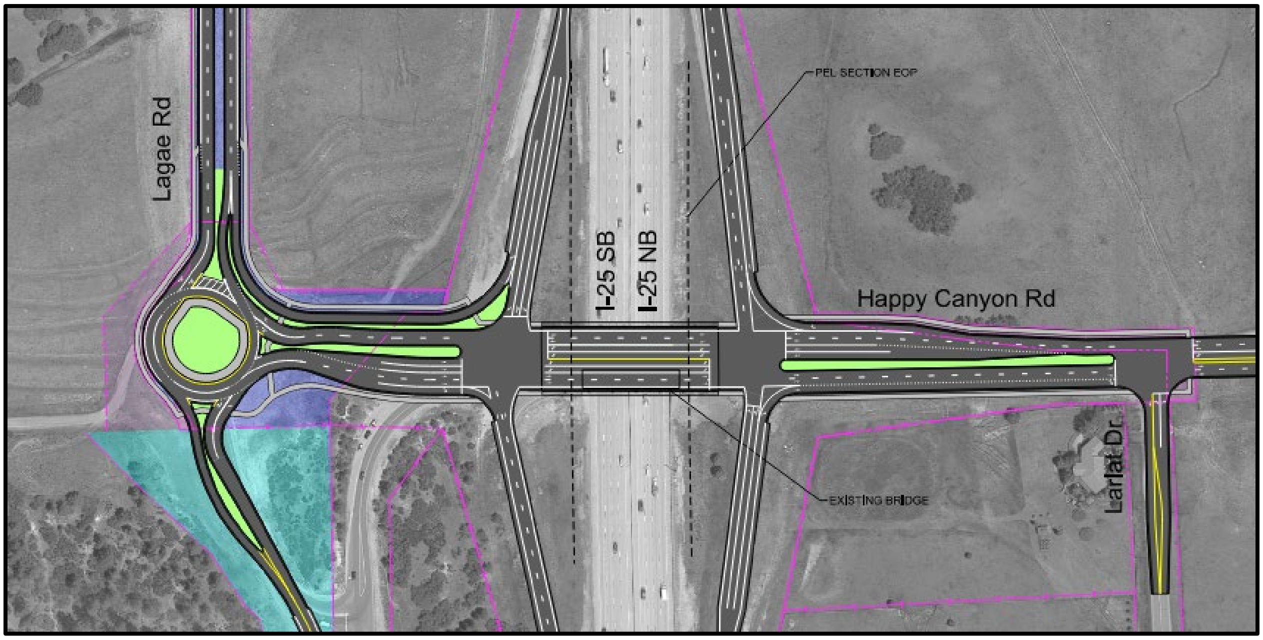


Figure 21. Signalized Diamond Interchange Alternative

Table 16 shows the 2050 LOS and delays for the intersections within the study area for the signalized diamond alternative. The LOS and delay values shown in the table are based on the average of 15 runs of the VISSIM 2050 models. **Appendix J** provides additional detail regarding the intersection levels of service.

Table 16. 2050 Signalized Diamond Interchange Levels of Service

Control	Intersection	LOS/Delay [in seconds/vehicle] (Critical Movement)	
		AM Peak Hour	PM Peak Hour
Roundabout	Castle Rock Pkwy & I-25 SB	**A** / 9.9	**A** / 6.6
Roundabout	Happy Canyon Rd & Lagae Rd	**A** / 8.2	**A** / 9.8
Signal	Happy Canyon Rd & I-25 SB	**C** / 21.9	**C** / 22.4
Signal	Happy Canyon Rd & I-25 NB	**B** / 17.1	**B** / 12.4
Signal	Castle Pines Pkwy & I-25 SB	**D** / 40.6	**C** / 25.9
Signal	Castle Pines Pkwy & I-25 NB	**A** / 9.3	**A** / 8.4

Diverging Diamond Interchange Alternative

The diverging diamond interchange alternative that was fully analyzed is shown in **Figure 22.**

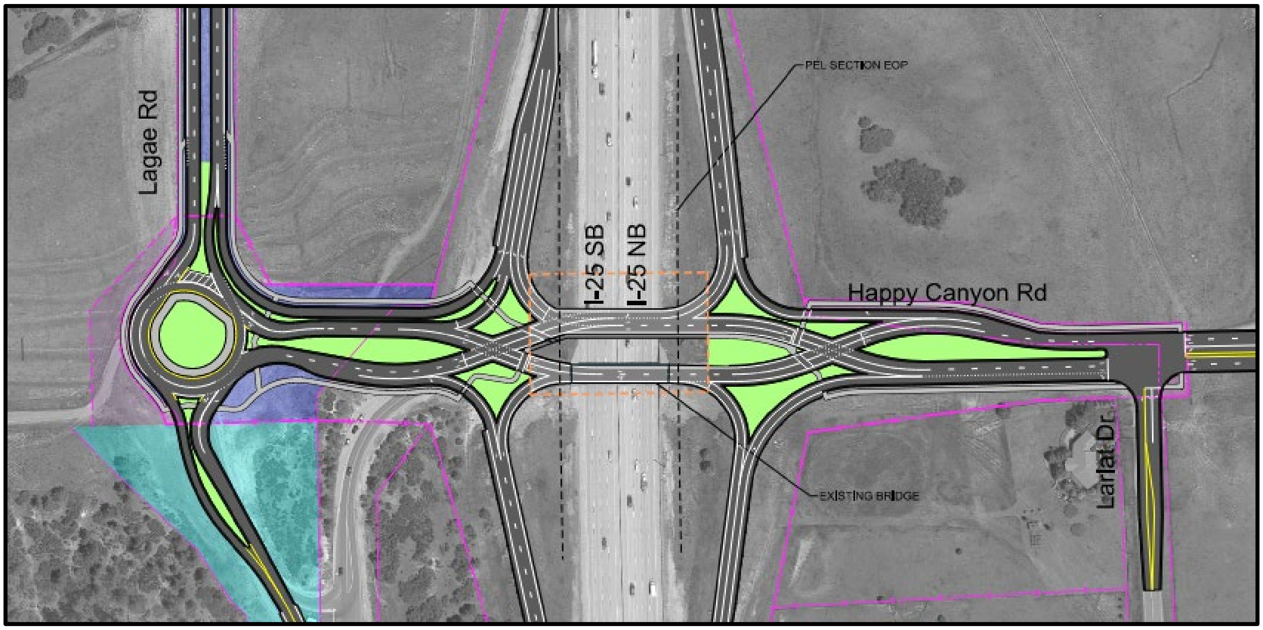


Figure 22. Diverging Diamond Interchange Alternative

Table 17 shows the 2050 LOS and delays for the intersections within the study area for the diverging diamond alternative. The LOS and delay values shown in the table are based on the average of 15 runs of the VISSIM 2050 models. **Appendix J** provides additional detail regarding the intersection levels of service.

Table 17. 2050 Diverging Diamond Interchange Levels of Service

Control	Intersection	LOS/Delay [in seconds/vehicle] (Critical Movement)	
		AM Peak Hour	PM Peak Hour
Roundabout	Castle Rock Pkwy & I-25 SB	**A** / 9.7	**A** / 6.5
Roundabout	Happy Canyon Rd & Lagae Rd	**A** / 7.3	**A** / 8.7
Signal	Happy Canyon Rd & I-25 SB	**A** / 9.6	**B** / 10.2
Signal	Happy Canyon Rd & I-25 NB	**A** / 8.5	**A** / 6.1
Signal	Castle Pines Pkwy & I-25 SB	**D** / 41.2	**C** / 25.8
Signal	Castle Pines Pkwy & I-25 NB	**A** / 9.4	**A** / 8.4

Traffic Operations Analysis Conclusions

The No Action alternative is unable to accommodate the forecasted 2050 traffic volumes without significant delays and failing LOS due to the failing operations at the I-25/Happy Canyon Road interchange. However, both the signalized diamond interchange alternative and diverging diamond interchange alternative are shown to fully accommodate the forecasted 2050 traffic volumes without significant vehicle queues or delays. As shown in **Table 16** and **Table 17**, the diverging diamond interchange is reported to operate more efficiently than the signalized diamond interchange demonstrated by the better LOS and less delay at the I-25/Happy Canyon Road ramp termini intersections.

Development of Traffic Impact Analysis

Large-scale development project entitlements have been approved within the study area that will use the I-25/Happy Canyon Road interchange as a primary or secondary access to I-25. At buildout, as shown in **Table 18**, these developments will add approximately 6,540 residential units and 2.7 million square feet (MSF) of commercial uses to the I-25/Happy Canyon Road travel shed. As shown in **Table 19**, this level of development will produce a total of 120,890 daily site-generated trips at buildout.

Funding responsibilities included in the development agreements for The Canyons and Castle Pines Town Center include participation in funding I-25/Happy Canyon interchange ramp metering, ramp terminal intersection signalization, ramp intersection approach improvements, and sharing of costs for larger interchange improvement elements. Generally, the development agreement funding responsibilities for larger improvement costs will be based on estimated shares of site-generated development traffic shares of total traffic expected to use the interchange, and development-based traffic cost sharing was stipulated as either actual share of total traffic or capped as a maximum share in the development agreements. The development agreement(s) for Lagae Ranch, which was nearly built out by 2022, did not include participation in I-25/Happy Canyon interchange improvements, but did include cost sharing responsibilities for other infrastructure improvements.

To develop an understanding of the impact of new development on the I-25/Happy Canyon interchange, traffic impact studies submitted to support the Castle Pines and Douglas County development review process were used to estimate study area site-generated traffic volumes and development distribution to routes and intersections, including the I-25/Happy Canyon interchange ramp intersections. Shares of site-generated traffic from The Canyons, Castle Pines Town Center, and Lagae Ranch PA-7 (last filing) of 2050 total traffic using these intersections were calculated as shown in **Table 20**.

The analysis results show that 47% of 2050 design year total traffic using the I-25/Happy Canyon Road interchange can be expected to consist of regional background traffic, while the of the remaining 53% of traffic using the interchange, 34% and 19% can be expected to be generated by The Canyons development and the Castle Pines Town Center development, respectively. Lagae Ranch PA-7 traffic using the interchange intersections would be minimal, amounting to less than 1% of the 2050 design year total traffic using the interchange ramp terminal intersections.

Table 18. Development Entitlements Land Use Summary

Development	Development Entitlements		
Phase/Approval Description	**Approval Dates**	**Residential (DUs)**	**Commercial (MSF)**
North Canyons/Shea Canyons	2009/2017	2,500	1.6
North Canyons PD Amendment 1	2019	1,000	0.0
North Canyons PD Amendment 2	2019	1,500	0.5
The Canyons – Total Approved		**5,000**	**2.1**
Castle Pines Town Center	2018	525	0.0
Castle Pines Town Center PD Amendment 1	2019	453	0.5
Castle Pines Town Center – Total Approved		**978**	**0.5**
Lagae Ranch	2019	611	0.0
Lagae Ranch PD Amendment 1	2019	-48	0.0
Lagae Ranch – Total Approved	2017	**563**	**0.0**
Total Development Entitlements		**6,541**	**2.7**

Table 19. Development Entitlements Trip Generation Summary

Parcel	Land Use	Size	Daily Trips
	North Canyon PD (Minus Shea Canyons Transfer)		
	Commercial - Retail	*450 KSF*	*28,615*
	Office	*1,094 KSF*	*11,3125,890 95*
	Multi-Family Residential	*500 DU*	*2,960*
	Hotel	*480 Rooms*	*3,515*
	Assisted Living	*30 KSF*	*130*
	Gross Subtotal		**46,615**
	Shea Canyons PD		
	Single-Family Residential	*2,000 DU*	*16,365*
	Commercial - Retail	*30 KSF*	*2,655*
	Gross Subtotal		**19,020**
	North Canyons 1st PD Amendment – Phase 1		
13	*Single-Family Residential*	*375 DU*	*3,510*
13	*Multi-Family Residential*	*96 DU*	*685*
14	*Single-Family Residential*	*426 DU*	*3,945*
14	*Multi-Family Residential*	*51 DU*	*345*
15	*Single-Family Residential*	*70 DU*	*750*
16	*Single-Family Residential*	*100 DU*	*1,040*
17	*Single-Family Residential*	*41 DU*	*460*
17	*Multi-Family Residential*	*68 DU*	*475*
18	*Multi-Family Residential*	*167 DU*	*1,040*
19	*Multi-Family Residential*	*106 DU*	*670*
19	*Commercial - Retail*	*90 KSF*	*5,600*
	Gross Subtotal		**18,520**
	North Canyons – 2nd PD Amendment – Phase 2		
13	*High School*	*2,500 Students*	**5,075**
	The Canyons - Gross Subtotal		**89,230**
	The Canyons - Internal Capture Reduction (8%)		-7,140
	The Canyons Total – Net Vehicle Trips		**82,090**
	Lagae Ranch		
	Single-Family Residential	*563*	6,030
	Lagae Ranch - Gross Subtotal		**6,030**
	Internal Capture Reduction (8%)		-405
	Lagae Ranch – Net Vehicle Trips		**5,625**
	Castle Pines Town Center		
	Single-Family Residential	*778*	8,335
	Multi-Family Residential	*200*	1,265
	Commercial - Retail	*500 KSF*	31,795
	CP Town Center - Gross Subtotal		**41,495**
	CP Town Center - Internal Capture Reduction (8%)		-3,320
	CP Town Center – Net Vehicle Trips		**38,175**
	Study Area Entitlement Totals		
	Entitlements Gross Total Vehicle Trips		**136,755**
	Entitlements Total Internal Capture Reduction (8%)		-10,865
	Entitlements Total Net Vehicle Trips		**125,890**

Table 20. Traffic Shares Calculation Worksheet

Intersection/Movement	PM Peak Hour Traffic Volumes							Site-Generated Growth Share			
	2022 Existing [1]	2050 Background [2]	The Canyons Total Traffic [3,4,5]	Castle Pines Town Center [6,7,8,9]	Lagae Ranch PA-7 [10]	Site-Generated Total Traffic[11]	2050 Total Traffic[12]	The Canyons Total Traffic	Castle Pines Town Center	Lagae Ranch PA-7	Regional Traffic Share
4. I-25/Happy Canyon Road SB Ramps											
EB Through	337	515	26	216	10	252	795				
EB Right-Turn	178	250	0	210	1	211	510				
SB Left-Turn	45	325	480	0	0	480	805				
SB Through	1	5	0	0	0	0	5				
SB Right-Turn	282	435	0	232	0	232	675				
WB Left-Turn	28	75	420	0	0	420	495				
WB Through	172	270	15	295	19	329	605				
Intersection Total Traffic	**1,043**	**1,875**	**941**	**954**	**30**	**1,924**	**3,890**				
Intersection Traffic Share						**49%**		**24%**	**25%**	**0%**	**51%**
5. I-25/Happy Canyon Road NB Ramps											
EB Left-Turn	335	510	0	187	0	187	720				
EB Through	49	330	506	29	10	545	880				
WB Through	28	85	435	36	2	473	550				
WB Right-Turn	30	335	284	0	0	284	535				
NB Left-Turn	171	260	0	259	17	276	550				
NB Through	6	10	0	0	0	0	10				
NB Right-Turn	23	105	408	0	0	408	510				
Intersection Total Traffic	**642**	**1,635**	**1,633**	**512**	**29**	**2,174**	**3,755**				
Intersection Traffic Share						**58%**		**44%**	**14%**	**0%**	**42%**
I-25/Happy Canyon Interchange											
Interchange Total Traffic			**2,574**	**1,466**	**59**	**4,099**	**7,645**				
Interchange Total Traffic Share						**54%**		**34%**	**19%**	**0%**	**47%**

Notes: 1) From Peak Hour TMCs conducted in February 2022.

2) Estimated from February 2022 counts using a 1.52 growth factor derived from analysis of DRCOG Travel Model 2020 and 2050 raw assignment volumes, with additional traffic added at Happy Canyon Rd/Canyonside Blvd and the I-25/Happy Canyon Rd interchange ramp termini to account for traffic that would use the new I-25 connection to/from the east, based on North Canyons Traffic Impact Study Addendum - 2nd PD Amendment, FHU, October 2019, Figure 9 (Long-Term Total Traffic Volumes with High School).

3) Shea Homes Development Transportation Impact Study, Fehr & Peers, May 2017, Figure 8 (Trip Assignment 2025 - Intersections 1-9) and Figure 9 (Trip Assignment 2025 - Intersections 10-19).

4) North Canyons Traffic Impact Study, Felsburg, Holt & Ullevig, January 2019, Figure 11 (long-Term Site Trip Distribution and Traffic Assignment) - January 17, 2019.

5) North Canyons Traffic Impact Study Addendum - 2nd PD Amendment, Felsburg, Holt & Ullevig, October 2019, Figure 6 (Long-Term Site Trip Distribution and Traffic Assignment).

6) Castle Pines Town Center Traffic Impact Analysis Final Report, Felsburg, Holt & Ullevig, December 2011, Figure 8 (Buildout (Year 2030) Trip Distribution and Site-Generated Traffic Assignment) - December 15, 2011.

7) Volume reductions to account for an estimated 178 occupied homes within Castle Pines Town Center at the time of the traffic counts (February 2022).

8) Volume adjustments to account for a land use revision, based on information contained in Table 2 of the Castle Pines Town Center - Land Use Revisions memo by Felsburg, Holt & Ullevig, dated October 11, 2013.

9) Castle Pines Town Center PA-12, Focused Traffic Impact Analysis, Rick Engineering Company, December 9, 2019, Exhibit 7 (Project Trip Assignment).

10) Lagae Ranch PA-7, Focused Traffic Impact Analysis, Rick Engineering Company, August 8, 2019, Exhibit 7 (Project Trip Assignment); the remainder of Lagae Ranch was built out at the time of the traffic counts (February 2022).

11) Total of the three columns to the left.

12) Total of 2050 Background Volumes and Site-Generated Total Traffic Volumes.

Safety Analysis

Safety Performance of Diverging Diamond Interchanges

A literature search was conducted to examine the safety performance of DDI replacements of conventional diamond interchanges. Published FHWA guidance[5,6] (2009, 2020) states that *compared to a conventional diamond interchange, the DDI reduces vehicle-to-vehicle conflict points by nearly 50 percent and eliminates many of the most severe crash types*. Additionally, FHWA guidance indicates that pedestrian safety is improved at DDIs when compared to traditional signalized diamond interchanges because pedestrians need to cross fewer lanes.

Detailed empirical data is presented in a 2021 paper published in the National Academy of Science Transportation Research Record[7]. The 2021 study collected a nationwide sample of 80 DDIs located in 24 states, including 3 in Colorado, and developed Crash Modification Factors (CMF) for predictive analysis. The conclusions drawn from this research are that converting a conventional diamond interchange to a DDI can *significantly decrease the total, fatal-and-injury, rear-end, and angle/left-turn crashes by 14%, 44%, 11% and 55%, respectively*.

The final safety performance functions that were developed from the study also implied that both a longer distance between crossover/ramp terminals and lower speed limits on freeway exit ramps are additional factors that result in lower crash frequency at diverging diamond interchanges.

Predictive Crash Analysis Comparison for Interchange Alternatives

Crash prediction analysis for the I-25 / Happy Canyon Road interchange was completed using the HSM (Highway Safety Manual) Part C predictive method[8] using the Interactive Highway Safety Design Model (IHSDM). IHSDM is a software created by the FHWA that uses the HSM predictive method to predict crash totals, frequencies, and severities for freeway segments and speed-change lanes, freeway ramps and ramp terminals, arterial roads, and intersections. The evaluation period predicted crashes over a 20-year period from Opening Year (2030) to Design Year (2050).

Predictive models are comprised of the following elements as outlined in the HSM (p. 3-16 to 3-17):

- SPFs – Statistical "base" models used to estimate the average crash frequency for a facility type with specific base conditions.
- CMFs – CMFs are the ratio of the effectiveness of one condition in comparison to another condition. CMFs are multiplied with the crash frequency predicted by the SPF to account for the difference between site conditions and specified base conditions.
- Calibration Factor (C) – A factor multiplied with the crash frequency predicted by the SPF to account for differences between the jurisdiction and time period for which the predictive models were developed and the jurisdiction and time period to which they are applied by HSM users.

[5] FHWA, Double Crossover Diamond Interchange - FHWA-HRT-09-054 (dot.gov), 2009.
[6] FHWA, *Diverging Diamond Interchange: An Innovative Proven Solution for Improving Safety and Mobility at Interchanges*, 2020.
[7] NAS TRR, *Systematic Safety Evaluation of Diverging Diamond Interchanges Based on Nationwide Implementations Data*, 2021.
[8] FHWA, *Highway Safety Manual*, 2010.

The base form of the crash prediction equation is shown below:

$$N_{predicted} = N_{spfx}\ x\ \left(CMF_{1x}\ x\ CMF_{2x}\ x\ \ldots\ CMF_{yx}\right)\ x\ C_x$$

Where:

$N_{predicted}$ = predictive model's estimate of crash frequency for a specific year on site type x (crashes/year)

N_{spfx} = predicted average crash frequency determined for base conditions with the Safety Performance Function representing site type x (crashes/yr)

CMF_{yx} = Crash Modification Factors specific to site type x

C_x = Calibration Factor to adjust for location conditions for site type x.

SPFs and CMFs were selected based on the roadway facility site types and conditions. Calibration factors were not used as part of the predictive analysis due to none being recommended by CDOT staff for predictive analysis within Colorado.

The following two predictive models were developed for safety screening of the two alternatives:

1. Signalized Diamond Interchange
2. Diverging Diamond Interchange

To develop these models, the Signalized Diamond Interchange was first created using IHSDM by entering all the roadway features necessary for a predictive HSM analysis (such as horizontal curvature, lane widths, signal control, etc.) as well as the traffic volumes for Opening Year (2030) and Design Year (2050). The program automatically interpolated the traffic volumes for years between 2030 and 2050 when the predicted crashes covering the full 20-year evaluation period were extracted.

The geometric inputs to IHSDM were based on the conceptual design of the Signalized Diamond Interchange as shown in **Figure 21**. A screenshot of how IHSDM depicts the geometric inputs is shown in **Appendix K**. Opening Year (2030) peak-hour and daily traffic volumes were forecasted for the purpose of the safety analysis and 2050 daily traffic volumes were calculated based on the peak-hour volumes shown in **Figures 17** and **18**. The 2030 and 2050 daily traffic volumes used as inputs to IHSDM are shown in **Appendix K**.

To model the DDI alternative, a copy of the Signalized Diamond Interchange was created, and two CMFs were applied at the ramp terminal intersections to capture the differences in predicted crashes between the two alternatives. The summation of crashes from 2030 to 2050 for the DDI were then extracted.

Details of the CMFs are listed below:

Convert a Conventional Diamond Interchange to Diverging Diamond Interchange (DDI) (Fatal and Injury Crashes)

- CMF ID: 10762
- CMF Value (Fatal & Injury Crashes): 0.558
- Crash Reduction Factor (Fatal & Injury Crashes): 44.2%

Convert a Conventional Diamond Interchange to Diverging Diamond Interchange (DDI) (Property Damage Only Crashes)

- CMF ID: 10763
- CMF Value (PDO Crashes): 0.92
- Crash Reduction Factor (PDO Crashes): 8%

Although the IHSDM model also produced predicted crash totals for the roadway segments (non-intersection crashes) and for the Happy Canyon Road/Lagae Road roundabout, only the intersection crashes at the two ramp termini have been summarized for this report, since the purpose of the safety analysis is to compare the predicted safety performance of the two interchange alternatives. Other than at the ramp termini, the predicted crash totals for all other roadway elements within the IHSDM model are identical for the two alternatives. The sum of all ramp termini crashes over the 20-year evaluation period extracted from the program for each alternative are summarized in **Table 21. Table 22** compares the total entering vehicle crash rates at the ramp termini for each alternative measured in crashes per million vehicle miles. The Crash Prediction Evaluation Reports produced by IHSDM for each alternative, from which the values for total crashes and crash rates in **Tables 21** and **22** were taken, are included in **Appendix K**.

As shown in **Table 21**, the DDI Alternative is predicted to experience approximately 20% fewer total crashes and 44% fewer fatal and injury crashes than the Signalized Diamond Interchange Alternative over a 20-year period. Additionally, **Table 22** shows a 21% lower crash rate at the I-25 SB Ramps / Happy Canyon Road ramp terminal and a 19% lower crash rate at the I-25 NB Ramps / Happy Canyon Road ramp terminal in the DDI alternative when compared against the Signalized Diamond Interchange Alternative. Therefore, the predictive safety analysis results indicate that the DDI is expected to result in fewer crashes than the Signalized Diamond Interchange over a 20-year period.

Table 21. Predicted 20-Year Crash Total Comparison of Interchange Alternatives

Location	Signalized Diamond Interchange				Diverging Diamond Interchange[1]				Difference (Signalized Diamond vs. DDI)				Percent Difference (Signalized Diamond vs. DDI)			
	PDO	**INJ**	**Fatal**	**Total**	**PDO**	**INJ**	**Fatal**	**Total**	**PDO**	**INJ**	**Fatal**	**Total**	**PDO**	**INJ**	**Fatal**	**Total**
I-25 SB Ramps / Happy Canyon Rd Ramp Terminal	*161.24*	*88.56*	*0.08*	*249.89*	*148.34*	*49.42*	*0.05*	*197.81*	*-12.90*	*-39.14*	*-0.04*	*-52.08*	*-8%*	*-44%*	*-44%*	*-21%*
I-25 NB Ramps / Happy Canyon Rd Ramp Terminal	*210.52*	*97.69*	*0.09*	*308.31*	*193.68*	*54.51*	*0.05*	*248.24*	*-16.84*	*-43.18*	*-0.04*	*-60.06*	*-8%*	*-44%*	*-44%*	*-19%*
Total	**371.76**	**186.25**	**0.17**	**558.19**	**342.02**	**103.93**	**0.10**	**446.05**	**-29.74**	**-82.32**	**-0.08**	**-112.14**	***-8%***	***-44%***	***-44%***	***-20%***

Notes: 1) 20-year crash totals for the DDI were determined by applying two CMFs (IDs 10762 & 10763) to the Signalized Diamond Interchange predictive safety model.
2) The crash totals come from Table 9 of the Signalized Diamond Interchange IHSDM Crash Prediction Evaluation Report and Table 11 of the Diverging Diamond Interchange IHSDM Crash Prediction Evaluation Report, both of which are located in Appendix K.

Table 22. Predicted Crash Rate Comparison of Interchange Alternatives

Location	Signalized Diamond Interchange	Diverging Diamond Interchange[1]	Difference (Signalized Diamond vs. DDI)	Percent Difference (Signalized Diamond vs. DDI)
	Intersection Crash Rate (crashes/million-vehicles)	**Intersection Crash Rate (crashes/million-vehicles)**	**Intersection Crash Rate (crashes/million-vehicles)**	**Intersection Crash Rate (crashes/million-vehicles)**
I-25 SB Ramps / Happy Canyon Rd Ramp Terminal	*1.04*	*0.82*	*-0.22*	*-21%*
I-25 NB Ramps / Happy Canyon Rd Ramp Terminal	*1.31*	*1.06*	*-0.25*	*-19%*

Notes: 1) Crash rates for the DDI were determined by applying two CMFs (IDs 10762 & 10763) to the Signalized Diamond Interchange predictive safety model.
2) The crash rates come from the right-most column in Table 6 of the Signalized Diamond Interchange IHSDM Crash Prediction Evaluation Report and the right-most column in Table 8 of the Diverging Diamond Interchange IHSDM Crash Prediction Evaluation Report, both of which are located in Appendix K.

Environmental Considerations

An environmental overview evaluation was conducted for the interchange area in May 2018 to support potential interim upgrades to the I-25/Happy Canyon Road interchange. That environmental overview was updated in February 2022 to support a City of Castle Pines project (Phase 1 Project) to complete safety improvements at the Lagae Road/ Happy Canyon Road intersection that is located to the west of the interchange. A biological resources assessment was also conducted in 2023. All three environmental reports are included in **Appendix L**.

The Project A improvements, currently under construction, will address safety issues that exist with the existing "buttonhook" connection from Lagae Road to Happy Canyon Road, west of I-25. The Project A improvements generally consist of a roundabout intersection and associated work to construct it while making a temporary connection into the existing interchange. The improvements include installation of interim traffic signals at the I-25 ramp terminals. The Phase 1 Project roundabout intersection is compatible with both the DDI and Signalized Diamond interchange alternatives.

The findings of these evaluations do not favor one interchange alternative over the other. Further, none of these reports constitutes any environmental clearance but instead assesses existing conditions to determine what the appropriate NEPA class of action might be for the proposed Happy Canyon Road Phase A improvements project. The findings of these initial assessments are summarized below in **Table 23**.

Table 23. Summary of Resources Evaluated

#	Resource/Topic	Assessment for I-25/Happy Canyon Road Improvements
1	Air quality	No hotspot analysis required for the Phase 1 project but will likely be required for the interchange project.
2	Noise	A noise study I not required for the Phase 1 project but will be required for the interchange improvements larger study area to evaluate potential noise impacts.
3	Hazmat ISA/MESA	Hazmat database search conducted; no known sites within one mile radius.
4	T&E/State Species	No impacts to sensitive/imperiled federal species are anticipated.
5	Wetlands	No impacts are anticipated.
6	Paleontology	CDOT in-house assessment will be needed no impacts anticipated.
7	Archaeology	CDOT in-house assessment will be needed; no impacts anticipated.
8	History	No nearby resources listed on the National Historic Register. Two structures more than 50 years old located along Happy Canyon Road should be evaluated by a qualified historian.
9	4(f) Historic	
10	4(f) Non-Historic	No nearby public parks/recreation/wildlife refuges; no impacts.
11	Section 6(f)	There are no nearby recreational resource recipients of Federal LWCF grants.

Further work needed for an environmental clearance will include CDOT internal archaeological and paleontological work, as well as assessment by a qualified historian. Coordination with CDOT will be needed to review the above information on a resource-by-resource basis to determine whether any further information will be needed.

Based on the minimal impacts anticipated by this scope of improvements in this location, it appears that a Categorical Exclusion would be the appropriate level of NEPA documentation for the Happy Canyon Road Phase 1 improvement project. The NEPA Class of Action for the interchange is to be determined.

Multimodal Accommodations

The current two-lane interchange is 59 years old, was built as part of the I-25 construction in 1965 and is devoid of any pedestrian or cycling infrastructure. When first constructed Happy Canyon Road was a rural interchange providing access to ranch land in unincorporated Douglas County where multimodal infrastructure, especially sidewalks, trails, and/or bike lanes, were not needed. Over the years this condition has slowly been changing, but with the approved developments of the Castle Pines Town Center and The Canyons the area is rapidly changing in a more significant way.

Today, there are still no sidewalks or trails leading up to the I-25/Happy Canyon Road interchange. However, with the rapid growth occurring in the area around the I-25/Happy Canyon Road interchange, initiatives including multimodal accommodations in roadway project design and implementation, adoption of multimodal option supporting planning documents, and requirements for new developments to include integrated multimodal facilities as part of their developments are in place. As a result, the approved plans for The Canyons and Castle Pines Town Center include extensive networks of multi-use trails, sidewalks, and on-street bike facilities to accommodate non-motorized and micromobility transportation. This committed network of multimodal infrastructure will connect to and use the new multimodal path that is part of the designs for both the DDI and Signalized Diamond interchange alternatives. Performance relative to multimodal accommodations will improve existing conditions and will be similar for both the DDI and the Signalized Diamond interchange alternatives.

Cost and Constructability

Cost Estimates

Conceptual planning level cost estimates were prepared for the DDI and Signalized Diamond interchange alternatives. The cost estimates total $38,007,000 and $48,377,000 in 2023 dollars for the DDI and Signalized Diamond interchange alternatives, respectively.

The primary difference in cost between the two alternatives results from the larger bridge size and additional pavement required for the signalized diamond, due to the presence of left-turn lanes that are not needed with the DDI.

Detailed cost sheets for the two alternatives including estimates of cost escalation through 2027, the anticipated year of opening, are included in **Appendix M**.

Constructability

The DDI Alternative provides more flexibility in phasing and implementation compared to the signalized diamond alternative because it is designed with two parallel bridge structures rather than one wide bridge structure. The parallel structures offer better integration with the roundabout at Lagae Road during construction. In the DDI, the northern bridge can be constructed first, completely offline from existing roadways. Once the northern bridge is constructed, the project will have the flexibility to either shift traffic and construct the southern bridge, or to implement the DDI utilizing the existing structure. The Signalized Diamond alternative is constrained vertically and does not offer the same flexibility in implementation. This is because the bridge and roadway are not separated, so a split roadway profile cannot be utilized to make up the grade difference between the existing and new bridges.

Construction of the bridge in the signalized diamond will be slightly more difficult than the DDI as it requires bridge widening adjacent to traffic rather than independent structures to be built. Ramp and roadway constructability outside of the bridge would be similar for both alternatives.

Alternatives Screening Summary

The performance of the DDI and Signalized Diamond interchange alternatives was compared based on seven criteria. The results of that comparison, summarized in **Figure 23**, show that the DDI interchange alternative performs equal to or better than the Signalized Diamond on five out of the seven screening criteria.

Traffic Operations: The DDI and Signalized Diamond interchange alternatives both accommodate forecast 2050 traffic volumes without significant vehicle queues or delays. However, the DDI alternative operates more efficiently than the Signalized Diamond alternative as demonstrated by better ramp termini intersection LOS and 50-55% less delay at each ramp terminal.

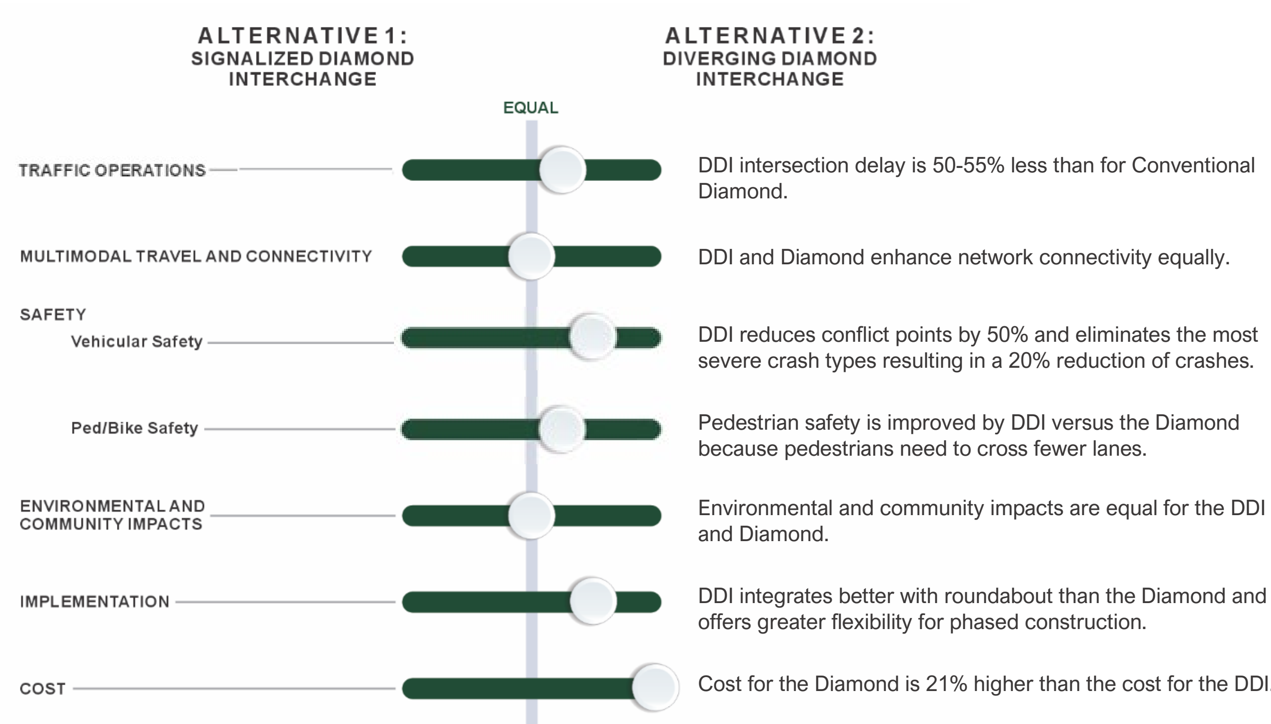
Multimodal Travel and Connectivity: The DDI and Signalized Diamond interchange alternatives both enhance roadway network connectivity. The two alternatives contribute equally to improved non-motorized travel connectivity by adding sidewalks and a multiuse trail through the interchange that do not exist today.

Safety: The DDI alternative can be expected to provide better safety performance compared to the signalized diamond alternative. Compared to a conventional diamond interchange, a DDI reduces vehicle-to-vehicle conflict points by nearly 50 percent and eliminates many of the most severe crash types. Pedestrian safety is improved at DDIs when compared to conventional signalized diamond interchanges because pedestrians need to cross fewer lanes.

Environmental: The findings of environmental overview evaluation for the full interchange study area do not favor one alternative over the other.

Implementation: The DDI alternative provides better integration with the roundabout and offers more flexibility for implementation because it is designed with two parallel bridges rather than a single wider bridge.

Cost: Planning level cost estimates were prepared for the DDI and Signalized Diamond interchange alternatives. These cost estimates total $38,007,000 and $48,377,000 in 2023 dollars for the DDI and Signalized Diamond interchange alternatives, respectively.



Prepared by

WILSON
& COMPANY

5755 Mark Dabling Boulevard, Suite 100
Colorado Springs, Colorado 80919
719-302-6752