FINAL REPORT

Traffic Engineering Study

Broadway Boulevard, Euclid Avenue to Country Club Road

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Regional Transportation Authority

CITY OF TUCSON FOUNDED 1775

KITTELSON & ASSOCIATES, INC.
TRANSPORTATION ENGINEERING/PLANNING

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EXECUTIVE SUMMARY

The Regional Transportation Authority (RTA) plan approved by Pima County voters in 2006 includes widening Broadway Boulevard from Euclid Avenue to Country Club Road to a 6-lane divided arterial with two dedicated transit lanes. As part of the planning and preliminary engineering phase of the project, a traffic study was conducted to determine the capacity requirements of the roadway and intersections, traffic control and access control requirements, and facilities to address multi-modal needs.

A preliminary traffic assessment prepared in 2009 evaluated corridor capacity requirements based on projected 2030 traffic demands. This report updates the initial capacity recommendations to reflect the 2040 planning horizon and provides a detailed assessment of arterial operations and multi-modal needs.

Analysis of roadway and intersection capacity was conducted utilizing the analytical procedures provided in the Highway Capacity Manual. Detailed evaluation of corridor operations, particularly the impact of dedicated transit, or multi-use lanes, was conducted using a microscopic simulation model that was developed for a one mile section of the corridor, Cherry Avenue to Tucson Boulevard. The findings of this traffic study are summarized below.

- Current (2010) daily traffic volumes on Broadway Boulevard range from 34,000 to 41,000 vehicles per day (vpd). 2040 traffic demands are projected to range from 40,000 to 56,000 vpd. The capacity analysis indicates that a 6-lane roadway with appropriate turn-lane capacity and storage at signalized intersections will be required to serve future demand at a satisfactory level of service.
- At Euclid Avenue, dual left-turn lanes will be required on the eastbound and westbound approaches to serve projected 2040 peak-hour traffic volumes. At Campbell Avenue, dual left-turn lanes and exclusive right-turn lanes will be required on all approaches. Even with the recommended capacity improvements, some movements at Campbell Avenue will likely operate at or near capacity during the evening peak period. At Country Club Road, dual left-turn lanes and right-turn lanes are required to serve projected future turning demand, however due to constrained right-of-way, it is likely that only single left-turn lanes can be provided. As such, it is expected that this intersection will become congested during the evening peak traffic period based on 7-10 years of projected traffic growth. Recommended intersection lane requirements are provided in Exhibit 13.
- A review of historical crash data covering the most recent 3-year period indicated that over 400 crashes occurred on Broadway Boulevard from Euclid Avenue to Country Club Road. Rear-end crashes accounted for approximately 40% of all crashes. Widening the roadway and reducing intersection congestion will reduce rear-end crash potential.
- Providing a high level of access control will optimize roadway capacity and reduce crash potential. Based on a potential shift of the Broadway Boulevard alignment to the north, a conceptual plan for the location of median openings was prepared in this study. An access

management plan should be developed for the corridor based on the final roadway alignment and anticipated redevelopment of adjacent properties. This plan should strive to minimize the number of driveways that provide direct access onto Broadway Boulevard.

- The current pedestrian activity at the Treat Avenue marked crossing does not justify installation of a pedestrian signal; however, it is anticipated that a signal will be required in the future to accommodate the City's plan to convert Treat Avenue into a bike boulevard.
- To optimize Broadway Boulevard operations, it is critical that all pedestrian signals, either HAWK or Pelican, be integrated into the corridor's coordinated signal operations. This will require that the HAWK signals be designed and operated as 2-stage crossings.
- Based on current side street and driveway traffic volumes, no additional traffic signals will be required. It is recommended that all traffic signals be equipped with transit signal priority technology to enhance transit performance and support ridership within the corridor.
- Microscopic simulation models were developed for the 6-lane and 6-lane with multi-use lanes scenarios. The multi-use lanes are expected to serve three functions – dedicated bus lanes, right-turn deceleration lanes, and bike lanes, as they currently do on much of Broadway Boulevard to the east of Columbus Road. The simulation results indicate that the multi-use lanes will improve transit performance. Average delay of buses will be approximately 12% less, number of stops will be 15% less, and the average speed of buses will be 6% higher. The benefit to vehicles in the general traffic lanes is marginal. Considering current local bus service and the potential future implementation of Bus Rapid Transit (BRT) service on Broadway Boulevard, provision of a dedicated lane is not essential, however it will benefit transit operations. What is essential if multi-use lanes are not included are pull thrus/outs at signalized intersections and other major transit stops, although not at minor stops. Reducing driveway density along the corridor will also benefit transit and bicycle operations if multi-use lanes are not provided.

1. BACKGROUND AND SCOPE

The City of Tucson Department of Transportation is moving ahead with plans to widen Broadway Boulevard from Euclid Avenue to Country Club Road as part of the Regional Transportation Authority (RTA) transportation improvement program. Kittelson & Associates, Inc. (KAI) was retained by HDR Engineering to evaluate existing and future traffic conditions along Broadway Boulevard. This report documents the evaluation results, including existing conditions, projected traffic growth within the corridor, and roadway capacity and control requirements to serve traffic demand. Specific recommendations were developed for the design of improvements on Broadway Boulevard, including the lane configuration at signalized intersections, turn lane storage requirements, and needed traffic control. The study limits are defined in Exhibit 1.

The traffic assessment conducted included five signalized intersections - Euclid Avenue, Highland Avenue, Campbell Avenue, Tucson Boulevard and Country Club Road; four intersections with HAWK pedestrian signals - Park Avenue, Cherry Avenue, Norris Avenue and Plumer Avenue; and a two-way stop-controlled intersection with pedestrian crossing at Treat Avenue. Existing intersection peak period turning movement counts, 24-hour segment counts with vehicle classification data, and 24-hour counts on eleven side streets were collected during February 16, 2009 and February 19, 2009 and were used to establish the existing conditions. Socioeconomic data, driveway activity data, pedestrian counts, lane utilization information, and crash data were also collected.

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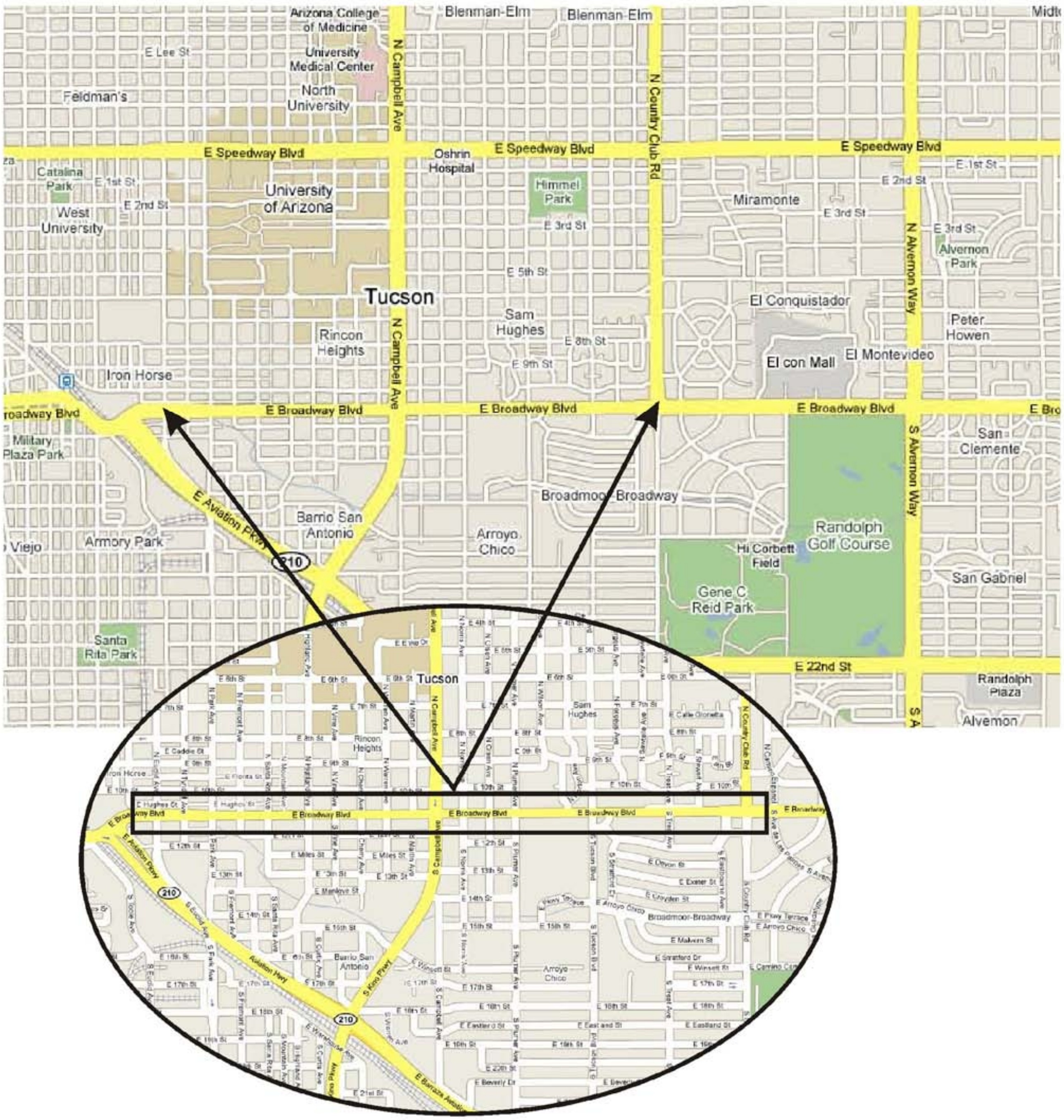

LOCATION & VICINITY MAP

EXHIBIT
1

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2. EXISTING CONDITIONS

2.1 ROADWAY

Broadway Boulevard currently has a 6-lane cross section with a raised between Euclid Avenue and Tyndall Avenue, transitioning to a 5-lane cross section with a center two-way left-turn lane (TWLTL) between Tyndall Avenue and Park Avenue, and a 5-lane cross section between Park Avenue and just west of Country Club Road. The TWLTL accommodates access to adjacent commercial and residential properties. The current cross sections include 11-foot travel lanes with 5-foot bike lanes. A short frontage road located on the north side of Broadway Boulevard, extending from 400 feet west of Treat Avenue to Stewart Avenue provides access to twelve residences. No on-street parking exists within the study corridor. Sidewalk or paved areas on both sides of the roadway are available for pedestrians along the entire roadway section. Current access (driveways and side streets) along Broadway Boulevard is summarized in Exhibit 2.

Exhibit 2 Existing Access Points

Broadway Section	North Side	South Side
Euclid Ave. - Highland Ave.	19	27
Highland Ave. - Campbell Ave.	23	16
Campbell Ave. - Tucson Blvd.	37	34
Tucson Blvd. - Country Club Rd.	19	25
Total	98	102

2.2 LAND USE

The study section of Broadway Boulevard is fully developed. Residential and small retail commercial are the principal land uses between Euclid Avenue and Campbell Avenue. Retail commercial, including several strip commercial buildings, is the principal land use between Campbell Avenue and Country Club Road. Nearly all of these developments currently have full access onto Broadway Boulevard.

2.3 SPEED LIMIT

The existing posted speed limits within the study limits are as follows:

- Broadway Boulevard - 30 mph from Euclid Avenue to Campbell Avenue, 35 mph from Campbell Avenue to Country Club Road.
- Euclid Avenue - 30 mph north of Broadway Boulevard, 35 mph south of Broadway Boulevard.
- Highland Avenue - 25 mph.

- Campbell Avenue - 35 mph north of Broadway Boulevard, 40 mph south of Broadway Boulevard.
- Tucson Boulevard - 30 mph north of Broadway Boulevard, 35 mph south of Broadway Boulevard.
- Country Club Road - 35 mph.
- All other side streets - 25 mph.

2.4 TRAFFIC OPERATIONS

Traffic counts collected between February 16, 2009 and February 19, 2009 include peak-period turning movement counts at the study intersections. Daily (24-hour) directional traffic counts were collected on Broadway Boulevard between Campbell Avenue and Tucson Boulevard and on eleven side streets. Recent daily traffic counts were also obtained from the Pima Association of Governments (PAG). The hourly and daily traffic volume data are summarized in Exhibit 7 and the detailed counts (including pedestrian counts) are included in Appendix A.

2.4.1 Traffic Factors

The traffic factors listed in Exhibit 3 were calculated from the 24-hour roadway counts. The K-factor represents the percentage of daily traffic that occurs during the peak hour and the D-factor represents the percentage of traffic in the heaviest direction of travel. The hourly segment count data indicates that existing demand remains heavy throughout the day with the two-way volume exceeding 2,000 vehicles per hour from 7 AM until 7 PM.

Exhibit 3 Traffic Factors

Broadway Boulevard	K		D	
	AM	PM	AM	PM
Campbell Ave. to Tucson Blvd.	7%	8%	56% WB	53% EB

Four hour vehicle classification counts were taken on September 1, 2011 on Broadway Boulevard near Norris Avenue. The observed heavy vehicle percentage during the peak periods (7-9 AM and 4-6 PM) is about 2%. The Federal Highway Administration (FHWA) defines 13 vehicle categories. Heavy vehicles as those in Categories 5 thru 13. The vehicle classification data is summarized in Exhibit 4.

Based on the 24-hour segment and peak period intersection turning movement count data, the morning peak hour occurs from 7:30 to 8:30 AM and evening peak hour from 4:30 to 5:30 PM. Traffic operations were evaluated for these two peak hours.

Exhibit 4 Summary of Vehicle Classification Data

	1	2	3	4	5	6	7	8	9	10	11	12	13
Peak Period	Motor-cycles/ Bikes	Pass. Cars	Trucks, Vans, etc	Bus	Single Unit Trucks			Truck with Trailer			Truck with Multi Trailers		
					2Axle, 6 Tire	3 Axle	4 Axle	<5 Axle	5 Axle	>6 Axle	< 6 Axle	6 Axle	>6 Axle
AM	0.5%	48.4%	47.1%	1.3%	1.7%	0.0%	0.0%	0.6%	0.3%	0.0%	0.0%	0.0%	0.0%
PM	0.6%	50.0%	47.9%	0.7%	0.5%	0.0%	0.0%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%

2.4.2 Pedestrian and Bicycle Volumes

Pedestrian counts taken at each of the four existing HAWK signals and at the unsignalized pedestrian crossing during the vehicular peak hour (7:30-8:30 AM and 4:30-5:30 PM) on Broadway Boulevard are summarized in Exhibit 5. These data were collected in February 2009 and again in September 2011. The 2011 counts also include the number of times that HAWK signals were activated during each peak hour. A detailed evaluation of the impact of these HAWK signals on traffic flow on Broadway Boulevard was conducted using a microscopic traffic simulation model (VISSIM) and the results are discussed in Section 3.2.4.

Exhibit 5 Peak Hour Pedestrian Volumes

Intersection	2009 Ped. Vol. During Pk Hrs on Broadway		2011 Ped. Vol. (Signal Activations)		
			During Pk Hrs on Broadway		Peak Ped. Crossing Activity
	AM	PM	AM	PM	
Park Ave./Broadway Blvd. (HAWK)	0	19	22 (18)	11 (9)	41 (15); 9:15-10:15 AM
Cherry Ave./Broadway Blvd. (HAWK)	31	40	19 (11)	14 (12)	21 (9); 7:45-8:45
Norris Ave./Broadway Blvd. (HAWK)	1	15	3 (3)	6 (5)	15 (9); 3:15-4:15 PM
Plumer Ave./Broadway Blvd. (HAWK)	16	16	17 (12)	14 (13)	27 (12); 3:15-4:15 PM
Treat Ave./Broadway Blvd. (marked crosswalk)	3	35	1 (NA)	1 (NA)	6 (NA); 9:45-10:45

The peak-hour of pedestrian activity at each crossing is also provided in Exhibit 5 for the 2011 counts. At Plumer Avenue and Norris Avenue, the number of pedestrians peaked from 3:15 to 4:25 PM; at Park Ave, the peak pedestrian activity occurred between 9:15 – 10:15 AM with 41 pedestrians in 15 signal activations; at Cherry Ave the highest pedestrian volume observed was 21 pedestrians between 7:45 – 8:45 AM; the pedestrian activity at the Treat Ave crossing was low with a maximum of 6 pedestrians observed between 9:45 and 10:45 AM.

Bicycle counts were collected at the Norris Avenue intersection on September 1, 2011 between 4:30 and 5:30 PM. Six bicyclists were observed travelling in the eastbound direction and one in the westbound direction along Broadway Blvd.

2.4.3 Arterial Traffic Flow

Travel time data was collected on February 19, 2009 between 7 and 9 AM and between 4 and 6 PM using the floating car method. The average travel times on the 1.92 mile section of Broadway Boulevardfrom Euclid Avenue to Country Club Road are provided in Exhibit 6. The Synchro models developed for capacity analysis were calibrated to better reflect the observed travel times. The travel time and speed outputs given by the calibrated Synchro models are also provided in Exhibit 6 for comparison. The results show the Synchro model outputs match the field data reasonably well with the exception of the westbound traffic flow during the evening peak period. This may be due to the impacts of the HAWK signals, which are included in the field data, however are not cannot be modeled by Synchro.

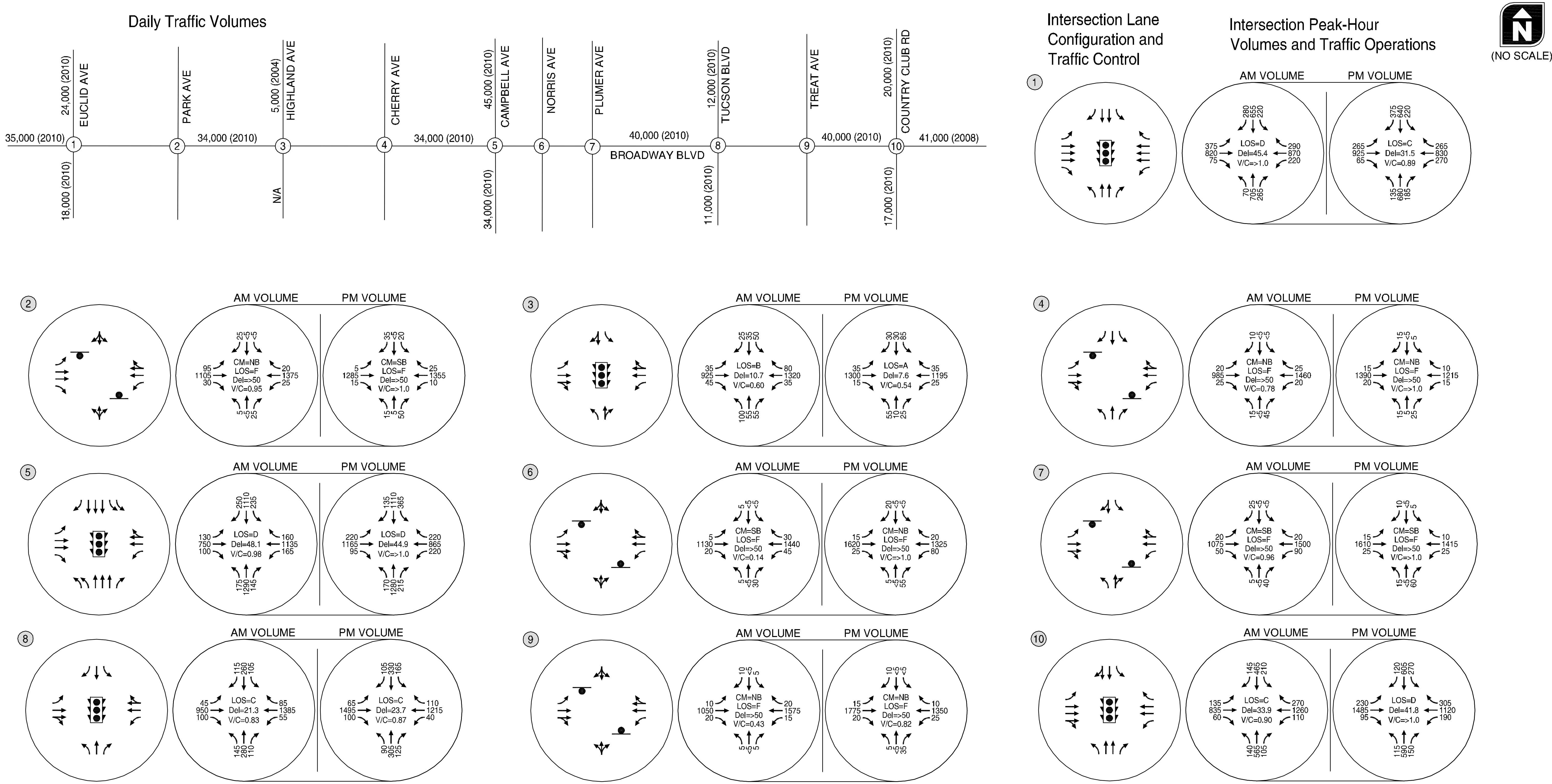
Assuming a free-flow speed of 30/35 mph (the same as the posted speed limits) the average delay traveling on Broadway Boulevard between Euclid Avenue and Country Club Road is 27 seconds during the morning peak period and 57 seconds during the evening peak period in the eastbound direction and 56 seconds during morning peak period and 80 seconds during evening peak period in the westbound direction.

Exhibit 6 Travel Time Summary

Broadway Boulevard	Field Data								Synchro Outputs			
	# of Runs		Avg. Travel Time (sec)		Travel Time Standard Deviation (sec)		Avg. Travel Speed (mph)		Avg. Travel Time (sec)		Avg. Travel Speed (mph)	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Eastbound	10	8	240	270	19.4	39.6	28.8	25.6	231	270	30	25.7
Westbound	10	8	269	293	41.5	38.7	25.6	23.5	262	247	26.4	28.2

2.4.4 Intersection Capacity

Intersection capacity analysis was performed using the Synchro 7 traffic analysis software which utilizes the current Highway Capacity Manual procedures. The analysis results of existing traffic conditions at the signalized intersections are summarized in Exhibit 7. The detailed capacity analysis worksheets are included in Appendix B. The results show that overall traffic operations at the Euclid Avenue, Highland Avenue, Campbell Avenue, Tucson Boulevard and Country Club Road intersections are at LOS D or better during the morning and evening peak periods. Several movements at some intersections operate at LOS E or F during at least one of the peak periods. The eastbound and southbound left-turn movements at the Euclid Avenue intersection operate at LOS F with a volume-to-capacity (v/c) ratio greater than 1.00 during the morning peak period. A v/c ratio exceeding 1.00 indicates significant congestion. During the evening peak period, the eastbound and



LEGEND

CM = CRITICAL MOVEMENT (UNSIGNALIZED)
LOS = INTERSECTION LEVEL OF SERVICE (SIGNALIZED)/CRITICAL MOVEMENT LEVEL OF SERVICE (UNSIGNALIZED)
Del = INTERSECTION AVERAGE CONTROL DELAY (SIGNALIZED)/CRITICAL MOVEMENT CONTROL DELAY (UNSIGNALIZED)
V/C = CRITICAL VOLUME-TO-CAPACITY RATIO

EXISTING TRAFFIC CONDITIONS

EXHIBIT 7

westbound left-turn movements at the Campbell Avenue intersection operate at LOS F with a v/c ratio greater than 1.00. The southbound left-turn, through and right-turn movements at the Country Club Road intersection also operate at LOS F with a v/c ratio greater than 1.00 during the evening peak period.

2.4.5 Signal Warrants

Based on peak-hour counts taken at the unsignalized intersections, the highest volume on a side street was 79 veh/hr. To warrant a signal based on vehicular volume, the 8th highest hour side street volume would need to exceed 75 veh/hr for Warrant 1 (Eight-Hour Vehicular Volume) and the 4th highest hour side street volume would need to exceed 80 veh/hr for Warrant 2 (Four-Hour Vehicular Volume). As such, no additional signals are currently warranted based on existing volumes.

2.4.6 Pedestrian Signal Warrants

A marked crosswalk is currently located at Treat Avenue. A pedestrian signal warrant analysis was conducted for this crossing for current conditions following the City of Tucson HAWK signal warrant criteria. Based on the analysis results, the intersection received 16 points which does not meet the minimum score of 25 points for consideration of a HAWK signal installation. The warrant evaluation for the Treat Avenue pedestrian crossing is included in Appendix C. Although a pedestrian signal is not currently warranted, future City of Tucson plans to convert Treat Avenue into a bike boulevard will increase demand at the Broadway Boulevard crossing, likely requiring the installation of a pedestrian signal.

2.5 CRASH HISTORY

The City of Tucson provided historical crash data for the 3-year period from January 1, 2008 to December 31, 2010. The data includes the number of crashes and crash type, but not injury level or severity. During the 3-year period no fatalities occurred along Broadway Boulevard within the study limits. The segment and intersection crash data are summarized in Exhibit 8.

The intersection accident rates ranged from 0.30 to 1.21 accidents per million vehicles entering the intersection. The highest number of accidents occurred at the Campbell Avenue intersection. Of the 101 accidents, 41 were rear end crashes, with 20 occurring on Broadway Boulevard, 12 on Campbell Avenue, and 9 on Kino Parkway. As a comparison, the average 3-year (2007-2009) accident rate at signalized intersections on the Pima County roadway system was 0.81 accidents per million vehicles with a standard deviation of 0.52. Therefore, the range of observed signalized intersection accident rates on the Pima County system was 0.29 to 1.33 accidents per million vehicles, which is consistent with the rates observed on Broadway Boulevard. Average accident rate information within the City of Tucson is not available for comparison.

The 3-year segment accident rates along Broadway Boulevard range from 0.77 to 2.69 accidents per million vehicle miles travelled on a segment. The segment from Campbell Avenue to Tucson Boulevard experienced the highest number of crashes (59) with rear-end crashes being the most predominant (33). Rear-end crashes are typically the most common on roadways that experience heavy congestion and which have frequent driveways and side streets. The average 3-year (2007-2009) accident rate on high volume roadway segments (daily traffic > 10,000) within Pima County system is 1.26 accidents per million vehicle miles with a standard deviation of 1.08. Therefore, the range of observed segment accident rates on the Pima County system is 0.18 to 2.34 accidents per million vehicle miles.

Exhibit 8 Crash Data Summary (January 1, 2008 to December 31, 2010)

Signalized Intersections										
	Euclid Avenue		Highland Avenue		Campbell Avenue		Tucson Blvd		Country Club Road	
Total Accidents	67		12		101		51		70	
Angle	5	7%	1	8%	12	12%	2	4%	5	7%
Rear-End	16	24%	3	25%	41	41%	17	33%	24	34%
Turning	13	19%	3	25%	20	20%	10	20%	11	16%
Other	33	49%	5	42%	28	28%	22	43%	30	43%
Daily ADT:	55,500		36,500		76,500		51,500		63,500	
Accident Rate[1]	1.10		0.30		1.21		0.90		1.01	

Roadway Segments								
	Euclid Ave to Highland Ave (0.5 mile)		Highland Ave to Campbell Ave (0.4 mile)		Campbell Ave to Tucson Blvd (0.5 mile)		Tucson Blvd to Country Club Rd (0.5 mile)	
Total Accidents	27		26		59		21	
Angle	1	4%	1	4%	3	5%	0	0%
Rear-End	8	30%	9	35%	33	56%	15	71%
Turning	4	15%	9	35%	11	19%		0%
Other	14	52%	7	27%	12	20%	6	29%
Daily ADT:	34,000		40,000		40,000		36,740	
Accident Rate[1]	1.45		1.48		2.69		0.77	

1. Intersection accident rates refer to the number of accidents per million vehicles entering the intersection. Rate = (number of 3-year accidents x 10^6)/(3 years x weekday entering volume x 365 days).
2. Segment accident rates refer to the number of accidents per million vehicles-miles of travel. Rate = (number of 3-year accidents x 10^6)/(3 years x weekday segment volume x 365 days x segment length).

2.6 TRANSIT SERVICE

Current Sun Tran service along Broadway Boulevard includes one fixed route and one express route - Route 8 (Broadway/6th Ave) and Route 108X (Broadway-Downtown Express). Route 8 runs from the Roy Laos Transit Center on South 6th Avenue to the Ronstadt Transit Center downtown, then to Houghton Road. Route 8 is has the highest Sun Tran ridership. Bus headways range from 10 minutes during the peak commute periods to 30 minutes during other periods. Sample daily ridership data for Route 8 is provided in Exhibit 9.

Route 108X, the Broadway-Downtown Express, is served by buses stationed at the Ronstadt Transit Center with three morning runs and three evening runs. The route is the same as that of Route 8 but has no stop within the study limits. Route 108X service is planned for expansion to six morning runs and six evening runs by 2012.

There are three bus pull-outs within the project area, two of which are located near the Campbell Avenue intersection. The third one is located on the north side of Broadway Boulevard, between Olsen Avenue and Plumer Avenue. There are 16 bus stops within the study limits.

Exhibit 9 Sample Route 8 Daily Ridership Data

	2009 EB		2009 WB		2011 EB		2011 WB	
	Board	Alight	Board	Alight	Board	Alight	Board	Alight
Euclid Ave	168	85	N/A	N/A	155	69	34	105
Park Ave	N/A	N/A	62	71	N/A	N/A	23	45
Freemont Ave	45	69	62	31	40	49	33	21
Highland Ave	29	46	41	21	23	35	20	26
Cherry Ave	45	39	51	29	33	41	42	26
Campbell Ave	118	153	143	126	125	148	128	116
Plumer Ave	67	56	63	66	49	61	76	46
Tucson Blvd	56	76	71	46	52	65	59	68
Treat Ave	15	38	31	16	7	21	12	21
Total	543	562	524	406	484	489	427	474

3. Future Conditions

3.1 PLANNED IMPROVEMENTS

The Regional Transportation Authority (RTA) 20-year improvement plan includes the widening of Broadway Boulevard, Euclid Avenue to Country Club Road to a 6-lane divided arterial with two dedicated bus lanes, bike lanes, and sidewalks. The High Capacity Transit (HCT) plan for the PAG region has established Broadway Boulevard as a priority corridor, identifying Bus Rapid Transit (BRT) as the most viable HCT option. Beyond the possible addition of a BRT system, no other planned roadway improvements within this section of the Broadway Boulevard corridor, including the cross streets, are part of the PAG 2040 Regional Transportation Plan.

3.1.1 High Capacity Transit

As a primary transit corridor within the region, Broadway Boulevard has long been considered a potential candidate for the implementation of a HCT system. Assessment and planning for HCT on Broadway Boulevard began in 1989 with the Broadway Corridor Study. This study concluded that the best long range HCT option was to install dedicated bus lanes between the downtown and Pantano Road. An 8-lane divided cross section that accommodates this option is essentially in place between Columbus Boulevard and Pantano Road. However, the outside "multi-use" lanes that are in place do not operate solely as dedicated bus lanes, but serve several other functions including right-turn deceleration lanes and bike lanes.

The PAG High Capacity Transit Study, completed in 2009, recommended that BRT is the best HCT option on Broadway Boulevard. While the optimal application is to run BRT in dedicated travel ways similar to Light Rail Transit (LRT), applications of BRT in general travel lanes on arterials and parkways are gaining increasing popularity across the country due to the prohibitive cost associated with implementing dedicated transit travel ways. Both the original Broadway Corridor Study and the High Capacity Transit Study concluded that LRT is not a viable long term option on Broadway Boulevard due to insufficient ridership and very high cost. The High Capacity Transit Study did suggest that extending the Tucson Modern Streetcar from downtown to El Con Mall could be considered depending upon several factors, including the success and cost of the initial streetcar line between downtown and the University of Arizona and redevelopment along Broadway Boulevard at the mall. The mall redevelopment is nearly complete and includes no residential uses which are integral to supporting a street car option.

BRT operation on Broadway Boulevard can be achieved in both a 6-lane and 6-lane plus multi-use lane cross section. An analysis of the operational characteristics of each cross section was conducted as part of this traffic study. The findings are discussed in Section 3.3.4.

3.1 TRAFFIC PROJECTIONS

Future traffic demands for this study were developed based on the 2040 projections produced by the PAG regional traffic forecasting model. The 2040 PAG traffic projections are provided in Exhibit 10. The projections indicate that traffic demand on Broadway Boulevard is expected to see moderate annual growth, essentially ranging from 0.5% to 1.3%. Considering that Broadway Boulevard is located within a heavily urbanized and developed area, annual traffic growth ranging from 1% to 1.5% is reasonable.

On the major cross streets, Euclid Avenue, Campbell, Avenue, Tucson Blvd, and Country Club Road, low to moderate annual traffic growth is projected. On Highland Avenue, a major collector roadway, very high annual growth (6.7%) is projected. Given the nature and limitations of the regional traffic forecasting model, projected 2040 volumes, which is assumed to be the design year for the Broadway Boulevard improvements, were adjusted for several roadway segments included in this traffic study. These adjustments are discussed below.

- Euclid Avenue – The roadway capacity, land use, and characteristics of Euclid Avenue north and south of Broadway Boulevard are not conducive to a doubling of traffic volumes over the next 30 years. To the north, Euclid Avenue has a 5-lane cross section, however the impact of pedestrian crossing facilities at Tucson High and the University of Arizona diminish roadway capacity. To the south, the 5-lane section narrows to 3 lanes at 22nd Street. As the 2040 regional plan does not include a project to increase the capacity on Euclid Avenue and since the surrounding areas are well developed, more moderate growth rates (1.7% and 2.0%) were assumed for this study.

- Highland Avenue – Highland Avenue is a two-lane residential collector road that has historically carried 5,000 to 7,000 vpd. North of Broadway Boulevard, there exist speed bumps that discourage high speed and volume. South of Broadway Boulevard, Highland Avenue terminates at Barraza Aviation Parkway. As such, it is very unlikely that future traffic growth on Highland Avenue can reach 17,000 vpd without substantial capacity improvements. A more reasonable 9,000 to 10,000 vpd was assumed.

- Campbell Avenue/Kino Parkway – PAG's 2040 projection for the south Kino Parkway leg is 70,000 vpd. Since Campbell Avenue is not planned to be widened beyond its current 6-lane cross section, volumes on Campbell Avenue won't be able to reach this level. Historically, the daily traffic volumes on the north and south legs have been comparable. As such, annual growth rates of 0.7% and 2.2% were assumed for the north and south legs, respectively, resulting in a more realistic future volume.

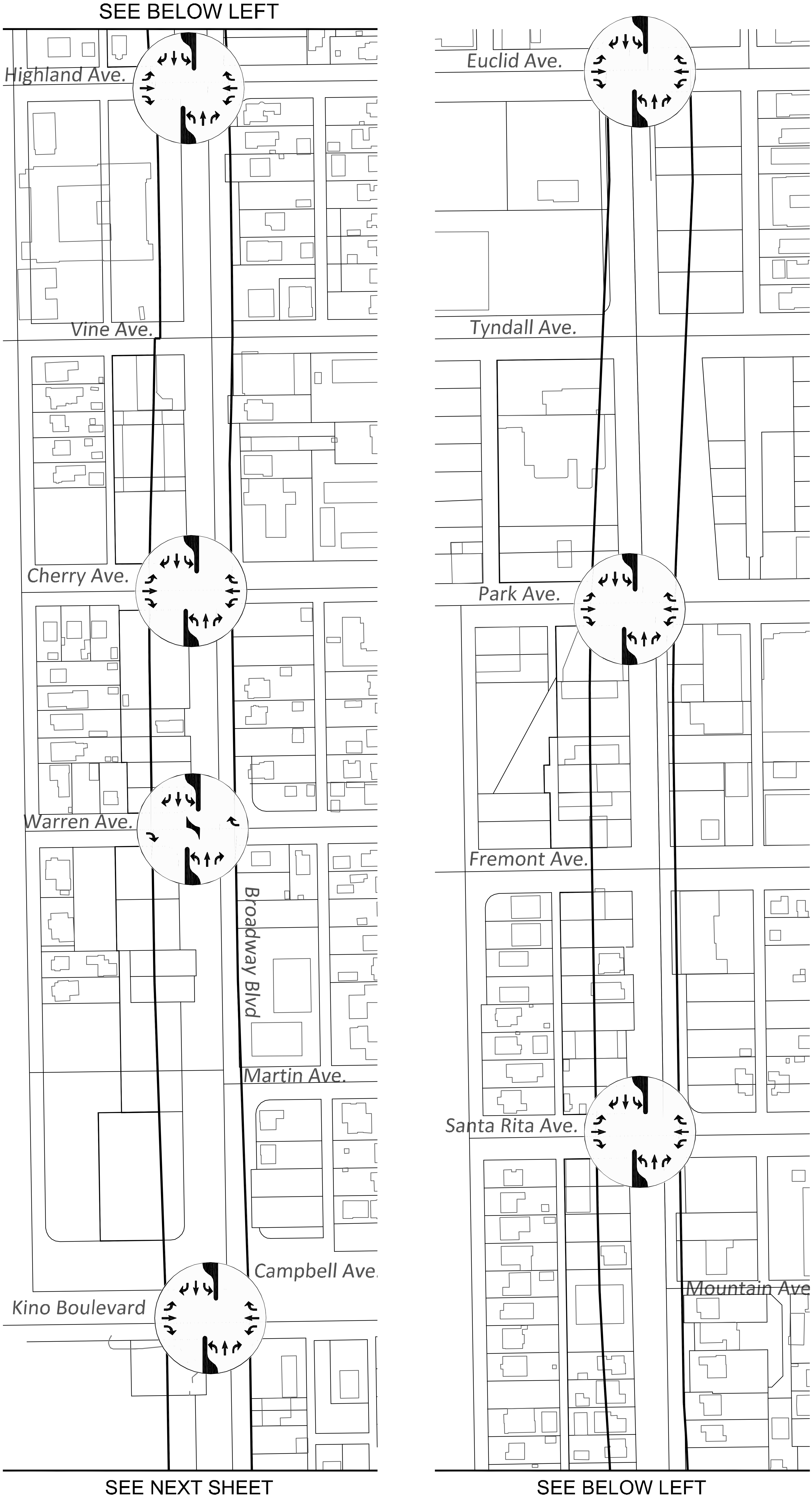
Using the existing traffic factors, turning movement counts, and design year ADTs, 2040 peak period turning volumes were developed for use in the analysis of future intersection and roadway capacity requirements. Worksheets used to develop the future turning movement volumes are provided in Appendix D.

Exhibit 10 Traffic Projections

Roadway	Segment	Current Daily Volume (Year)	PAG Daily Volume Projection		Daily Volume Assumed For This Study	
			2040	Annual Growth Rate	Design Year (2040)	Annual Growth Rate
Euclid Ave	North	24,000 (10)	46,000	3.0%	36,000	1.7%
	South	18,000 (10)	44,000	4.8%	29,000	2.0%
Highland Ave	North	5,000 (04)	17,000	6.7%	9,000	2.2%
	South	7,000[1] (09)	NA	NA	10,000	1.4%
Campbell Ave	North	45,000 (10)	55,000	0.7%	54,000	0.7%
Kino Pkwy	South	34,000 (10)	70,000	3.5%	56,000	2.2%
Tucson Blvd	North	12,000 (10)	12,000	0.0%	15,000	0.7%
	South	11,000 (10)	12,000	0.3%	14,000	0.7%
Country Club Rd	North	20,000 (10)	26,000	1.0%	31,000	1.8%
	South	17,000 (10)	22,000	1.0%	25,000	1.6%
Broadway Blvd	West of Euclid Ave	35,000 (10)	33,000	-0.2%	39,000	0.4%
	Euclid Ave to Highland Ave	34,000 (10)	41,000	0.7%	41,000	1.1%
	Highland Ave to Campbell Ave	34,000 (10)	46,000	1.2%	46,000	1.2%
	Campbell Ave to Tucson Blvd	40,000 (10)	56,000	1.3%	56,000	1.3%
	Tucson Blvd to Country Club Rd	40,000 (10)	46,000	0.5%	47,000	0.6%
	East of Country Club Rd	41,000 (08)	53,000	1.0%	53,000	0.9%

3.3 MEDIAN OPENINGS

As specified in the City's Major Streets and Routes Plan for high volume arterials, the widening of Broadway Boulevard will include a raised median. The City's Transportation Access Management Guidelines specifies 660 feet as the minimum spacing between full access median openings on an arterial. Based on this guideline and examination of existing cross street traffic demand, network connectivity, and potential future development, a conceptual median opening plan for Broadway Boulevard, Euclid Avenue to Country Club Road is presented in Exhibit 11.



CONCEPTUAL MEDIAN OPENING LOCATIONS

EXHIBIT 11

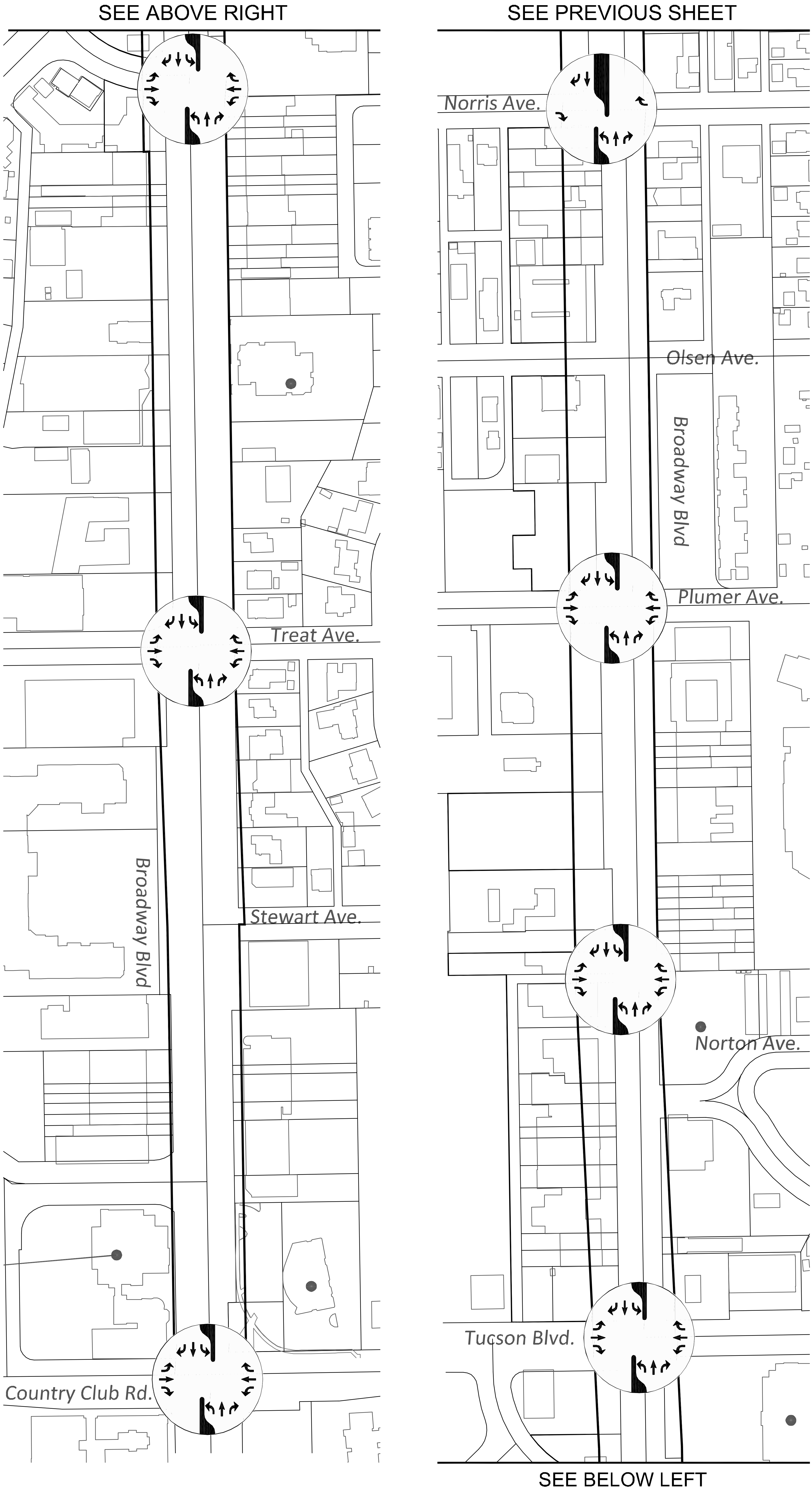


FIGURE 11

CONCEPTUAL MEDIAN OPENING LOCATIONS (CONT.)

3.4 CAPACITY AND LEVEL OF SERVICE ANALYSIS

3.4.1 Methodology

Future intersection and roadway lane requirements were determined based on the results of capacity and level of service analysis of the 2040 traffic forecasts. The following criteria were assumed for the analysis:

- Percentages of heavy vehicles are the same as existing conditions if they are greater than 2%, otherwise they are 2%.
- For Broadway Boulevard and major cross streets, peak-hour factors are the same as existing if greater than 0.92, otherwise they are 0.92. A minimum peak-hour factor of 0.92 was used for future conditions because variation in traffic demand tends to decrease during peak periods as traffic demand increases. On the minor cross streets, peak-hour factors are the same as existing.
- 4-phase signal operation with permitted/protected left-turn phasing.
- Cycle lengths are 90 seconds with optimized timing to minimize intersection delay.
- Right-turns on red are permitted.
- Platoon arrival Type 4, representing coordinated signal operations.

.3.4.2 Intersection Capacity

The intersection capacity analysis results indicate that with the provision of sufficient turn lane capacity, a 6-lane cross section will provide overall operations of LOS D or better at each intersection. Intersection capacity and level of service analysis worksheets are provided in Appendix E. The intersection level of service analysis results are summarized in Exhibit 152. Intersection lane requirements are presented in Exhibit 12.

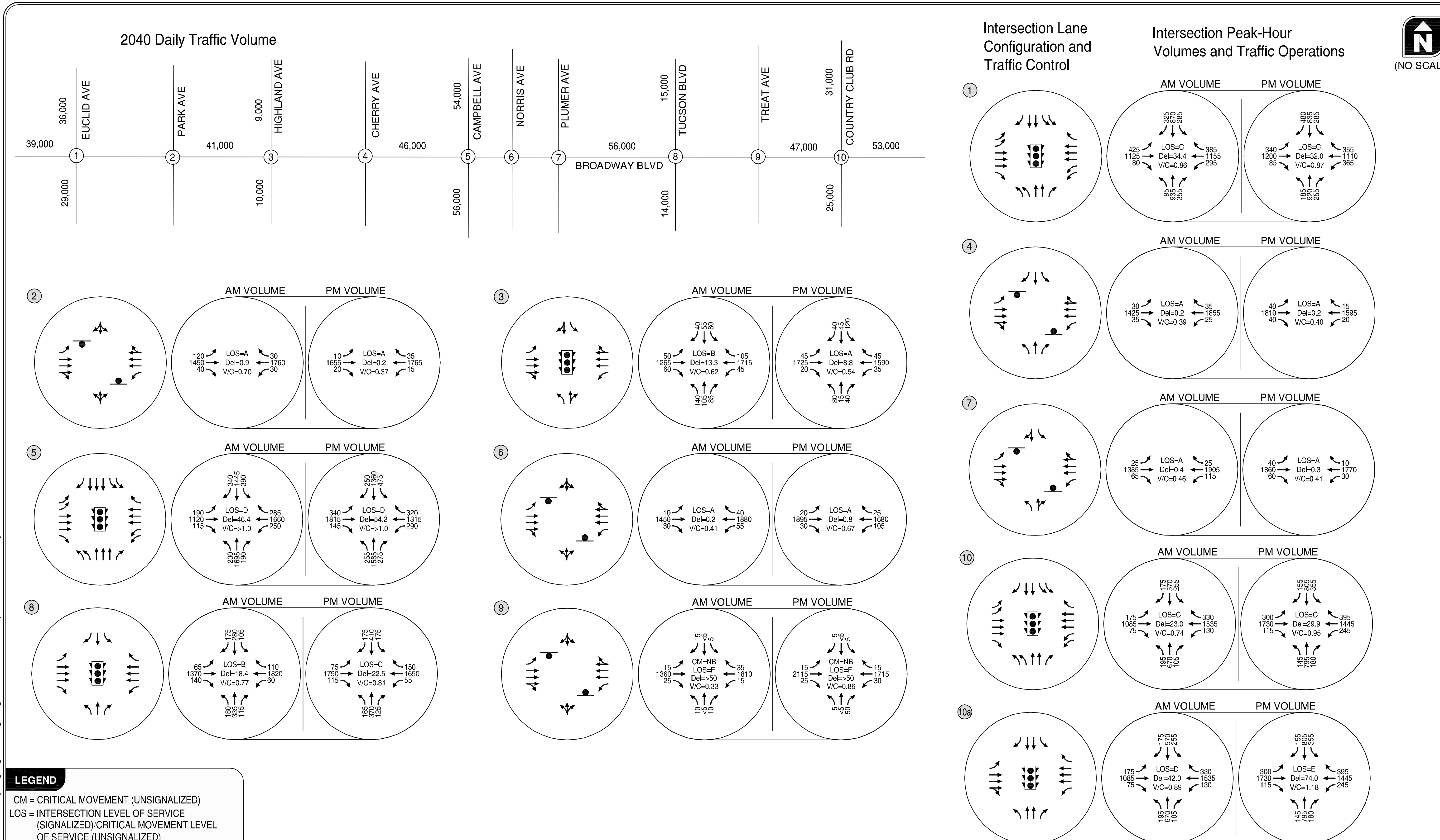
At Campbell Avenue, the eastbound and southbound left-turns may operate at LOS F even with dual left-turn lanes provided and several through movements are predicted to operate at LOS E. Several potential solutions to increase intersection capacity include utilizing left-turn overlap phasing at the Campbell Avenue intersection or potentially implementing a traffic adaptive signal control system on Broadway Boulevard. Adding overlap phasing for the eastbound and westbound left-turn movements was evaluated to assess the potential benefit to intersection operations. The results are included in Appendix E. Overall intersection operations will improve slightly with the greatest benefit realized by the eastbound left-turn.

At the Euclid Avenue intersection, dual eastbound and westbound left-turn lanes are required.

At Country Club Road, substantial right-of-way constraints, particularly on the southeast and southwest corners will make it difficult to achieve the required left-turn lane capacity on the southbound approach. Implementing single left-turn lanes on each approach and right-turn lanes on all but the eastbound approach will provide satisfactory operation during the morning peak period,

Exhibit 12 Summary of 2040 Capacity Analysis Results

Intersection		Movement/ Approach	LOS and Average Delay (s/veh) AM	LOS and Average Delay (s/veh) PM	Intersection		Movement/ Approach	LOS and Average Delay (s/veh) AM	LOS and Average Delay (s/veh) PM
Euclid Ave./ Broadway Blvd.	EB	LT	D(38)	D(40)	Tucson Blvd./ Broadway Blvd.	EB	LT	C(33)	C(34)
		TH	C(34)	C(28)			TH	B(17)	C(23)
		RT	C(23)	B(20)			RT	B(13)	B(15)
		Approach	C(34)	C(30)			Approach	B(17)	C(23)
	WB	LT	C(30)	D(46)		WB	LT	B(14)	B(12)
		TH	C(35)	C(27)			TH	A(8)	A(8)
		RT	D(37)	C(27)			RT	A(1)	A(1)
		Approach	C(34)	C(31)			Approach	A(8)	A(7)
	NB	LT	C(32)	C(33)		NB	LT	D(41)	D(52)
		TH	D(41)	D(36)			TH	D(47)	D(38)
		RT	C(24)	C(23)			RT	C(27)	C(26)
		Approach	D(36)	C(34)			Approach	D(42)	D(39)
	SB	LT	D(46)	D(43)		SB	LT	D(36)	D(42)
		TH	C(32)	C(31)			TH	D(37)	D(48)
		RT	C(22)	C(35)			RT	C(30)	C(27)
		Approach	C(33)	C(34)			Approach	C(34)	D(42)
	Intersection		C(34)	C(32)		Intersection		B(18)	C(22)
Highland Ave./ Broadway Blvd.	EB	LT	C(30)	B(11)	Country Club Rd/ Broadway Blvd.	EB	LT	B(17)	D(37)
		TH+RT	A(7)	A(6)			TH	A(9)	B(15)
		Approach	A(8)	A(6)			RT	A(1)	A(4)
	WB	LT	A(9)	B(11)			Approach	A(10)	B(18)
		TH+RT	A(8)	A(6)		WB	LT	C(22)	D(42)
		Approach	A(9)	A(6)			TH	C(23)	C(24)
	NB	LT	D(43)	C(34)			RT	B(18)	C(22)
		TH+RT	C(34)	C(31)			Approach	C(22)	C(26)
		Approach	D(37)	C(33)		NB	LT	C(32)	D(36)
	SB	LT	D(48)	D(38)			TH	D(36)	D(42)
		TH+RT	C(28)	C(32)			RT	C(26)	C(26)
		Approach	D(37)	D(36)			Approach	C(34)	D(39)
	Intersection		B(13)	A(9)		SB	LT	C(38)	**E(70)**
Campbell Ave./ Broadway Blvd.	EB	LT	D(44)	**F(97)**			TH	C(32)	D(43)
		TH	C(28)	**E(59)**			RT	C(27)	C(26)
		RT	C(20)	B(19)			Approach	C(33)	D(49)
		Approach	C(30)	**E(62)**		Intersection		C(23)	C(30)
	WB	LT	**E(60)**	**E(62)**	Country Club Rd/ Broadway Blvd. – Alternative A: single LT Lanes, no exclusive EB RT Lane	EB	LT	D(46)	D(52)
		TH	**E(61)**	C(27)			TH+RT	D(43)	**E(71)**
		RT	C(25)	C(22)			Approach	D(43)	**E(69)**
		Approach	**E(56)**	C(32)		WB	LT	C(29)	**F(221)**
	NB	LT	D(37)	D(36)			TH	D(53)	**E(78)**
		TH	**E(55)**	**E(78)**			RT	C(24)	C(31)
		RT	C(20)	C(27)			Approach	D(46)	**F(86)**
		Approach	D(50)	**E(66)**		NB	LT	C(33)	D(38)
	SB	LT	**F(115)**	**F(104)**			TH	D(42)	**E(60)**
		TH	C(29)	D(44)			RT	C(27)	C(28)
		RT	C(23)	C(26)			Approach	D(39)	D(52)
		Approach	D(44)	**E(55)**		SB	LT	D(40)	**F(198)**
	Intersection		D(46)	D(54)			TH	C(34)	D(39)
							RT	C(27)	C(25)
							Approach	C(34)	**F(81)**
						Intersection		D(42)	**E(74)**



LEGEND

CM = CRITICAL MOVEMENT (UNSIGNALIZED)
LOS = INTERSECTION LEVEL OF SERVICE (SIGNALIZED)/CRITICAL MOVEMENT LEVEL OF SERVICE (UNSIGNALIZED)
Del = INTERSECTION AVERAGE CONTROL DELAY (SIGNALIZED)/CRITICAL MOVEMENT CONTROL DELAY (UNSIGNALIZED)
V/C = CRITICAL VOLUME-TO-CAPACITY RATIO

2040 TRAFFIC CONDITIONS AND LANE REQUIREMENTS

EXHIBIT 13

but will be insufficient for the westbound and southbound left-turn demands in the evening peak. Considering the critical intersection movements – southbound left-turn, eastbound through, northbound through, and westbound left-turn, this alternative intersection configuration will provide sufficient capacity to accommodate 7-10 years of projected traffic growth before movements begin to fail. Potential solutions to optimize capacity include utilizing overlap phasing for the southbound and westbound left-turn movements and implementing traffic adaptive signal control.

The recommended storage lengths for turn lanes at the signalized intersections are summarized in Exhibit 14. They are based on the estimated 95% percentile queue lengths calculated by the Synchro, software and the minimum storage requirements specified in the PCDOT/TDOT Pavement Marking Design Manual, 2nd Edition. Storage length calculations are included in Appendix F.

Exhibit 14 Estimated Queue Storage Length Requirements

Intersection Broadway Blvd at	Eastbound		Westbound		Northbound		Southbound	
	Left	Right	Left	Right	Left	Right	Left	Right
Euclid Ave.	170 x 2	110	150 x 2	290	110 x 2	210	140	350
Highland Ave	110	110	110	110	140	-	120	-
Campbell Ave	160 x2	110	130 x 2	200	130 x 2	200	220 x 2	200
Tucson Blvd	110	110	110	110	170	110	170	130
Country Club Rd	140 x 2	110	130 x2	220	110 x2	150	160 x 2	130
Country Club Rd (Alt. A)	300	-	300	150	200	110	400	110

1. Minimum storage length of 110 ft per PCDOT/TDOT Pavement Marking Design Manual.
2. Storage lengths do not include tapers.

3.4.3 Roadway Segment Capacity

Detailed roadway segment capacity analysis for 6 through lanes was performed using the Synchro 7 traffic analysis software. Synchro is not able to evaluate the impacts of continuous multi-use lanes used for transit, bicyles, and right-turns. The analysis results summarized in Exhibit 15 show that a 6-lane arterial operates at an overall LOS C in both the eastbound direction during the evening peak period and the westbound direction during the morning peak period.

Exhibit 15 Arterial Analysis Results

Broadway Blvd	Ave. Travel Time (sec)		Ave. Travel Speed (mph)		Arterial LOS	
	AM	PM	AM	PM	AM	PM
Eastbound	362	398	20.8	18.9	C	C
Westbound	428	382	20.5	23.0	C	C

3.4.4 VISSIM Modeling

In addition to the intersection and arterial capacity analyses, microscopic simulation modeling of corridor operations was conducted to more precisely evaluate impacts of the HAWK signals, transit signal priority, dedicated transit lanes, bus pull-outs/pull-thrus, and Bus Rapid Transit (BRT). The VISSIM software was used to develop the models. Since the primary purpose of the VISSIM modeling was to evaluate the operational impacts of specific corridor elements and not to determine intersection capacity, only a portion of the corridor and only the evening peak hour were modeled. The section of Broadway Boulevard modeled extends from west of the Cherry Avenue intersection to east of the Tucson Boulevard intersection. The model was calibrated so that the simulated turning movement volumes essentially matched the estimated 2040 turning movement volumes. Models were developed for the following two scenarios:

- Six general purpose lanes with bus pull thrus/outs at signalized intersections, and
- Six general purpose lanes with outside multi-use lanes for use by transit vehicles, right-turning vehicles, and cyclists.

The following outlines the modeling techniques and assumptions used in the evaluation of the two scenarios.

GENERAL MODEL

The following features and assumptions were included as part of the model:

- Intersection lane configurations matched the recommendations (Exhibit 13) developed from the capacity analysis.
- The basic signal timing (cycle length, phasing, phase splits, clearance intervals) were consistent with those used for the intersection capacity analysis.
- The 2040 evening peak-hour was modeled, including a 15 minute warm-up period and 30 minute cool-down period.
- Median openings for side street and driveway access were as shown in Exhibit 11.
- Turning volumes at each minor side street were estimated based on existing traffic counts. Due to the complexity of modeling the many closely spaced residential driveways and commercial driveways at the strip centers, a single driveway, representing multiple closely spaced driveways was modeled at each location. Peak-hour volumes for driveways and minor side streets were as follows:
  - Safeway right-in/right-out driveway – volumes estimated from data collected; 160 in, 70 out
  - Sonic Drive-In entry/exit –40 right-in, 40 right-out
  - All other driveways – 20 right-in, 20 right-out
- 2% truck volumes assumed

- 0.5% bike volumes assumed
- Pedestrian volumes increased 25% for 2040

6-LANE MODEL

A typical section of the 6-lane arterial is illustrated in Exhibit 16. Bus pull-thru/out lanes are provided at each signalized intersection.

6-LANE W/MULTI-USE LANES MODEL

A typical section of the 6- arterial with multi-use lanes is illustrated in Exhibit 16. The multi-use lane is dedicated to buses/BRT and bikes, and also can be used by right-turners for deceleration. If rail is implemented in the future, dedicated transit and bike lanes will be required and right-turning vehicles would be prohibited from using either lane.

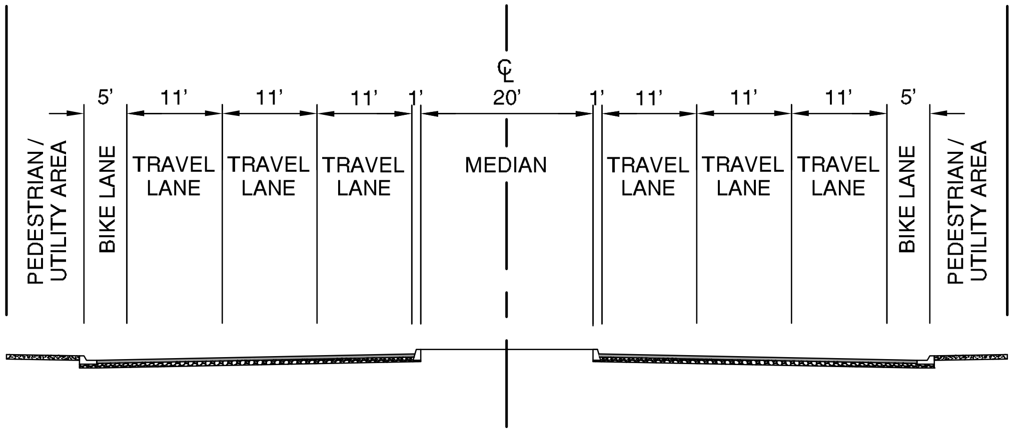
HAWK SIGNAL OPERATIONS

The HAWK signals at Cherry Avenue and Plumer Avenue were modeled as two-stage actuated crossings, unlike the current one-stage crossing, allowing them to be included in the coordinated system on Broadway Boulevard. HAWK signal operations were modeled as follows:

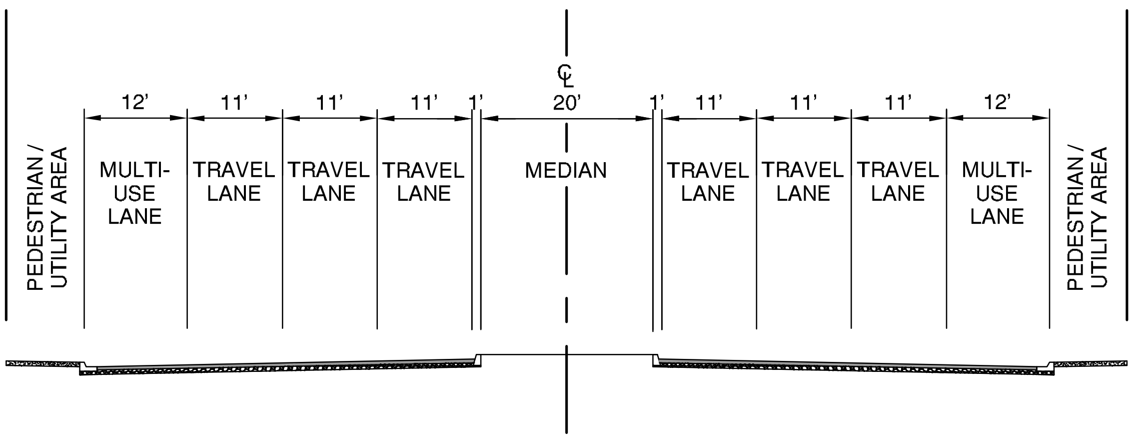
- 3 second flashing yellow for vehicles
- 3 second solid yellow for vehicles to come to stop
- Vehicles are then shown red for 5 seconds while the pedestrian is given the Walk signal
- The flashing red is then displayed to vehicles while the Flash Don't Walk is displayed to pedestrians for the appropriate amount of time (12/15/18 seconds depending on number of lanes the pedestrian is required to cross)
- Due to VISSIM's limitations, it was assumed that cars remain stopped while the flashing red is displayed.

TRAFFIC SIGNAL OPERATIONS

The traffic signals at Campbell Avenue and Tucson Boulevard were included in the model. Signal phasing and timing was based on the optimized settings developed with the Synchro model, with minor adjustments made to accommodate demand. Each signal was controlled using a Ring Barrier Controller, which includes the transit priority feature that can call a phase early or extend a phase (up to 3 seconds) to allow a bus or BRT vehicle to continue through the intersection without stopping. The signals were coordinated based on start of green for eastbound and westbound Broadway traffic (phases 2 & 6). Protected/permitted left-turns were coded as overlap phases.

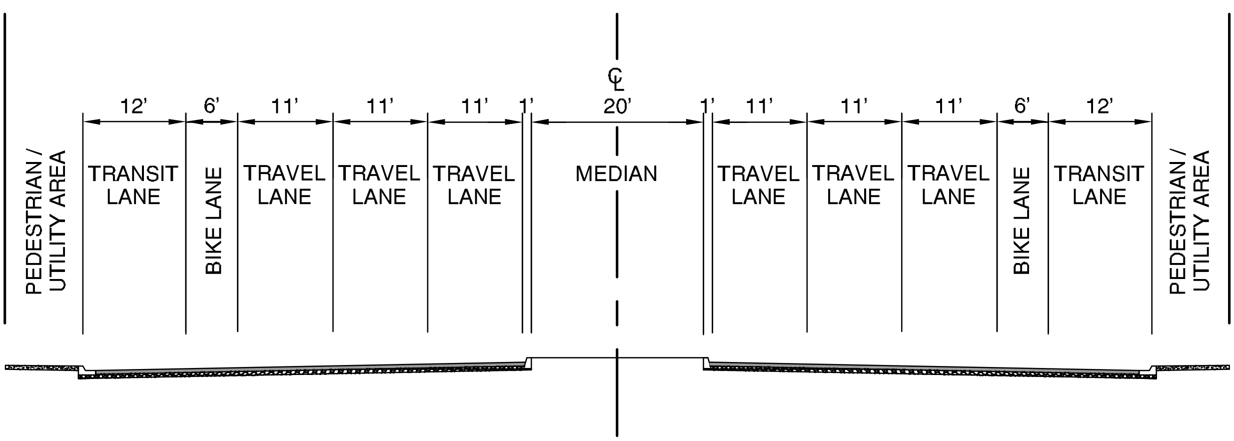


6-LANE CROSS SECTION
(NOT TO SCALE)



8-LANE CROSS SECTION - MULTI USE LANE*
(NOT TO SCALE)

*BUSES, BICYCLES, RIGHT-TURNING VEHICLES



8-LANE CROSS SECTION - TRANSIT LANES
(NOT TO SCALE)

TYPICAL CROSS SECTION ALTERNATIVES

EXHIBIT **16**

H:\projfile\8795 - Broadway\dwgs\figs\8795 TypSec.dwg Mar 12, 2012 - 6:53am - traddeman Layout Tab: Fig16

TRANSIT OPERATIONS

Local buses were modeled at 10-minute headways (i.e., six buses during the peak hour). In the 6-lane model, the buses either stop in the outside lane at mid-block or unsignalized intersection stops or pull into the bus bay at signalized intersections to drop off and collect passengers. These buses stop at all bus stops on the route. BRT vehicles were modeled at 15-minute headways (i.e., 4 buses during the peak hour). BRT vehicles stop only at the Broadway Boulevard/Campbell Avenue intersection, pulling into the bus bay. BRT vehicles are typically articulated buses, 60 feet in length.

At major transit stops where route transfers occur, such as at Campbell Avenue, bus and BRT vehicles dwell for 30 seconds. At minor bus stops, including Cherry Avenue, Plumer Avenue, and Tucson Boulevard, the dwell time is 15 seconds.

MODELING RESULTS

Four network performance measures (average delay per vehicle, average number of stops per vehicle, average speed, and average travel time) were collected by vehicle type (cars/trucks and transit vehicles) from the VISSIM simulation runs for the evening peak-hour, 4:30 to 5:30 PM. Ten model runs were made for each scenario and the performance measures produced by each run were averaged. The network performance results are summarized in Exhibit 17.

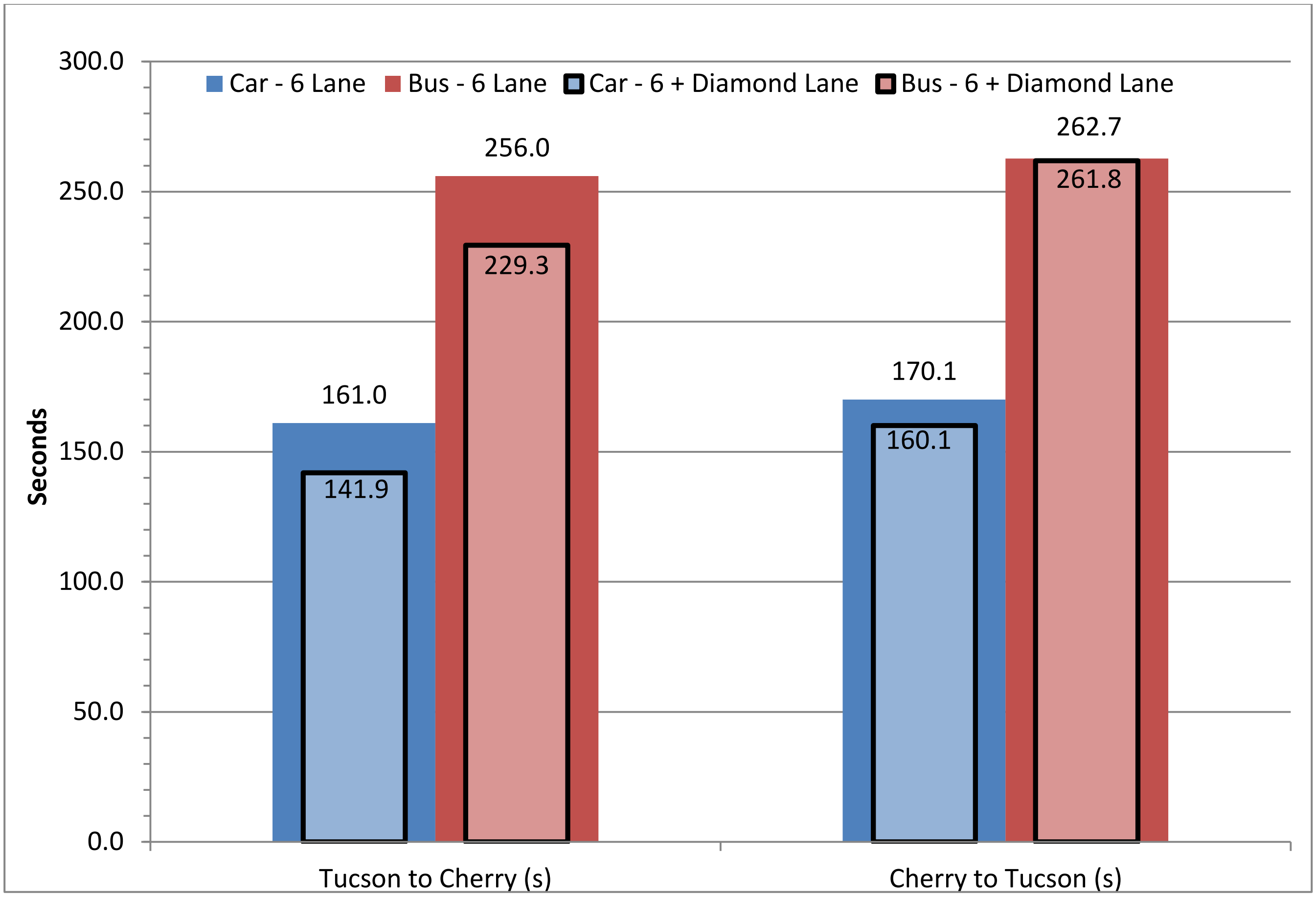
The results show that multi-use lanes will provide marginal improvement, less than 2%, in delay, number of stops, and travel speed for general traffic (cars/trucks). Transit vehicles, bus or BRT, would realize benefits from multi-use lanes, with 12% lower delay, 15% fewer stops, and 6% higher travel speed.

Average vehicle travel time by direction (seconds per vehicle) are also graphically depicted in Exhibit 18. In the eastbound, or heaviest direction of travel during the evening peak period, a multi-use lane reduces car/truck travel time by approximately 6%, however has no impact on bus travel time. Travel times in the westbound direction are 13% and 11% lower for cars/trucks and buses, respectively, with a multi-use lane.

Exhibit 17 Simulation Performance Measures

Performance Measures	6-Lanes w/Multi-use Lanes		6-Lanes		Percent Change	
	General Traffic	Buses	General Traffic	Buses	General Traffic	Buses
Average Delay per Vehicle., secs	78.8	92.6	79.3	103.3	+0.6%	+11.6%
Average Number of Stops per Vehicle.	2.12	1.37	2.16	1.58	+1.9%	+15.3%
Average Speed, mph	17.3	16.3	17.1	15.3	-1.2%	-6.1%
Average Eastbound Travel Time; sec	160	260	170	260	+6.3%	0.0%
Average Westbound Travel Time; sec	142	230	161	255	+13.4%	+10.9%

Exhibit 18 Travel Time Comparison



3.4.5 Multi-Modal Operations Analysis

Evaluation of pedestrian, bicycle, and transit level of service within a widened (6-lane) Broadway Boulevard with projected 2040 traffic demand was conducted utilizing the multi-modal urban streets methodology (MMLOS) provided in the 2010 Highway Capacity Manual. The MMLOS analysis method assigns LOS for each mode of travel based on a range of parameters that affect the user perception of the facility. The parameters considered for bicycle, pedestrian, and transit travel on an urban street are listed on the following page. Bicyclists, for instance, consider the availability of a dedicated bike lane or wide outside travel lane, the volume of traffic in the outside travel lane, the amount of truck traffic, the quality of the pavement, traffic speed, density of driveways and sides streets and driveways, and width of cross streets at signalized intersections. These parameters generally describe the level of comfort that a bicyclist feels when traveling along an urban street. Similar parameters are defined for transit riders and pedestrians.

Bicycle

- Vehicle volume in outside (right) lane
- Heavy vehicle percentage
- Vehicle speeds
- Travel lane and bicycle lane widths
- Pavement quality
- Signalized intersection cross street width
- Unsignalized intersections/driveways

Pedestrian

- Vehicle volume in outside (right) lane
- Vehicle speeds
- Presence and width of sidewalk and buffer
- Lateral separation between vehicles and pedestrians
- Right-turns on red and permitted left-turns during "Walk" phase
- Crossing delay (signalized and uncontrolled)

Transit

- Service Frequency
- Perceived wait time and travel time
- Actual speed
- Provisions for waiting passengers

Based on the 2040 evening peak hour volumes in the eastbound direction and a divided 6-lane roadway with bicycle lanes or multi-use lanes, transit stops with shelters, and sidewalks, multi-modal operations were evaluated. Three bike lane options were evaluated – 5-ft bike lane, 6-ft bike lane, and 12-ft multi-use lane. A 6-ft wide sidewalk immediately behind curb was assumed. The MMLOS worksheets are included in Appendix G.

The results, provided in Exhibit 19, indicate that a 6-lane roadway with 5-ft or 6-ft bike lanes will provide good level of service for transit users and pedestrians, however bicyclists will experience poor level of service (LOS E). The primary factors affecting bicycle level of service are high traffic volumes and high density of driveways and side streets. Wider multi-use lanes may improve bicycle level of service simply based on a more lateral clearance between a cyclist and adjacent traffic, however the effects of conflicting transit vehicles and right-turn traffic using the same lane could very well make it a worse condition for cyclists. The HCM MMLOS methodology does not address these effects.

Exhibit 19 Summary MMLOS Analysis Results

Broadway Cross Section		Transit	Bike	Ped
6 lane divided w/5 ft bike lanes & 6 ft sidewalk	MMLOS Score	1.27	4.37	3.19
	LOS	A	E	C
6 lane divided w/6 ft bike lanes & 6 ft sidewalk	MMLOS Score	1.27	4.27	3.18
	LOS	A	E	C
6 lane divided w/12 ft multi-use lanes & 6 ft sidewalk	MMLOS Score	0.25	3.59	3.11
	LOS	A	D	C

4. Conclusions

Proposed roadway improvements are based on the analysis results of the existing and future traffic operations, analysis of crash data, and the City's Transportation Access Management Guidelines. The following proposed roadway improvements are intended to increase the capacity on Broadway Boulevard in order to serve future traffic demand which is expected to increase 30-50% over the next 30 years.

4.1 ROADWAY CROSS SECTION

The results of an evaluation of the intersection and roadway capacity requirements utilizing the analytical procedures provided in the Highway Capacity Manual and an analysis of traffic operations using a microscopic simulation modeling effort both indicate that six through lanes with the provision of appropriate turn-lane capacity at signalized intersections and pull thrus/outs at transit stops will provide sufficient capacity to serve projected future traffic demands and transit operations at acceptable levels of service. Increased roadway capacity will not only reduce congestion, but will also reduce crash potential, particularly rear-end type crashes.

The simulation modeling indicates that adding multi-use lanes for use by transit vehicles, right-turning vehicles, and bicycles, will provide marginal capacity and operational benefits to general traffic. Transit vehicles, including local buses and future BRT vehicles would benefit using the multi-use lanes, potentially realizing a 12% reduction in vehicle delay, reduced number of stops, and increased travel speed. While having a dedicated lane for local buses and BRT is optimal, the modeling results suggest that the benefits offered by the multi-use lanes for transit operations may be diminished due to their multi-functionality. The results indicate that buses and BRT can operate effectively within the general purpose lanes on Broadway Boulevard. Providing multi-use lanes on Broadway Boulevard is not essential, as long as pull thrus/outs that can accommodate buses and larger BRT vehicles (60 feet in length) are provided at signalized intersections and other major transit stops. Pull thrus/outs would not be required at minor stops. Implementing transit signal priority along Broadway Boulevard will benefit transit operations. Finally, reducing the density of driveways on Broadway Boulevard will benefit general traffic operations.

While BRT can operate in a general purpose lane on an arterial, introducing rail (i.e. a street car) into a general purpose arterial lane will adversely impact operations of both general traffic and the street car. Although street car operation was not modeled, the need for frequent stops and the typically lower operating speed relative to general traffic requires that a street car be placed within a dedicated running way on a higher speed arterial. Although not desirable a street car could share a multi-use lane with right-turning vehicles. However, a separate bicycle lane would be required due to the presence of rail. The viability of extending street car from Downtown to El Con Mall, as suggested in the PAG High Capacity Transit Study, is unclear at this time and will heavily depend upon the success of the initial street car route and the redevelopment of Broadway Boulevard to support street car usage.

4.2 INTERSECTION LANE CONFIGURATION

Based on the capacity analysis results, the intersection lane configurations provided in Exhibit 13 are recommended. At Country Club Road, since provision of dual left-turn lanes may not be possible given right-of-way constraints, the lane configuration provided in Alternative A should be constructed. Recommended storage lengths for exclusive left and right-turn lanes are provided in Exhibit 14.

4.3 SIGNALS

Unless redevelopment within the corridor produces high access demand onto Broadway Boulevard from a side street, no additional traffic signals are expected on Broadway Boulevard between Euclid Avenue and Country Club Road. Several modifications to signal system operations should be considered as part of the corridor improvements, including adding transit signal priority and potentially implementing adaptive signal control.

Pedestrian signals will need to be re-installed at Park Avenue, Cherry Avenue, Norris Avenue, and Plumer Avenue. To optimize traffic flow on Broadway Boulevard, the City of Tucson prefers the application of a HAWK signal design that allow for a 2-stage crossing so that these signals can be included in the coordinated signal operations on Broadway Boulevard. A Pelican pedestrian signal design could be considered instead of the HAWK. The marked pedestrian crossing at Treat Avenue should also be reinstalled and infrastructure for a future pedestrian signal installation included with the roadway improvements. A pedestrian signal warrant analysis of the Treat Avenue crossing should be conducted as the roadway construction plans are being finalized.

4.4 MULTI-MODAL FACILITIES

Bus pull thrus/pull outs will be required on Broadway Boulevard on the departure side of each signalized intersection. At Campbell Avenue, the bus bays should be of sufficient length to accommodate an articulated transit vehicle. This may require rearranging the location of the right-in/right-out driveway at the Safeway shopping center on the southeast corner. Bus pull thrus/outs will also be required on the north and south legs of the Euclid Avenue, Campbell Avenue, and Country Club Road intersections. Due to right-of-way constraints, it may not be possible to install a bus pull thru on southbound Country Club Road. Shelters should be provided at all transit stops.

Continuous sidewalk will be required on both sides of Broadway Boulevard. Bike lanes will be required with a 6-lane section or can be incorporated into the multi-use lane if one is provided and provision for future rail is disregarded.

4.5 ACCESS

A raised median, a minimum of 20-ft wide, will be required to provide appropriate access control for a 6-lane arterial. Conceptual median opening locations are presented in Exhibit 11, however additional assessment will be required as more information on potential redevelopment within the corridor becomes available. It is recommended that an access management plan be prepared. The plan should include locations of full and partial (left-in only) median openings, driveways, and right-turn deceleration lanes, if needed. Reducing driveway density will be important if multi-use lanes are not provided. The City of Tucson typically does not include right-turn deceleration lanes at unsignalized side streets or driveways on 6-lane arterials, however including a deceleration lane on eastbound Broadway Boulevard at the Safeway center should be considered given the relatively high volume of right-in/right-out traffic. As the existing driveway is located some 120 feet from the Campbell Avenue intersection and there is a bus bay present, implementing a deceleration lane may require relocating the driveway and bus bay.

4.6 SPEED LIMIT

A speed limit of 35 mph is recommended for this section of Broadway Boulevard and is consistent with the speed limit to the east.

4.7 LIGHTING

Street lighting is currently in place and will need to be included in the roadway widening. The street lighting provides improved visibility of driveways, pedestrians, and bicycles, thereby reducing the potential of nighttime crashes. Street lighting also provides improved security for pedestrians.

REFERENCES

1. Broadway Corridor Transportation Study, City of Tucson Department of Transportation, 1987.

2. Transportation Access Management Guidelines for the City of Tucson, July 2010.

3. Major Streets & Routes Plan, City of Tucson, January 2000.

4. 2040 Regional Transportation Plan Projected Traffic Volumes Map, Pima Association of Governments, updated in August 2010.

5. PAG High Capacity Transit Study; Pima Association of Governments, 2009.