8.0 Travel Demand Forecasting

8.1 Introduction

This chapter documents the process by which the Nashville MPO's regional transportation model was modified and employed to develop ridership estimates and other information to support the analysis of alternatives and selection of a preferred alternative. Further documentation of these modifications and copies of the new model developed as part of the study have been provided to the MPO outside the context of this report. Results of the ridership testing and other information provided as outputs of the model are discussed in Chapters 5, 9 and 10 of this report.

8.2 Modeling Methodology

8.2.1 Model Development

The Nashville regional model has recently been updated based on a TransCAD software platform[1]. However, the model did not include a formal mode choice step. Therefore, as a part of this study, PB developed a mode choice model and transit assignment procedures to allow the model to forecast specific transit demand by zone, route and transit stop. This also required the development of a transit network, and transit level of service matrices.

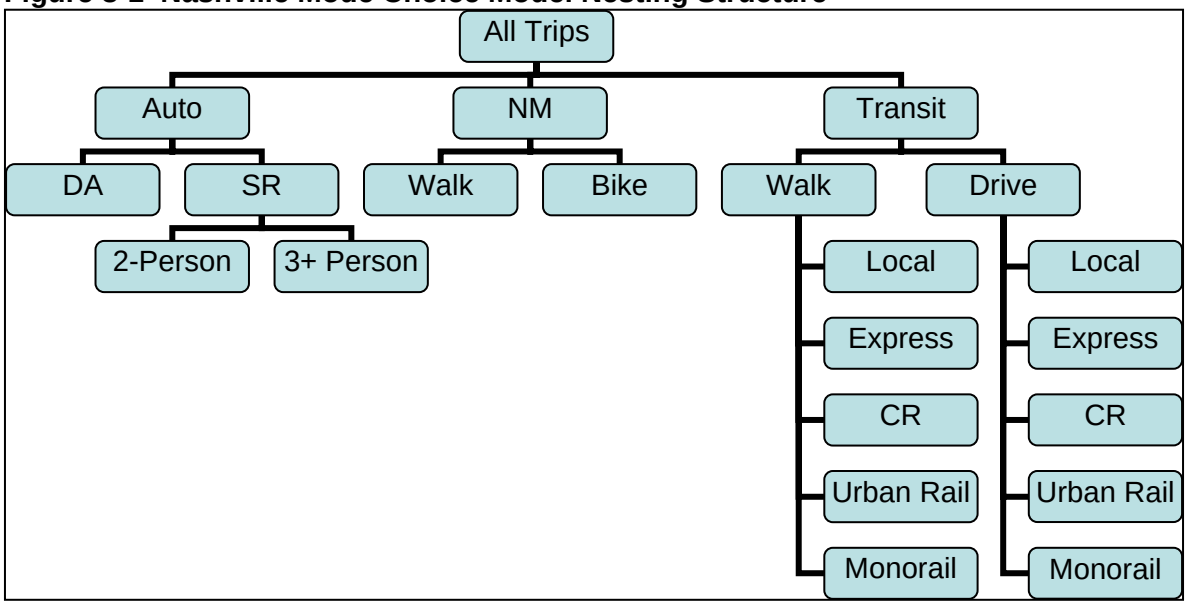
Fortunately, the current model's trip generation and distribution steps were developed to include all person-trips, and not just auto vehicle-trips. Therefore, no change was required in the trip generation or distribution steps of the current model. The mode choice model was inserted after trip distribution, and was used to calculate not only transit trips, but auto trips (by occupancy) and non-motorized trips as well. The factors that are used to adjust person trips to vehicle trips are effectively removed, in place of the modal trip tables produced by the new mode choice model.

The mode choice model is designed as a stand-alone program (coded in Fortran) that reads and writes fixed-format binary (noted by a "bin" extension) file, which, along with an associated dictionary file is compatible with TransCAD input and output formats. The program was based on the Memphis mode choice model, and borrows the same behavioral coefficients (in-vehicle time, out-of-vehicle time, cost) as are used in the Memphis model. The latter has been used for multi-modal corridor analyses, and uses coefficients that are within generally-accepted ranges. Mode and market-specific constants were modified to match target totals for modal travel, based on the 1997 home interview survey and the 2006 transit on-board survey.

Figure 8-1 shows the nesting structure. The model is a nested logit model, and estimates shares for auto, non-motorized and transit modes and sub-modes.

[1] "Nashville MPO Travel Demand Model" 2005. Prepared by PBS&J for the Nashville MPO.

Figure 8-1 Nashville Mode Choice Model Nesting Structure



Specific travel markets that are considered in the model include purpose-markets, access markets, and auto ownership markets. Purposes include Home-Based Work (HBW), Home-Based Other (HBO), and Non-Home Based. Transit access markets divide each origin/destination pair into short, long and no walk access combinations at the production and attraction ends. A "short" access/egress walk is defined as less than 0.25 miles; a "long" access/egress walk is defined as between 0.25 and 0.50 miles. Any market with more than a 0.5 mile walk distance is available to drive access only. Short walk times are constrained to a maximum of 5 minutes, and long walk times are constrained to a maximum of 10 minutes. Auto ownership markets divide trips by 0, 1 and 2+ households at the production end for HBW and HBO trip purposes. Auto ownership markets are determined based on a simple logit model that uses average zonal autos per household. Figure 8-2 shows how household market segments are determined based on the average household size value.

The household shares are then multiplied by average total trip rates by household size and normalized to determine the trip share markets. The household trip factors are shown in Table 8-1.

Figure 8-2 Nashville Auto Ownership Submodel

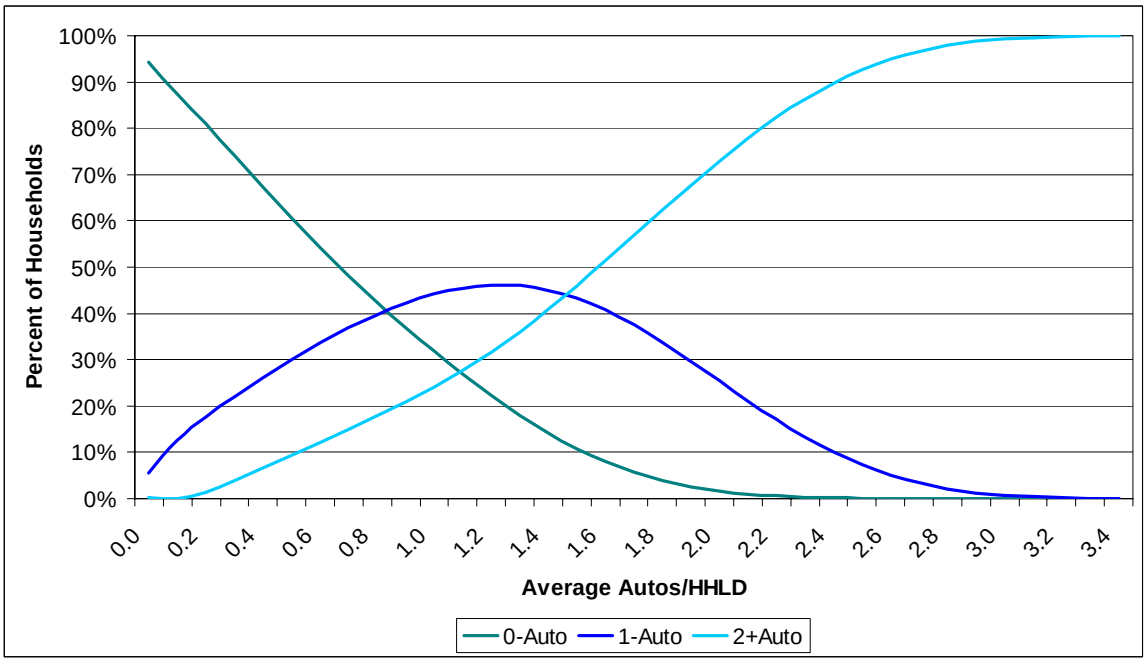


Table 8-1 Trip Rates for HBW and HBO Auto Ownership Markets

Auto Markets	HBW Trip Rate	HBO Trip Rate
0-Auto	0.26619	1.4509
1-Auto	1.24823	3.9936
2+ Auto	2.21788	6.0160

Constants for auto ownership are applied at the top and mid level, as well as at the lower level for the 2 and 3+ auto occupancy choice. There is no auto ownership stratification specific to the transit line-haul choices, however.

Tables 8-2 and 8-3 show the coefficients and constants used in the model

Table 8-2 Coefficients for the Nashville Mode Choice Model

Coefficients	Description	Purposes		
		HBW	HBO	NHB
CIVT	In-Vehicle Time (min)	-0.0250	-0.0125	-0.0200
CWAIT1S	Short Initial Wait (<5 min)	-0.0500	-0.0250	-0.0400
CWAIT1L	Long Initial Wait (>5 min)	-0.0500	-0.0250	-0.0400
CWAIT2	Transfer Wait (min)	-0.0500	-0.0250	-0.0400
CWALK	Walk Time (Walk mode)	-0.0375	-0.01875	-0.0400
CTWALK	Walk Time (Transit access/egress)	-0.0375	-0.01875	-0.0300
CDRIVE	Drive In-Vehicle Time	-0.0500	-0.0250	-0.0400
CCOST	Cost (parking, Op & fare)	-0.0046	-0.00809	-0.0046
ACPM	Auto Cost per Mile (cents)	12.0	12.0	12.0
OCC3P	Average 3+ Occupancy	3.5	3.5	3.5
INTDA	Intra-Zonal Drive-Alone share	0.73	0.73	0.73
INT2P	Intra-Zonal 2-Person Auto share	0.21	0.21	0.21
INT3P	Intra-Zonal 3+ Person Auto Share	0.06	0.06	0.06
CLSPRM	Logsum coefficient, Primary modes	0.75	0.75	0.75
CLSSUB	Logsum coefficient, SR & DA	0.75	0.75	0.75
CLSPTH	Logsum coefficient, transit line-haul	0.65	0.65	0.65
Coefficient Statistics				
	Wait/IVT Ratio	2.0	2.0	2.0
	Walk/IVT Ratio	1.5	1.5	2.0
	Walk access/IVT Ratio	1.5	1.5	1.5
	Drive IVT/IVT Ratio	2.0	2.0	2.0
	Cost/Hr	$3.26	$0.93	$2.61

Table 8-3 Constants for the Nashville Mode Choice Model

Coefficients	Description	Purposes		
		HBW	HBO	NHB[1]
KTRN -0	Transit – 0 auto	3.6995	-0.1230	-2.6223
KTRN -1	Transit – 1 auto	-1.1268	-2.7151	
KTRN -2	Transit – 2+ auto	-3.2622	-3.8965	
KNMOT-0	Non-Motorized – 0 auto	6.7695	0.9500	1.3517
KNMOT-1	Non-Motorized – 1 auto	0.3629	-0.8202	
KNMOT-2	Non-Motorized – 2+ auto	0.3102	-0.8138	
KSR – 0	Shared Ride – 0 auto	0.0000	0.0000	-0.1121
KSR – 1	Shared Ride – 1 auto	-1.0401	-0.0382	
KSR – 2	Shared Ride – 2+ auto	-1.7375	0.1638	
K3P – 0	3+p occupant auto – 0 auto	-0.5356	-0.8307	0.2042
K3P – 1	3+p occupant auto – 1 auto	-0.4552	0.3066	
K3P – 2	3+p occupant auto – 2+ auto	-0.9668	0.3066	
KBIKE – 0	Bike – 0 auto	-11.5566	-4.6412	-8.5362
KBIKE – 1	Bike – 1 auto	-6.3393	-6.1293	
KBIKE – 2	Bike – 2+ auto	-6.3392	-8.3327	
KDTRN - 0	Drive-Transit – 0 auto	-5.2934	-3.5595	-2.9819
KDTRN - 1	Drive-Transit – 1 auto	-3.0133	-2.6546	
KDTRN - 2	Drive-Transit – 2+ auto	-2.7462	-2.6546	

Notes:
[1] NHB trip purpose is not stratified by auto ownership

8.2.2 Use of Survey Data

Both the 1997 home interview survey and the 2006 on-board survey were used to generate the observed target values for the mode choice model calibration. A 2002 base year was used for the calibration. Table 8-4 shows the target shares used to calibrate the mode choice model. They are stratified by auto ownership and trip purpose. AM peak congested times were used for the HBW trip purpose, and off-peak times were used for the HBO and NHB trip purposes.

8.2.3 Model Calibration

The mode choice model calibration utilized a built-in “self-calibration” routine, which systematically adjusts each constant to match the observed transit shares. Shares were matched to (at most, in one instance) within 0.5% and virtually all calibration comparisons matched to well within 0.1%. The calibration also included the inclusion of a transit distance-specific term, which adjusts the transit mode attractiveness by distance. The distance-specific constants shown in Table 8-5 were developed based on transit on-board data.

Table 8-4 Regional Daily Mode Choice Target Totals

						Local			Express					
	DA	SR2	SR3+	Walk	Bike	walk	pnr	knr	walk	pnr	knr	Transit	Non-Transit	Total
HBW 0 Auto	0	2,707	1,034	1,906	100	2,389	0	64	55	0	10	2,518	5,747	8,265
HBW 1 Auto	130,830	29,949	13,224	2,068	3,659	1,556	166	194	15	42	28	2,001	179,729	181,730
HBW 2+ Auto	560,651	54,714	10,075	5,198	3,938	370	170	9	98	153	4	804	634,577	635,381
Total HBW	691,480	87,370	24,333	9,171	7,698	4,315	336	267	168	195	42	5,323	820,053	825,376
HBO 0 Auto	0	20,426	4,755	5,084	1,222	2,012	0	92	73	0	0	2,177	31,486	33,663
HBO 1 Auto	158,780	106,336	168,114	5,182	344	994	38	69	42	13	0	1,156	438,756	439,912
HBO 2+ Auto	428,781	342,538	551,255	17,856	197	273	47	130	50	17	23	540	1,340,626	1,341,166
Total HBO	587,561	469,300	724,125	28,121	1,762	3,279	85	291	165	30	23	3,873	1,810,869	1,814,742
NHB	489,843	317,971	441,038	21,526	1,234	1,377	161	287	30	39	46	1,940	1,271,612	1,273,552
Total	1,768,885	874,640	1,189,496	58,818	10,694	8,971	582	845	363	264	111	11,136	3,902,534	3,913,670

Table 8-5 Transit Distance Coefficient

Distance Range	HBW			HBO			NHB
	0 Auto	1 Auto	2+ Auto	0 Auto	1 Auto	2+ Auto	
0-5 miles	0.4770	-0.2917	-0.4411	-0.2623	-0.2656	-0.8020	-0.5186
5-10 miles	0.2386	0.3339	0.1848	0.4378	0.3939	0.5498	0.6448
10-15 miles	-1.0009	0.1124	0.5149	0.6144	0.4047	0.4701	0.5166
15-20 miles	-1.2000	0.0000	0.3000	0.7000	0.4500	0.6000	0.5000
20-25 miles	-1.1000	0.3000	0.5000	0.7000	0.5000	0.7000	0.5000
25-30 miles	-1.0000	0.7000	0.9000	0.7000	0.5500	0.7500	0.5000
30-35 miles	-0.9000	0.9000	1.1000	0.7000	0.6000	0.9000	0.5000
35-40 miles	-0.8000	1.1000	1.3000	0.7000	0.6500	1.0000	0.5000
40-45 miles	-0.8000	1.2000	1.5000	0.7000	0.7000	1.2000	0.5000
45-50 miles	-0.8000	1.3000	1.6000	0.7000	0.7500	1.3000	0.5000
50-55 miles	-0.8000	1.3000	1.6000	0.7000	0.8000	1.3500	0.5000
55-60 miles	-0.8000	1.3000	1.6000	0.7000	0.8500	1.4000	0.5000
60-65 miles	-0.8000	1.3000	1.6000	0.7000	0.9000	1.4500	0.5000
65-70 miles	-0.8000	1.3000	1.6000	0.7000	0.9500	1.5000	0.5000

There were sufficient observations only for up to 15 miles from the observed data, so above this limit, the constants were extrapolated, based on patterns in previous experience from the Los Angeles area. The data did, however generally indicate a rising transit mode share with distance.

Appendix A contains the user's guide for the mode choice model.

8.2.4 Network Development

Figure 8-3 shows the year 2030 No-Build transit network. Since the Nashville model did not previously have a transit network, the existing network was coded from the current schedule information. In addition, both walk and drive access links were added, as appropriate. The maximum drive access connector distance is 10 miles, and is limited within the pathbuilder to 30 minutes. The maximum walk time is limited by the pathbuilder to 20 minutes. The pathbuilder method is TransCAD's "Pathfinder" method.

Other pathbuilding parameters include:

Transfer time weight = 2.0
Transfer penalty = 7.5 min (5 min penalty x 1.5 weight)
Initial wait time weight = 2.0
Transit stop dwell time = 15 seconds
Maximum number of transfers = 3
Walk time weight = 1.5
Walk speed = 3 mph
Maximum initial wait time = 30 min
Maximum transfer wait time = 60 min
Minimum wait time = 2 min
Wait time = ½ headway
Maximum overall impedance = 240 min
Non-favored modes weighted by 10% during path-building

Bus speed model:

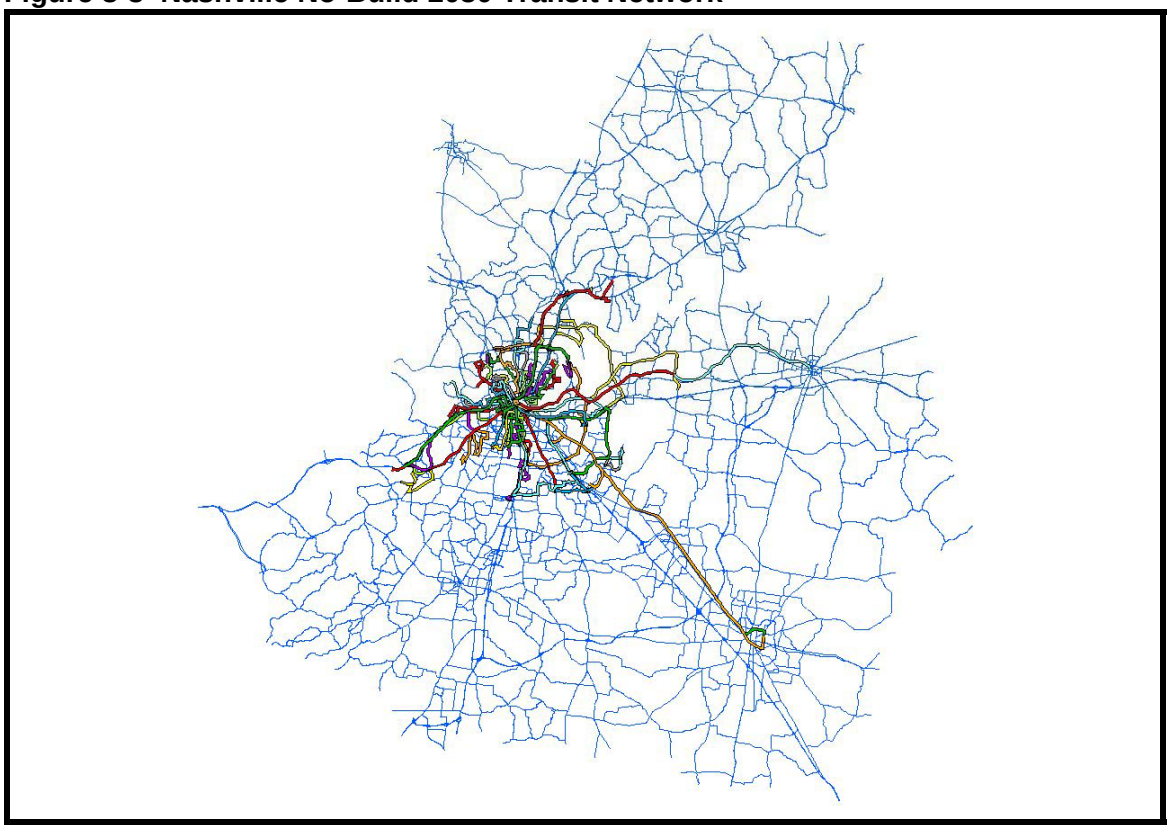
15 seconds/stop dwell time
Transit speed, area type 1 (High Density Urban) – congested speed reduced by 45%
Transit speed, area type 2 (Dense Urban) – congested speed reduced by 40%
Transit speed, area type 3 (Urban) – congested speed reduced by 35%
Transit speed, area type 4 (Suburban Business) – congested speed reduced by 30%
Transit speed, area types 5-7 (suburban, exurban, rural) – congested speed reduced by 25%

Overall correlation to schedule speeds is 85.2%

Note that weights and penalties are used only to determine path choices. Transit LOS variables, such as access/egress, wait and in-vehicle time reflect the actual time spent in these activities.

The on-board survey was assigned to the current network, and total boardings agreed with observed boardings to within 0.5% or about 50 boardings.

Figure 8-3 Nashville No-Build 2030 Transit Network



8.3 Detailed Screening Alternatives

The following section briefly describes the modeled alternatives. For a complete description of the alternatives, refer to Chapter 5, the Phase II Screening of Alternatives.

8.3.1 No-Build

The No-Build alternative includes those changes to the transit system that are described in the region's Transportation Improvement Program (TIP) or the financially-constrained portion of the region's Long Range Transportation Plan (LRTP). These include changes that have been planned and programmed, and for which there is a reasonable expectation for funding. The largest single change is the inclusion of the RTA's East Commuter Rail line connecting Lebanon to the Nashville CBD, which began in October 2006. Other transit improvements involved primarily service duration and frequency changes for routes 11, 12, 15, 18, 25, 32x, 33x, 37x, and 38x. Notably, no changes are programmed for the Route 96 "Relax and Ride" service to Murfreesboro. These changes, along with the 2030 highway network, were incorporated in the TSM and build alternatives.

8.3.2 Low Cost (TSM or Enhanced Bus)

The Low Cost alternative consisted of the proposed transit routes and Station/Park-and-Ride improvements proposed in Alternative A, the I-24 BRT alternative. All services

identified under Alternative A, including circulator routes, express and local pattern bus routes would be operated under the Low Cost alternative under nearly the same alignments. Under the Low Cost alternative, no significant guideway (busway or bus lane) or new roadway improvements would be implemented. This elimination of the busway is the primary difference between Alternative A and the Low Cost alternative and all other differences between the two alternatives stem from this single change. Park-and-ride lots would remain available at all identified station locations from Bell Road/Hickory Hollow Mall south. Stations would remain in place in locations similar to those identified in Alternative A, but would not be located adjacent to the roadway right of way.

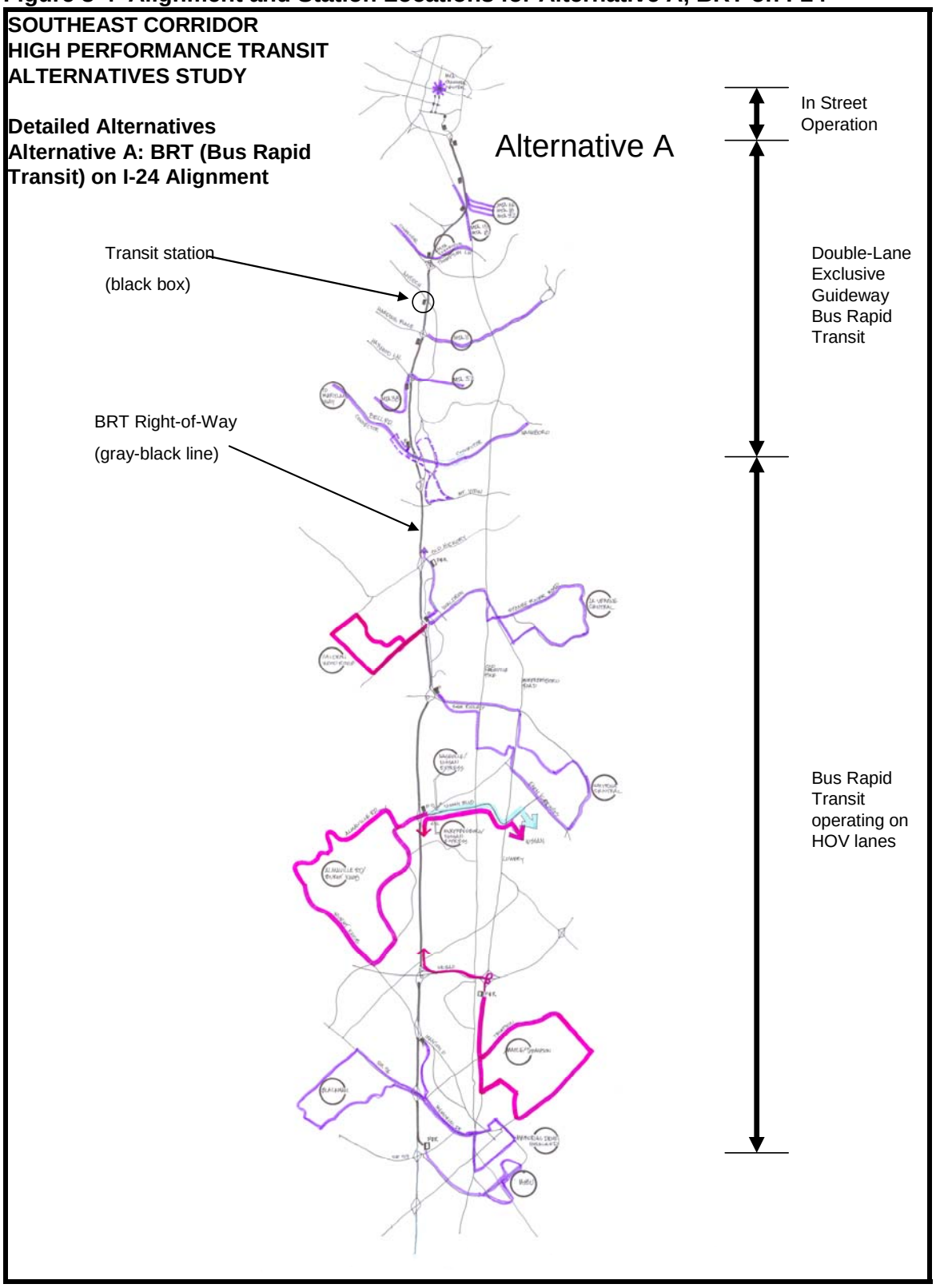
A variant of the low-cost alterative was also tested with the assumption of more concentrated land use around stations. This was done by assuming than all new growth to 2030 would be placed within 0.25 miles of a transit stop within the corridor.

8.3.3 Alternative A: I-24 Alignment, BRT

Alternative A consists of an all-day bus service operating mainly in the I-24 alignment. The alternative includes a two lane busway connecting downtown Nashville to the Bell Road/Hickory Hollow Mall area, with a single-lane reversible busway continuing south to Murfreesboro. The reversible busway south of Bell Road would operate north during the morning peak travel period and south during the afternoon peak period. During other periods the busway would be unused. The alternatives' alignment, station and park-and-ride locations, and circulator route alignments are shown in the map in Figure 8-4. The alignment begins in the north at the MTA Transit Center in downtown Nashville (assumed to be located on the north side of Charlotte Street between Fourth and Fifth Avenues). The alignment in downtown Nashville will be re-examined in further development; however, for the purposes of ridership buses would operate southbound on Fourth Avenue and northbound on Third Avenue. Buses would operate in downtown streets in existing lanes shared with local traffic and would stop at local bus stops along their alignment.

The operating plan combines long distance service to downtown Nashville from Murfreesboro, LaVergne, Smyrna, and other areas of Rutherford and southern Nashville-Davidson County with services oriented to shorter-distance trips within the corridor and services for reverse commuters to Murfreesboro and MTSU, Interchange City, Nissan, and other attractions in the corridor. The proposed new services all use the portion of the guideway that passes the congested point on I-24 between Fairfield and Harding Road that currently delays travelers in that area of the corridor. A series of shuttle routes in the southern areas of the corridor would begin their morning service circulating as local bus services through neighborhoods in communities in the south of the corridor. These same buses would then serve park-and-ride lot stations at the nearest major interchange along I-24 before entering the busway to complete their trip to downtown Nashville. In the Nashville-Davidson County portion of the corridor, intersecting bus routes would allow passengers to transfer to the BRT at stations located along the busway. Some trips would continue through downtown Nashville beyond the

Figure 8-4 Alignment and Station Locations for Alternative A, BRT on I-24



Charlotte Street terminal and continue to the West End and Vanderbilt University areas, providing on those trips a one-seat ride from southern portions of the corridor to the West End/Vanderbilt areas.

8.3.4 Alternative B: Commuter Rail CSX Alignment

This alternative consists of commuter rail service in the rail corridor extending south from downtown Nashville through LaVergne and Smyrna to Murfreesboro. This line is owned by CSX Transportation, Inc. (CSX), which uses it extensively in their freight operations. The alternative presumably would use conventional railroad equipment or DMU vehicles that meet the crash-worthiness and other safety standards set by the Federal Railroad Administration (FRA). This would make it permissible for the commuter rail trains to operate in mixed traffic with freight rail equipment such as that operated by CSX on the existing tracks in this alignment. The proposed alignment of the commuter rail line, the locations of commuter rail stations, and the approximate alignments of feeder and circulator bus routes are shown in Figure 8-5.

Seven trains would operate during each two hour peak period, with four traveling in the peak and three in the off-peak direction. Five of the seven trains would operate in a skip stop station stopping pattern in which alternating stations would be bypassed on alternating trips, to reduce the number of stops on each train and thereby increase travel speed and reduce travel time. During the mid day period, a single train would operate once in each direction, essentially to provide emergency service for travelers who need to return home mid day from downtown Nashville.

Shuttle bus routes would operate in neighborhoods around the stations from Bell Road south. Corridor communities including Smyrna, LaVergne and Murfreesboro would be served by circulator routes, and these routes would connect transferring passengers at the commuter rail stations to destinations including Interchange City, Nissan and MTSU. These circulator routes would operate in the peak periods only and would be timed to connect to the commuter rail trips arriving and departing at each station. Existing MTA bus services would connect to the Bell Road and Harding Road stations. As noted above, a circulator route would distribute transferring rail passengers through downtown Nashville and connect them to the MTA's transfer center at Charlotte Street and to the West End area and Vanderbilt Campus.

8.3.5 Alternative C: BRT Murfreesboro Road/Old Nashville Pike Alignment

In Alternative C BRT service would operate on an alignment along Murfreesboro Road (US 41) and Old Nashville Pike. This alternative consists of an all-day bus service operating on a two lane busway from downtown Nashville on Lafayette Street to Oak Street and then south along Murfreesboro Road to Bell Road. A single lane busway would continue south from the Bell Road area to Old Nashville Pike along Murfreesboro Road, and along Old Nashville Pike to Murfreesboro. The reversible busway south of Bell Road would operate in the prevailing commuter traffic directions, north during the morning peak travel period and south during the afternoon peak period. During other periods the busway would be unused. The proposed alignment and station locations for Alternative C are shown in Figure 8-6.

Figure 8-5 Alignment and Station Locations for Alternative B: Commuter Rail

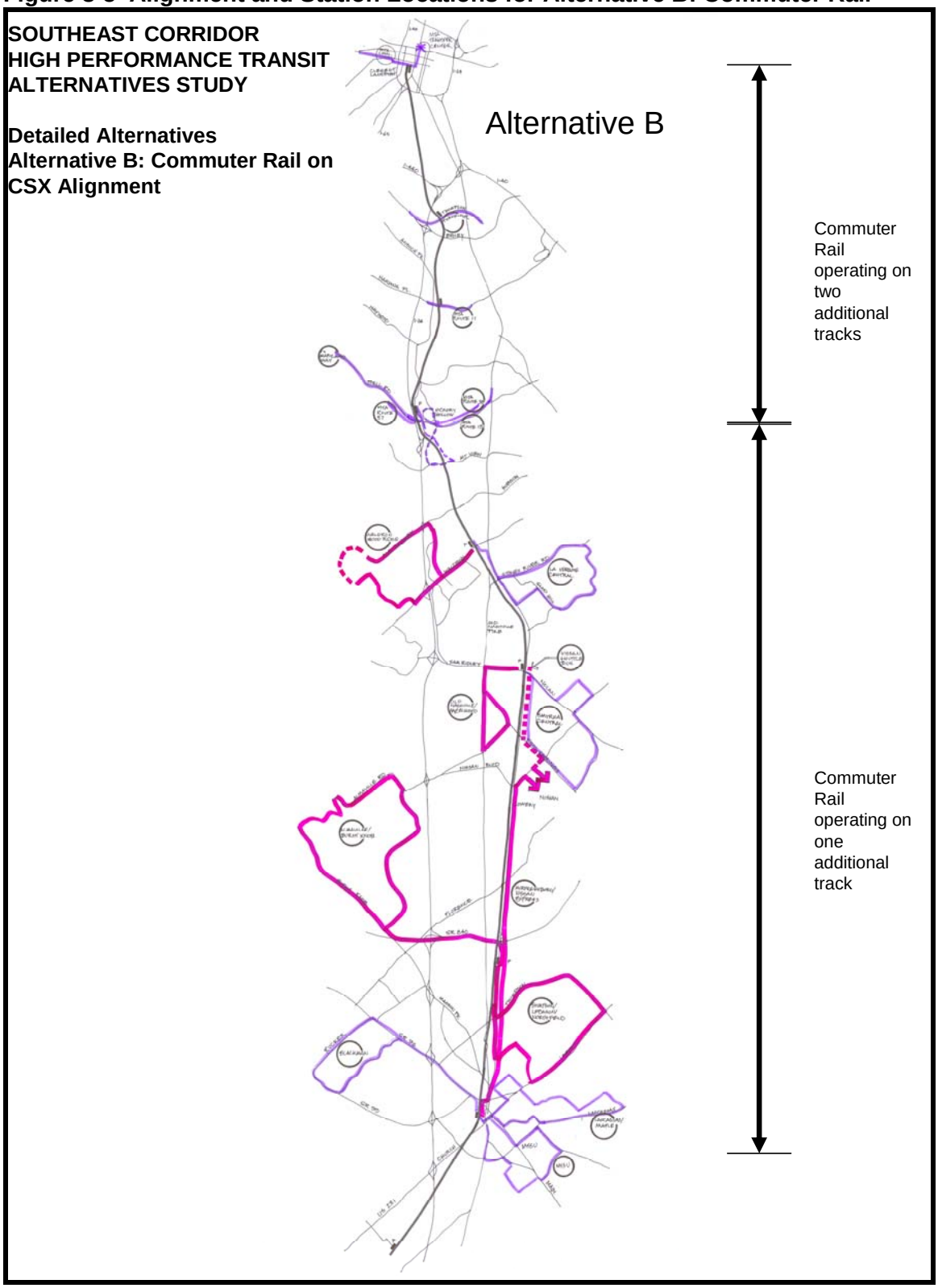
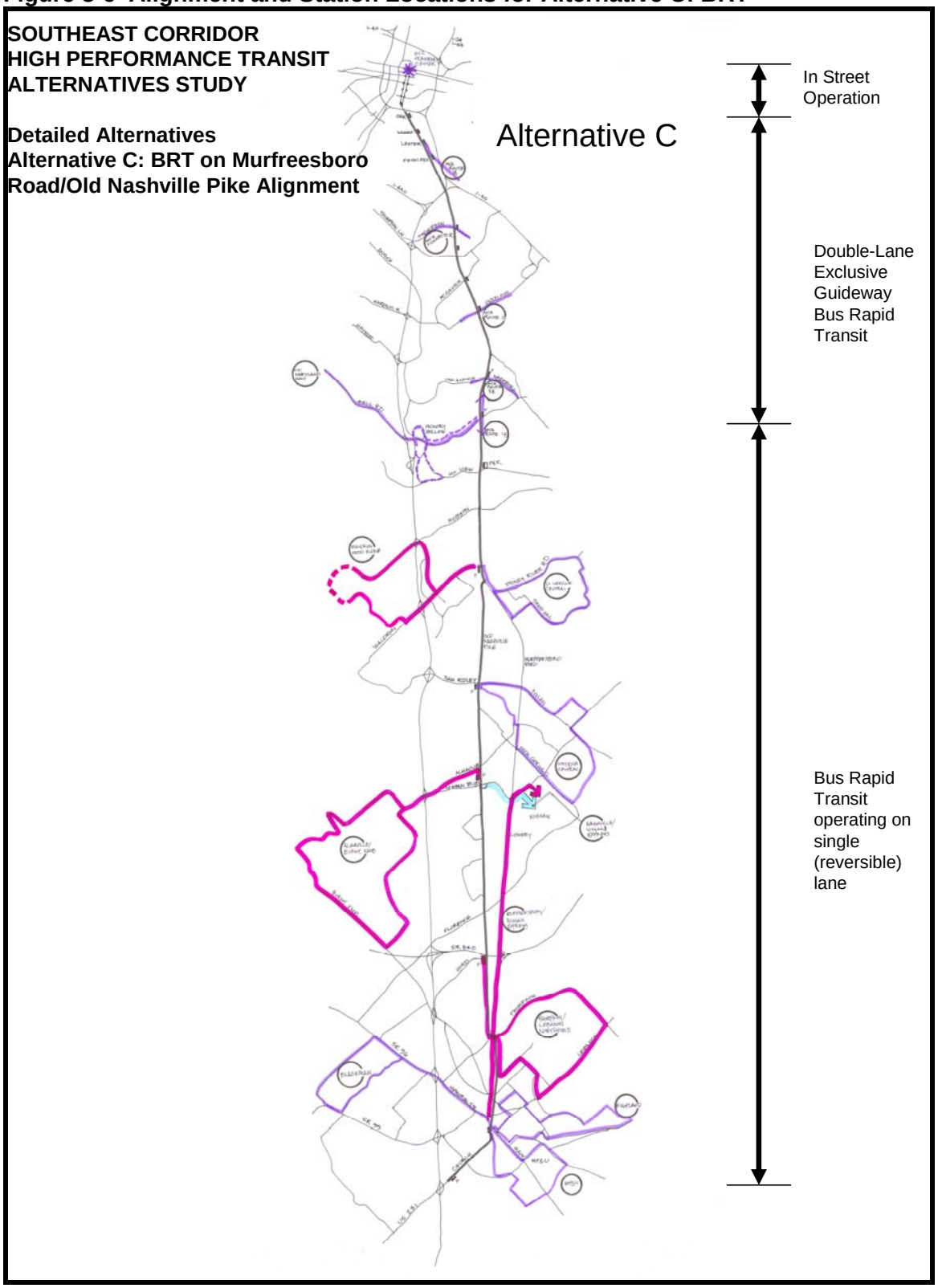


Figure 8-6 Alignment and Station Locations for Alternative C: BRT



The operating plan for Alternative C combines longer distance express services oriented to commuters to downtown Nashville with services oriented to shorter distance trips within the corridor. As in Alternative A, circulator routes would circulate through neighborhoods in the south of the corridor (LaVergne, Smyrna and Murfreesboro) before entering the busway along Nashville Pike or Murfreesboro Road to complete a high speed express trip to downtown Nashville. In the Nashville-Davidson County portion of the corridor, intersecting bus routes would permit passengers to transfer to the BRT at stations along the busway. Some trips operate continuously from the Charlotte Street transit center to the West End and Vanderbilt University areas, providing passengers bound to those areas with a one seat ride from areas in the south of the corridor.

8.4 Transportation Model Results

8.4.1 Transit Ridership

Table 8-6 shows the results of the mode choice model, applied to the alternatives. The ranges represent the difference between a base model run and the cumulative application of five mode choice adjustments. These adjustments include:

1. A commuter rail mode-specific constant equal to 18 minutes of equivalent In-Vehicle Time and a BRT mode-specific constant equal to 6 minutes of equivalent In-Vehicle time.
2. A 25% discount on commuter rail In-Vehicle time
3. The application of a calibrated distance-based coefficient for all transit (discussed earlier)
4. An adjustment of one cent (from $0.12 to $0.13) in the auto operating cost, based on historical gas prices
5. An adjusted drive-access coefficient for one- and two-auto households, based on experience in Los Angeles. The adjustment consisted of an equivalent 15 minutes for one-auto households and 25 minutes for two-auto households.

Table 8-6 Year 2030 Transit Linked-Trip Summary

Alternative	System Total	Corridor Guideway	Change from NB	Change from TSM
No-Build	15,500-16,800	-NA-		-900 - -1,100
TSM	16,400-17,900	-NA-	1,100	
Alt A (BRT on I-24)	15,600-17,200	800-1,600	100-400	-700 - -800
Alt B (CR)	16,000-17,600	200-900	500-800	-300 - -400
Alt C (BRT on MBR Rd)	16,300-18,100	900-1,900	800-1,300	-100 – 200
Enhanced Bus	16,800-18,300	-NA-	1,300-1,500	400
Enhanced Bus, Modified Land Use	17,300-18,900	-NA-	1,800-2,100	900 – 1,000

Ranges represent assumptions regarding
- use of a CR mode-specific constant,
- a 25% discount on CR IVT,
- use of transit distance-based coefficients,
- auto operating cost adjustment and
- a drive-access coefficient adjustment.

The TSM alternative and alternative C show a similar improvement over the no-build alternative, while the Enhanced Bus further improves on ridership performance. With a more concentrated land use, the Enhanced Bus improves by about 500 transit trips per day.

8.4.2 Boardings and Alightings

Table 8-7 shows the total boardings for corridor routes, by alternative. Alternative A and the Enhanced Bus alternatives show the greatest change from the TSM or no-build alternatives. With a more concentrated land use, the Enhanced Bus shows a significant increase in boardings.

Table 8-7 Year 2030 Transit Boardings in the Corridor

Alternative	Total Boardings	Change from NB	Change from TSM
No-Build	3,100		-1,900
TSM	5,200	2,200	
Alt A (BRT on I-24)	6,300	3,200	1,100
Alt B (CR)	5,200	2,200	0
Alt C (BRT on MBR Rd)	6,100	3,000	900
Enhanced Bus	6,500	3,400	1,300
Enhanced Bus with Modified Land Use	7,300	4,200	2,100
Corridor Routes include: 15, 32, 96(relax & ride), All corridor Guideway routes, all Corridor feeder routes			

8.4.3 VMT and VHT change

Table 8-8 shows a summary of the vehicle-miles and vehicle-hours of travel for each of the alternatives. This was a matrix-based calculation, using a fixed highway time and distance matrix, multiplied by the vehicle-trip table for each alternative.

There is very little difference between the alternatives in terms of overall VMT and VHT. The build alternatives show from -0.03% to -0.07% change from the no-build alternative.

Table 8-8 VMT and VHT for Alternatives, Region-Wide

Alternative	VMT	VHT	Avg. Speed
No-Build	30,160,420	1,052,491	28.66
TSM	30,149,191	1,052,128	28.66
Alt A (BRT on I-24)	30,144,716	1,052,050	28.65
Alt B (CR)	30,145,286	1,052,044	28.65
Alt C (BRT on MBR Rd)	30,139,361	1,051,874	28.65
Enhanced Bus	30,142,546	1,051,944	28.65
Enhanced Bus with Modified Land Use	30,138,541	1,051,796	28.65