DIN 01924 Rev 2

APPENDIX B.1: Travel Demand Methodology and Results Report [Rev2]

Durham-Orange Light Rail Transit Project

GO Triangle

November 2016

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List of Acronyms and Abbreviations

Acronym/Abbreviation	Definition
AA	Alternatives Analysis
CAMPO	Capital Area Metropolitan Planning Organization
CAT	Capital Area Transit
CHT	Chapel Hill Transit
Civtt	coefficient of in-vehicle time
Covtt	coefficient of out-of-vehicle time
CS	Cambridge Systematics
C-Tran	Cary Transit
DATA	Durham Area Transit Authority
DCHC MPO	Durham-Chapel Hill-Carrboro Metropolitan Planning Organization
DEIS	Draft Environmental Impact Statement
D-O	Durham-Orange
D-O LRT	Durham-Orange Light Rail Transit
EIS	Environmental Impact Statement
FTA	Federal Transit Administration
HBO	home-based other
HBSc	home-based school
HBSh	home-based shopping
HBU	home-based university
HBW	home-based work
HOV	high occupancy vehicle
HOV2	high occupancy vehicle for two persons
HOV3+	high occupancy vehicle for three or more persons
I-40	Interstate 40
LPA	Locally Preferred Alternative
LRT	light rail transit
mphps	miles per hour per second
MPO	Metropolitan Planning Organization
MTP	Metropolitan Transportation Plan
NC	North Carolina
NCCU	North Carolina Central University
NCSU	North Carolina State University
NHB	non-home-based
NHBW	non-home-based work
NHC	New Hope Creek
NHNW	non-home-based-non-work
NHBNW	non-home-based non-work
RMSE	root-mean-square error
RTP	Research Triangle Park
TOB	transit on-board

Acronym/Abbreviation	Definition
TRM	Triangle Regional Model
TRMSB	Triangle Regional Model Service Bureau
UNC	University of North Carolina
US	United States
VMT	vehicle miles traveled
VOT	Value of Time
WBNH	work-based non-home

1. Introduction

This document provides an update to the Travel Demand Methodology and Results Report, which is Appendix K02 of the *Durham-Orange Light Rail Transit Project DEIS*, published in August 2015. Since the DEIS publication, changes have been made on the travel demand forecasting methodology and assumptions for the Durham-Orange Light Rail Transit (D-O LRT) Project as part of the New Starts Application submission to the Federal Transit Administration (FTA). Section 2 presents an overview of the changes to the Triangle regional travel demand forecasting model. Section 3 discusses the ridership forecast results for the D-O LRT alternative from UNC Hospitals to North Carolina Central University (NCCU).

2. Model Refinements, Calibration, and Validation

The TRM Version 5 model, which was used to develop travel demand forecasts for the *Durham-Orange Light Rail Transit Project DEIS,* was further reviewed and refined, using the new 2014 Transit on-Board Survey. A new base year 2014 was used, and the model was re-validated to the 2014 conditions, using survey data and transit ridership data in the corridor.

2.1 Further Model Testing and Validation based on the 2014 Transit On-Board Survey

The TRM Version 5 model was calibrated using the transit on-board travel survey completed in 2006. Since that time, transit ridership in the region has increased. To better understand the travel patterns of transit users in the D-O LRT study area, GoTriangle conducted a transit on-board (TOB) survey in the fall of 2014 (September to November). The survey was conducted on 58 existing bus routes in or near the proposed D-O LRT corridor, including GoDurham, CHT, and some GoTriangle bus routes, among which 18 routes have been designated as in-corridor routes. The combined ridership of all surveyed bus routes is approximately 53,000. The 2014 TOB survey collected 5,831 samples. Methodologies and techniques in the survey were developed and deployed to be consistent with FTA guidance and requirements.

The 2014 TOB survey has been cleaned and processed to be compatible with TRM Version 5. It was then used to conduct the following analysis:

- Calculated the average transit fare;
- Developed an observed transit trip table and assigned it to the 2014 network; and
- Prepared a TRM 2014 model run and compared the model results with the observed travel patterns collected from the 2014 TOB survey.

2.2 Weighted Average Fare

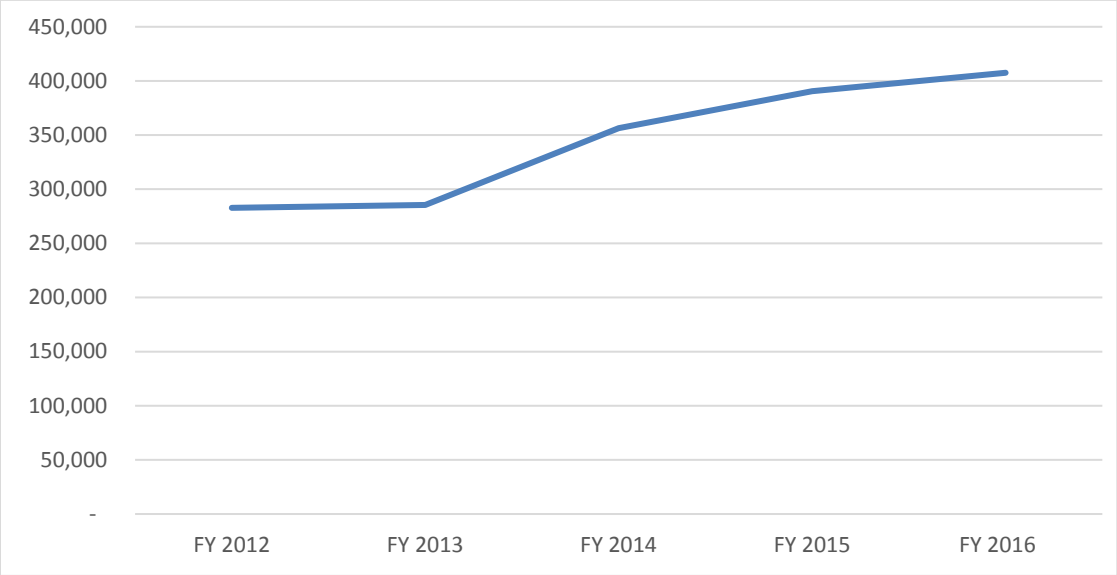
A weighted fare, used in the modeling, accounts for the current mix of free pass-wielding, discount fare-wielding, and walk up fare payers in the project environs. As a conservative assumption, this mix is not changed for modeling the future years even though there are trends showing increasing levels of free pass-wielding patrons. This treatment of discounted fares – arriving at a weighted average fare - is typical in other regional modeling constructs.

With this approach in the modeling, D-O LRT fares collected will be a hybrid of cash fares and pass usages, with an average fare expected to be heavily influenced by employer-based pass programs and incentives to use day passes over cash fare, as is the case today.

Since the early 2000s, GoTriangle has worked steadily to expand transit markets in the region through its signature employer-based transit pass program, the GoPass. UNC-Chapel Hill was the first major employer to adopt a GoPass back in 2003. Duke University became a GoPass employer in 2011, and other major employers in the D-O LRT corridor have since followed suit, including NCCU.

UNC employees receive the GoPass for free; Duke employees receive the GoPass for $25 per year. These types of programs make transit available in the two counties at zero marginal cost to employees at these major employers. Figure 2-1 below shows the growth of UNC-based GoPass usage on GoTriangle services over the past few fiscal years.

Figure 2-1: Annual UNC Go Pass Trips on GoTriangle Services – FY12 to FY16



Use of the Duke GoPass on GoTriangle services in FY 16 was approximately 182,000 boardings through the first 11 months of FY 2016, with another 257,000 on GoDurham services.

In a 2013 customer service survey, at the system level for GoTriangle, 28% of riders paid the cash fare while 72% used another fare type, with GoPass being the largest fare category at 43%.

For GoDurham, a 2015 survey found that only 15% of GoDurham passengers paid the GoDurham cash fare, while 47% used a Day Pass. GoPass usage on the GoDurham system rose from 3% of fares paid in 2011 to 13% of fares paid in 2015.

While the UNC and Duke GoPass programs dominate GoPass usage in the corridor, GoTriangle has recently expanded to several other area employers including NCCU, Durham Tech Community College (Durham Tech), and the American Tobacco Campus, which is GoTriangle's first GoPass relationship with a property management company that provides GoPass administrative support to dozens of small companies onsite. Significant growth has occurred since the earliest adoption of these three pass programs to the most recent quarterly report data. NCCU GoPass holders contributed to approximately 5,100 boardings in December 2015, American Tobacco GoPass holders had about 4,600 boardings in March 2016, while Durham Tech GoPass holders had roughly 30,300 boardings in March 2016.

The findings from the new 2014 TOB survey provide further evidence of widespread use of discounted fares on the system (a phenomenon which was previously noted during the modeling efforts for the initial D-O LRT Project Development submission). The 2014 TOB survey provides the market share of different prepaid and discount transit programs, and has been used to calculate the weighted average fare for each surveyed service provider. The results are summarized in Table 2-1.

Table 2-1: Weighted Average Boarding Fare

Transit Operator	Routes	Weighted Average Fare
GoTriangle	Local Routes	$0.79
	Express Routes	$1.52
CHT	All Routes	$0.00
GoDurham	Robertson Scholar Express (RSX)	$0.25
	Bull City Connector (BCC)	$0.00
	Other Routes	$0.73

Table 2-1 shows that the prepaid and discount transit programs significantly lower the weighted average fare. For example, the full cash fare for GoTriangle local routes is $2.25 and the weighted average fare is $0.79.

There are five existing routes that run in/nearby the proposed D-O LRT corridor. They are the BCC route from GoDurham, the 400 and 405 routes from GoTriangle, and the FCX, S, and HU routes from Chapel Hill Transit (CHT). The average fare on these five routes provide a reference for the average fare of the proposed D-O LRT.

The average fare is calculated by summing up the market shares of each fare type times the corresponding cost per ride for each fare type. The market shares are summarized from the 2014 Transit On-Board survey. The cost per ride is either obtained from the fare schedule of each transit agency, or if transit passes are used, it is calculated as the cost of a transit pass divided by the average swipes per card. The average swipes per card is calculated based on transit passes used in September and October in 2014.

The analysis also indicates that along the proposed D-O LRT (FCX, S, HU, 400, 405 and BCC), the weighted average fare is $0.12, which was used as the fare of the proposed D-O LRT in the model.

2.3 Assignment of the Observed Transit Trip Table

For this validation test a 2014 TRM model application was prepared and the observed transit trip tables from the 2014 TOB survey were assigned to the 2014 transit network. The transit assignment results were analyzed and compared to the survey results. This analysis provides insights on how the TRM understands the transit market and helps to identify any network issues, if any, for refinements.

The 2014 TRM model was prepared based on the TRM model for 2015 (which was used in the MTP development) with the following adjustments:

- Coded the 2014 transit network

  This 2014 transit network was coded based on the 2013 transit network acquired from TRMSB. The routes that were surveyed in the 2014 TOB survey were reviewed and modified to make sure they match the routing and schedule in 2014. The routes that were not surveyed remain unchanged, and the 2014 TOB survey shows that only one percent of transit trips have segments on routes that were not surveyed.

- Incorporated the weighted average fares developed in Section 2.2

  The weighted average fares shown in Section 2.2 are in 2014 dollars. They were converted to 2006 dollars by reducing 14.8 percent since the TRM Version 5 base year model used fares in 2006 dollars.

- Updated the timed transfer tables

  The timed transfer tables were updated to reflect the coordination of the 2014 routes at Durham Station.

- Added PnR lots in the highway network

  Seven PnR lots showed high usage in the 2014 TOB survey, but they were not coded in the 2015 MTP highway network, such as the PnR lot at Durham Station and Regional Transit Center. They were added, and the maximum drive times were all set to be 30 minutes.

- Developed the 2014 socioeconomic (SE) data

  The 2014 SE data were created by interpolating the TRM 2010 and 2015 MTP SE data. The population data were then adjusted to match the 2014 county total for the three core counties (Raleigh, Durham and Orange). The county level population estimates are from North Carolina State Office of State Budget and Management (http://www.osbm.state.nc.us/). The household data were updated based on the adjusted population and the interpolated household size from the 2013 SE data from TRMSB and the 2015 MTP SE data. The employment data were factored to match the county total employment, which is an interpolation of the total employment in the 2013 and the 2015 MTP SE data.

The TRM 2014 model was run, and the resulting congested highway network was used to permit the assignment of the observed transit trip table. These transit assignment results were used to explore network coding, mode choice (especially, auto-intercept versus transit mode), and mode-of-access issues (especially, drive access behavior). The analysis of these assignment results informed some network coding corrections.

This analysis also suggested the need to increase the weight of drive access time. With the current weight, too many transit riders chose in the model to use PnR lots closer to destinations. Different values of drive access time weight were then tested. Based on a review of the results, it was determined to use 5.0 for peak trips and 5.5 for off-peak trips.

It should be noted that, in addition to the conventional PnR market where a traveler uses a PnR lot closest to his or her home and takes transit to a destination far away, a second PnR market known as auto intercept plays an important role in this study area. As indicated in the mode choice structure in Section 3.1, auto intercept was treated as a mode in which, due to parking constraints at UNC, travelers drive from their homes (a relatively long distance for some drivers) to park at satellite parking lots and take a shuttle bus to campus. These drivers "choose" a satellite PnR lot closer to their destinations, while the satellite lots essentially substitute for on-campus or on-site parking. This behavior was confirmed in both 2006 and 2014 Transit on-Board surveys. A GoTriangle analysis of the 2014 TOB survey shows that the median distance from respondent's homes to satellite PnR lots was 14.2 miles, three times as long as the median distance traveled to a conventional PnR lot (4.6 miles).

The mode choice model is used to model travelers' choice behaviors among modes. We deem the mode choice model to be working properly if it can replicate the observed mode shares. The current auto intercept component does not accurately predict the choice of specific fringe PnR lots, but we believe it does produce the correct total number of auto intercept trips. The original TRM Version 5 mode choice model was validated at the regional level, including auto intercept trips, but not at the individual PnR lot level. The new Transit-On-Board survey provided the latest data that were used as the basis for the adjustment of the estimated auto intercept PnR lot choices.

The analysis of the observed transit trip table indicates a discrepancy in the auto intercept PnR lot choices between the observed and modeled auto intercept trips. The 2014 TOB survey shows that the most used satellite parking lot is the Friday Center parking lot, which is to the east of the UNC campus. It attracted 65% of auto intercept trips. The next most popular satellite parking lots are the Southern Village parking lot to the south (14%) and the Eubanks parking lot to the north (10%). The 2006 TOB survey shows similar patterns. However, the TRM Version 5 model estimates that the majority (86%) of the modeled auto intercepts trips used the Estes parking lot to the north, and only 6% of them used the Friday Center parking lot.

To address this discrepancy, we added a step in the TRM after the mode choice step to redistribute the modeled auto intercept trips according to the observed patterns in the 2014 TOB survey. The re-distributed auto intercept trips were then added to the transit trip tables for transit assignment. This step was also used in the forecast of D-O LRT ridership. For the no-build scenarios, the auto intercept distribution patterns observed in the 2014 TOB survey were used.

For the build scenarios, the parking lots to the east of the UNC campus (the Friday Center and Leigh Village parking lots) were each assumed to account for 15% of the auto intercept trips to reflect the reduction of CHT services along the D-O corridor. This was deemed a conservative assumption from the perspective of forecasting the D-O LRT ridership. In the build alternative, Leigh Village PnR lot will be built and will be the second PnR lot located to the east of the campus. Chapel Hill Transit (CHT) services between Friday Center and the campus will be removed and a new Bus Rapid Transit (BRT) service will be provided from the Eubanks Road PnR lot and the campus via the Estes Road PnR lot. With these changes, it is believed that the share of trips handled by PnR lots to the east of the campus will drop from 65% and the share handled by PnR lots to the north will increase. Given the increasing role of Eubanks and Estes PnR lots and historical role of Friday Center PnR lot, the share of PnR lots to the east is expected to drop from 65% to 30%, with Friday Center and Leigh Village each attracting 15%. The two PnR lots to the north (Eubanks Rd and Estes Rd) receive a proportional distribution of 35% of auto intercept trips, based on their shares in the 2014 TOB survey. The remaining PnR lots (Carrboro Plaza, Jones Ferry Rd and South Village) keep their shares observed in the 2014 TOB survey.

An auto intercept trip has two trip segments, the auto portion and the transit portion. Thus, when the mode choice step in the TRM creates outputs for auto intercept trips, two groups of files are created. One group is for the auto portion of auto intercept trips, and it records the production TAZ, the PnR TAZ, and the number of person trips. These trips are added to the highway OD matrices in the PA to OD step. Another group is for the transit portion of auto intercept trips, and it records the PnR TAZ, the attraction TAZ, and the number of person trips. These trips are added to the transit OD matrices in the PA to OD step.

There are nine matrices in a transit OD matrix file, each for a combination of transit type (local, express and rail) and access mode (walk, park-and-ride, and kiss and ride). When rail routes are not present in the transit network, the transit portion of auto intercept trips is added to the “express park-and-ride” OD matrix. Otherwise, it is added to the “rail park-and-ride” OD matrix. Then auto intercept trips would be treated in the same way as the other park-and-ride trips in transit assignment, and assigned to corresponding park-and-ride transit networks.

In the no-build alternative, transit trips in auto intercept mode are added to the “express park-and-ride” OD matrix, and are assigned to the “express park-and-ride” transit network (also called drive-to-express transit network). However, this does not mean all auto intercept transit trips are assigned to express buses. The “express park-and-ride” transit network consists of both local buses and express buses. However, in this network, local buses have an in-vehicle-travel-time (IVTT) weight of 1.5 and express

buses have a weight of 1.0, to reflect the preference that riders would show for using express buses. But, local buses do exist in the "express park-and-ride" transit network, and they will be chosen if their generalized cost (with the differential weighting) is lower than express buses.

In the build alternative, transit trips in auto intercept mode are added to the "rail park-and-ride" transit network. However, not all auto intercept transit trips are assigned to rail. All fringe PnR lots are used in the build alternative. Since auto intercept transit trips are distributed among these PnR lots based on the observed pattern in the 2014 TOB survey, 35 percent of auto intercept transit trips would use PnR lots that are not rail-adjacent.

The "rail park-and-ride" transit network consists of local buses, express buses, and rail routes. In this network, local and express buses have an IVTT weight of 1.5, and rail routes have a weight of 1.0. These auto intercept transit trips will most likely be assigned to express buses or local buses, because even with a weight of 1.5 on the IVTT, their generalized cost is most likely still lower than rail routes.

The results of assigning the observed transit trip table are shown in Table 2-2 through Table 2-4. The comparison is made to the same observed ridership as was used to weight the TOB survey, the average ridership over several days in October 2014[1]. As shown in Table 2-2, the model results are slightly higher than the observed ridership, with a deviation of 0.7 percent for all surveyed routes. The model results compare well with the observed ridership at the provider level, with deviations less than 5 percent for CHT and GoDurham and around 10 percent for GoTriangle.

Table 2-3 is a similar table as Table 2-2, but it only lists the results for the 21 routes that are defined as in-corridor routes in the 2014 TOB survey. Table 2-3 shows that the model underestimates the observed ridership by 8.5 percent for the 21 routes as a whole. At the provider level, the percent deviations from the observed ridership are around 10 percent or less for GoTriangle and CHT, and around 11 percent for GoDurham routes in the Orange-Durham corridor. A detailed review of the GoDurham ridership indicates that GoDurham has some competing routes, especially around Durham Station, which makes it difficult to replicate the observed ridership at the route level. Table 2-2 shows that at the provider level, GoDurham is only 1.2 percent below the observed ridership.

Table 2-4 compares the observed ridership for each of the 21 in-corridor routes with the model's estimated ridership. At the route level, the percent deviation from the observed ridership varies, typical of transit assignments from a regional model. Some routes' observed ridership is small, and a small difference in the observed and modeled ridership could yield a large percent deviation. It is also challenging to distribute transit trips among competing routes. Overall, the percent deviation is -8.5 percent for all 21 in-corridor routes, which is acceptable.

[1] This ridership is used as the observed ridership in the analysis of assigning the observed transit trip table because the 2014 TOB survey is weighted and expanded to this ridership.

Table 2-2: Ridership by Transit Operator for all Surveyed Routes from the Assignment of the Observed Transit Trip Table

Transit Operator	Observed Ridership[2] for Surveyed Routes	Modeled Ridership for Surveyed Routes	Difference	Percentage Deviation
GoTriangle	5,193	4,601	-592	-11.4%
CHT	25,373	26,623	1,250	4.9%
GoDurham	22,350	22,080	-270	-1.2%
Total	**52,916**	**53,304**	**388**	**0.7%**

Table 2-3: Ridership by Transit Operator for Routes in the Orange-Durham Corridor from the Assignment of the Observed Transit Trip Table

Transit Operator	Observed Ridership[3] for D-O Corridor Routes	Modeled Ridership for D-O Corridor Routes	Difference	Percentage Deviation
GoTriangle	5,193	4,601	-592	-11.4%
CHT	3,223	3,377	154	4.8%
GoDurham	11,264	10,021	-1,244	-11.0%
Total	**19,680**	**17,998**	**-1,682**	**-8.5%**

Table 2-4: Ridership by Route for Routes in the Orange-Durham Corridor from the Assignment of the Observed Transit Trip Table

Route[3]	Observed Ridership[3]	Modeled Ridership	Difference	Percentage Deviation
GoTriangle-400	972	820	-152	-15.6%
GoTriangle -405	566	538	-28	-5.0%
GoTriangle -420	296	193	-102	-34.6%
GoTriangle -700	727	384	-343	-47.2%
GoTriangle -800	1,087	915	-172	-15.9%
GoTriangle -805	595	792	197	33.1%
GoTriangle -CRX	484	471	-12	-2.5%
GoTriangle -DRX	466	487	21	4.6%
CHT-FCX	1,527	1,685	158	10.3%
CHT-HU	310	536	226	72.8%
CHT-S	1,386	1,156	-230	-16.6%

[2] Observed ridership is based on the October 2014 APC observations which were used to weight the TOB survey.
[3] Only 20 routes are listed in Table 2-4 because GoDurham -10 and GoDurham -10A are listed together in the row for GoDurham -10A. They are coded as one route in the transit network since they follow the same routing but GoDurham -10A operates before 7:00 pm and GoDurham -10 operates after 7:00 pm.

Route[3]	Observed Ridership[3]	Modeled Ridership	Difference	Percentage Deviation
GoDurham-5	2,371	2,521	150	6.3%
GoDurham-6	963	725	-239	-24.8%
GoDurham - 8	1,339	1,064	-275	-20.5%
GoDurham-11	1,024	989	-34	-3.4%
GoDurham-12	939	1,154	215	22.9%
GoDurham-10A	2,022	1,961	-61	-3.0%
GoDurham-6B	681	493	-188	-27.6%
GoDurham-RSX	342	222	-120	-35.2%
GoDurham-BCC	1,583	892	-692	-43.7%
Total	**19,680**	**17,998**	**-1,682**	**-8.5%**

2.4 TRM 2014 Model Validation

The TRM 2014 model setup was updated with the improved highway and transit network based on the analysis of assigning the observed transit trip table described in the prior section. A TRM 2014 model run was then completed and the results are shown in this section.

Table 2-5 compares the observed daily traffic volumes with the modeled highway assignment results by functional class group. The 2014 observed daily traffic volumes are currently unavailable, so the 2013 volumes were obtained from TRMSB and used in this comparison. Table 2-5 shows the modeled highway assignments in the study area overestimate traffic volumes by five percent for the region's highway systems as a whole, and they overestimate for each of the functional class groups. The observed traffic volumes are from 2013, which are most likely lower than those in 2014. If 2014 observed traffic volumes are used, the percentage deviations would be smaller. Overall, these highway assignment indicate that the 2014 model performs well in the study area.

Table 2-5: Observed and Estimated Daily Traffic Volumes (2014) by Functional Class Group

Functional Class Group	Model Estimates	Observed	% Deviation	%RMSE
Freeway	10,833,898	10,328,700	5%	16%
Major arterial	13,158,160	12,189,750	8%	29%
Minor arterial	11,150,918	10,826,170	3%	36%
Collector	4,525,534	4,360,930	4%	46%
Local road	3,086,576	2,823,700	9%	67%
Total	**42,755,086**	**40,529,250**	**5%**	**34%**

Comparison of the observed and modeled transit assignment results are shown in Table 2-6 through Table 2-8. The 2013 annual average weekday ridership was obtained from TRMSB and used as the observed ridership in these tables. Annual average weekday ridership was deemed more appropriate as a comparison for model validation purposes than the October 2014 observations used above.

As shown in Table 2-6, the model results are higher than the observed ridership, with a deviation of 4.8 percent for all surveyed routes. The model results compare well with the observed ridership at the provider level with deviations less than 10 percent, except for GoTriangle. Considering that Table 2-6 is

comparing the 2014 transit assignment results to the 2013 observed ridership and that GoTriangle ridership has increased rapidly in recent years, the percentage deviation for GoTriangle should be smaller if 2014 annual average weekday ridership were available for the comparison.

Table 2-7 is a similar table as Table 2-6, but it only lists the results for the 21 routes that are defined as in-corridor routes in the 2014 TOB survey. Table 2-7 shows that the model overestimates the observed ridership by 19.7 percent for the 21 routes as a whole. At the provider level, the percent deviations for GoDurham is less than 10 percent and above 30 percent for CHT and GoTriangle.

Table 2-8 compares the observed ridership for each of the 21 in-corridor routes with the model's estimated ridership. At the route level, the percent deviation from the observed ridership varies, typical of transit assignments from a regional model. Several factors could contribute to these deviations, including small observed ridership at the route level, the model's ability to distribute transit trips among competing routes, and the 2014 transit assignment results comparing to the 2013 observed ridership. Overall, the transit assignment results show that the 2014 model performs well in the study corridor area.

Table 2-6: Modeled Ridership by Transit Operator for all Surveyed Routes

Transit Operator	Observed Ridership[4] for Surveyed Routes	Modeled Ridership for Surveyed Routes	Difference	Percentage Deviation
GoTriangle	4,600	6,265	1,665	36.2%
CHT	26,407	27,585	1,178	4.5%
GoDurham	21,501	20,979	-522	-2.4%
Total	**52,508**	**54,829**	**2,321**	**4.4%**

Table 2-7: Modeled Ridership by Transit Operator for Routes in the Orange-Durham Corridor

Transit Operator	Observed Ridership[5] for D-O Corridor Routes	Modeled Ridership for D-O Corridor Routes	Difference	Percentage Deviation
GoTriangle	4,600	6,264	1,664	36.2%
CHT	4,151	5,641	1,490	35.9%
GoDurham	11,282	12,077	795	7.0%
Total	**20,033**	**23,982**	**3,949**	**19.7%**

Table 2-8: Modeled Ridership by Route for Routes in the Orange-Durham Corridor

Route	Observed Ridership[5]	Modeled Ridership	Difference	Percentage Deviation
GoTriangle-400	862	1,140	278	32.3%
GoTriangle-405	569	366	-203	-35.6%
GoTriangle-420	296	119	-177	-59.7%

[4] Observed ridership is based on the 2013 annual average weekday ridership as computed and supplied by TRMSB.

Route	Observed Ridership[5]	Modeled Ridership	Difference	Percentage Deviation
GoTriangle-700	699	339	-360	-51.5%
GoTriangle-800	766	2,051	1,285	167.7%
GoTriangle-805	496	1,484	988	199.2%
GoTriangle-CRX	452	495	43	9.5%
GoTriangle-DRX	460	270	-190	-41.2%
CHT-FCX	1,927	2,891	964	50.0%
CHT-HU	526	1,447	921	175.2%
CHT-S	1,698	1,303	-395	-23.3%
GoDurham - 5	2,574	2,810	236	9.2%
GoDurham - 6	922	825	-97	-10.5%
GoDurham - 8	1,152	792	-360	-31.2%
GoDurham -11	1,058	1,416	358	33.8%
GoDurham -12	867	1,205	338	39.0%
GoDurham -10A	2,032	1,915	-117	-5.7%
GoDurham -6B	661	900	239	36.2%
GoDurham -RSX	463	202	-261	-56.3%
GoDurham -BCC	1,553	2,012	459	29.6%
Total	**20,033**	**23,982**	**3,949**	**19.7%**

Figure 2-2 shows the comparison of observed and modeled transit trip shares by trip purpose. Only the transit trips in the transportation analysis districts along the D-O corridor are considered. In Figure 2-2, the modeled trip purpose shares are compared to three observed shares: the 2014 TOB survey, the 2006 TOB survey, and the 2006 TOB survey but only considering the routes that were surveyed in the 2014 TOB survey, which is referred as the 2006 (2014 routes) TOB survey in this report. This last set of observed shares is important because the 2006 and 2014 TOB surveys cover different areas in the Triangle region. Considering only the 2014 routes in the 2006 TOB survey makes these two TOB surveys comparable and can help reveal the changes in transit patterns between 2006 and 2014.

Figure 2-2 shows that the modeled share of trip purpose is different from the observed share from the 2014 TOB survey. However, it is much closer to the observed share from the 2006 TOB survey, which is not surprising since the TRM Version 5 was calibrated to the 2006 TOB survey. It is worth noticing that the observed shares from the 2014 TOB survey are different from the 2006 TOB survey. They are closer to the 2006 (2014 routes) TOB survey, but the differences indicate changes in the transit market from 2006 to 2014.

Figure 2-2: Modeled and Observed Shares of Trip Purposes

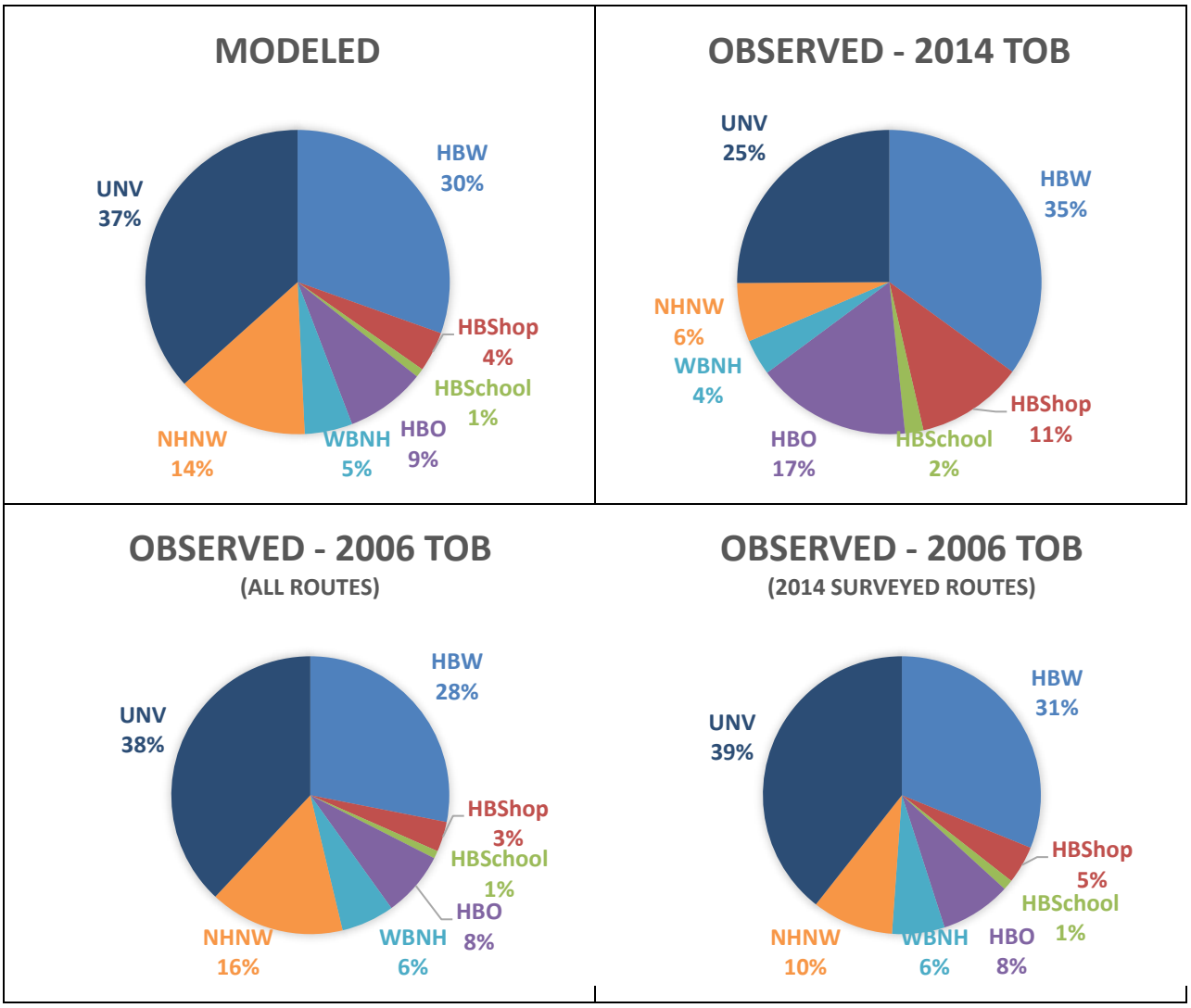


Figure 2-3 is the comparison of observed and modeled transit trip shares by access mode. It shows similar patterns as in Figure 2-2. The modeled walk access share and park-and-ride share are 79 percent and 14 percent, respectively, which are different from the 2014 TOB survey, but similar to the 2006 TOB survey. The comparison of the 2014 and the 2006 (2014 routes) TOB survey reveals that the walk access might have increased and the park-and-ride share might have decreased from 2006 to 2014.

Figure 2-3: Modeled and Observed Shares of Access Modes

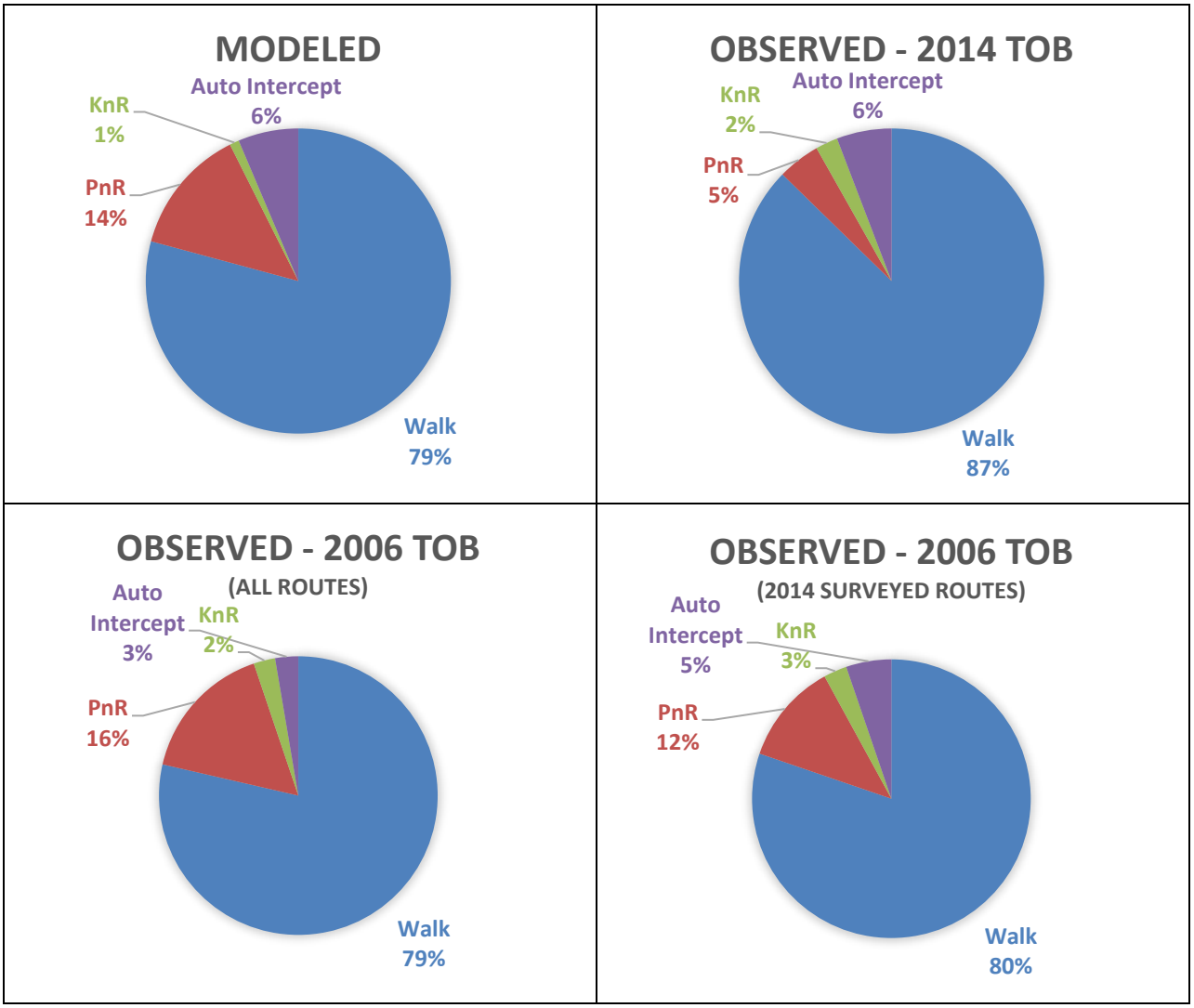
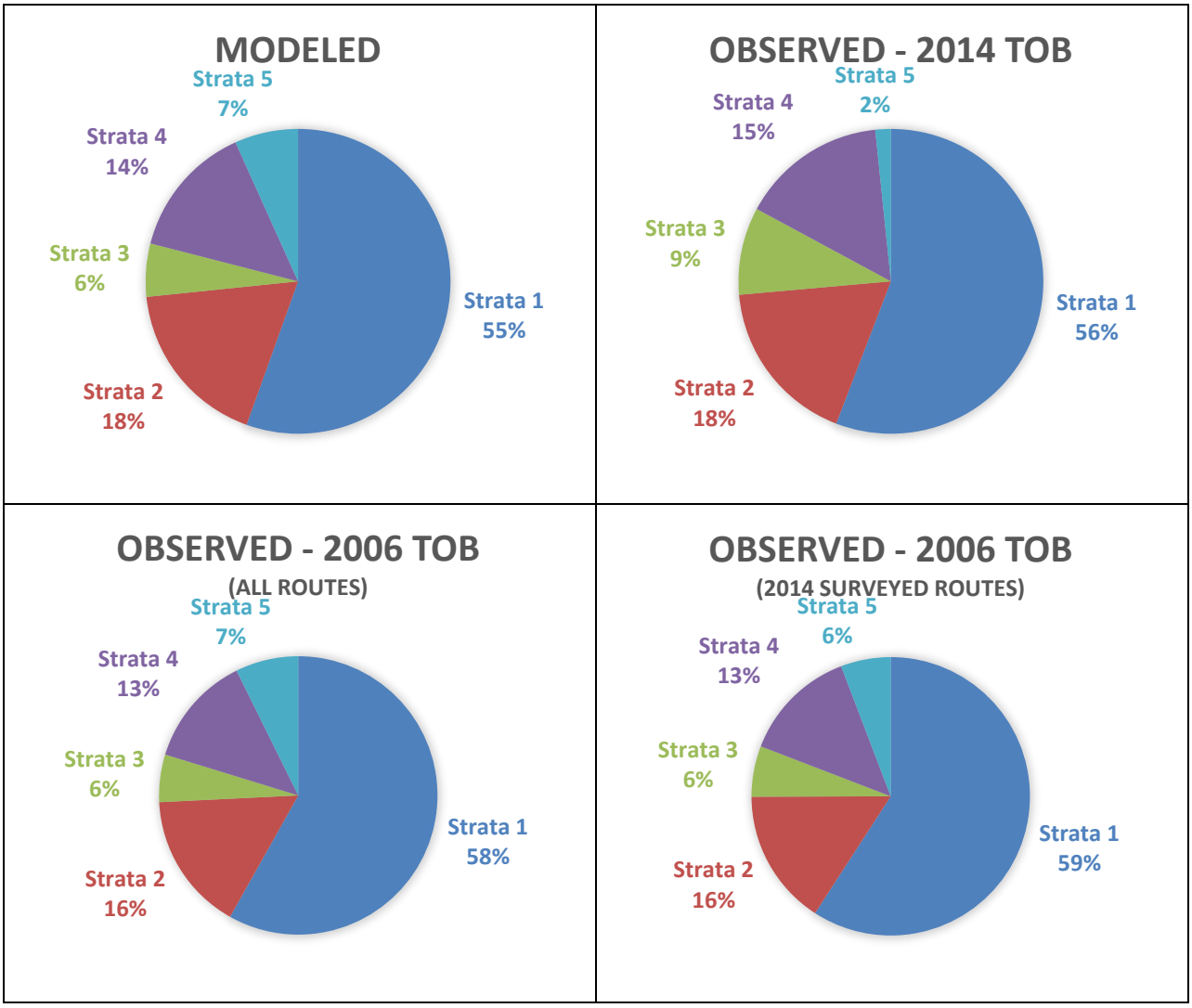


Figure 2-4 shows the comparison of observed and modeled transit trip shares by stratum. The strata shares in Figure 2-4 are similar, expect that Strata 5 from the 2014 TOB survey is smaller than the other three. This is related to the choice of income break point for high income. In the processing of the 2014 TOB survey, Strata 5 is defined as households with income greater than $100K and having vehicles. The income break point in the 2006 TOB survey was $90K and having vehicles rather than $100K and having vehicles. If another income break point in the survey, $75K, was selected, the share of Strata 5 would be around 7 percent.

Figure 2-4: Modeled and Observed Shares of Strata



The modeled district-to-district transit flows from the TRM 2014 are also compared to the 2014 TOB survey to validate the distribution of transit trips. Eleven districts are defined, as shown in Figure 2-5. These eleven districts cover almost all the areas surveyed in the 2014 TOB survey. However, the TRM 2014 addresses the entire Triangle region, including area in the eleven districts and areas outside of these districts. To align the comparison, only the transit trips among these eleven districts are compared. Duke University Transit was not surveyed in the 2014 TOB survey, and most of its routes are within District 4 shown in Figure 2-5. So the intra-district trips in District 4 are also excluded from the comparison.

Figure 2-5: District Definition in the Study Corridor

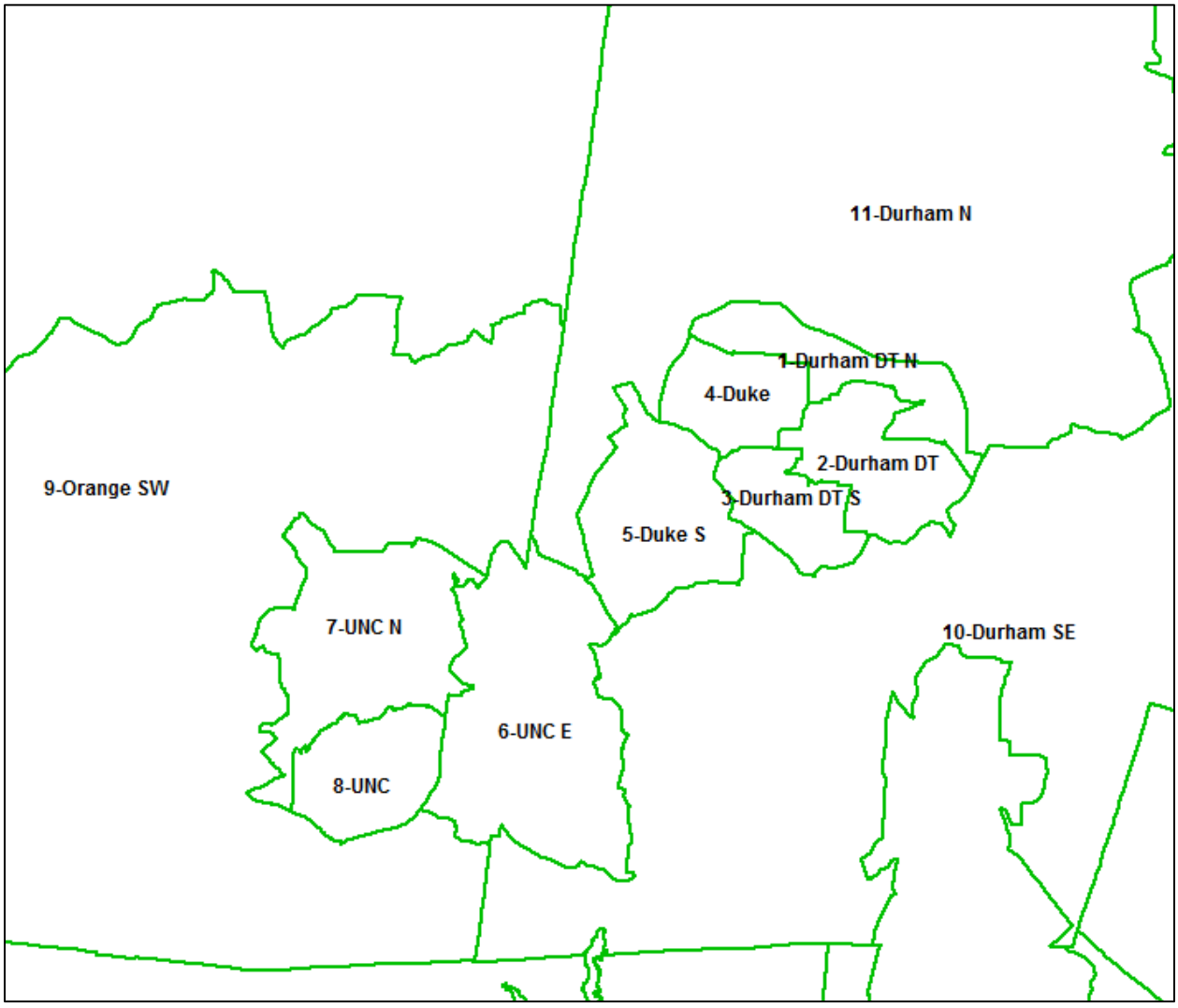


Table 2-9 lists the districts in descending order of transit trip productions, and compares the order from the 2014 TOB survey (observed) and the TRM 2014 (modeled). In both the observed and modeled lists, UNC is the top district in terms of transit productions. It produces 19 percent of observed and 28 percent of modeled transit trips. Overall, the transit production results show that TRM 2014 model reasonably replicates the observed transit production patterns.

Table 2-9: Comparing the Transit Productions by District

	Observed		Modeled	
Rank	Production District	Percent	Production District	Percent
1	8-UNC	19%	8-UNC	28%
2	7-UNC N	17%	6-UNC E	12%
3	9-Orange SW	13%	10-Durham SE	10%
4	2-Durham Downtown	12%	9-Orange SW	10%
5	6-UNC E	11%	7-UNC N	9%
6	10-Durham SE	8%	11-Durham N	8%
7	11-Durham N	7%	2-Durham Downtown	7%
8	3-Durham Downtown S	4%	4-Duke	4%
9	1-Durham Downtown N	4%	5-Duke S	4%
10	4-Duke	3%	1-Durham Downtown N	3%
11	5-Duke S	3%	3-Durham Downtown S	3%
Total		**100%**		**100%**

Table 2-10 lists the districts in the descending order of transit trip attractions, and compares the order from the 2014 TOB survey (observed) and the TRM 2014 (modeled). In both the observed and modeled lists, UNC is the top district in terms of transit attractions, and it attracts about half of the transit trips. Duke district has a higher share of transit attractions in the model results than in the observed data. A possible reason is that the 2014 TOB survey did not survey any Duke University Transit routes but the TRM 2014 does model Duke University Transit routes. Although the intra-district transit trips for the Duke district are excluded from the comparison, the modeled transit trips include some trips on Duke University Transit routes from other districts. Overall, the transit attraction results show that the TRM 2014 model reasonably replicates the observed transit attraction patterns.

Table 2-10: Comparing the Transit Attractions by District

	Observed		Modeled	
Rank	Attraction District	Percent	Attraction District	Percent
1	8-UNC	54%	8-UNC	46%
2	2-Durham Downtown	12%	4-Duke	12%
3	10-Durham SE	6%	2-Durham Downtown	8%
4	11-Durham N	6%	7-UNC N	8%
5	4-Duke	6%	10-Durham SE	6%
6	7-UNC N	4%	6-UNC E	5%
7	1-Durham Downtown N	4%	11-Durham N	4%
8	6-UNC E	3%	5-Duke S	3%
9	9-Orange SW	2%	9-Orange SW	3%
10	5-Duke S	2%	1-Durham Downtown N	2%
11	3-Durham Downtown S	1%	3-Durham Downtown S	2%
Total		**100%**		**100%**

Table 2-11 lists the district pairs in descending order of share of district-to-district transit trips, and compares the order from the 2014 TOB survey (observed) and the TRM 2014 (modeled). Only five district pairs are listed because the rest of the pairs account for three percent of transit trips or less, and the five listed district pairs account for about half of transit trips. In Table 2-11, the same district pairs appear among the top four of both observed and modeled results. Overall, the district-to-district transit trip results show that TRM 2014 model reasonably replicates the observed district-to-district transit trip patterns.

Table 2-11: Comparing the District to District Transit Trips

	Observed			Modeled		
Rank	Production District	Attraction District	Percent	Production District	Attraction District	Percent
1	7-UNC N	8-UNC	14%	8-UNC	8-UNC	19%
2	8-UNC	8-UNC	14%	6-UNC E	8-UNC	9%
3	9-Orange SW	8-UNC	12%	9-Orange SW	8-UNC	7%
4	6-UNC E	8-UNC	9%	7-UNC N	8-UNC	6%
5	2-Durham Downtown	2-Durham Downtown	4%	8-UNC	7-UNC N	4%
Total			**54%**			**45%**

3. Model Applications and Ridership Forecasting

The TRM Version 5 model was tested two base year model sets (2014 No-Build and 2014 with D-O LRT), two 2035 model sets (2035 No-Build and 2035 with D-O LRT), and two 2040 model sets (2040 No-Build and 2040 with D-O LRT).

The Light Rail Alternatives consist of LRT service from UNC Hospitals in Chapel Hill to NCCU in Durham, with 18 stations proposed along this alignment. The Transit Operating Plan has detailed descriptions of the alignment by segment, station locations, estimated LRT travel times, the proposed service plan, and estimated operating requirements.

- The proposed service frequencies are every 10 minutes for peak and every 20 minutes for off-peak on a weekday.
- Station-to-station travel times were developed and coded for the D-O LRT Alternative.
- To account for the pre-paid transit pass program, a weighted average fare input was developed for each service provider using available survey data on average fare paid, as discussed in Section 2.2.
- To integrate with the LRT, bus systems were modified for GoTriangle, GoDurham, and CHT routes in the corridor, including elimination of competing bus services, modifications to the background bus network to work with the LRT, and introduction of new feeder bus routes.

Travel times were calculated for the D-O LRT Alternative based on operational and alignment characteristics such as horizontal curves, vertical grades, and operating environment (i.e., exclusive right-of-way versus mixed traffic). The calculations assume a 20 second dwell time for each station stop and a 3.0 miles per hour per second (mphps) acceleration and deceleration rate. Potential delays when crossing at-grade intersections were estimated with the assistance of project engineers, considering intersections likely to have full priority given to LRT (i.e., gated crossings or full signal preemption) and those assumed to have partial signal preemption.

For the D-O LRT alternatives, drive access to transit stations has the following assumptions:

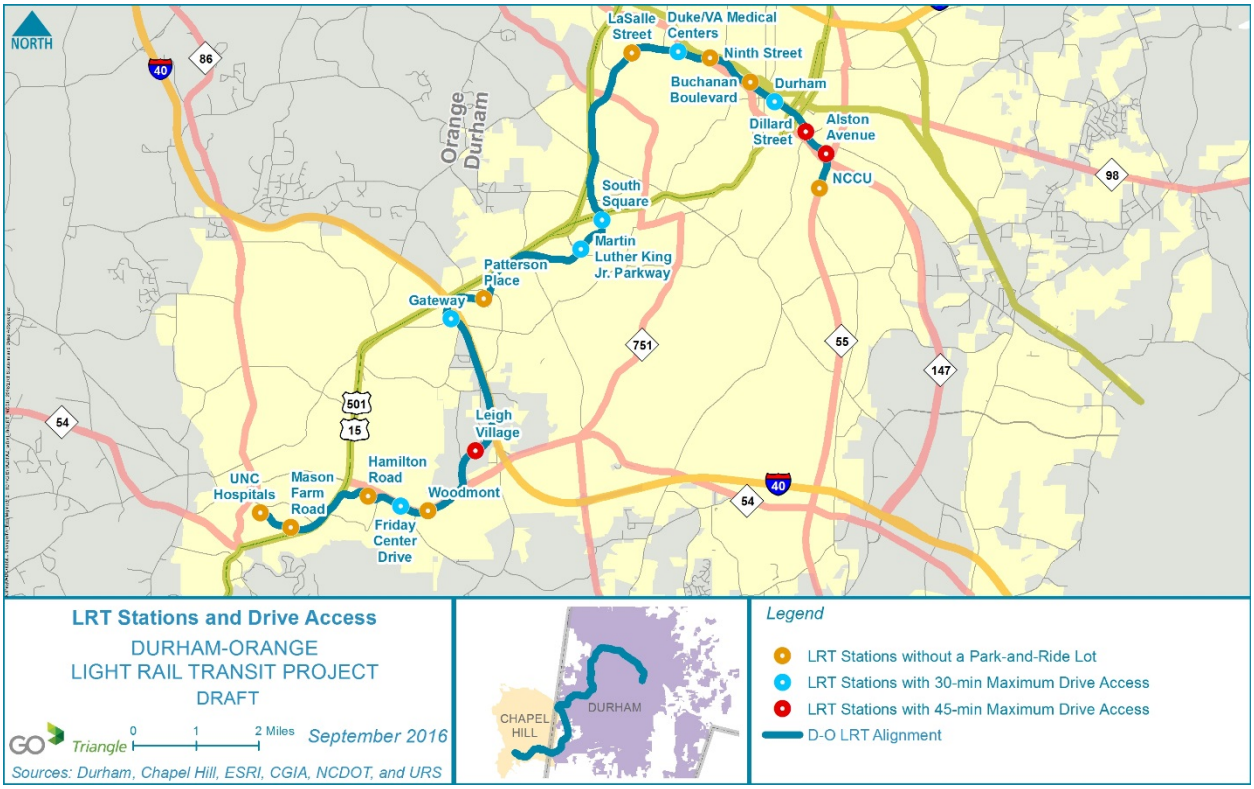
- Drive access link coding was limited to 45 minutes for auto intercept lots and rail termini, and 30 minutes for the remaining lots (Figure 3-1).
  - Table 3-1 summarizes the PnR lot locations with 45-minute and 30-minute maximum drive time in the four scenarios: 2014 No-Build, 2014 Build, 2035/2040 No-Build, and 2035/2040 Build. It shows that three of the PnR lots have the maximum drive time of 45 minutes in the two build scenarios. They are the PnR lots at Alston Avenue, Dillard Street, and Leigh Village, and they are all connected to the Durham-Orange Light Rail Transit (D-O LRT).
  - Next to the east terminal station NCCU, Alston Avenue station and Dillard Street station, having parking facilities, are assumed to behave similarly to a terminal station with a parking capacity, with an easy access to the freeway interchange. Empirical evidence indicates that a terminal station tends to have a larger market to draw drivers than an intermediate station. Leigh Village station will be designed with a parking-and-ride lot which will serve the UNC community in a manner similar to an intercept PnR lot currently operating around the campus. For UNC-bound commuters coming from Southeast Durham, Morrisville, Cary, and Raleigh, Leigh Village station effectively acts as a terminus station for that travel market, even though the station is in the middle of the line. This type of PnR lots tends to attract users from far away, as evidenced from the Transit on-Board Survey. Therefore, in all these

three locations, a higher maximum drive time (45 min) is used than a regular PnR at an intermediate station.

Table 3-1: Summary of Park-and-Ride Lots with 45-min and 30-min Maximum Drive Time

Drive Shed	2014 No-Build	2014 Build	2040 No-Build	2040 Build
Park-and-ride lots with 45-minute maximum drive time	None	3 (Alston Avenue, Dillard Street, and Leigh Village)	None	3 (Alston Avenue, Dillard Street, and Leigh Village)
Park-and-ride lots with 30-minute maximum drive time	53	57	163	167

Figure 3-1: Park-and-Ride Lot Locations for the 2035 Build Scenario



3.1 2040 Ridership Forecasts

Table 3-2 shows the shares of LRT ridership forecasts by trip purposes and transit-dependent population. Station-level activities for boardings and deboardings by directions are displayed in Tables 3-3.

Some of the major findings are:

- Boarding forecasts are in the range of approximately 26,880 boardings for an average weekday in 2040.

- Work-related trips (home-based work and work-based non-home trips) were estimated to account for almost half of the total estimated LRT ridership, and home-based university student trips were forecast to share 21 percent of total daily ridership.
- Zero-vehicle households were estimated to take 45 percent of the total daily ridership, while low-income households with any vehicle will share a quarter of the total daily ridership.
- Major attraction stations include UNC Hospitals, Alston Avenue, and Duke/VA Medical Centers stations, with the largest numbers of deboardings in the morning peak period.
- Major production stations include Leigh Village, Friday Center, and new NCCU stations, with the largest numbers of boardings in the morning peak period.
- On a daily basis, walk access to the project was forecast to account for more than half of the total project ridership, with the remaining project access split between drive access (24 percent) and bus transfers (23 percent).

Table 3-2: 2040 Daily Ridership Forecasts by Trip Purposes and Transit-Dependent Populations

Alternative	Trip Purposes	Share (%)
UNC Hospitals -- NCCU	Work (Home-Based Work)	37%
	Shopping (Home-Based Shopping)	10%
	School (Home-Based School)	2%
	Other (Home-Based Other)	11%
	Work-Based Non-Home Trips	8%
	Non-Home-Based Non-Work Trips	11%
	College (Home-Based University)	21%
	Zero Vehicle Households	45%
	Low-Income Households with any Car	25%

Table 3-3: 2040 Daily Ridership Forecasts by Stations

Station	UNC-Alston Boardings	UNC-Alston Deboardings	Alston-UNC Boardings	Alston-UNC Deboardings
UNC Hospitals	3,580	0	0	3,580
Mason Farm Road	1,030	40	40	1,030
Hamilton Road	220	80	80	220
Friday Center Drive	660	1310	1310	660
Woodmont	310	380	380	310
Leigh Village	500	1,560	1,560	500
Gateway	740	700	700	740
Patterson Place	520	620	620	520
Martin Luther King Jr. Parkway	720	880	880	720
South Square	870	360	360	870
LaSalle Street	660	770	770	660
Duke/VA Medical Centers	940	530	530	940
Ninth Street	390	300	300	390
Buchanan Boulevard	270	240	240	270
Durham	560	1,210	1,210	560
Dillard Street	340	1,570	1,570	340
Alston Avenue	1130	730	730	1130
NCCU	0	2160	2160	0
TOTAL	13,440	13,440	13,440	13,440

* Average weekday ridership estimates. Rounding was used and may lead to discrepancy in totals.