2045 Long Range Transportation Plan (LRTP)

MODEL DOCUMENTATION AND APPENDIX

Mobile Area Transportation Study (MATS)
Metropolitan Planning Organization (MPO)
Long Range Transportation Plan (LRTP)

Adopted: April 22, 2020

Prepared by the South
Alabama Regional Planning Commission (SARPC)
110 Beauregard St., Ste 207
Mobile, AL 36602

2045 Long Range Transportation Plan (LRTP)
Model Documentation and Appendix

Prepared for the Mobile Area Transportation Study (MATS) Metropolitan Planning Organization (MPO) by the South Alabama Regional Planning Commission (SARPC)

This document is posted at
https://www.envision2045.org/

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PREFACE

This Mobile Area Transportation Study (MATS) Long-Range Transportation Plan to the year 2045 was begun in 2015 under the guidance of the Mobile Urban Area Metropolitan Planning Organization (MPO). The study was conducted by the South Alabama Regional Planning Commission with the assistance of the Alabama Department of Transportation, the Mobile County Engineering Department, The Wave Transit System, and the City of Mobile Transportation, Planning, and Engineering Departments. Funding has been provided by the U. S. Department of Transportation's Federal Highway Administration and Federal Transit Administration, by the Mobile County Commission, and by the cities of Mobile, Prichard, Chickasaw, Saraland, Satsuma, Creola, Bayou La Batre and Semmes.

The Destination 2045 Transportation Plan is multi-modal in scope, encompassing long-range plans for highway, public transportation, and bicycle/pedestrian networks. Regional growth, economic development, and accessibility within the study area along with environmental concerns necessitate that the long-range plan addresses not only improved vehicular travel but also improvements to alternative modes. Preservation of the existing transportation system coupled with enhancement of all modal choices will contribute to the improvement of the overall quality of life in the region.

The MPO's objective in initiating the plan update was to identify, to the maximum extent feasible, the multi-modal transportation improvements which will be needed in the Mobile urban area between now and the year 2045 in order to maintain an acceptable level of mobility. Where possible, these needs were quantified in terms of dollar costs and prioritized based on the availability of funding, the anticipated impact of the proposed improvement, and expected development patterns and timing. The Plan is not proposed as a rigid, inflexible blueprint, but rather is intended to guide decision-makers' actions within a regional context and thus maintain system coordination across the various political boundaries which divide the MATS area.

This document explains the technical aspects of the update process, particularly the traffic modeling and forecasting portion. The Envision 2045 Plan itself, an Executive Summary, or fold-out maps of the various plan elements can be obtained from the Transportation Planning staff of the South Alabama Regional Planning Commission, P.O. Box 1665, Mobile, 36633-1665. SARPC’s telephone number is (251)433-6541; the fax number is 433-6009; and the physical address is 110 Beauregard Street, Suite 207, 36602. SARPC maintains an internet site at http://www.sarpc.org. Any e-mail concerning this report or the Envision 2045 Transportation Plan itself should be addressed to transportation@sarpc.org.

Appendix A TRAVEL MODEL INPUT

The basic factors which determine travel characteristics in any area are residential and commercial land use patterns, historical and projected development rates, and personal income levels. Computer models utilize this data to develop relationships between socio-economic factors and travel characteristics. These relationships, in turn, can be used with projected socio-economic characteristics to simulate future trip-making. However, prior to development of the travel simulation models, some additional information or assumption is required. Some of this missing data is related to the physical characteristics of the trips themselves and will be discussed in the following section (Model Development and Validation), but some of the needed data involves the number of trips generated by the households in the study area (internal trips) and also the number of trips into or through the study area which are generated outside the study cordon (external trips).

Household income (and implicitly the number of automobiles owned) is a critical factor in travel behavior. In general, for a specific household at any given income level, access to more vehicles indicates the probability of more trips being made on a daily basis, and for any given number of vehicles per household, an increase in income will usually mean an increase in daily vehicle trips. In other words, the higher the income, the higher the vehicle ownership rate, and the greater the number of vehicles per household, the higher the trip rate per household. Vehicle ownership data by income for the MATS planning area is shown in Table 1; also shown is the distribution of households by income range for 2015 and 2045. Four important qualifications should be made regarding this table: (1) the distribution is based on *zonal median* income, not actual income for each household, (2) the income ranges are expressed in 2015 dollars, not current dollars, (3) the distribution of households by income is based on 2015 Census/DataStory data for the MATS planning area, and (4) vehicle ownership by income level is based on data published in 1998 by the Transportation Research Board in *NCHRP Report 365* for all urban areas in the United States grouped by population ranges.

Table 2 is the actual auto ownership/income data for Mobile County as published in the 2000 Census, this data was not available with 2010 Census or 2015 American Community Survey. Figure 1 is a graphical comparison of the NCHRP and the Census data sets. It is clear that the differences between them are not large — the curves are the same basic shape but the national data is shifted noticeably downward (fewer households) for zero vehicle households and upward (more households) for one vehicle households in the low income ranges, shifted upward for two and downward for three or more vehicles in the middle income ranges, and is smoother and has more continuity in the high income range. In terms of vehicle distribution per household (see the bottom of Tables 1 and 2), the trend of the new data is fewer zero vehicle households, little change in one auto households, more two vehicle households, and little change in three or more auto households. These changes since the 2000 Census are consistent with intuitive logic and the ownership rates produce good approximations of actual vehicle registration for Mobile County.

The data in Table 1 are used with a trip rate table to estimate the number of vehicle-trips which are made in the study area or produced by a specific traffic zone.

Table 1 MATS Percent Households By Vehicles/HH By Income and Household Income Distribution

TAZ Median Income (2000 $'s)	Vehicles/Household 0	1	2	3+	Percent of Total 2015	2045
$0 – 24,999	22	44	24	10	31.7	31.0
$ 25,000 - 49,999	6	35	41	18	26.1	26.1
$50,000 or more	3	26	49	22	42.2	42.9
Percent of Total						
2015	9.8	34.1	39.0	17.2		
2045	9.7	33.9	39.2	17.2		

Table 2 2015 Census Percent Households By Vehicles/HH By Income and Household Income Distribution

TAZ Median Income (2000 $'s)	Vehicles/Household 0	1	2	3+
$ 0 – 24,999	18	48	24	10
$ 25,000 - 49,999	5	35	42	18
$50,000 or more	1	16	51	32
Percent of Total	7.4	31.1	40.1	21.4

Figure 1 Comparison of Vehicle Ownership by Income Data

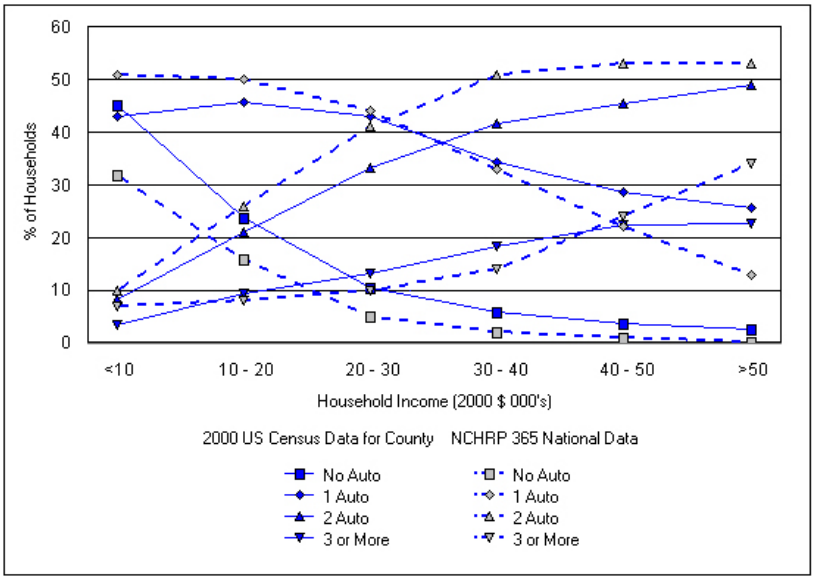


Table 3 contains the vehicle-trip rates by income by number of vehicles per household as used in *Envision 2045*; the average vehicle-trip rate for each income range is also included as is the weighted average trip rate by number of vehicles owned for 2015 and for 2045. These trip rates were also derived from *NCHRP Report 365* data for all U.S. urban areas with population of 250,000 to 500,000. NCHRP 365 prescribes low, medium and high income ranges for trip generation.

Table 3 Vehicle-Trip Rates By Vehicles/HH By Income (Derived from NCHRP 365*)*

TAZ Median Income	Vehicles/Household Average (2000 $'s)	0	1	2	3+	Rate
$ 0 – 24,999	0.0	5.0	6.0	7.0		4.34
$ 25,000 - 49,999	0.0	6.1	8.1	10.0		7.26
$50,000 or more	0.0	7.3	9.8	12.6		9.47
Weighted Average Rates						
2015		6.04	8.59	10.85		7.27
2045		6.05	8.61	10.89		7.30

In addition to the trips generated by each household, MATS models separately estimate the number of trips produced by college dormitories. Dormitory-based trips are generated at the areawide rate of one vehicle households. The average one vehicle household trip per day in 2015 was 6.04 trips and 6.05 trips per day in 2045. The dormitory trip rate was slightly lower at 5.4 for both base and future year. These two types of household-generated trips are known as "internal trips", or trips with both ends inside the study area. As mentioned at the

beginning of this section, the number and patterns of internal trips are determined by household demographics and location, commercial development patterns, and employment opportunities. These data are collected and analyzed in geographic units known as Traffic Analysis Zones (TAZ) or simply traffic zones. Figure 2 shows the current MATS zone structure of 343 zones — 312 internal TAZ's, 13 "dummy zones", and 18 cordon, or external, stations. Dummy zones are not actual geographic units and therefore do not appear on Figure 2; they are often included in model networks for ready availability to represent future developments or possible subdivisions of TAZ's; when needed, they are moved to the proper area of the system and "plugged in" the already developed network.

The MATS travel model uses seven independent variables to predict the trip-making characteristics of each TAZ. Most of this information is available from standard sources such as the U.S. Census. The necessary data includes:

- Number of households
- Zonal median household income (which includes automobile ownership through cross classification)
- Number of retail sector employees
- Number of service sector employees
- Number of all other nonretail sector employees
- College enrollment (enrollment at all technical colleges, junior colleges, colleges, and/or universities)
- Number of campus dormitory units.

Figure 2 MATS Traffic Zones

The specific TAZ data for both the base year (2015) and the forecast year (2045) are included in Appendices 1 and 2 of this report. In order to make meaningful comparisons between different parts of the study area without having to examine each TAZ, the internal zones are aggregated into 30 Planning Districts as illustrated in Figure 3. Table 4 shows the socio-economic data summarized by planning district for 2015 and 2045. The next section explains *how* these factors interact and influence trip-making and area travel patterns, but the product of that interaction is shown here in Table 5, which summarizes trip-ends by planning district.

In addition to the household-generated trips, the roads in the study area will also have to provide capacity for trips which are generated by activities outside the MATS boundary. These trips are called *external trips* and can be categorized as *internal-external trips* or *through trips*. Internal-external trips are those with one end in the study area and one end outside the study area (work commute trips are a good example), while through trips are those with both ends outside the study area (a vacation traveler from Louisiana on I-10 bound for Disney World is a good example of this type). Therefore, two very different factors will affect the growth of external trips: growth and development inside the study area and immediately adjacent areas will to a large extent dictate the increase and pattern of internal-external trips, but factors completely unrelated to the study area will control through trips.

Future external trips were projected using an annual growth rate applied to ALDOT external count data obtained from ALDOT (see Table 4) called Long Growth. In percentage terms, the resulting increase in external trips is substantially higher than the increase in internal trips. As shown in Table 6, by 2045 internal vehicle-trip ends are projected to increase by 12%, but external trips are projected to increase by 52%.

Table 4 ALDOTs Annual Growth Rate for Future Externals

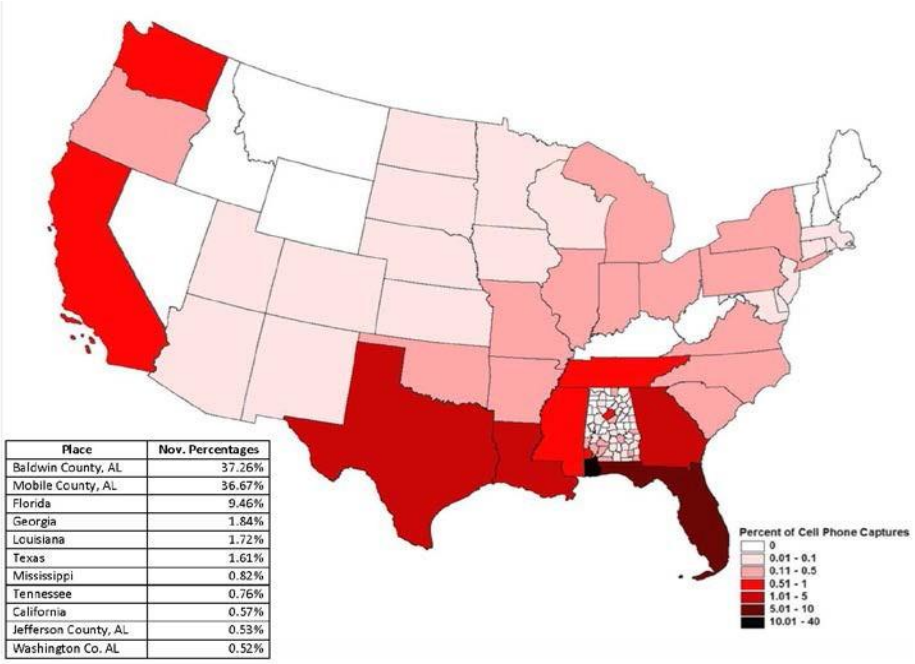
External Station	2015	Long Growth	2045*
I 10 E	75,500	1.0128	110,575
US 90	16,580	1.0163	26,930
Dauphin Island Pkwy	5,641	1.0157	9,000
SR 188	2,873	1.0100	3,900
US 90 W	5,830	1.0163	9,470
I 10 W	44,170	1.0128	64,690
Old Pascagoula Rd	1,100	1.0100	1,500
Grand Bay-Wilmer Rd	7,290	1.0100	9,825
Dawes Rd	3,200	1.0100	4,300
Jeff Hamilton Rd	1,720	1.0100	2,300
Airport Blvd	5,070	1.0100	6,800
Tanner-Williams Rd	4,850	1.0100	6,550
SR 158 Extension (US 98)	New Road	n/a	23,800
Moffett Rd (US 98)	16,000	1.0100	15,000
Lott Rd	6,160	1.0127	9,000
US 45	8,100	1.0128	9,800
Celeste Rd	4,520	1.0100	6,100
US 43	18,890	1.0126	27,500
I 65 N	21,580	1.0119	30,800

*Future Volume = Current Volume * (Long Growth^ Number of Years)

In November of 2013 and July of 2014, the Mobile MPO contracted with the company AirSage to capture cell phone data crossing the Mobile Bay. The company has the ability to capture anonymous cell phone frequencies at times that there are activities on the device, and archive that data. This was extremely useful because of the frequencies captured crossing the Mobile Bay, Airsage had the average home location of those frequencies. It produced a snapshot of who was using the Bayway and Causeway, and what state they were from. This data increased the percentage of external-external trips that were thought to have been using the Bayway. Figure 3 and Figure 4 depict the cell phone frequencies that were captured, and the average State or Alabama County of those frequencies. In November of 2013 about 74% of the trips crossing the Mobile Bay were from Mobile and Baldwin County, however in July 2014, only about 55% of the trips on the Bayway were from Mobile and Baldwin County. This suggests that in July, 2014, 45% of the trips crossing the Mobile Bay are not from the region Historically, it was thought that 25%-30% of the trips on the Bayway were through trips, but because the cell phone data suggests more of the trips on the Bayway are through trips, the amount of through trips depicted in the model were increased to 40% through trips. The cell phone data captures from both the Causeway and the Bayway, and it is assumed the majority of the trips on the Causeway are local trips (internal-external). Because November had 26 % non-local trips, and July had 45% non-local trips on both the Bayway and the Causeway, it is assumed a large portion of those local captures were on the Causeway.

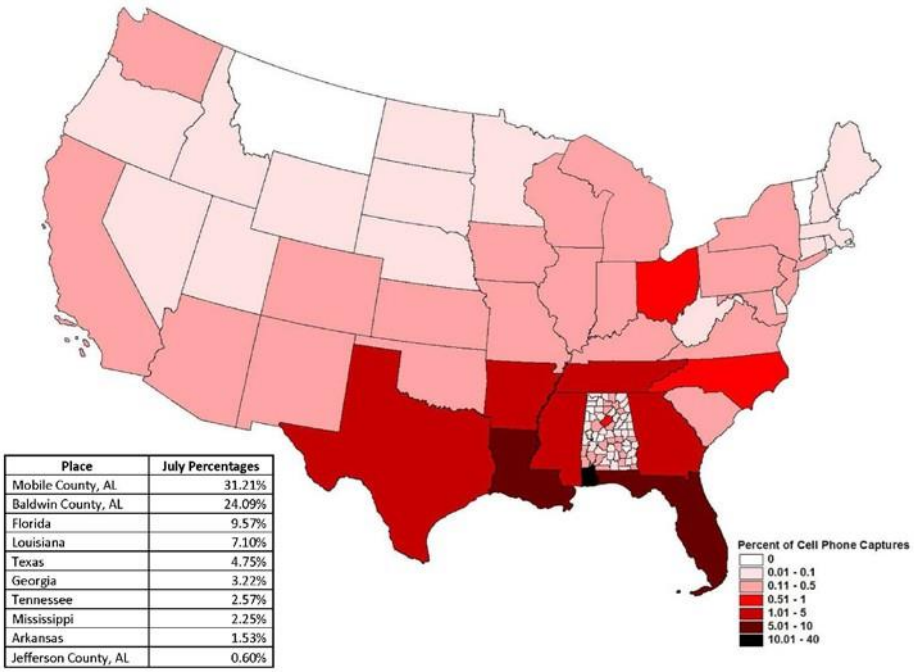
External trucks were forecasted using methodology *from NCHRP 570 Guidebook for Freight Policy, Planning, & Programming in Small- & Medium- Sized MPOs,* and methodology developed specifically for the Mobile MPO discussed later in this document.

Figure 3 November, 2013 Cell Phone Captures



Place	Nov. Percentages
Baldwin County, AL	37.26%
Mobile County, AL	36.67%
Florida	9.46%
Georgia	1.84%
Louisiana	1.72%
Texas	1.61%
Mississippi	0.82%
Tennessee	0.76%
California	0.57%
Jefferson County, AL	0.53%
Washington Co. AL	0.52%

Figure 4 July, 2014 Cell Phone Captures



Place	July Percentages
Mobile County, AL	31.21%
Baldwin County, AL	24.09%
Florida	9.57%
Louisiana	7.10%
Texas	4.75%
Georgia	3.22%
Tennessee	2.57%
Mississippi	2.25%
Arkansas	1.53%
Jefferson County, AL	0.60%

Figure 5 MATS Planning Districts

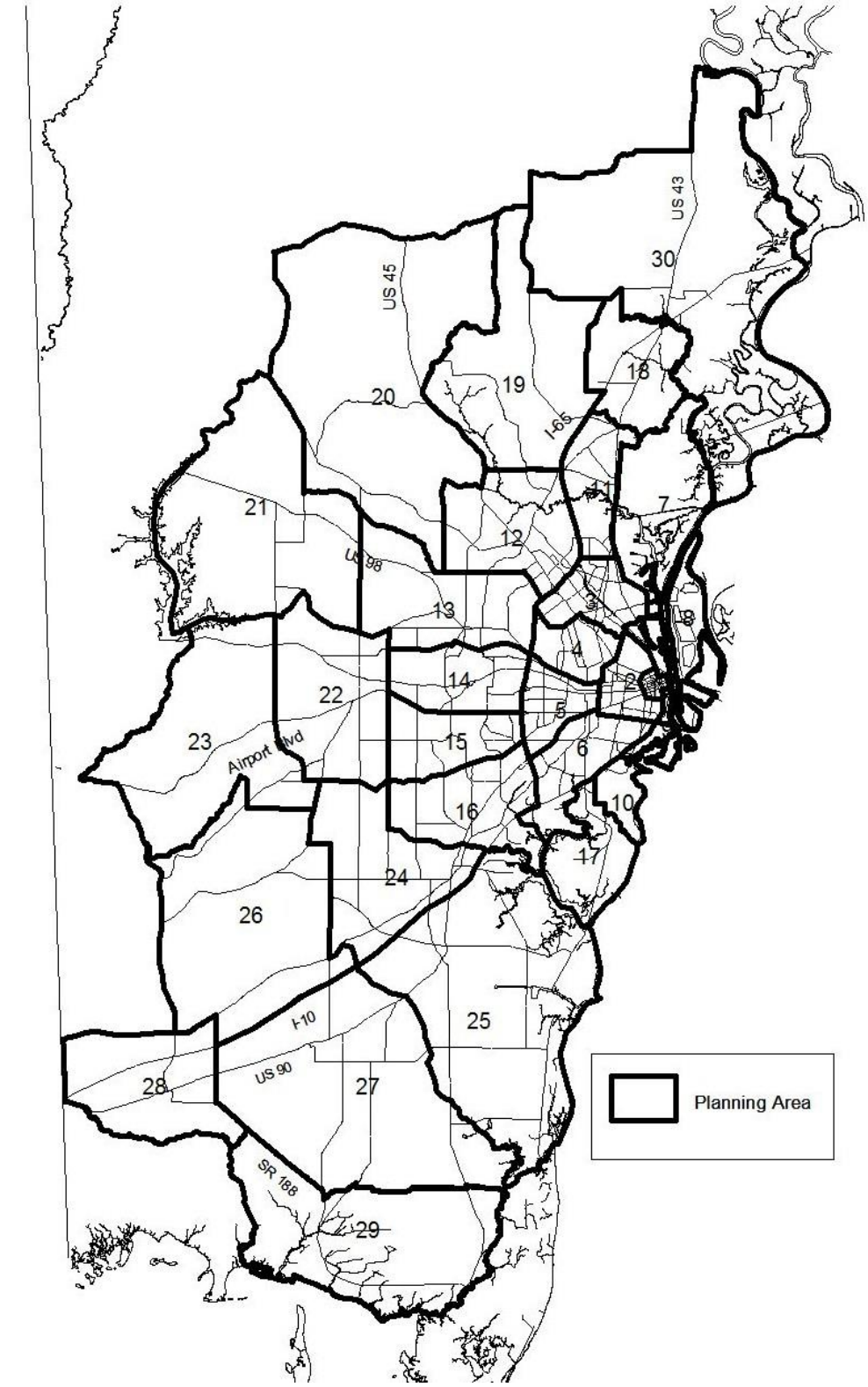


Table 5 Socio-Economic Data by Planning Area, 2015 - 2045

	2015			2045		
		Employment			Employment	
Area	HH	Retail	Total Emp	HH	Retail	Total Emp
1	713	705	12,014	1,139	1,285	15,489
2	6,186	625	6,392	6,339	666	7,121
3	5,599	243	3,820	5,613	333	4,152
4	5,944	630	8,525	5,957	784	9,872
5	6,951	6,108	15,600	6,958	6,482	17,211
6	8,935	665	5,530	8,997	2,982	9,497
7	95	987	3,276	115	1,132	4,181
8	0	150	1,918	0	317	2,436
9	6	102	2,071	31	239	7,782
10	193	134	3,176	209	334	5,276
11	5,119	1,720	4,090	5,181	2,573	6,239
12	3,942	1,082	2,683	4,492	1,601	5,071
13	8,277	833	5,138	8,446	1,308	7,537
14	9,913	2,423	12,735	9,973	2,789	15,785
15	15,581	3,639	20,969	15,610	4,155	24,742
16	9,661	1,374	8,906	9,775	1,908	12,282
17	4,401	290	1,199	4,532	782	2,974
18	2,821	245	1,196	3,309	782	3,236
19	2,416	96	585	2,842	625	2,092
20	3,752	102	741	3,992	546	4,242
21	6,475	1,024	2,768	7,184	2,058	5,577
22	9,319	3,568	8,894	9,522	5,019	13,719
23	4,158	265	927	6,332	591	2,042
24	8,993	3,206	6,788	9,174	4,785	11,852
25	6,345	1,089	9,536	10,244	3,219	19,091
26	4,445	163	1,033	5,633	487	2,256
27	5,007	284	1,413	5,731	1,286	5,048
28	2,232	317	724	2,709	1,093	2,517
29	1,652	259	2,065	2,025	1,012	4,901
30	1,409	52	2,388	1,592	339	4,232
Total	150,540	32,380	157,100	163,656	51,512	238,452

(Mobile MPO)

Table 6 MATS Daily Trip-Ends (2015 & 2045)

Planning District	2015	2045	Change	Percent
1	72,944	81,678	8,734	12%
2	88,985	79,970	-9,015	-10%
3	53,524	49,309	-4,215	-8%
4	93,769	86,366	-7,403	-8%
5	225,751	196,729	-29,022	-13%
6	94,004	128,197	34,193	36%
7	28,734	27,537	-1,197	-4%
8	8,771	10,734	1,963	22%
9	8,809	24,164	15,355	174%
10	16,520	22,373	5,853	35%
11	83,045	90,305	7,260	9%
12	61,444	73,380	11,936	19%
13	94,808	100,355	5,547	6%
14	233,539	227,593	-5,946	-3%
15	289,753	267,778	-21,975	-8%
16	139,402	141,449	2,047	1%
17	40,746	50,566	9,820	24%
18	30,837	45,301	14,464	47%
19	22,036	35,352	13,316	60%
20	31,952	50,991	19,039	60%
21	77,052	96,058	19,006	25%
22	168,556	182,663	14,107	8%
23	41,309	62,069	20,760	50%
24	149,992	168,398	18,406	12%
25	100,192	173,709	73,517	73%
26	40,899	54,769	13,870	34%
27	45,967	72,818	26,851	58%
28	24,743	41,995	17,252	70%
29	23,779	41,437	17,658	74%
30	19,420	27,164	7,744	40%
Total Internal	2,411,282	2,711,207	299,925	12%
External				
New US 98	0	23,800	23,800	NA%
I-10 E	75,500	110,575	35,075	46%
US 90 E	16,580	26,930	10,350	62%
Dauphin Island Pkwy	5,641	9,000	3,359	60%
SR 188	2,873	3,900	1,027	36%
US 90 W	5,830	9,470	3,640	62%
I-10 W	44,170	64,690	20,520	46%
Old Pascagoula	1,100	1,500	400	36%
Grand Bay-Wilmer	7,290	9,825	2,535	35%
Dawes	3,200	4,300	1,100	34%
Jeff Hamilton	1,720	2,300	580	34%
Airport	5,070	6,800	1,730	34%
Tanner-Williams	4,850	6,550	1,700	35%
US 98 W	16,000	15,000	-1,000	-6%
Lott	6,160	9,000	2,840	46%
US 45 N	8,100	9,800	1,700	21%
Celeste	4,520	6,100	1,580	35%

US 43 N	18,890	27,500	8,610	46%
I-65 N	21,580	30,800	9,220	43%
Total	249,074	377,840	128,766	52%

(Mobile MPO)

SECTION 2 MODEL DEVELOPMENT AND VALIDATION

As mentioned at several points previously, transportation models are used to develop reliable mathematical relationships between socio-economic data — *e.g.*, number of households, household size and income, number of automobiles owned or available, school enrollment, number of people employed and the type of their employment — and trip-making. By manipulating these relationships and comparing predicted trips with known trip patterns, an accurate method for predicting future travel demand can be developed. The overall accuracy of this model depends on the accuracy of trip generation (how well does the model estimate the number and kinds of trips actually made in the area, both regionally and locally?) and the accuracy of trip distribution (how well do the actual trip lengths compare to the model estimates and are the actual trip patterns well duplicated, *e.g.*, does the model accurately predict the number of screenline crossings between a given suburban area and the CBD?). This accuracy level, in turn, is dependent on both the quality of the input data and the relationships developed from that data *and* the way the model actually assigns the estimated trips to the road system. So while good data is required to develop a good model, it does not insure one; the model must also handle the estimated "traffic" the way that the area's street network does.

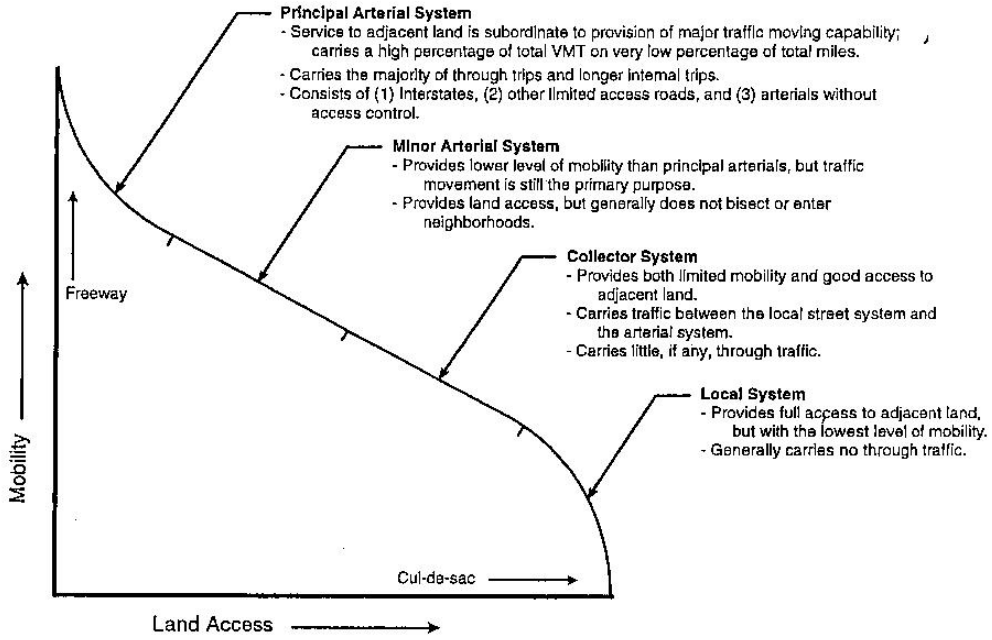
2.1 Network Development

A model network is made up of "zones" representing trip-ends (socio-economic data), "nodes" representing intersections, and "links" representing roadways. The trips to and from zones enter the road system through the nodes, which are connected by links. A set of links connecting any two zones is called a path, and a trip will always be assigned to the path with the lowest "cost" (measured as time or distance). However, depending on how much "traffic" is already on a street (path), the individual link costs — reflected by speed — are altered; therefore, paths can change. The relationship of speed and traffic volume is a function of capacity.

In the real world, the capacity of a road is *usually* determined by the capacity of its intersections and can be expressed as the capacity of each of the intersection approaches -- or links. This capacity depends on numerous factors — among them are number of through lanes, number of turn lanes, lane width, peaking characteristics, and signalization. Of these factors, several are categorized as physical characteristics and several as operating characteristics. Models normally group links by *both* their physical and operating characteristics.

Different types of streets provide different types of service. The hierarchy of streets and roads ordered by the type of service each provides is called "functional classification". Generally, roads within each functional class will exhibit similar operating characteristics which will, in turn, vary between classifications. Since operating characteristics will to a large degree determine roadway capacity, it is extremely important that links are correctly classified in any travel model. The

Figure 6 Functional Classification and Mobility vs Access

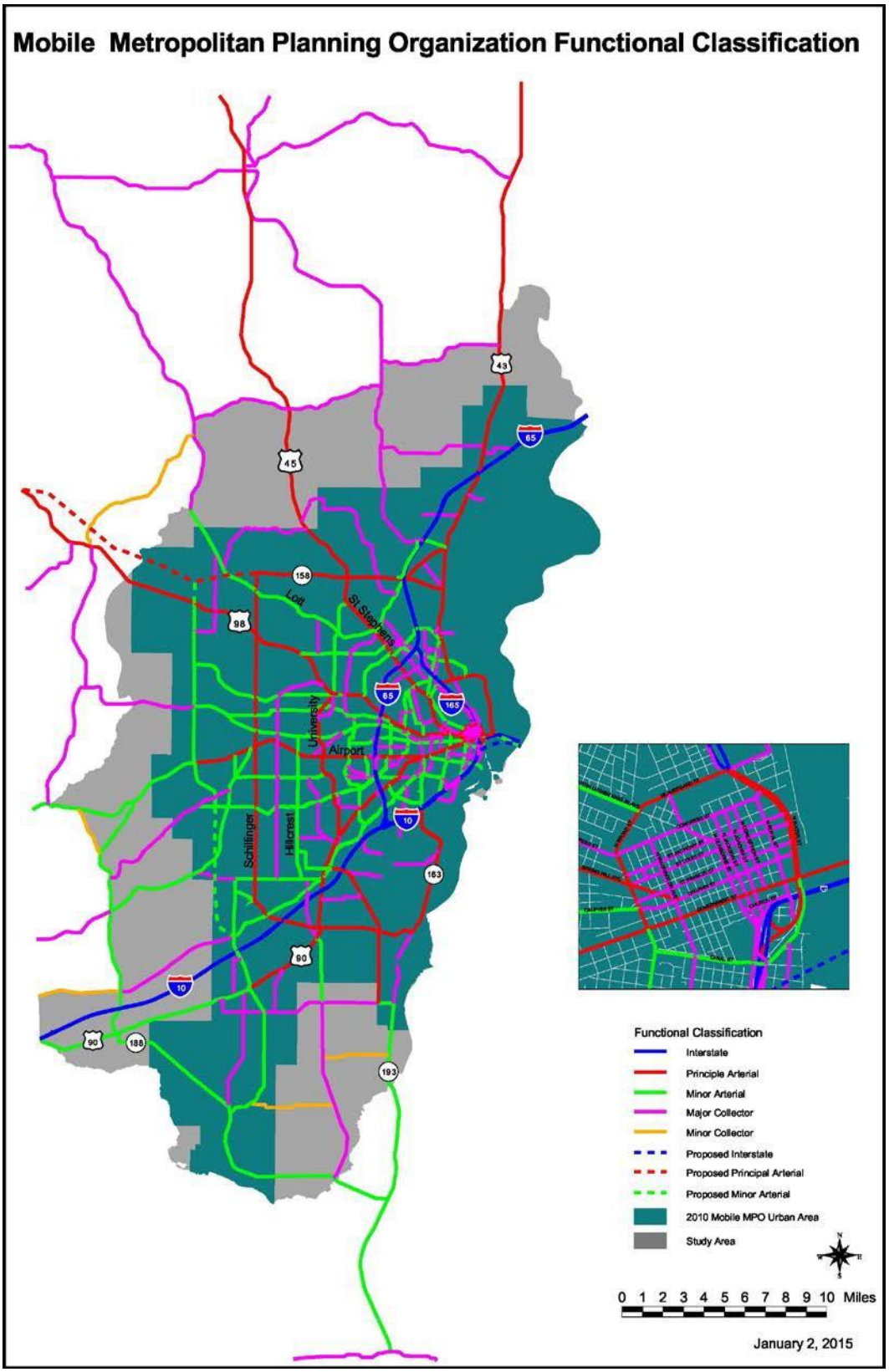


Functional classification system used in urban areas is summarized in Figure 6. Figure 7 illustrates the functional classification used for the 2015 model network (local streets are not shown).

As noted above, the principal use of functional classification in modeling is to group roads throughout a system by their primary purpose, thus allowing the development of a single set of general values to describe the operating characteristics of all roads of a given type. Two of the most important operating characteristics are speed and capacity — and the relationship between the two. Since most traffic assignment models operate on the premise that as traffic volumes approach capacity, speed decreases, they adjust link speed in some predetermined manner based on the relationship between a given load and a coded capacity. This speed adjustment will affect the paths taken between zones. When testing future networks, however, speeds will need to be coded for roads that are not yet constructed, so the coding criteria must also be defined by some tangible characteristic that can be applied in a uniform manner. Therefore, link speeds are determined by either the physical features of the road and its surroundings (such as number of lanes, its physical design characteristics, or the type of adjacent development), the road's functional classification (operational characteristics), or a combination of the two; MATS uses a combination.

CUBE Voyager is the transportation planning package licensed to ALDOT and supported by the State for MPO use. In order to provide the required flexibility in delineating roadway characteristics, the software allows three two-digit fields to be input as link group codes, each capable of describing 99 link types. Each group code can be used

Figure 7 Mobile Urban Area Functional Classification



to describe some specific aspect or group of aspects of each link (piece of road) in the system. For example, the first link group field might be coded for a road's functional classification, the second for number of lanes, and the third for the type of adjacent land use. Any specific combination of these three codes identifies a unique set of road characteristics which corresponds to a specific speed and a specific operating capacity.

MATS uses the first link group to specify functional classification and cross-section; the first digit designates functional class and whether the road is one-way or two-way, and the second digit specifies the total number of lanes (except for freeways and expressways where the second digit specifies lanes in each direction); Table 7 below shows the link group one numbering scheme used in MATS models. The second link group is used to code the development density of the adjacent land — five categories are used (Central Business District, activity center, urban, suburban, and undeveloped) and will impact the traffic speed and/or capacity on any link. The third link group is a "wild card" field used to flag certain attributes based on link group codes one and two — for example, link group three designates standard or substandard lane widths for all arterial links and posted speed limits for all freeway links. The preloading is accomplished by coding the assignment group in the link record file 1 through 4. Links with assignment group code 2, allow vehicle trips and vehicle through trips. There are no links with an assignment group code 3 (which means all trips are allowed) and links with assignment group code 4 are not allowed to have trucks or preloaded vehicles, only internal and internal external trips.

Table 7 MATS Link Group 1 Codes

Access Controlled	Freeway	Expressway	Principal Arterial
4-lane, divided	12	22	25
6-lane, divided	13	23	27
8-lane, divided	14	24	29
10-lane, divided	15		
12-lane, divided	16		

No Access Control	Principal Arterial	Minor Arterial	Collector
2-lane	32	42	52
2-lane, with turning lane	33	43	53
4-lane	34	44	54
5-lane or 4-lane divided	35	45	55
6-lane	36	46	56
7-lane or 6-lane divided	37	47	57
8-lane	38	48	
9-lane or 8-lane divided	39	49	

One Way	Principal Arterial	Minor Arterial	Collector	Ramp
1-lane				91
2-lane	62	72	82	92
3-lane	63	73	83	93
4-lane	64	74	84	94

Time Barriers	98
Local (Centroid Connectors)	99

Land use and development density are extremely important criteria in model validation since they impact both the speed and capacity of a road network. As noted above, the link group two field is used to indicate one of five land use densities. These densities will change over time, of course, so this factor will have variable impacts on the traffic model as study area conditions change. In addition to network link speeds and capacities, changes in the development density will impact terminal times (the elapsed time between leaving the public road system and entering the destination) and intrazonal times (the time required to complete a trip within a single zone without leaving the local road system). Since future development will change the current patterns, it is important to develop a quantitative methodology or index that will allow known or projected factors (*i.e.*, socio-economic data) to represent future development conditions. In this way, a more accurate scenario of the impact of specific development on future road systems will be achieved. This is accomplished in the MATS models through the use of an "Activity Index" which quantifies development in terms of its density (units per acre) by traffic zone.

In the MATS application, no determination was made regarding the relative impacts of commercial versus residential development; similarly, no distinction has been made between retail and other employment types. The index is calculated by simply adding households, college dormitory units, total employment, and post-secondary education enrollment and then dividing the total by the size of the traffic zone in acres. The break points between land development types were determined based on base year conditions and the relationship of the calculated densities to known development levels; large gaps in the series of calculated densities were also utilized to stratify the levels. The break points are then fixed, and future development scenarios are evaluated based on the calculated future index, with the necessary and appropriate adjustments made throughout the model chain. The result of this approach is shown on Figure 8 which illustrates 2015 conditions and Figure 9 which shows 2045 indices. The break points (thresholds) were set at .5 units/acre for suburban, 2.5/acre for urban, 10.0/acre for activity center, and 30.0 units/acre for CBD.

The true importance of the land use index is its use in determining network speeds and roadway capacity. The speeds coded in the traffic models are often referred to as "free" speeds. They are not the posted speeds or speed limits, but are intended to represent the actual average speed — including intersection delay — of a vehicle during light traffic conditions. The coded speeds were calculated from posted speeds using procedures found in the 1985 and 1994 *Highway Capacity Manuals* and in *NCHRP Report 387, Planning Techniques to Estimate Speeds and Service Volumes for Planning Applications*. Table 8 shows the assumed posted speeds by land use type and roadway functional classification; it also includes the assumptions made regarding arterial signal spacing. Table 9 summarizes the speeds coded in the MATS traffic models. The relatively low speeds coded on freeways are to prevent them from attracting a disproportionate number of trips and resulting in poor trip distribution and assignments in later stages of the model's application. The dominant pattern obvious from Tables 8 and 9 is an increase in speeds as functional classification goes up, and an increase in speeds as development density goes down.

The "level-of-service" (LOS) concept is used to define the operational characteristics of roads at various traffic volumes. It can be used to establish the most severe conditions which are acceptable to the public. This is not to say or imply that the limits of acceptability are a desirable goal — but simply that they are tolerable.

Figure 8 MATS 2015 Land Use Indices

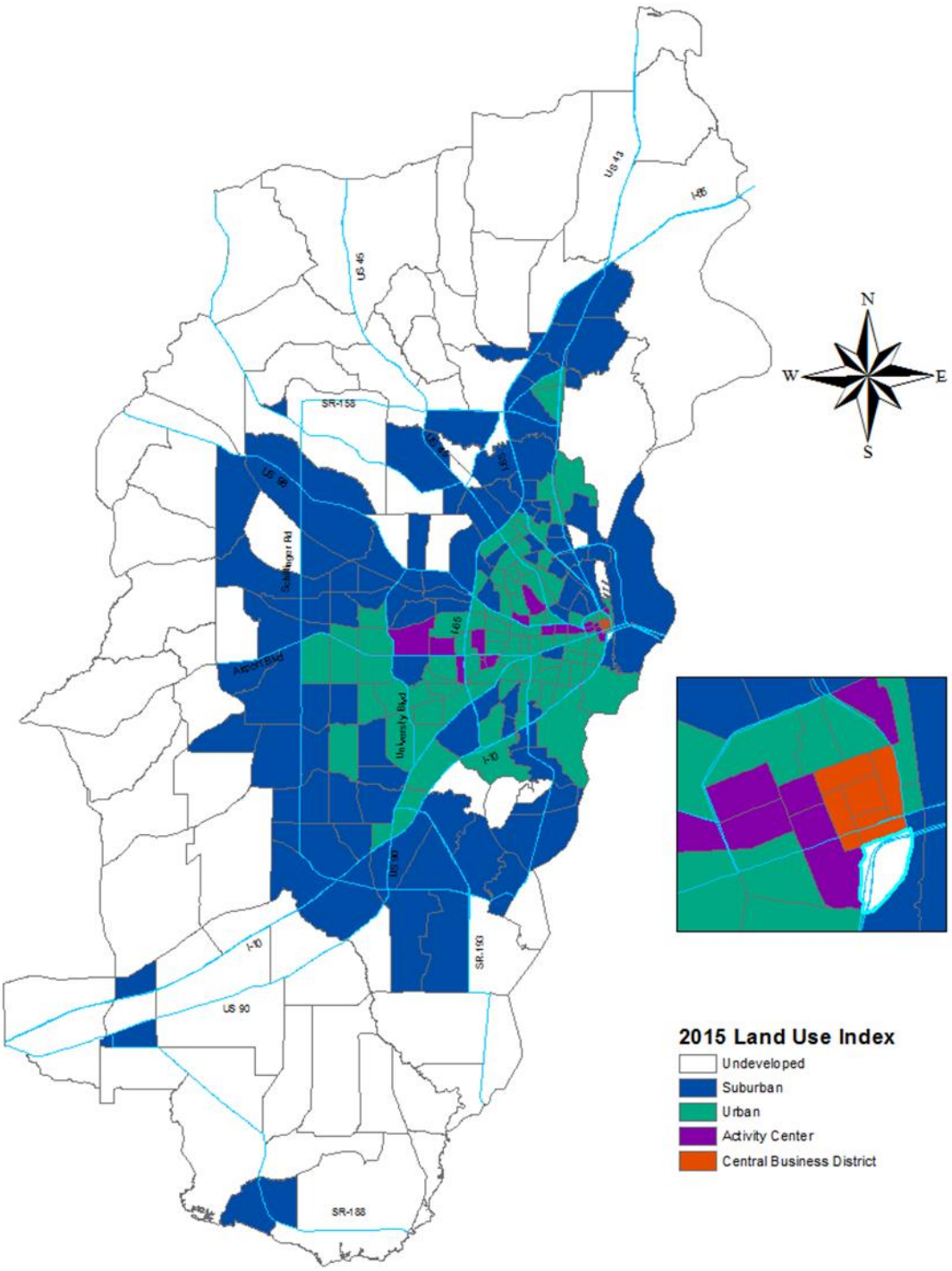


Figure 9 MATS 2045 Land Use Indices

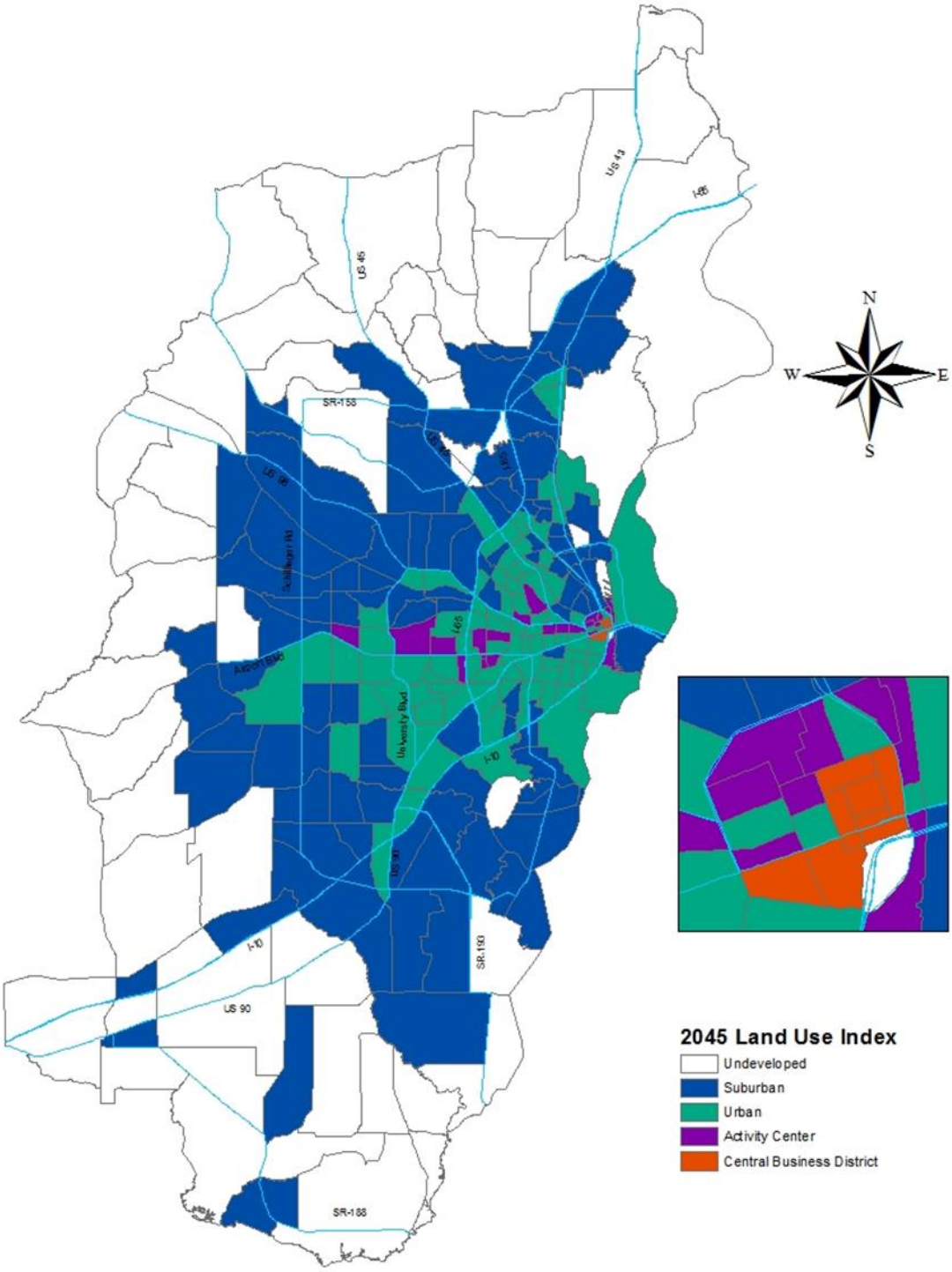


Table 8 MATS Network Assumptions

	CBD	Activity Center	Urban	Suburban	Undeveloped
Traffic Signals/Mile	5	4	2	1	0
Posted Speeds					
Freeway	55	65	65	65	70
Principal Arterial	35	40	45	50	55
Minor Arterial	30	35	40	45	50
Collector	25	30	35	40	45
Local	20	25	30	35	40

Table 9
MATS Network Free Speeds

	CBD	Activity Center	Urban	Suburban	Undeveloped
Freeway	52	61	61	61	67
Controlled Access Artl.	27	32	38	47	52
Principal Arterial	21	27	33	42	45
Minor Arterial	18	24	30	37	40
Collector	15	21	27	32	37
Local	12	18	24	27	30

Levels-of-service range from A through F, with A being the best (least amount of traffic) and F being the worst (capacity, unstable flow). Abbreviated definitions of the levels-of-service as stated in the *Highway Capacity Manual* (*HCM*) follow.

- LOS A is free flow. Drivers are virtually unaffected by others; freedom to select desired speed and maneuverability is high. Level of comfort/convenience is excellent.

- LOS B marks the point at which freedom to maneuver begins to decline. Ability to select speed is still good, but presence of others begins to affect driver behavior. Comfort and convenience are good.

- LOS C is where individual drivers are significantly affected by interaction with other vehicles. Selection of speed and maneuverability are both affected by the traffic stream. Noticeable decline in comfort and convenience levels.

- LOS D is high-density, but stable, flow. Speed and maneuverability are severely

restricted. Small traffic increases will cause operational problems. Comfort and convenience levels are poor.

- LOS E is operation just below capacity. Speeds are reduced to low levels. Virtually no room for maneuverability without forcing another vehicle to yield. Operation is usually unstable, as any traffic increase causes breakdown. Comfort and convenience levels are extremely poor; driver frustration is high.

- LOS F is forced, or breakdown, flow. Operation is characterized by stop-and-go waves which are very unstable. The amount of traffic approaching a point is greater than the amount which can pass the point.

For urban areas the size of Mobile, the minimum acceptable level-of-service is generally LOS D. The conditions described above would usually occur only during a portion of the peak hour and only on the most heavily traveled roads in the area. Based on accepted practices of traffic engineering, the maximum flows (capacities) for LOS D for each type of road can be quantified. As would be expected, the capacities of arterial and collector roads vary in inverse proportion to the number of signals per mile and in direct proportion to the amount of available "green" time. Therefore, land use and development densities play significant roles in determining capacity. Conversely, uninterrupted flow (freeway) capacity is normally dependent only on posted speed. The capacity values ultimately used in the MATS models were derived from the procedures recommended in TRB's *NCHRP Report 387*. The assumptions used to calculate capacities and the basic LOS D capacity values are contained in Table 10; a complete capacity table by link type as coded with land use index and posted speed adjustments is given in Appendix A-6.

Table 9 MATS Basic Roadway Capacity

- Posted Speeds and Signal Spacing as shown in Table 8; Free Speeds as shown in Table 9
- Heavy Vehicles (including RV's) = 15% Freeways, 10% Rural Arterials, 5% Other Arterials; Terrain = Level
- Lane Width Factor = .93
- CBD Arterial Adjustment Factor = .90
- PHF = .90, K = 10%, PkDir = 55%
- g/C = .50 Controlled Access Arterials, .45 Other Principal Arterials, .40 Minor Arterials, .35 Collectors

	Number of Lanes					
LOS D Daily Capacity	2	4	6	8	10	12
Divided or Center Turn Lane						
Freeway		69,600	104,500	139,500	174,200	177,400
Expressway (None Coded)						
Controlled Access Arterial		33,600	50,500	67,200		
Other Principal Arterial	14,700	29,300	44,000	58,500		
Minor Arterial	13,100	26,000	39,100	52,000		
Collector	11,500	22,800	34,200			
Divided with Narrow Lanes (<10')						
Principal Arterial	13,700	27,200	40,900	54,400		
Minor Arterial	12,200	24,200	36,400	48,400		
Collector	10,700	21,200	31,800			
Undivided						
Principal Arterial	13,300	26,700	40,000			
Minor Arterial	11,800	23,800	35,600			
Collector	10,300	20,800	31,100			
Undivided with Narrow Lanes (<10')						
Principal Arterial	12,400	24,800	37,200			
Minor Arterial	11,000	22,100	33,100			
Collector	9,600	19,300	28,900			
One Way	1	2	3	4		
Ramps	11,000	22,000	33,000	44,000		
Principal Arterial		16,200	24,300			
Minor Arterial		14,400	21,600			
Collector		12,600	18,900			
Narrow Lanes (<10')						
Principal Arterial		15,000	22,500			
Minor Arterial		13,300	20,000			
Collector		11,700	17,500			

SECTION 3 TRIP GENERATION

Trip generation refers to the procedure used to convert socio-economic data and study area cordon counts to trip-ends. As discussed in the first section, both the 2000 (from US Census, not available in 2010 Census or 2015 American Community Survey) MATS auto ownership distribution (see Table 1) and the internal vehicle-trip rates (see Table 3) were developed from national data published by TRB in *NCHRP Report 365.* Average trip rates for each income range can be derived by multiplying the trip rate table by the auto ownership table and adding across each row. The median household income of a traffic zone is then used to determine an approximate vehicle-trip rate for each household in that zone; the trip rate times the number of households yields the estimated trips "produced" by the zone. As also noted earlier, college dormitories are treated as households for the purpose of trip generation, but the trip rate used for them is the areawide rate for one-auto households as opposed to being income-dependent. Table 11 below summarizes the MATS internal automobile trip rates, both by income range and by autos per household.

Table 10 Average Vehicle-Trips per Household

TAZ Median Income (2000 $'s)	Average Trips/Household	Autos per Household	Avg. Trips/HH 2015	2045
Less than $25,000	4.34	1	6.04	6.05
$25,000 - 49,999	7.26	2	8.59	8.61
$50,000 or more	9.47	3+	10.85	10.89
		Weighted Average Rate	7.27	7.30

In addition to estimating the total number of trips produced by a specific zone, trip generation is used to estimate those trips by purpose. Internal automobile trips are divided into three purposes based on the location of each end of the trip: home-based work (HBW) trips have the "production" end at home, the "attraction" end at work; home-based non-work or home-based other (HBO) trips have the production at home, the attraction anywhere except work; and nonhome-based (NHB) trips have neither end at home. Two types of calculations are made independently during trip generation — trip productions by purpose by zone and trip attractions by purpose by zone.

The MATS trip generation has been partially based on assumptions from the the 10980's NCHRP 187; person-trip splits of 21% HBW, 56% HBO, and 23%NHB. However, in 2012, the MPO contracted with Airsage to calibrate the gravity model based on cell phone data (see Appendix A-10). The cell phone data suggested that the trip purpose percentages of that calculated from the cell phone data was more person-trip splits of 11% HBW, 51% HBO, and 38%NHB. The data that was produced from the cell phone study is more in line with what is recommended in report NCHRP 716. NCHRP 716 suggests for HBW 14%-15%, for HBW, 54%-56% and for NHB 30%-31%. Because the data was derived from local trips collected from the cell phone

study, the trip generation has a trip purpose split as derived from the cell phones, HBW=11%, HBO=51% and NHB =31%.

The MATS vehicle-trip generation equations are summarized below:

HBW Productions =	.11 X [(HH X TR)+(D X TR1)]
HBO Productions =	.51 X [(HH X TR)+(D X TR1)]
NHB Productions =	.38 X [(HH X TR)+(D X TR1)]

Where: HH = Households in the TAZ
TR = Vehicle-trips per household
D = College dormitories in the TAZ
TR1 = Study area average trip rate for one-vehicle households.

Mobile's attraction equations are derived from the NCHRP Report 365 data, but a separate rate for college students was added. The equations include rates for dwelling units (both households and dorms), retail employment, service employment, all other employment, and the aforementioned college students. "College students" includes enrollment at all education facilities above the high school level, *i.e.*, junior colleges, state trade/technical schools, universities, and colleges. Even though students at lower level schools are not explicitly included in the attraction equations, the employment recorded in the zone for teachers, administrative staff, and support staff appears to adequately account for the school trips. The unfactored internal attraction equations used in MATS are as follows:

HBW Attractions =	1.45 X (RE+SE+OE)
HBO Attractions =	.9 X (HH+D)+(1.5 X CS)+(9.0 X RE)+(1.7 X SE)+(.5 X OE)
NHB Attractions =	.5 X (HH+D)+(4.1 X RE)+(1.2 X SE)+(.5 X OE)

Where: RE = Number of employees at businesses in the TAZ classified as “retail” based on NAICS code
SE =Number of employees at businesses in the TAZ classified as “service” based on NAICS code
OE =Number of employees at businesses in the TAZ classified as “other” based on NAICS code not classified as retail or service. This includes manufacturing
HH = Households in the TAZ
D = College dormitories in the TAZ
CS = Enrollment at higher education facilities in TAZ.

The final step in trip generation involved defining the external trips as "through" trips or "internal-external" in order to locate both ends of each trip which crosses the study area boundary (cordon stations). While traffic counts were taken at each cordon station, the type of trip cannot be determined from these counts, so some assumptions must be made. Based on several data sources, through trips constitute between 5% and 20% of an area's external trips depending on the

area's population; the MATS area should have about 10% through trips and 90% internal-external trips as a percentage of the total cordon crossings. The through trips are separated at the cordon

using a rate based on the functional classification of the facility; although logical, these rates are arbitrary because contemporary documentation of through trip rates is sparse. Table 12 summarizes the data for the external end of all MATS trips.

The through trips at the I-10 east cordon appear to be inconsistent with those at the other Interstate stations due to a difference in estimation methodology. Traffic patterns on the I-10 Bayway are heavily influenced by local trips between Mobile and Baldwin Counties — particularly the Eastern Shore and Spanish Fort (State Highway 225) areas of Baldwin County. These trips are almost exclusively internal-external trips with very few through trips. In order to avoid distortion of the true external trip distribution at the east cordon, the trip purpose calculation is made east of the first I-10 interchange in Baldwin County (between US 98 in Daphne and SR 181 in Malbis). Since the count at the actual MATS cordon is substantially higher than at this point, the percentage of through trips at the I-10 cordon station appears to be low. While there may be a slight under estimation of through trips using this procedure, the error is significantly less than that produced by applying the through trip percentage factor to the trips crossing the actual cordon.

Table 11External Trip Productions and Attractions, 2015

Functional Classification	Through Trips as Percent of Count
Interstate	30
Other Principal Arterial	25
Selected Minor Arterials	10
Other Minors & Collectors	0

Station	Count	% Thru	Thru P&A	Trucks	Int-Ext
Interstate 10 E	75,500	40	27,000	8,000	40,500
US Highways 90&98 E	16,580	0	0	0	16,580
Dauphin Island Pkwy	5,640	10	560	0	5,080
SR 188	2,870	10	290	0	2,590
US Highway 90 W	5,830	0	0	0	5,830
Interstate 10 W	44,170	40	14,700	7,400	22,060
Old Pascagoula Rd	1,100	0	0	0	1,100
Grand Bay -Wilmer	7,290	10	730	0	6,560
Dawes Road	3,200	0	0	0	3,200
Jeff Hamilton Road	1,720	0	0	0	1,720
Airport Boulevard	5,070	10	500	0	4,560
Tanner Williams Road	4,850	0	0	0	4,850
US Highway 98 W	16,000	25	3,450	2,200	10,350
Lott Road	6,160	0	0	0	6,160
US Highway 45	8,100	25	1,850	700	5,550
Celeste Road	4,520	0	0	0	4,520

US Highway 43	18,890	25	4,300	1,720	12,880
Interstate 65	21,850	35	6,080	4,200	11,300
Total Trips	249,070		59,460	24,220	165,390

Internal-external trips are normally assumed to be produced at the external station and attracted to the internal zone. However, in many cases the internal end is actually the production end of the trip in a literal sense (an example would be a "reverse commute" HBW trip from west Mobile to Pascagoula, MS). The degree to which internal zones produce external trips depends on the demographics of the study area. A strong central urban area will likely attract far more external trips than it produces, but a more uniformly developed area might approach an even split. Furthermore, different trip purposes will exhibit different characteristics, so local knowledge is important in distributing the internal ends of internal-external trips. The approach used in this update was to generate the internal-external trips as a separate purpose and to distribute the internal ends based on a specified "production/attraction" split depending on trip type. This method requires two general estimates — determination of the true production end of external trips and a break-down of external trips by true purpose. If an internal-external trip is produced by a study area resident, the internal end is the production end and the trip end is assigned to a traffic zone based on internal trip productions; the external end is now considered the attraction side of the trip. If the external trip is produced by a non-resident, the internal end is the attraction and the external end the production; in this case, the internal end is assigned based on a traffic zone's internal trip attractions. This update assumes an approximate 2:1 ratio of external productions to attractions — for convenience, this was rounded to 30% attractions and 70% productions. In other words, of the 165,390 internal-external trips shown in Table 12, about 49,617 were made by MATS residents to and from an external attraction, and about 115,773 were made by non-residents to and from an internal attraction.

The second estimation necessary is disaggregation of the external trips to the three internal trip purposes. In regions with a strong employment center such as Mobile, the purpose splits of external trips are normally more heavily weighted (about 2:1) toward home-based work trips than are internal trips; non-home based trips are generally about the same for internal and external trips. In the case of MATS, those two approximations yield an external trip split of 44% HBW, 34% HBO, and 22% NHB — these were "smoothed" to 45/35/20. By definition, NHB trips are split equally between residents and non-residents (attractions and productions) and by observation, HBW trips are inbound during the morning peak by a 3:1 ratio (34:11 — based on the 45% split — rounded to 35:10). Therefore, external HBW attractions are 10% of the total externals and productions are 35%, and NHB productions and attractions are each equal to 10% (half of 20%) of the external trips. Finally, based on the HBW and NHB attractions of 10% each, the HBO attractions must be 10% also (30% total attractions from preceding paragraph), and the HBO productions are therefore 25% (since total HBO trips are 35% of the externals). The external distribution derived as outlined above and ultimately used in this update is shown in Table 13; it must be emphasized that these splits are based on local knowledge only and are entirely subjective in nature.

Table 12 MATS External Trip-End Summary, 2015

	Percent by Purpose				
Internal-External Trips	Total	HBW	HBO	NHB	Total Trips
Resident (Attractions)	30	10	10	10	49,620
Non-resident (Productions)	70	35	25	10	115,770
Total %	100	45	35	20	165,390
Total Trips	165,390	74,420	57,890	33,080	

The internal ends of all internal-external trips were distributed to the internal zones based on the data in Table 12. The location of each trip-end was determined as a function of a traffic zone's internal trip-ends by purpose; each zone's external trip attractions are calculated as that zone's percentage of internal attractions multiplied by the total internal-external attractions by purpose. The same procedure is used to locate the internal end of external trips produced internally. The study area trips by purpose and final trip generation coefficients after balancing are shown in Table 13 (base year data). The actual P's and A's by trip purpose by zone for the 2015 base year are contained in Appendix A-4 and those for 2045 may be found in Appendix A-5.

SECTION 4 TRUCKS

Historically, understanding current and future freight movements relies on an estimated percentage of heavy trucks per total Average Annual Daily Traffic (AADT), at a minimum. With the assistance of Streetlight, we have a better understanding of the flow within the MATs area. Streetlight is a company that specializes in connected car services and transportation analytics using INRIX data. Streetlight conducted an Origin-Destination study by monitoring all of our Traffic Analysis Zones (TAZ) and eight locations that trucks typically enter/exit the study area. Each truck with a GPS unit, going through a monitored location, would continue to be tracked throughout the study area. Streetlight provided the MPO with an Origin-Destination table that revealed the percentage of trucks going from zone to zone. Using truck count percentages provided by ALDOT, the MPO staff was able to create the present and future volume of trucks going zone to zone based on those percentages and Streetlights OD matrix. This mode is preloaded in the model and only is allowed on roads that would typically have heavy trucks. Volumes were crosschecked by use of FAF4 data, commodity flow data, and surveys done by local terminals. See Appendix 9 for truck information.

Figure 10 Streetlight Heavy Trucks Monitoring Locations

SECTION 5 TRIP DISTRIBUTION

Trip distribution is the process of matching the production end of each trip with an attraction end, *i.e.*, connecting trip-ends together to form trips; the "gravity model" is the mathematical expression

Table 13 Internal Trip-End Data, 2015

	Study Area Trips		Average Trip-Ends Per: Occupied Dwelling	College Student	Employee Service	Employee Retail	Employee Other
HBW	123,525	P	.95				
		A			.79	.79	.79
HBO	572,709	P	3.34				
		A	.83	1.39	1.57	8.32	.46
NHB	426,724	P & A	.65		1.57	5.36	.65
INX	49,620	Resident	.24				
	115,770	Non-res.	.08	.10	.60	1.39	.45
Total	1,288,345						
Average Trip-Ends			6.94	1.49	6.10	21.22	3.01

used to construct these trips. Its premise is that the number of trips between two zones increases as the activity (trip-ends) in the zones increases and decreases as the separation of the zones increases. In traffic models, separation is called impedance and is usually expressed as time, although distance or a combination of time and distance is occasionally used. Three basic data elements are needed as input to the gravity model: (1) productions and attractions for each trip purpose for each zone, (2) the impedance values for trips between each pair of zones, and (3) a set of friction factors for each trip purpose covering the range of impedance values found in the network. The development of zonal productions and attractions has already been discussed. Determination of zone-to-zone impedance values involves some assumptions which must be documented for later reference.

Impedance has at least three components, and some models use more. At a minimum, impedance includes the costs "skimmed" from the paths through the network between each zone pair, the costs incurred by trips with both ends inside a single traffic zone ("intrazonal" trips), and terminal costs, also called "excess" costs, which are incurred at the beginning and end of any trip (finding parking, walking to a final destination, etc.). Terminal time (cost) varies considerably as a function of land use at the trip-end (land use index), or more generally by geographic location of the traffic zone. Intrazonal times are determined by the size and development characteristics (land use index) of a given zone. The terminal and intrazonal times for each zone in the Mobile model are included in Appendix A-7.

As part of this plan update, friction factors for the three internal trip purposes were developed from data derived from the *Origin-Destination Study using Cellular Dat*a detailed in Appendix A-10. As part of the study, friction factors were developed for the Mobile travel demand forecast model. For the first time in the history of the Mobile MPO, the travel demand forecast model was calibrated. The model was calibrated to actual cell phone trip patterns, average trip lengths and trip length frequency distribution curve. Through an iterative process, friction factors were developed until the average trip length and trip length frequency distribution curve matched for both data derived from the cell phone study, and the model. Figures 11-13 are the trip length frequency distribution curves for both the cell phone data and the 2010 MATS gravity model, used for 2015 as well.

Figure 11 HBW Trip Length Frequency Distribution Curve

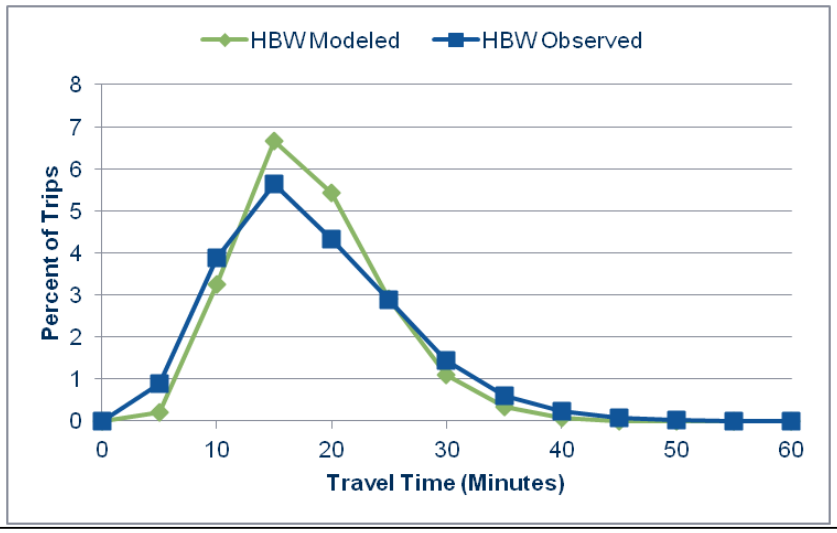


Figure 12 HBO Trip Length Frequency Distribution Curve

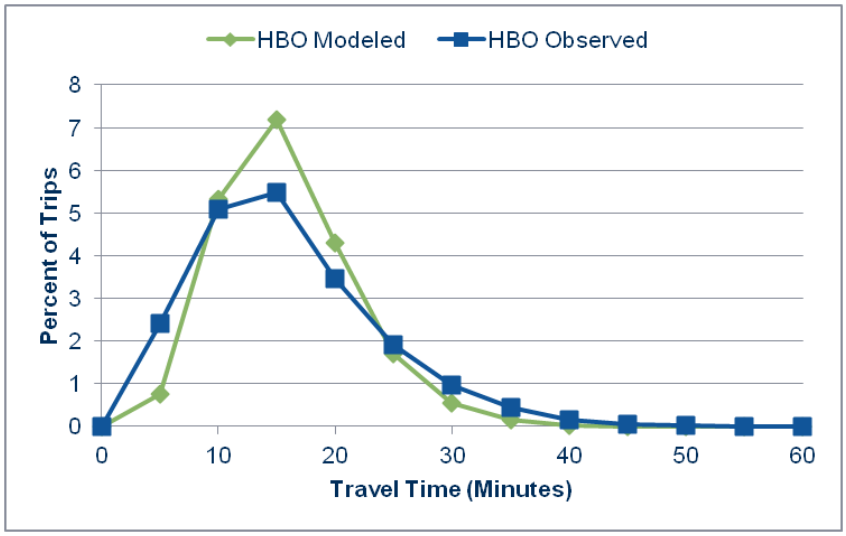
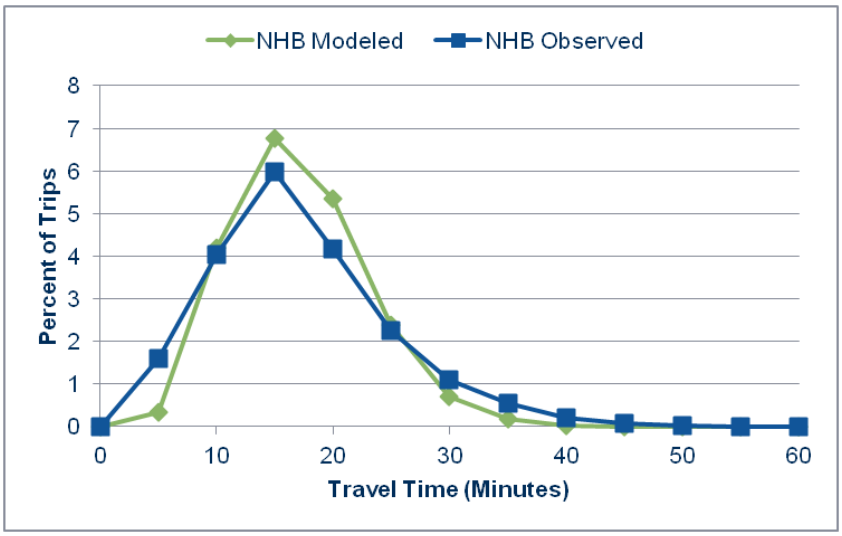


Figure 13 NHB Trip Length Frequency Distribution Curve



The resulting average trip length distribution from the cell phone data for home based work (HBW), home based other (HBO) trips and non-home based (NHB) trips matched as close as possible to the travel demand forecast model's average trip length distribution. The resulting average trip lengths is below in Table 15.

Table 14 Average Trip Length

Trip Purpose	Cell Phone	MATS Model
HBW	18.19	18.18
HBO	15.87	15.81
NHB	17.20	17.10

The friction factors used in this update for the four trip purposes are included in Appendix A-8.

The output of the gravity model is a matrix for each trip purpose which records the trips from each zone to each of the other zones. These four matrices (HBW, HBO, NHB, and internal-external) are combined into one matrix — showing all trips from each zone to each of the other zones — and used later to assign trips to the network. Through trips are separated from internal-external trips using the procedure described previously and historically distributed between cordon stations using a growth factoring procedure known as the "Fratar" distribution instead of with the gravity model. The fratar method relies heavily on established, consistent trip patterns over time and is therefore considered reliable for through trips. However, with this update of the long range plan, the fatar method was not an option due to the increased external-external trip percentages given to I-10 as suggested by the cell phone data. Because frataring the externals was not an option, the external–external trips were run through the gravity model using the internal–external friction factors. This presented a concern, as the I-10 East (bayway) trips attracted a large percentage of

trips coming from I-65 North overloading I-165 with external-external trips. Knowing that any trip coming south on I-65 to Baldwin County, would have already exited from I-65 in Baldwin County on either US 59 or SR 225. For this reason K-factors were used for that external zone pair only (I-65 to I-10 East). K-factors allow the trips between the zonal pairs to be modified to realistic patterns.

It should be noted that the MATS models do not allow several physically possible through movements which are illogical due to 180° paths or preferable routes outside the study area. Appendix 6 lists the external zones which have through movements and the pairs which are permitted.

5.1 Preloading

The MATS traffic model "preloads" trucks and through trips on the network prior to the assignment of internal trips. Trucks are assigned to only the roads that heavy trucks would travel, and only to and from externals and Freight Analysis Zones (FAZs). The TAZ to FAZ equivalency table is in Appendix A9. Similarly, the through trips are not necessarily assigned to the quickest path between a pair of zones, but to a route that has been determined to be the most probable for a trip traversing the entire study area (generally only federal and some state highways). The purpose of this approach is two-fold — to keep the through trips on higher level "posted" facilities and to prevent diversion of through traffic during capacity-restrained assignments.

The preloading is accomplished by coding the assignment group in the link record file 1 through 4. An assignment code “1" means the link is on a route determined to allow vehicles and trucks, but no vehicle preloads. Links with assignment group code 2, allow vehicle trips and vehicle through trips. There are no links with an assignment group code 3 (which means all trips are allowed) and links with assignment group code 4 are not allowed to have trucks or preloaded vehicles, only internal and internal external trips. An external-external trip table is added to the origin-destination table that the network is assigned to. Trucks are considered mode 2 and the preloads are considered as a third mode (mode 3) in the model and are merely assigned (all-or-nothing) to the network to only those links that have and assignment group code of “2". Figure 14 is a schematic plot of the 2015 network showing preloaded through trips for vehicles and Figure 15 shows preloaded truck trips.

Figure 14 MATS 2015 Through Trips

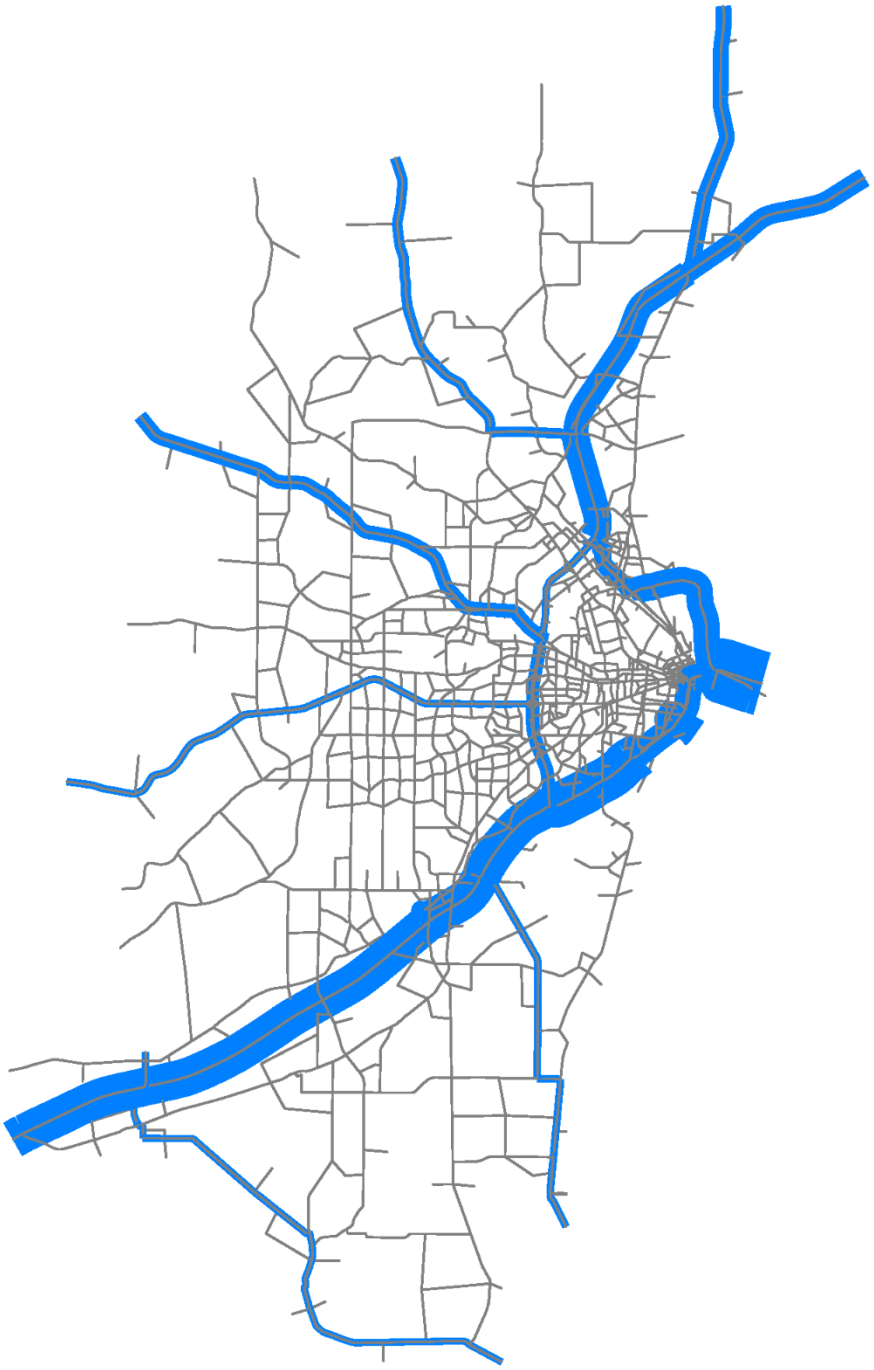
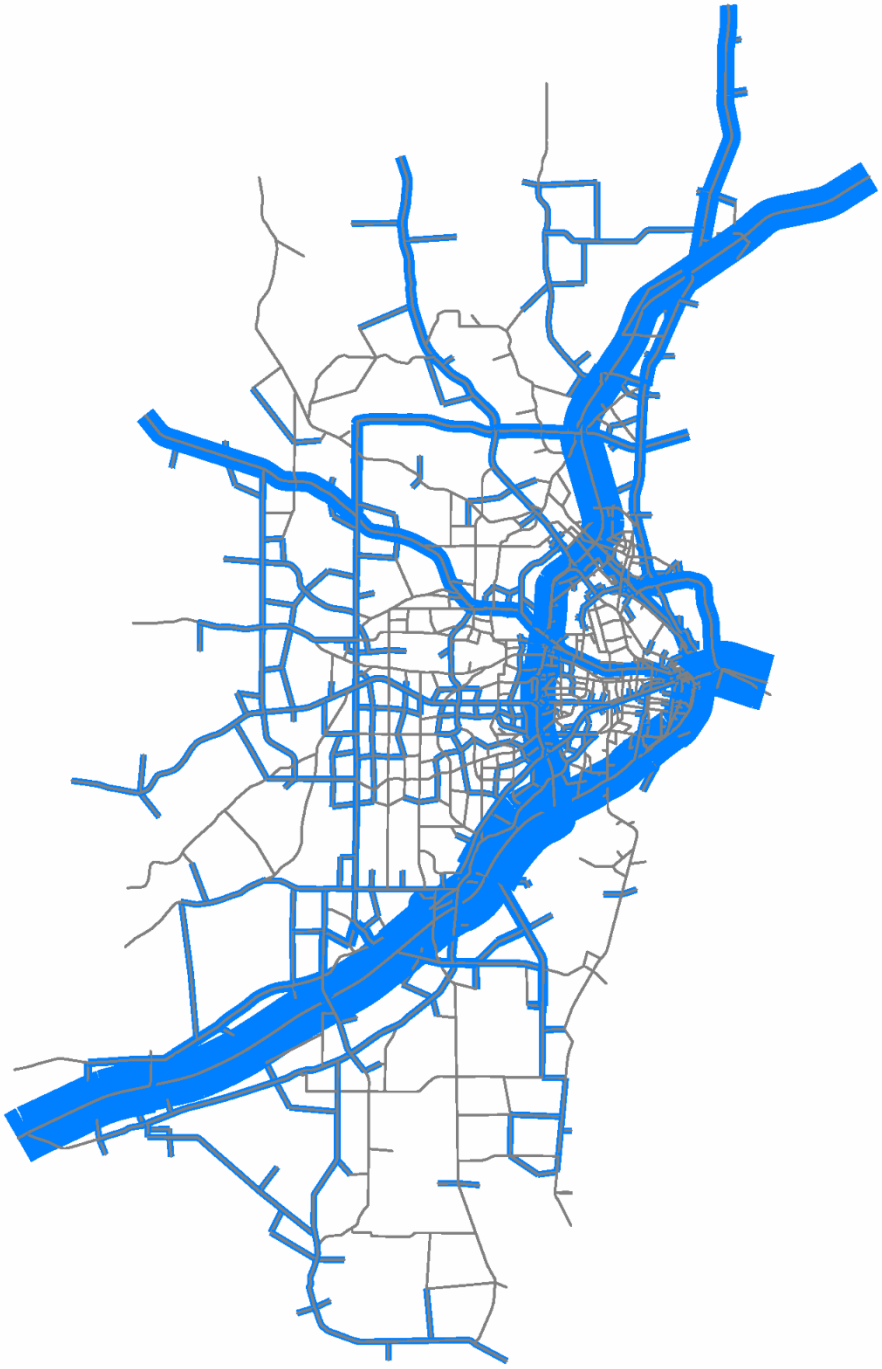


Figure 15 MATS 2015 Truck Trips



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SECTION 6 TRAFFIC ASSINGMENT AND MODEL VALIDATION

Traffic assignment is basically the product of the entire modeling procedure; all prior steps in developing the model are brought together at this point. Traffic assignment refers to placing the trip matrix (the trips from each zone to each other zone) on the individual facilities which make up the highway network. Models use one of three types of assignment: all-or-nothing, capacity restraint, or random. All-or-nothing assigns all trips between each zone pair to the minimum time path (quickest route), regardless of the total number of trips assigned to those roads relative to their capacity limitations. Capacity restraint is an iterative assignment procedure which adjusts paths between each network loading to account for lower speeds due to congestion on the minimum time path between each zone pair; thus, different paths may be selected during different iterations. - Two basic options are available for capacity restraint assignments (depending on software) — the user controls the total number and weighting of each iteration to determine the final assignment, or the iterations continue at weightings which are based on "optimum" or balanced conditions as determined by the software (equilibrium assignment). Random (stochastic or multi-route) assignment is based on the premise that more than one desirable path exists between each zone pair; the desirability of each path can be calculated with several methods and certain capacity restraint procedures can be effectively used. The distinction between stochastic models and capacity restraint all-or-nothing models fades depending on the type of capacity restraint used. The traffic assignment methodology used in this update was equilibrium assignment with user-specified convergence and speed-capacity (volume-delay) curves.

Many of the adjustments and refinements mentioned in previous portions of this section cannot actually be made until after at least one assignment is completed, allowing a rough estimate of the trip movements and traffic patterns produced by the model and its empirical assumptions. The process of comparing a model's estimate of traffic to the traffic counts actually taken in the field is called "validation". Validation allows the error of the model to be minimized and its confidence limits to be established. Validation includes verification of network and facility assumptions, checks on areawide trip movement, and ultimately, the accuracy of assignments on individual links. Thus, validation is an iterative process of model development whereby the entire model chain is repeated numerous times as individual model parameters are modified and the assignment results compared — to each other as well as to actual conditions. Due to the nature of this document, great detail is not provided on the specifics of validation, but rather the process and results. Preceding portions of this report have detailed the end result of each stage of model development *after* completion of validation (*i.e.*, after inaccuracies were discovered and corrected). Similarly, this section provides comparisons between the final model assignments, ground counts, and acceptable error limits and outlines the end-product without delving into the numerous and varied paths taken to get there.

6.1 Traffic Counts

The Alabama Department of Transportation (ALDOT) took traffic counts throughout the study area in 2015. However, because half of the traffic counts were taken before

Table 15 Distribution of 2015 Traffic Counts

Functional Classification	Number of Links Total	Counted	% Counted
Freeway/Expressway	108	50	46%
Other Principal Arterials	685	395	58%
Minor Arterials	960	548	57%
Collectors	1,022	579	57%
All	2,775	1,572	57%

Average Daily Traffic	Number of Links Total (Est)	Counted	% Counted
Below 5,000	1,568	916	58%
5,000 – 9,999	617	353	57%
10,000 – 19,999	468	247	53%
20,000 – 29,999	46	17	37%
30,000 – 39,999	53	29	55%
40,000 – 49,999	23	10	44%
All	2,775	1,572	

ALDOT performed areawide traffic counts in 2015 for purposes of validating the travel demand forecast model. These counts included vehicle classification counts for identifying trucks at 46 locations. The City of Mobile and Mobile County also provided average daily traffic (ADT) information for the period in. The 2775 links included in the 2015 MATS network and the 1,572 counted links are distributed by functional classification and ADT as shown in Table 16.

An all-or-nothing assignment was the first step in validating the 2015 model. That assignment was used primarily to determine the accuracy of "area-to-area" movements, *i.e.* wide-scale trip distribution and total daily vehicle-miles-traveled (VMT). The results of this first effort were used to fine tune the network and the basic parameters which make up the model. Information gained from this assignment included the approximate level of VMT which would be generated by the final model,

Table 16 2015 All-or-Nothing Assignment VMT

Functional Classification	All Links Estimate	Model	% Diff	Counted Links Actual	Model	% Diff
	ALL		%	Counted		%
	ADT	Model	Diff	ADT	Model	Diff
Freeway/Expressway	32,511	33,449	3	33,043	35,601	7
Principal Arterials	10,286	11,458	11	9,861	10,843	10
Minor Arterials	5,725	5,463	-5	5,519	5,239	-5
Collectors	2,129	2,076	-2	2,208	2,139	-3
	6,569	6,785	3	6,569	6,471	3

information regarding orientation of traffic flows in the network (checked with screenlines, and with cutlines in some cases), information regarding the capacity restraint parameters which must be used, and the extent of "split paths" in the network which required centroid connector time adjustment.

As a first check of the model's validity to this point, the all-or-nothing VMT was compared to the estimated VMT; the estimated counts (see above) were used to approximate areawide VMT. Table 17 shows VMT on both counted links and all links (estimated) as compared to the first all-or-nothing assignment on the network. In general, the overall comparison is poor — VMT is only slightly high (±5% is considered an allowable range) and the distribution by functional classification is not acceptable.

The next check involved the orientation of trips within the study area. Screenlines - and to a lesser extent cutlines - were used to compare the actual and simulated travel patterns in the MATS area. The locations of the screenlines are shown on Figure 16; specific screenline information is provided in Appendix A-8. *NCHRP Report 255* provides data for the maximum desirable deviation for total screenline 24-hour ground counts which is represented as Figure 17; also plotted on this figure is the screenline data for the initial all-or-nothing assignment.

Figure 16 Network Screenlines and Cutlines

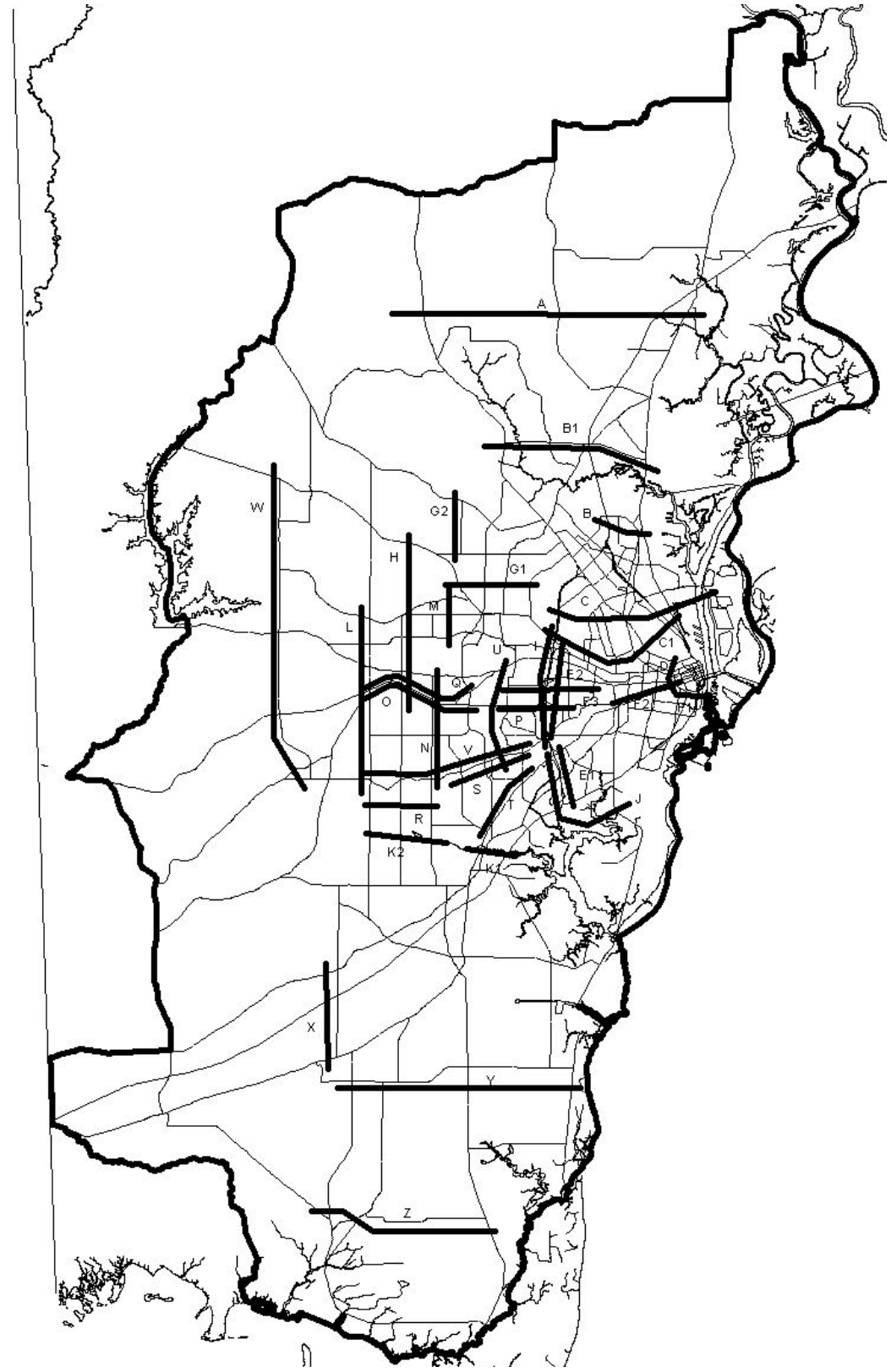
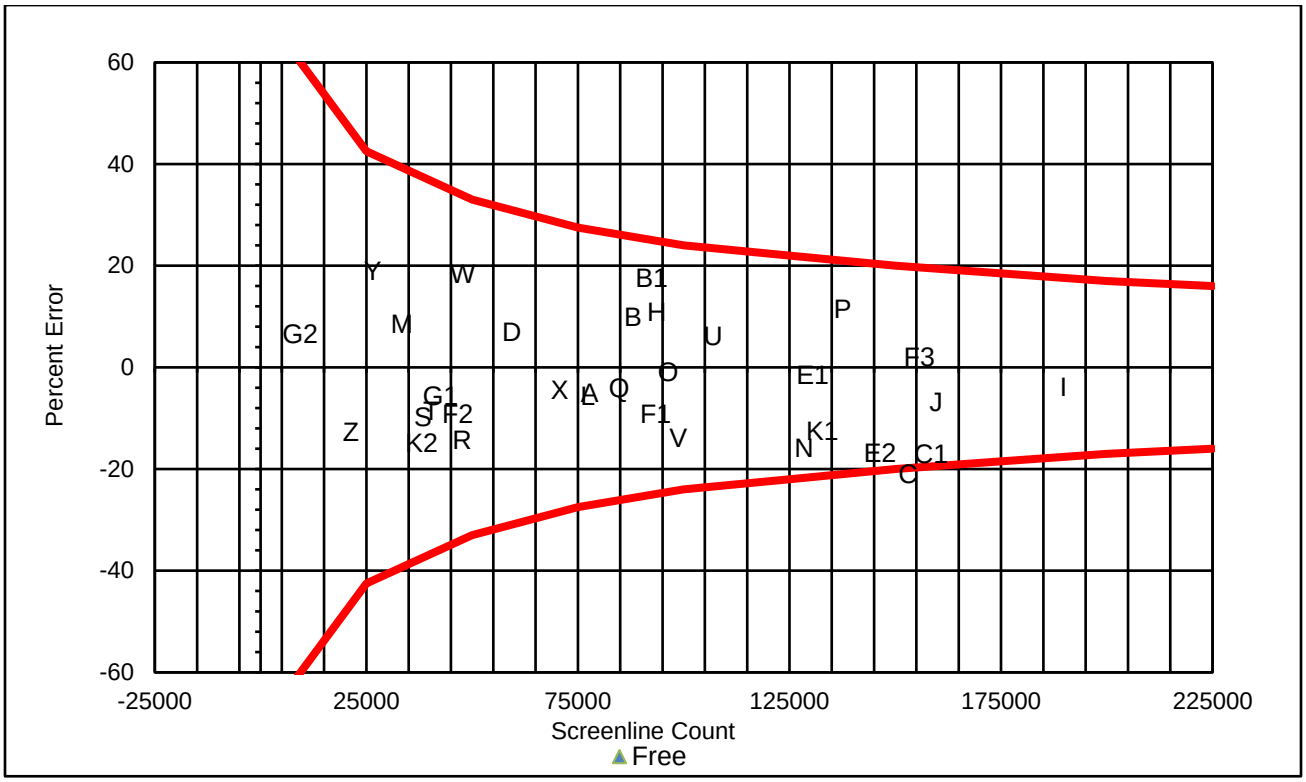


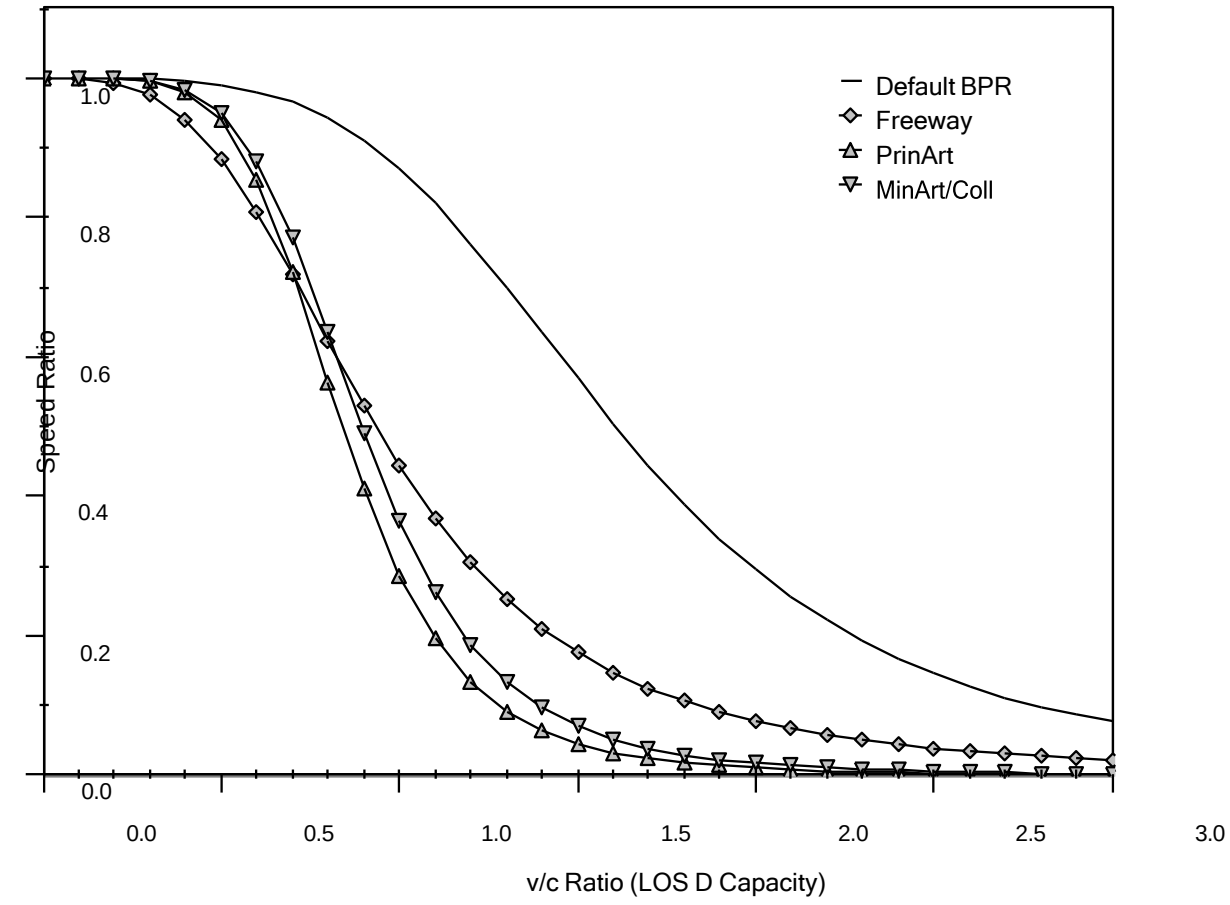
Figure 17 2015 All-or-Nothing Assig nment Screenline Error



In the past, the Mobile travel demand forecast model relied on k-factors to correct screenline errors. However, as seen in Figure 16, there is minimal error in the screenlines from the free assignment, or all or nothing assignment. This is largely due to the calibration of the gravity model.

Because no obviously large interchanges between individual zone pairs were found to cross either the Theodore or Prichard screenlines, time barriers were used along the north and south city limits of Mobile. The south time barrier is three minutes and follows Halls Mill Creek and Dog River. The north time barrier is two minutes and is located between Three Mile Creek and the Prichard-Mobile city limits from US Highway 43 west to I-65, then northwest to Eight Mile Creek, and continuing to north of Bear Fork Road. Figure 16 documents the resulting all-or-nothing screenline error; see Appendix A-8 for complete screenline information for this assignment. During validation of the models, several capacity sets and iteration closure values and several speed-flow curves were tested and evaluated. The volume-delay (speed-flow) curves ultimately selected are shown on Figure 18; Table 9 in the Network Development section and Appendix A-6 of this report document the Level-of-Service D capacities used in link coding. Figure 19 graphically summarizes the screenline error present in the restrained assignment.

Figure 18 MATS Volume-Delay Curves



Several measures were used to evaluate the adequacy of the various assignments made, *i.e.*, to validate the model results. The use of screenlines has been discussed and demonstrated previously. Comparisons of VMT were made system-wide and by functional classification. Comparisons of assigned and counted volumes were also made system-wide, by functional classification, and by ADT groups. For the more important roads in the study area, comparisons were made on a facility basis and occasionally on a link-by-link basis where loading problems were obviously contributing factors to assignment error.

On a system-wide basis, both ADT and VMT should be within 5% of actual, measured values. The suggested error limits by functional classification (system-wide) as published by FHWA are ±7% for freeways and expressways, ±10% for other principal arterials, ±15% for minor arterials, and ±25% for collectors. Table 17 summarizes the all-or-nothing and restrained assignment comparisons against actual (and estimated) 2015 ADT and VMT by functional classification.

Based on the data in Table 17, the restrained model assignment appears well within acceptable limits. However, this comparison alone is somewhat misleading in that an assignment error of 4000 high on one link and an assignment error of 4000 low on another would result in an "average" error of zero; the accuracy of this example assignment is, in fact, ±4000.

Figure 19 2015 Capacity Restrained Assignment Screenline Error

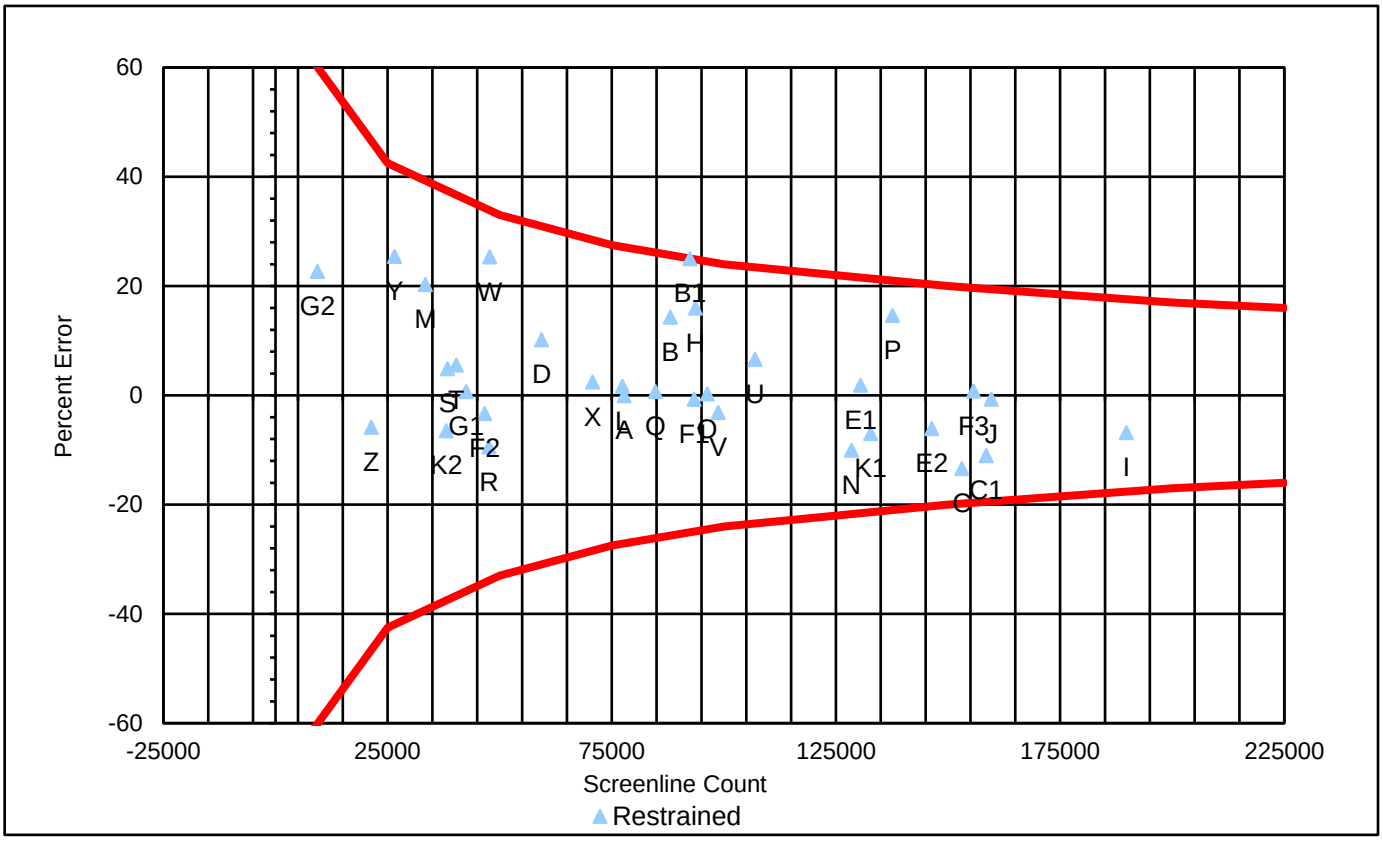


Table 17 2015 Assignment Error by Functional Classification

Counted links	error Limit	-	AoN Model	AoN Diff	CapRst Model	CapRst error	avg ADT	CapRst Model	CapRst error
Freeway/Expressway	± 7%	2,116	2,250	6.3%	2,172	2.6%	33,043	33,133	0.3%
Principal Arterials	±10%	1,927	2,122	10.1%	2,088	8.4%	9,861	10,400	5.5%
Minor Arterials	±15%	1,484	1,367	-7.8%	1,529	3.0%	5,519	5,785	4.8%
Collectors	±25%	615	597	-3.0%	651	5.8%	2,208	2,321	5.1%
	± 5%	6,157	6,357	3.2%	6,466	5.0%	6,266	6,539	4.4%
All links (includes estimates)									
	error Limit	-	AoN Model	AoN Diff	CapRst Model	CapRst error	avg ADT	AoN Model	AoN Diff
Freeway/Expressway	± 7%	3,378	3,533	4.6%	3,409	0.9%	32,511	33,449	2.9%
Principal Arterials	±10%	2,815	3,152	12.0%	3,102	10.2%	10,286	11,458	11.4
Minor Arterials	±15%	2,316	2,146	-7.3%	2,415	4.3%	5,725	5,463	-4.6%
Collectors	±25%	949	924	-2.6%	1,020	7.5%	2,129	2,076	-2.5%
	± 5%	9,478	9,779	3.2%	9,974	5.2%	6,569	6,785	3.3%

A much more meaningful measure of model accuracy is the concept of "Root-Mean-Square", or RMS, error. In general terms, RMS error is roughly equal to the average of the *absolute values* of the individual errors; thus, the RMS error of the above example would be about 4000 instead of 0. To illustrate the substantial differences of the two error measurement standards, Table 19 below compares the 2015 assignment RMS error to the average error as given in Table 18.

Table 18 Comparison of Average and RMS Error by Functional Classification

Functional Classification	Avg ADT	AoN Model	AoN Error	AoN RMS Error	CpRst Model	CpRst Error	CpRst RMS Error
(Counted Links Only)							
Freeway/Expressway	33,043	35,601	7.7%	14.3%	33,133	0.3	11.0%
Other Principal Arterials	9,861	10,843	10.0%	29.0%	10,400	5.5%	24.2%
Minor Arterials	5,519	5,239	-5.1%	37.8%	5,785	4.8%	39.3%
Collectors	2,208	2,139	-3.1%	74.2%	2,321	5.1%	75.3%
Total	6,266	6,471	3.3%	36.6%	6,539	4.4%	33.9%
(All Links - includes estimates)							
Freeway/Expressway	32,511	33,449	2.9%	14.8%	31,566	-2.9%	12.9%
Other Principal Arterials	10,286	11,458	11.4	31.7%	10,977	6.7%	26.8%
Minor Arterials	5,725	5,463	-4.6%	37.8%	6,010	5.0%	38.8%
Collectors	2,129	2,076	-2.5%	88.8%	2,260	6.1%	89.9%
Total	6,569	6,785	3.3%	35.9%	6,850	4.3%	33.8%

Since some error is expected in the traffic counts to which the assignment is compared, and since some error will be present in any model simulation no matter how good, the concept of allowable RMS error is used in analyzing assignment accuracy similar to the way maximum allowable screenline error was used in evaluating general travel patterns — the higher the volume, the lower the allowable percentage error. Since every link in the network will probably not be within the established error limits, links are usually grouped based on the counted (or estimated) ADT. The RMS error of each of these ranges is then compared to the error limitations to evaluate the overall performance of the model. Table 20 includes the maximum allowable percentage error based on ADT range and summarizes the 2015 assignments in relation to these standards; the data in Table 20 is also shown graphically on Figure 20. As is obvious from Table 20 and Figure 20, the capacity restrained model assignment is well within the established error limits for grouped ADT data.

As a final and most stringent comparison, link-by-link scatter plots of the all-or-nothing and capacity restrained assignments were constructed. The resulting plots are shown in Figures 21. Figure 21 includes plots of both assignments and is based on the model's actual error for each link. The lines above and below the diagonal axis indicate the desired maximum and minimum error ranges. This type of plot shows any bias of the model in terms of under or over-assignment in any given ADT range. It is best used for major corrections early in the model development

process. For example, Figure 21 shows a tendency of the all-or-nothing assignment to under-assign the lower volume links (less than 30,000 ADT) while over-assigning the higher volume links (40,000 and up). The same figure also shows no obvious bias related to volume in the capacity restrained model assignment. As a final note regarding these plots, the accuracy of the assignment is usually of little concern on roads with less than 10,000 ADT, and certainly on those below 5,000; therefore, the lack of graph detail below 10,000 ADT is generally acceptable.

Table 20 shows an overall RMS error of 34.0% of the restrained assignment including all links. The restrained assignment with just the counted links there is an overall error of 36.1%

Table 19 2015 Assignment RMS Error by ADT Group

(COUNTED Links)				RESTRAINED				FREE			
ADT	Max Err	# Links	ADT	Model	Error	Diff	RMS Error	Model	Error	Diff	RMS Error
< 5,000	>47%	937	2,507	2,697	7.6%	1,586	63.2%	2,453	-2.2%	1,548	61.7%
5 - 9,999	35-47%	359	6,961	7,217	3.7%	2,336	33.6%	6,986	0.4%	2,458	35.3%
10 - 19,999	27-35%	250	13,061	13,690	4.8%	2,988	22.9%	13,831	5.9%	3,206	24.5%
20 - 29,999	24-27%	19	22,199	21,697	-2.3%	2,295	10.3%	23,764	7.1%	4,702	21.2%
30 - 39,999	22-24%	29	35,721	34,978	-2.1%	4,063	11.4%	38,232	7.0%	5,011	14.0%
40 - 49,999	20-22%	10	44,851	45,203	0.8%	3,329	7.4%	48,909	9.0%	5,466	12.2%
ALL		1,604	6,247	6,496	4.0%	2,124	34.0%	6,430	2.9%	2,293	36.7%

(ALL Links - Includes Estimates)				RESTRAINED				FREE			
ADT	Max Err	# Links	ADT	Model	Error	Diff	RMS Error	Model	Error	Diff	RMS Error
< 5,000	>47%	1,589	2,446	2,639	7.9%	1,759	71.9%	2,400	-1.9%	1,729	70.7%
5 - 9,999	35-47%	623	6,939	7,350	5.9%	2,506	36.1%	7,084	2.1%	2,548	36.7%
10 - 19,999	27-35%	473	13,039	13,691	5.0%	3,139	24.1%	13,737	5.4%	3,426	26.3%
20 - 29,999	24-27%	48	22,930	22,945	0.1%	3,578	15.6%	25,654	11.9%	6,172	26.9%
30 - 39,999	22-24%	53	36,434	34,935	-4.1%	4,609	12.7%	37,440	2.8%	5,291	14.5%
40 - 49,999	20-22%	23	44,245	42,285	-4.4%	4,803	10.9%	45,749	3.4%	4,434	10.0%
ALL		2,809	6,560	6,826	4.1%	2,369	36.1%	6,762	3.1%	2,539	38.7%

Table 21 summarizes all comparative data by functional classification for the validated model and actual 2015 conditions, including estimated counts. Figure 21 shows how the free assignment slightly overloaded the majority of the volume groups. The restrained assignment tries to correct this with almost no error on the higher volume roads.

Figure 20 2015 Assignment Error, By Link

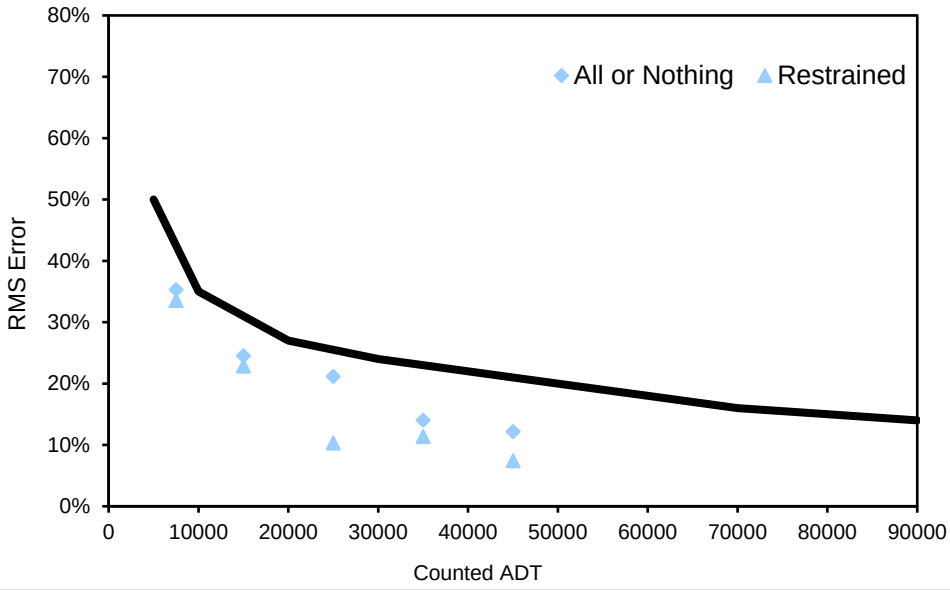


Figure 21 Summary Comparisons: Model vs 2015 Conditions, Including Estimated Counts

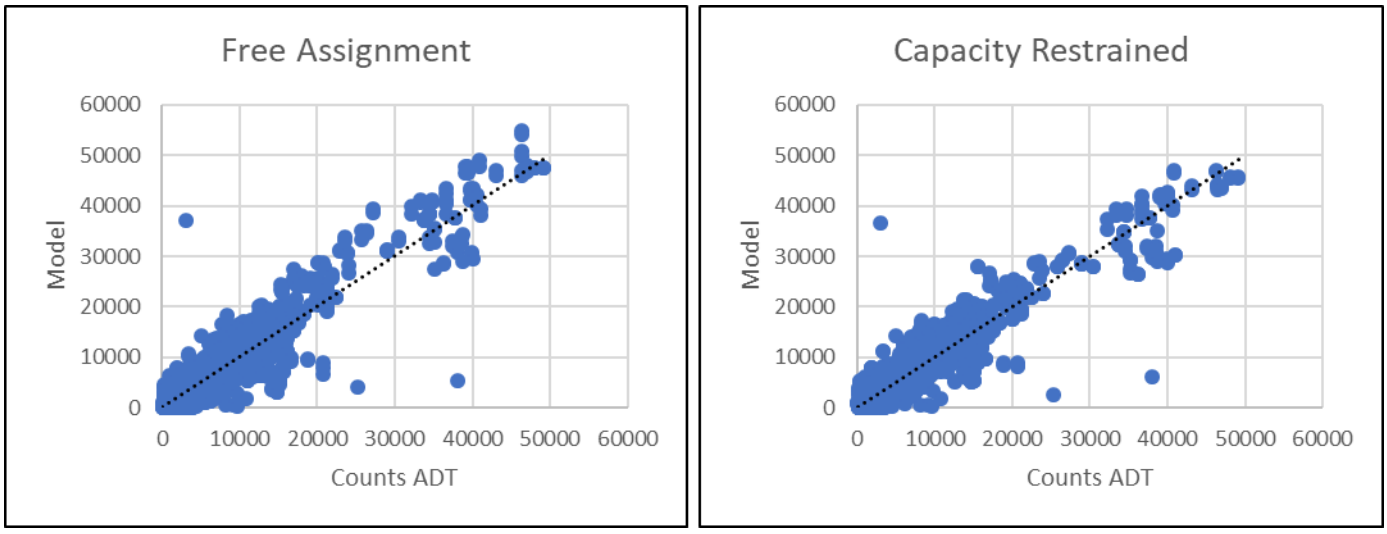


Table 20 Summary Comparisons: Model vs 2015 Conditions, Including Estimated Counts

ALL Links

	# Links	ADT	RESTRAINED	Error	Diff	RMS Error	FREE	Error	Diff	RMS Error
Freeway/Expressway	108	32,511	31,566	2.9%	4,178	12.9%	33,449	2.9%	4,821	14.8%
Principal Arterials	685	10,286	10,977	6.7%	2,761	26.8%	11,458	11.4%	3,263	31.7%
Minor Arterials	960	5,725	6,010	5.0%	2,222	38.8%	5,463	-4.6%	2,163	37.8%
Collectors	1,022	2,129	2,260	6.1%	1,915	89.9%	2,076	-2.5%	1,891	88.8%
TOTAL	2,775	6,569	6,850	4.3%	2,223	33.8%	6,785	3.3%	2,359	35.9%

COUNTED Links

	# Links	ADT	RESTRAINED	Error	Diff	RMS Error	FREE	Error	Diff	RMS Error
Freeway/Expressway	50	33,043	33,133	0.3%	3,621	11.0%	35,601	7.7%	4,710	14.3%
Principal Arterials	395	9,861	10,400	5.5%	2,383	24.2%	10,843	10.0%	2,858	29.0%
Minor Arterials	548	5,519	5,785	4.8%	2,168	39.3%	5,239	-5.1%	2,085	37.8%
Collectors	579	2,208	2,321	5.1%	1,663	75.3%	2,139	-3.1%	1,639	74.2%
TOTAL	1,572	6,266	6,539	4.4%	2,121	33.9%	6,471	3.3%	2,294	36.6%

Appendix A2 2015 Socio-Economic Data

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
1	7	2	1	0	0	46	927	215
2	0	0	0	0	0	36	1,079	977
3	8	3	3	0	0	100	289	53
4	10	3	4	0	0	9	262	1389
5	0	0	0	0	0	91	1,923	658
6	20	6	7	0	0	2	144	146
7	60	17	19	0	0	61	83	54
8	34	9	12	0	0	191	68	65
9	112	31	37	0	0	51	221	5
10	99	27	33	0	0	68	110	154
11	1	0	0	0	0	8	138	137
12	22	6	7	0	0	4	244	123
13	7	2	2	0	0	3	430	0
14	57	15	19	0	0	6	183	42
15	9	2	0	0	0	7	136	774
16	0	0	0	0	0	22	6	164
17	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	52	8
19	4	0	0	0	0	12	166	767
20	2	0	0	0	0	30	2	135
21	0	0	0	0	0	60	55	844
22	0	0	0	0	0	150	7	1117
23	0	0	0	0	0	0	0	500
24	0	0	0	0	0	0	80	64
25	36	9	10	0	0	0	0	30
26	131	71	26	0	0	2	36	39
27	131	93	30	0	0	1	12	0
28	215	124	51	0	639	6	79	0
29	213	67	27	0	2,264	19	495	503
30	199	95	74	0	0	28	361	275
31	123	83	77	0	0	30	328	11
32	26	11	23	0	0	35	1,612	44
33	155	72	143	0	0	14	68	157
34	116	152	313	0	0	118	302	2
35	146	137	105	0	0	76	153	12
36	90	50	83	0	0	128	279	82
37	325	149	404	0	0	86	168	49
38	323	119	173	0	0	13	23	10
39	206	86	59	0	0	25	222	107
40	101	48	81	0	0	13	15	87
41	225	142	238	0	0	31	190	16
42	144	67	87	0	0	1	8	8
43	301	136	81	0	0	9	260	48
44	234	134	92	0	0	9	121	425
45	413	100	70	0	0	4	83	527
46	185	54	34	0	0	11	21	27
47	524	65	31	0	0	0	0	14
48	527	161	74	0	0	14	56	8
49	103	65	25	0	130	134	1,017	2025
50	196	110	95	0	0	9	67	1
51	148	72	93	0	304	3	208	11
52	287	155	60	0	0	33	0	1
53	95	82	53	0	0	0	9	1
54	120	72	57	0	0	2	8	0
55	143	137	86	0	0	20	303	64

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
56	355	324	335	0	0	29	128	209
57	68	118	121	0	0	247	610	164
58	107	106	81	0	0	66	111	74
59	68	53	75	0	0	704	86	18
60	293	254	255	0	0	192	214	28
61	15	11	4	0	0	1800	625	118
62	56	97	143	0	0	78	112	49
63	133	87	108	0	0	113	461	183
64	305	223	135	0	0	49	166	153
65	185	103	63	0	0	46	80	98
66	18	20	42	0	0	28	163	231
67	131	140	286	0	0	24	36	212
68	98	177	263	0	0	167	141	32
69	99	147	325	0	0	89	236	8
70	56	135	205	0	0	39	384	3
71	25	14	31	0	0	2	3,057	7
72	96	64	157	0	0	6	25	0
73	39	65	196	0	0	69	240	32
74	220	69	29	0	0	57	196	49
75	104	40	14	0	0	210	421	324
76	214	82	29	0	0	569	724	241
77	141	44	17	0	0	60	953	1202
78	138	198	171	0	0	42	151	27
79	349	207	175	0	0	11	53	23
80	0	0	0	0	0	1694	168	35
81	301	268	180	0	0	210	755	106
82	0	0	0	0	0	10	142	215
83	214	160	71	0	0	195	224	580
84	477	113	100	0	0	212	143	154
85	191	123	115	0	378	6	1,691	282
86	400	157	135	0	0	5	169	1
87	209	157	123	0	0	7	159	52
88	459	266	135	0	0	70	251	75
89	346	106	52	0	0	21	78	4
90	278	127	68	0	0	69	176	28
91	320	155	123	0	0	27	30	0
92	173	110	82	0	0	0	10	0
93	7	2	3	0	0	0	0	342
94	193	50	74	0	0	1	36	0
95	48	27	17	0	0	0	50	39
96	215	89	68	0	0	18	31	60
97	176	77	57	0	0	43	154	282
98	170	96	74	0	0	4	101	0
99	125	75	20	0	0	11	70	75
100	122	67	17	0	0	0	136	0
101	97	44	12	0	0	0	39	188
102	19	3	0	0	0	0	0	409
103	267	48	4	0	0	12	0	135
104	0	0	0	0	0	0	0	0
105	120	77	63	0	0	0	36	60
106	217	138	65	0	0	4	58	251
107	218	92	42	0	0	11	19	330
108	227	73	42	0	220	60	341	203
109	91	34	17	0	0	2	8	0
110	272	116	57	0	0	31	39	55

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
111	334	48	18	0	0	4	66	0
112	140	27	25	0	0	1	4	27
113	64	12	11	0	0	7	0	0
114	173	106	70	0	0	3	28	39
115	68	28	11	0	0	29	11	186
116	130	10	12	0	0	2	4	7
117	246	124	141	0	0	13	13	60
118	264	216	109	0	0	116	96	266
119	0	0	0	0	0	0	50	0
120	44	29	22	0	0	0	52	796
121	0	0	0	0	0	12	0	1025
122	412	287	311	0	0	81	124	59
123	60	126	80	0	0	1	0	47
124	152	111	100	0	0	0	16	41
125	300	161	128	0	0	786	93	39
126	447	105	116	0	0	186	393	193
127	16	43	64	0	0	1	24	0
128	4	9	14	0	0	0	0	3
129	58	33	39	0	0	59	151	2
130	209	166	264	0	0	28	113	15
131	259	180	254	0	0	5	60	13
132	128	74	87	0	0	16	281	0
133	92	60	103	0	0	19	26	11
134	287	185	319	0	0	95	239	63
135	110	66	91	0	0	51	392	1800
136	129	74	244	0	0	98	211	69
137	162	149	242	0	0	114	73	1
138	64	91	272	0	0	19	309	25
139	132	206	709	0	0	148	84	96
140	122	96	339	0	0	270	364	19
141	143	184	351	600	1,496	205	993	30
142	0	0	0	0	0	58	3,090	180
143	327	487	470	0	0	418	287	7
144	104	234	806	0	0	438	590	278
145	579	402	602	0	0	311	1,988	114
146	305	495	345	0	0	38	592	114
147	190	94	25	0	35	19	277	141
148	768	661	501	0	1,241	1195	2,749	466
149	160	136	103	0	0	158	625	253
150	656	212	190	0	0	122	531	18
151	63	92	276	0	0	371	1,897	632
152	161	206	410	0	0	78	570	23
153	89	159	324	0	0	135	249	45
154	495	611	898	0	0	352	493	142
155	155	225	354	0	0	127	381	495
156	136	183	284	0	0	140	673	939
157	75	117	211	0	0	0	7	142
158	35	64	197	0	0	0	20	21
159	191	203	310	0	0	0	18	8
160	111	111	75	0	0	45	21	4
161	192	171	196	0	0	14	68	33
162	115	125	188	0	0	3	28	2
163	283	158	154	0	0	27	23	4
164	226	151	174	0	0	23	72	19
165	117	163	145	0	0	51	241	177

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
166	213	186	211	0	0	46	22	1
167	134	55	43	0	0	81	163	5
168	116	184	374	0	0	6	142	21
169	313	501	1,148	0	0	118	458	156
170	173	230	1,205	0	0	47	157	18
171	552	436	1,003	0	0	76	497	24
172	226	497	665	0	0	86	417	11
173	553	635	753	0	0	241	458	24
174	227	409	1,418	0	0	1018	1,935	49
175	486	524	773	0	35	375	5,947	100
176	806	544	428	0	0	460	248	46
177	486	389	492	0	0	169	613	20
178	0	0	0	4211	14,522	140	2,596	0
179	161	91	275	0	0	0	15	0
180	426	147	84	0	0	0	142	0
181	404	264	253	0	0	19	24	45
182	109	229	371	0	0	1	199	2
183	249	330	512	0	0	164	111	6
184	55	121	228	0	0	18	25	1
185	72	118	175	0	0	25	21	238
186	305	415	614	0	0	179	260	85
187	146	246	637	0	0	89	115	3
188	87	89	110	0	0	3	5	53
189	168	176	227	0	0	21	17	20
190	24	24	29	0	0	0	94	0
191	62	63	78	0	0	36	192	53
192	88	113	294	0	0	153	116	80
193	99	129	335	0	0	557	190	370
194	174	224	528	0	0	246	163	139
195	109	201	475	0	0	0	49	46
196	385	389	455	0	0	43	98	197
197	11	4	4	0	0	8	17	551
198	217	95	72	0	0	58	211	124
199	35	32	43	0	0	378	71	37
200	15	13	19	0	0	298	305	1137
201	95	209	680	0	0	54	250	19
202	348	495	2,162	0	0	815	839	136
203	493	396	972	0	0	1620	253	259
204	172	128	851	0	0	167	167	40
205	97	146	583	0	0	8	164	46
206	171	207	902	0	0	414	247	110
207	75	178	475	0	0	32	23	10
208	161	194	222	0	0	81	52	138
209	250	226	145	0	0	275	367	26
210	22	19	9	0	0	1517	360	558
211	122	157	475	0	0	15	203	474
212	13	10	22	0	0	155	191	1258
213	25	19	44	0	0	21	273	767
214	98	76	170	0	0	78	302	358
215	81	63	141	0	0	2	4	184
216	86	121	208	0	0	126	67	208
217	30	60	77	0	0	85	16	538
218	0	0	0	0	0	120	22	470
219	333	172	287	0	0	215	136	1080
220	137	72	118	0	0	7	45	166

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
221	310	456	665	0	0	35	297	277
222	56	57	78	0	0	22	27	12
223	397	361	461	0	0	16	138	80
224	635	537	619	0	0	106	436	86
225	502	346	416	0	0	285	41	109
226	181	96	181	0	0	0	10	1
227	59	102	194	0	0	11	55	282
228	342	208	438	0	0	53	45	113
229	304	270	523	0	0	189	110	64
230	264	187	315	0	0	18	26	8
231	54	38	65	0	0	2	8	109
232	129	150	246	0	0	30	47	84
233	40	81	104	0	0	45	43	16
234	80	116	301	0	0	78	180	105
235	203	287	518	0	0	19	40	117
236	175	234	504	0	0	52	185	71
237	34	80	215	0	0	14	40	106
238	48	62	130	0	0	7	18	8
239	194	296	771	0	0	1	119	21
240	159	252	1,122	0	0	19	66	19
241	105	153	679	0	0	0	53	23
242	46	82	252	0	0	215	77	12
243	149	137	193	0	0	22	33	195
244	65	114	358	0	0	31	126	40
245	152	137	233	0	0	7	13	25
246	280	237	417	0	0	29	497	1
247	146	96	200	0	0	0	0	0
248	224	148	306	0	0	25	14	3
249	349	292	489	0	0	7	16	22
250	123	124	230	0	0	0	2	16
251	116	121	227	0	0	3	13	34
252	76	83	139	0	0	0	5	48
253	17	16	32	0	0	0	6	11
254	70	67	133	0	0	7	0	4
255	17	20	29	0	0	0	4	0
256	42	45	77	0	0	0	4	5
257	3	3	6	0	0	0	10	0
258	93	193	312	0	0	60	119	131
259	20	53	82	264	1,570	0	20	15
260	0	0	0	0	0	0	48	34
261	1	2	3	0	0	670	194	59
262	197	209	335	0	0	173	319	157
263	283	183	218	0	0	302	363	193
264	101	107	172	0	0	166	127	5
265	90	142	190	0	0	88	101	9
266	115	175	207	0	0	111	150	71
267	90	119	70	0	0	0	4	0
268	0	0	0	0	0	975	41	375
269	212	199	244	0	0	2	215	57
270	101	144	231	0	0	72	202	127
271	117	166	268	0	0	171	155	132
272	81	190	756	0	0	0	22	38
273	87	57	45	0	0	3	0	39
274	64	80	228	0	0	7	18	3
275	60	60	206	0	0	0	15	103

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
276	21	21	70	0	0	0	3	0
277	44	63	140	0	0	5	90	89
278	60	52	155	0	0	15	173	66
279	163	129	368	0	0	29	93	280
280	10	7	22	0	0	0	0	1456
281	2	2	3	0	0	0	0	50
282	59	42	71	0	0	0	65	52
283	162	149	247	0	0	59	155	410
284	0	0	0	0	0	20	237	203
285	100	67	28	0	0	45	647	9
286	119	154	240	0	0	25	35	41
287	103	82	123	0	0	458	428	17
288	68	72	103	0	0	108	313	493
289	166	204	293	0	0	25	33	13
290	122	161	266	0	0	14	9	23
291	129	109	184	0	0	66	9	50
292	63	63	214	0	0	0	2	51
293	156	56	153	0	0	2	81	2
294	93	129	304	0	0	6	0	6
295	66	81	220	0	0	22	1	11
296	90	74	127	0	0	97	5	4
297	29	25	59	0	0	71	20	8
298	70	64	152	0	0	69	176	26
299	70	59	113	0	0	12	35	23
300	101	142	204	0	0	2	19	3
301	118	120	193	0	0	0	24	5
302	194	174	281	0	0	9	84	14
303	299	162	102	0	0	131	265	255
304	108	75	88	0	0	28	90	637
305	103	109	150	0	0	14	102	183
306	29	23	24	0	0	77	123	13
307	83	66	71	0	0	9	8	93
308	19	15	17	0	0	0	16	6
309	31	27	51	0	0	0	7	8
310	24	44	105	0	0	0	7	50
311	78	137	383	0	0	0	125	64
312	17	15	18	0	0	105	217	170
313	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
314	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
315	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
316	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
317	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
318	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
319	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
320	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
321	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
322	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
323	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
324	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
325	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
326	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
327	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
328	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
329	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
330	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
331	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
332	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
333	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
334	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
335	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
336	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
337	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
338	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
339	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
340	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
341	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
342	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
343	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Appendix A3 2045 Socio-economic Data

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
1	49	19	26	0	0	146	1,127	215
2	0	0	0	0	0	36	1,079	977
3	8	3	3	0	0	200	339	53
4	10	3	4	0	0	39	362	1689
5	10	5	5	0	0	101	1,973	658
6	20	6	7	0	0	2	144	146
7	61	17	20	0	0	61	93	54
8	34	9	12	0	0	191	68	65
9	112	31	37	0	0	101	821	505
10	105	30	36	0	0	68	110	154
11	20	0	19	0	0	8	163	137
12	22	6	7	0	0	44	244	623
13	8	3	3	0	0	3	430	0
14	57	15	19	0	0	6	263	42
15	9	2	0	0	350	7	176	874
16	7	60	200	0	0	22	46	164
17	0	0	0	0	0	0	0	0
18	0	0	0	0	0	250	352	8
19	4	0	0	0	0	13	168	1569
20	19	8	0	0	0	43	58	289
21	0	0	0	0	0	183	612	4847
22	0	0	0	0	0	272	11	1317
23	0	0	0	0	0	0	0	499
24	0	0	0	0	0	20	114	97
25	38	10	10	0	0	12	20	49
26	132	72	26	0	0	8	47	50
27	134	95	31	0	0	23	49	36
28	215	124	51	0	639	7	80	1
29	213	67	27	0	2,264	19	495	503
30	199	95	74	0	0	28	361	275
31	123	83	77	0	0	30	328	11
32	26	11	23	0	0	35	1,613	445
33	155	72	143	0	0	14	218	157
34	116	152	313	0	0	118	302	2
35	146	137	105	0	0	76	153	12
36	90	50	83	0	0	128	279	82
37	374	179	466	0	0	86	168	49
38	324	119	173	0	0	13	23	10
39	206	86	59	0	0	25	222	107
40	101	48	81	0	0	13	15	87
41	225	142	238	0	0	31	190	16
42	144	67	87	0	0	1	8	8
43	301	136	81	0	0	9	260	48
44	234	134	92	0	0	9	121	425
45	413	100	70	0	0	4	83	527
46	185	54	34	0	0	11	21	27
47	524	65	31	0	0	0	0	14
48	527	161	74	0	0	14	56	8
49	110	69	30	0	130	334	1,517	3425
50	196	110	95	0	0	9	67	1
51	148	72	93	0	304	3	208	11
52	287	155	60	0	0	37	6	7
53	96	83	53	0	0	6	19	11

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
54	120	72	57	0	0	7	17	9
55	146	139	88	0	0	145	645	105
56	358	327	337	0	0	57	376	256
57	72	119	122	0	0	2247	900	204
58	107	106	81	0	0	66	111	74
59	69	54	76	0	0	810	96	28
60	293	254	255	0	0	192	315	29
61	16	12	5	0	0	1807	1,137	130
62	56	97	143	0	0	80	215	52
63	133	87	108	0	0	114	462	184
64	305	223	135	0	0	50	267	154
65	185	103	63	0	0	46	80	98
66	19	20	42	0	0	32	270	238
67	131	140	286	0	0	26	39	215
68	98	177	263	0	0	167	141	32
69	99	147	325	0	0	89	386	8
70	56	135	205	0	0	189	384	3
71	25	14	32	0	0	6	3,664	13
72	96	64	157	0	0	6	25	0
73	39	65	196	0	0	170	242	34
74	220	69	29	0	0	57	196	49
75	104	40	14	0	0	210	421	324
76	214	82	29	0	0	569	924	241
77	141	44	17	0	0	61	955	1203
78	138	198	171	0	0	45	157	33
79	349	207	175	0	0	9	50	20
80	0	0	0	0	0	1694	168	35
81	301	268	180	0	0	210	756	107
82	0	0	0	0	0	12	146	279
83	215	160	71	0	0	200	233	739
84	478	113	100	0	0	215	149	160
85	191	123	115	0	378	6	1,691	282
86	400	157	135	0	0	6	171	3
87	209	157	123	0	0	9	162	54
88	459	266	135	0	0	70	251	75
89	346	106	52	0	0	22	79	5
90	282	129	69	0	0	194	218	70
91	320	155	123	0	0	27	30	0
92	173	110	82	0	0	0	10	0
93	9	2	4	0	0	11	19	560
94	194	51	75	0	0	8	48	11
95	50	28	18	0	0	12	70	59
96	215	89	68	0	0	18	31	60
97	176	77	57	0	0	44	156	284
98	170	96	74	0	0	4	101	0
99	125	75	20	0	0	11	70	75
100	122	67	17	0	0	0	136	0
101	97	44	12	0	0	0	39	188
102	22	4	0	0	0	16	27	436
103	268	48	4	0	0	21	15	150
104	0	0	0	0	0	25	41	40
105	120	77	63	0	0	3	42	66
106	217	138	65	0	0	7	62	255
107	219	92	42	0	0	15	26	377
108	227	73	42	0	220	60	341	203

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
109	91	34	17	0	0	2	8	0
110	272	116	57	0	0	61	39	55
111	334	48	18	0	0	4	66	0
112	140	27	25	0	0	1	4	27
113	65	12	11	0	0	12	9	8
114	173	106	70	0	0	3	28	39
115	68	28	11	0	0	29	11	186
116	130	10	12	0	0	2	4	7
117	246	124	141	0	0	13	13	60
118	264	216	109	0	0	116	96	266
119	0	0	0	0	0	0	50	0
120	52	35	28	0	0	7	180	922
121	0	0	0	0	0	43	52	1076
122	416	290	315	0	0	125	198	132
123	75	144	90	0	0	13	20	67
124	141	97	82	0	0	80	36	89
125	301	161	128	0	0	791	102	48
126	513	123	137	0	0	266	420	219
127	22	50	74	0	0	9	171	0
128	5	10	16	0	0	16	26	29
129	58	33	39	0	0	64	259	10
130	262	215	312	0	0	131	286	185
131	277	196	270	0	0	63	191	109
132	128	74	87	0	0	31	706	25
133	95	63	107	0	0	56	88	72
134	287	185	319	0	0	136	358	130
135	110	66	91	0	0	108	487	1894
136	130	75	246	0	0	108	427	85
137	162	149	242	0	0	118	80	8
138	65	92	275	0	0	37	339	55
139	133	207	713	0	0	172	124	135
140	123	97	341	0	0	280	380	235
141	144	185	353	650	1,496	369	1,517	53
142	0	0	0	0	0	61	3,095	185
143	327	487	470	0	0	420	790	10
144	105	236	812	0	0	467	739	326
145	580	403	603	0	0	324	2,010	135
146	305	495	345	0	0	41	1,598	120
147	189	94	25	0	35	16	272	136
148	768	661	501	0	1,241	1197	2,753	870
149	160	136	103	0	0	158	625	253
150	658	213	191	0	0	134	550	37
151	64	93	278	0	0	387	1,924	659
152	162	207	412	0	0	92	593	46
153	89	159	325	0	0	139	256	52
154	496	613	901	0	0	426	533	181
155	159	231	366	0	0	209	818	930
156	139	187	292	0	0	347	1,069	1533
157	87	130	225	0	0	147	253	384
158	47	74	211	0	0	36	47	45
159	197	208	315	0	0	59	117	105
160	114	113	77	0	0	73	68	50
161	203	180	206	0	0	126	155	117
162	128	137	206	0	0	163	146	65
163	285	159	155	0	0	40	45	26

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
164	229	154	179	0	0	64	141	87
165	120	165	147	0	0	80	490	225
166	217	189	214	0	0	84	85	63
167	136	56	43	0	0	93	183	24
168	117	187	380	0	0	48	362	40
169	314	502	1,151	0	0	138	791	189
170	174	231	1,214	0	0	86	223	83
171	554	437	1,006	0	0	98	609	60
172	226	498	667	0	0	99	438	32
173	554	636	754	0	0	250	573	38
174	227	409	1,419	0	0	1026	1,948	62
175	489	527	777	0	35	812	7,308	160
176	806	544	428	0	0	465	456	54
177	488	390	495	0	0	193	904	60
178	0	0	3	5000	20,000	150	2,713	16
179	163	92	278	0	0	18	45	29
180	433	151	86	0	0	49	224	0
181	407	266	255	0	0	49	74	44
182	109	230	372	0	0	9	213	16
183	251	334	517	0	0	204	178	52
184	56	123	231	0	0	44	69	5
185	76	124	184	0	0	96	140	355
186	311	423	627	0	0	209	437	259
187	163	269	674	0	0	184	274	110
188	101	94	114	0	0	40	50	96
189	180	184	236	0	0	131	201	201
190	26	25	29	0	0	11	112	18
191	68	69	85	0	0	108	313	172
192	97	115	297	0	0	204	201	164
193	115	150	376	0	0	1218	375	552
194	183	234	545	0	0	383	392	365
195	195	316	701	0	0	65	125	167
196	407	402	467	0	0	123	249	493
197	19	9	8	0	0	69	119	652
198	221	98	74	0	0	90	465	177
199	37	33	45	0	0	398	104	70
200	21	16	28	0	0	366	420	1250
201	98	213	695	0	0	135	386	78
202	352	502	2,185	0	0	1643	1,953	347
203	494	397	974	0	0	1630	269	275
204	174	131	856	0	0	204	229	101
205	98	148	590	0	0	46	228	59
206	174	212	916	0	0	491	376	337
207	76	180	482	0	0	73	91	77
208	162	195	223	0	0	92	70	156
209	254	229	149	0	0	312	580	226
210	26	22	13	0	0	2462	936	913
211	148	181	528	0	0	134	403	770
212	20	16	37	0	0	260	368	1432
213	38	31	69	0	0	209	589	1077
214	107	84	188	0	0	207	518	571
215	83	65	146	0	0	40	68	247
216	97	131	230	0	0	287	337	473
217	51	83	106	0	0	354	267	838
218	0	0	0	0	0	382	260	1270

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
219	355	188	305	0	0	421	482	1620
220	152	83	130	0	0	149	282	400
221	321	469	683	0	0	193	557	477
222	96	105	140	0	0	73	113	97
223	399	364	465	0	0	50	196	137
224	647	547	626	0	0	216	720	267
225	526	366	429	0	0	497	197	409
226	198	107	203	0	0	183	117	301
227	82	117	224	0	0	270	255	482
228	384	239	495	0	0	340	460	215
229	337	297	570	0	0	393	386	129
230	283	211	374	0	0	50	65	237
231	68	47	79	0	0	10	40	187
232	669	1022	1834	0	0	127	82	138
233	76	139	210	0	0	79	67	87
234	92	131	325	0	0	164	491	211
235	261	374	653	0	0	76	121	187
236	196	267	571	0	0	101	237	160
237	36	83	223	0	0	65	60	189
238	54	72	151	0	0	49	46	22
239	309	476	1125	0	0	58	234	27
240	187	253	1,127	0	0	148	102	82
241	201	417	1519	0	0	45	96	52
242	157	216	807	0	0	308	102	165
243	158	142	207	0	0	123	153	262
244	73	124	400	0	0	82	355	63
245	161	145	246	0	0	21	24	38
246	292	257	452	0	0	81	619	117
247	152	102	209	0	0	0	0	11
248	222	146	303	0	0	17	16	26
249	362	304	507	0	0	69	38	289
250	130	133	244	0	0	12	90	101
251	120	126	234	0	0	67	1,723	90
252	79	88	146	0	0	1	9	60
253	18	17	33	0	0	8	19	24
254	95	99	176	0	0	61	10	12
255	20	24	36	0	0	0	8	0
256	47	52	87	0	0	23	8	192
257	19	24	33	0	0	12	30	20
258	98	199	320	0	0	360	419	372
259	75	122	175	325	2,500	120	121	213
260	0	0	0	0	0	17	76	62
261	1	11	3	0	0	702	248	112
262	198	210	337	0	0	273	346	184
263	289	187	225	0	0	521	615	374
264	102	108	173	0	0	376	143	21
265	92	145	194	0	0	222	257	64
266	116	176	209	0	0	225	374	94
267	91	121	72	0	0	0	37	32
268	0	0	0	0	0	1082	69	750
269	218	209	262	0	0	33	434	272
270	119	174	284	0	0	158	446	269
271	135	196	320	0	0	472	325	349
272	125	258	874	0	0	119	121	234
273	108	74	59	0	0	200	29	263

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
274	65	82	232	0	0	33	62	46
275	96	105	316	0	0	22	51	139
276	25	27	83	0	0	0	4	0
277	47	67	149	0	0	13	137	184
278	64	57	168	0	0	50	215	316
279	177	145	404	0	0	76	157	680
280	14	13	36	0	0	0	30	1806
281	3	3	4	0	0	0	0	76
282	74	51	87	0	0	0	168	101
283	165	152	251	0	0	95	416	470
284	0	0	0	0	0	20	237	203
285	100	67	28	0	0	45	647	9
286	130	171	272	0	0	151	63	113
287	105	84	125	0	0	481	787	56
288	71	76	108	0	0	153	639	1167
289	175	217	312	0	0	80	72	68
290	133	174	284	0	0	73	35	85
291	163	163	296	0	0	228	58	282
292	66	67	223	0	0	59	12	149
293	194	81	203	0	0	27	243	102
294	103	143	330	0	0	39	16	17
295	68	84	227	0	0	70	4	90
296	96	83	145	0	0	219	9	7
297	39	36	76	0	0	216	63	9
298	85	80	177	0	0	279	428	42
299	79	69	128	0	0	138	146	30
300	112	154	222	0	0	8	130	60
301	180	122	204	0	0	5	93	67
302	218	193	315	0	0	13	176	98
303	336	182	124	0	0	276	360	742
304	130	87	101	0	0	60	177	920
305	118	117	159	0	0	138	310	388
306	45	32	34	0	0	108	242	229
307	150	97	81	0	0	414	37	361
308	42	27	31	0	0	7	20	75
309	36	33	63	0	0	9	16	12
310	29	50	130	0	0	8	18	77
311	82	146	414	0	0	0	202	137
312	21	18	20	0	0	238	423	225
313	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
314	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
315	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
316	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
317	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
318	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
319	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
320	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
321	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
322	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
323	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
324	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
325	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
326	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
327	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
328	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Zones	Households by Income Range			College		Employment		
	Low	Medium	High	Dorms	Students	Retail	Service	Other
329	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
330	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
331	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
332	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
333	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
334	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
335	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
336	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
337	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
338	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
339	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
340	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
341	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
342	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
343	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Appendix A4 2015 Trip Ends

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
1	6	934	28	1,948	1,849	0	723
2	0	1,645	0	2,448	2,526	0	1,143
3	9	348	43	1,323	1,034	0	341
4	11	1,305	52	1,143	1,379	0	804
5	0	2,101	0	4,085	3,938	0	1,585
6	22	230	100	338	354	0	165
7	62	156	287	743	556	0	186
8	36	255	166	1,772	1,210	0	351
9	117	218	540	924	742	0	258
10	103	261	478	942	742	0	275
11	0	222	2	348	350	0	156
12	23	292	104	503	508	0	219
13	7	340	32	710	698	0	267
14	59	182	273	433	407	0	164
15	6	721	27	639	765	0	445
16	0	151	0	268	235	0	108
17	0	0	0	0	0	0	0
18	0	47	0	85	87	0	35
19	2	743	9	719	829	0	465
20	1	131	4	317	254	0	104
21	0	754	0	976	960	0	498
22	0	1,002	0	1,776	1,546	0	718
23	0	393	0	231	327	0	226
24	0	113	0	155	167	0	77
25	35	24	161	60	56	0	29
26	146	61	678	281	242	0	107
27	168	10	779	239	190	0	82
28	255	67	1,180	1,385	411	0	231
29	183	800	847	4,565	1,409	0	863
30	248	522	1,149	1,234	1,138	0	488
31	205	290	952	1,006	868	0	331
32	45	1,329	209	2,896	2,787	0	1,060
33	281	188	1,301	604	527	0	248
34	504	332	2,337	1,941	1,488	0	546
35	289	189	1,339	1,201	910	0	323
36	169	384	786	1,727	1,324	0	453
37	696	238	3,225	1,733	1,331	0	526
38	429	36	1,990	661	515	0	219
39	228	278	1,058	899	782	0	317
40	171	90	793	363	301	0	138
41	469	186	2,175	1,068	871	0	357
42	213	13	987	273	218	0	100
43	336	249	1,559	937	827	0	338
44	314	436	1,458	844	817	0	413
45	349	483	1,617	893	878	0	452
46	166	46	771	364	288	0	115
47	332	11	1,541	522	415	0	164
48	456	61	2,114	842	667	0	263
49	127	2,497	589	3,991	3,766	0	1,784
50	280	61	1,300	514	416	0	173
51	225	175	1,043	1,039	555	0	260
52	323	27	1,497	693	506	0	188
53	166	8	770	206	165	0	76
54	174	8	807	236	186	0	82

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
55	268	304	1,240	977	864	0	352
56	778	288	3,608	1,383	1,157	0	533
57	253	803	1,175	3,346	2,591	0	887
58	220	197	1,022	1,003	769	0	283
59	153	635	710	6,166	4,051	0	1,098
60	609	341	2,824	2,615	1,909	0	660
61	20	1,999	93	16,042	10,734	0	2,932
62	254	188	1,177	1,094	820	0	299
63	246	595	1,139	2,023	1,664	0	620
64	464	289	2,153	1,291	1,057	0	435
65	236	176	1,094	846	666	0	258
66	68	332	317	663	610	0	269
67	473	214	2,194	818	688	0	339
68	463	267	2,148	2,074	1,490	0	514
69	504	262	2,339	1,591	1,227	0	468
70	349	335	1,619	1,259	1,073	0	425
71	55	2,411	257	4,884	4,861	0	1,874
72	261	24	1,209	353	279	0	128
73	275	268	1,277	1,216	964	0	362
74	190	237	880	1,070	854	0	305
75	96	751	445	2,691	2,103	0	735
76	197	1,206	915	6,255	4,559	0	1,423
77	120	1,741	555	2,721	2,737	0	1,257
78	403	173	1,868	1,021	812	0	326
79	514	68	2,384	794	635	0	276
80	0	1,491	0	14,378	9,374	0	2,463
81	546	842	2,530	3,607	2,871	0	1,024
82	0	289	0	406	417	0	197
83	304	785	1,409	2,614	2,068	0	798
84	421	400	1,951	2,635	1,914	0	639
85	309	1,556	1,434	3,720	3,152	0	1,325
86	456	138	2,116	884	745	0	308
87	353	171	1,639	739	641	0	278
88	572	311	2,651	1,728	1,381	0	531
89	303	81	1,405	719	567	0	215
90	305	215	1,412	1,258	974	0	349
91	404	45	1,875	770	583	0	230
92	256	8	1,186	319	254	0	115
93	8	269	37	168	232	0	158
94	209	29	968	329	269	0	114
95	62	70	288	173	164	0	75
96	244	86	1,132	536	428	0	178
97	205	377	949	988	860	0	370
98	235	83	1,089	475	402	0	167
99	140	123	650	419	362	0	153
100	129	107	599	385	348	0	139
101	94	178	435	276	284	0	151
102	11	322	53	207	282	0	191
103	169	116	784	428	361	0	159
104	0	0	0	0	0	0	0
105	184	75	855	301	266	0	127
106	281	246	1,305	590	551	0	276
107	221	283	1,024	567	535	0	274
108	210	475	973	1,719	1,214	0	497

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
109	88	8	409	147	116	0	47
110	281	98	1,305	715	555	0	216
111	215	55	998	470	387	0	147
112	114	25	529	187	155	0	68
113	51	6	238	131	94	0	33
114	240	55	1,113	377	314	0	142
115	66	178	307	434	365	0	161
116	82	10	380	153	121	0	47
117	363	68	1,684	582	464	0	207
118	412	376	1,911	1,729	1,332	0	515
119	0	39	0	79	79	0	30
120	67	667	311	529	665	0	420
121	0	815	0	574	735	0	480
122	750	208	3,479	1,737	1,328	0	527
123	213	38	988	251	210	0	109
124	266	45	1,231	346	289	0	140
125	405	722	1,877	7,196	4,773	0	1,336
126	417	607	1,933	2,811	2,178	0	768
127	109	20	505	148	124	0	59
128	24	2	110	24	20	0	11
129	95	167	439	838	640	0	214
130	508	123	2,355	949	755	0	321
131	532	61	2,469	719	583	0	268
132	211	234	978	815	716	0	280
133	199	44	924	416	317	0	129
134	618	312	2,864	1,854	1,443	0	557
135	200	1,763	928	2,095	2,241	0	1,205
136	375	297	1,741	1,551	1,195	0	444
137	449	148	2,082	1,524	1,089	0	384
138	388	278	1,797	1,011	883	0	376
139	969	258	4,492	2,279	1,673	0	675
140	489	513	2,267	3,292	2,397	0	795
141	939	965	4,352	6,420	3,514	0	1,439
142	0	2,617	0	5,423	5,280	0	2,027
143	1,037	560	4,807	5,002	3,537	0	1,175
144	1,079	1,027	5,004	5,653	4,206	0	1,504
145	1,226	1,897	5,683	7,084	5,900	0	2,186
146	902	585	4,183	2,252	1,957	0	830
147	191	344	888	964	831	0	346
148	1,418	3,467	6,572	17,810	12,294	0	4,243
149	293	815	1,356	2,746	2,255	0	833
150	679	528	3,148	2,739	2,192	0	797
151	392	2,280	1,818	6,721	5,664	0	2,098
152	670	528	3,106	2,202	1,837	0	728
153	508	337	2,357	2,012	1,519	0	557
154	1,663	776	7,711	5,438	4,066	0	1,517
155	624	789	2,893	2,496	2,083	0	878
156	508	1,377	2,356	3,159	2,816	0	1,228
157	350	117	1,622	412	368	0	207
158	274	32	1,269	287	239	0	128
159	577	20	2,677	618	494	0	247
160	220	55	1,020	657	471	0	169
161	433	90	2,007	704	569	0	253
162	351	26	1,628	426	341	0	163

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
163	422	42	1,955	758	573	0	232
164	410	90	1,901	772	609	0	255
165	338	369	1,566	1,239	1,046	0	434
166	471	54	2,182	926	681	0	271
167	152	196	707	1,126	845	0	279
168	593	133	2,751	844	710	0	337
169	1,750	576	8,114	3,407	2,738	0	1,197
170	1,526	175	7,074	1,985	1,562	0	755
171	1,659	469	7,693	3,082	2,506	0	1,081
172	1,201	404	5,568	2,531	2,031	0	851
173	1,558	568	7,225	4,352	3,297	0	1,253
174	1,918	2,360	8,891	13,246	9,874	0	3,341
175	1,458	5,049	6,762	14,048	12,580	0	4,746
176	1,265	593	5,867	5,719	4,050	0	1,344
177	1,056	631	4,898	3,517	2,776	0	1,048
178	2,501	2,151	11,597	28,894	7,581	0	4,351
179	437	12	2,024	462	368	0	184
180	407	112	1,888	770	653	0	268
181	667	69	3,095	983	772	0	342
182	623	159	2,889	912	783	0	368
183	918	221	4,255	2,450	1,772	0	664
184	361	35	1,676	526	401	0	182
185	312	223	1,445	655	562	0	279
186	1,119	412	5,189	3,048	2,297	0	891
187	932	163	4,322	1,779	1,333	0	558
188	228	48	1,055	295	246	0	124
189	458	46	2,123	686	526	0	234
190	61	74	282	212	198	0	82
191	161	221	748	795	662	0	255
192	440	274	2,038	1,905	1,379	0	491
193	500	878	2,320	5,574	3,896	0	1,250
194	814	431	3,774	3,138	2,272	0	823
195	709	75	3,289	752	621	0	327
196	970	266	4,497	1,626	1,317	0	604
197	13	453	58	364	442	0	276
198	254	309	1,178	1,191	975	0	374
199	87	382	404	3,366	2,235	0	619
200	37	1,368	173	3,524	2,852	0	1,127
201	923	254	4,281	1,670	1,338	0	591
202	2,821	1,407	13,081	10,665	7,744	0	2,785
203	1,567	1,676	7,265	15,548	10,474	0	3,139
204	1,073	294	4,977	2,629	1,937	0	765
205	772	171	3,581	1,033	871	0	429
206	1,190	606	5,516	4,950	3,518	0	1,233
207	675	51	3,129	913	691	0	324
208	464	213	2,151	1,300	984	0	394
209	451	525	2,092	3,394	2,475	0	804
210	35	1,914	163	13,491	9,100	0	2,586
211	680	544	3,153	1,291	1,202	0	623
212	37	1,261	172	2,209	1,984	0	914
213	73	834	339	1,032	1,101	0	570
214	285	580	1,322	1,576	1,352	0	567
215	236	149	1,095	345	324	0	183
216	355	315	1,647	1,595	1,189	0	450

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
217	143	502	662	1,120	942	0	427
218	0	481	0	1,251	986	0	392
219	596	1,125	2,761	3,162	2,591	0	1,116
220	246	171	1,140	478	431	0	214
221	1,208	479	5,599	2,077	1,771	0	835
222	154	48	713	390	293	0	115
223	959	184	4,448	1,402	1,152	0	534
224	1,378	494	6,391	3,098	2,481	0	1,017
225	950	342	4,405	3,539	2,491	0	863
226	352	9	1,631	397	316	0	152
227	313	274	1,449	604	562	0	299
228	787	166	3,647	1,386	1,075	0	472
229	907	285	4,206	2,688	1,946	0	721
230	604	41	2,801	832	644	0	291
231	124	94	575	210	197	0	108
232	439	127	2,033	799	633	0	284
233	193	82	893	637	467	0	172
234	446	285	2,066	1,394	1,095	0	438
235	868	138	4,023	1,114	901	0	447
236	797	242	3,697	1,516	1,213	0	530
237	305	126	1,414	502	422	0	210
238	208	26	966	290	228	0	107
239	1,135	111	5,263	1,255	1,031	0	526
240	1,450	82	6,723	1,546	1,221	0	633
241	882	60	4,090	874	711	0	383
242	351	239	1,627	2,232	1,531	0	486
243	382	197	1,772	724	611	0	294
244	496	155	2,301	921	742	0	330
245	425	35	1,972	525	416	0	200
246	759	414	3,517	1,800	1,548	0	647
247	355	0	1,647	368	289	0	144
248	545	33	2,525	796	602	0	265
249	911	35	4,222	1,034	816	0	398
250	398	14	1,846	408	326	0	168
251	389	39	1,805	447	362	0	183
252	248	42	1,149	278	234	0	124
253	54	13	252	69	59	0	30
254	226	9	1,047	285	217	0	102
255	54	3	252	61	49	0	24
256	136	7	633	145	117	0	59
257	10	8	47	26	24	0	10
258	525	244	2,434	1,245	986	0	421
259	295	28	1,366	2,565	315	0	302
260	0	64	0	91	98	0	44
261	5	726	24	5,913	3,941	0	1,074
262	611	510	2,833	2,631	2,016	0	749
263	509	675	2,358	3,742	2,764	0	937
264	313	234	1,453	1,900	1,342	0	435
265	355	156	1,647	1,247	913	0	329
266	411	261	1,907	1,606	1,202	0	442
267	211	3	980	238	189	0	90
268	0	1,094	0	8,352	5,540	0	1,545
269	515	215	2,388	926	814	0	369
270	405	315	1,877	1,372	1,098	0	440

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
271	469	360	2,173	2,186	1,607	0	577
272	981	47	4,548	907	731	0	407
273	134	33	621	200	165	0	79
274	333	22	1,543	398	311	0	152
275	292	93	1,353	343	304	0	170
276	100	2	463	98	78	0	41
277	218	145	1,009	430	388	0	187
278	232	200	1,076	650	570	0	247
279	565	316	2,621	1,066	916	0	447
280	33	1,145	155	706	978	0	672
281	6	39	26	29	37	0	25
282	136	92	630	269	249	0	118
283	454	491	2,107	1,389	1,193	0	544
284	0	362	0	633	612	0	263
285	130	551	604	1,558	1,391	0	513
286	431	79	1,997	709	551	0	246
287	243	710	1,127	4,749	3,341	0	1,000
288	198	719	916	1,821	1,552	0	642
289	549	56	2,543	818	628	0	281
290	465	36	2,156	598	463	0	220
291	341	98	1,580	938	677	0	257
292	304	42	1,410	310	259	0	144
293	279	67	1,292	449	378	0	168
294	465	9	2,157	490	380	0	194
295	326	27	1,512	495	367	0	164
296	235	83	1,088	1,059	721	0	234
297	95	78	443	720	491	0	152
298	243	213	1,128	1,101	851	0	310
299	199	55	921	367	293	0	128
300	375	19	1,739	420	335	0	166
301	354	23	1,641	399	323	0	159
302	525	84	2,435	754	614	0	282
303	378	512	1,753	2,093	1,654	0	620
304	203	594	942	895	885	0	466
305	293	235	1,358	663	592	0	282
306	57	167	266	903	664	0	210
307	166	86	772	314	266	0	128
308	39	17	180	70	62	0	28
309	90	12	416	105	88	0	44
310	156	45	725	178	157	0	88
311	547	149	2,537	724	629	0	317
312	39	387	180	1,335	1,048	0	369
313	0	0	0	0	0	0	0
314	0	0	0	0	0	0	0
315	0	0	0	0	0	0	0
316	0	0	0	0	0	0	0
317	0	0	0	0	0	0	0
318	0	0	0	0	0	0	0
319	0	0	0	0	0	0	0
320	0	0	0	0	0	0	0
321	0	0	0	0	0	0	0
322	0	0	0	0	0	0	0
323	0	0	0	0	0	0	0
324	0	0	0	0	0	0	0

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
325	0	0	0	0	0	0	0
326	0	0	0	0	0	40,500	0
327	0	0	0	0	0	16,580	0
328	0	0	0	0	0	5,077	0
329	0	0	0	0	0	2,586	0
330	0	0	0	0	0	5,830	0
331	0	0	0	0	0	22,062	0
332	0	0	0	0	0	1,100	0
333	0	0	0	0	0	6,561	0
334	0	0	0	0	0	3,200	0
335	0	0	0	0	0	1,720	0
336	0	0	0	0	0	4,563	0
337	0	0	0	0	0	4,850	0
338	0	0	0	0	0	10,350	0
339	0	0	0	0	0	6,160	0
340	0	0	0	0	0	5,550	0
341	0	0	0	0	0	4,520	0
342	0	0	0	0	0	12,877	0
343	0	0	0	0	0	11,297	0

Appendix A5 2045 Trip Ends

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
1	66	844	304	2,427	2,115	0	1,048
2	0	1,186	0	1,878	1,939	0	1,172
3	9	336	43	1,713	1,266	0	532
4	11	1,185	52	1,295	1,454	0	1,065
5	14	1,549	65	3,270	3,134	0	1,683
6	22	166	100	259	272	0	172
7	63	118	294	583	440	0	207
8	36	184	166	1,360	929	0	371
9	117	809	540	1,929	1,749	0	954
10	111	188	516	731	576	0	300
11	29	175	136	321	318	0	192
12	23	517	104	818	806	0	515
13	9	246	43	547	538	0	277
14	59	176	273	428	408	0	224
15	6	599	27	946	685	0	562
16	260	132	1,208	425	362	0	265
17	0	0	0	0	0	0	0
18	0	346	0	2,023	1,458	0	587
19	2	993	9	845	1,046	0	847
20	15	221	71	464	406	0	240
21	0	3,200	0	3,626	3,925	0	2,877
22	0	907	0	2,217	1,795	0	1,009
23	0	283	0	177	251	0	230
24	0	131	0	300	268	0	145
25	36	46	169	155	127	0	73
26	147	60	684	272	230	0	146
27	172	61	798	385	302	0	175
28	255	50	1,180	1,070	322	0	270
29	183	577	847	3,502	1,082	0	914
30	248	377	1,149	947	873	0	528
31	205	209	952	772	666	0	362
32	45	1,187	209	2,365	2,342	0	1,282
33	281	221	1,301	644	585	0	377
34	504	239	2,337	1,489	1,143	0	617
35	289	137	1,339	922	698	0	365
36	169	277	786	1,325	1,016	0	487
37	808	172	3,744	1,420	1,093	0	674
38	430	26	1,992	508	396	0	271
39	228	201	1,058	689	600	0	350
40	171	65	793	279	231	0	159
41	469	134	2,175	819	668	0	417
42	213	10	987	209	167	0	125
43	336	180	1,559	719	635	0	384
44	314	315	1,458	648	627	0	456
45	349	348	1,617	685	674	0	499
46	166	33	771	279	221	0	135
47	332	8	1,541	401	318	0	204
48	456	44	2,114	646	512	0	319
49	139	2,992	643	5,448	5,028	0	3,095
50	280	44	1,300	395	320	0	207
51	225	126	1,043	797	426	0	292
52	323	28	1,497	566	415	0	240
53	167	20	776	213	170	0	115
54	174	19	807	227	179	0	119

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
55	273	508	1,264	1,979	1,614	0	807
56	784	391	3,635	1,561	1,330	0	848
57	257	1,901	1,192	15,703	10,597	0	4,060
58	220	142	1,022	769	590	0	316
59	155	530	721	5,424	3,565	0	1,334
60	609	304	2,824	2,128	1,587	0	811
61	22	1,743	104	12,975	8,893	0	3,411
62	254	197	1,177	977	763	0	404
63	246	431	1,139	1,560	1,283	0	668
64	464	267	2,153	1,119	938	0	561
65	236	127	1,094	649	511	0	291
66	69	306	320	666	617	0	359
67	473	159	2,194	645	542	0	404
68	463	193	2,148	1,591	1,144	0	582
69	504	274	2,339	1,401	1,122	0	629
70	349	327	1,619	1,924	1,441	0	693
71	57	2,089	262	4,507	4,483	0	2,322
72	261	18	1,209	271	214	0	159
73	275	253	1,277	1,581	1,159	0	552
74	190	171	880	821	655	0	336
75	96	542	445	2,064	1,614	0	771
76	197	983	915	5,040	3,741	0	1,626
77	120	1,259	555	2,097	2,108	0	1,305
78	403	133	1,868	812	646	0	389
79	514	45	2,384	592	474	0	332
80	0	1,076	0	11,030	7,195	0	2,588
81	546	609	2,530	2,769	2,206	0	1,118
82	0	248	0	352	365	0	237
83	304	665	1,411	2,105	1,699	0	943
84	421	297	1,953	2,050	1,492	0	718
85	309	1,122	1,434	2,854	2,420	0	1,396
86	456	102	2,116	687	580	0	368
87	353	128	1,639	584	505	0	329
88	572	225	2,651	1,325	1,060	0	608
89	303	60	1,405	559	441	0	256
90	309	273	1,433	1,833	1,338	0	622
91	404	32	1,875	590	448	0	279
92	256	6	1,186	245	195	0	145
93	10	335	47	301	357	0	291
94	211	38	979	317	257	0	163
95	65	80	301	243	212	0	124
96	244	62	1,132	411	328	0	208
97	205	275	949	768	667	0	405
98	235	60	1,089	364	309	0	197
99	140	88	650	322	278	0	172
100	129	77	599	296	267	0	157
101	94	129	435	211	218	0	164
102	14	272	63	306	330	0	249
103	169	105	786	410	341	0	210
104	0	60	0	223	172	0	80
105	184	63	855	259	227	0	160
106	281	184	1,305	478	442	0	321
107	221	237	1,026	486	460	0	336
108	210	343	973	1,319	932	0	535

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
109	88	6	409	113	89	0	58
110	281	88	1,305	740	549	0	296
111	215	40	998	361	297	0	175
112	114	18	529	143	119	0	82
113	52	16	241	146	108	0	56
114	240	40	1,113	290	241	0	171
115	66	128	307	333	280	0	172
116	82	7	380	117	93	0	57
117	363	49	1,684	446	356	0	251
118	412	271	1,911	1,327	1,023	0	574
119	0	28	0	60	60	0	31
120	82	629	380	662	766	0	590
121	0	664	0	719	780	0	590
122	759	258	3,518	1,735	1,332	0	770
123	245	57	1,137	328	266	0	190
124	230	116	1,068	790	578	0	303
125	405	534	1,880	5,567	3,700	0	1,459
126	485	513	2,247	2,776	2,100	0	1,022
127	128	102	593	357	316	0	184
128	27	40	126	164	127	0	66
129	95	189	439	807	646	0	310
130	623	341	2,887	1,751	1,373	0	779
131	571	206	2,645	1,146	917	0	562
132	211	432	978	1,243	1,136	0	608
133	207	123	961	658	506	0	278
134	618	354	2,864	1,851	1,454	0	805
135	200	1,412	928	2,119	2,117	0	1,438
136	379	352	1,756	1,523	1,228	0	657
137	449	117	2,082	1,206	864	0	458
138	392	244	1,817	940	805	0	487
139	974	244	4,517	1,968	1,454	0	877
140	492	508	2,283	2,687	2,011	0	1,002
141	972	1,100	4,505	6,646	4,043	0	2,185
142	0	1,895	0	4,187	4,074	0	2,098
143	1,037	692	4,807	4,457	3,331	0	1,646
144	1,088	869	5,043	4,724	3,556	0	1,832
145	1,228	1,400	5,694	5,553	4,621	0	2,429
146	902	998	4,183	2,962	2,730	0	1,580
147	191	240	886	712	617	0	366
148	1,418	2,734	6,572	13,823	9,653	0	4,746
149	293	588	1,356	2,107	1,731	0	892
150	682	409	3,161	2,210	1,766	0	934
151	395	1,684	1,834	5,302	4,462	0	2,262
152	673	415	3,122	1,817	1,509	0	868
153	509	254	2,362	1,580	1,195	0	644
154	1,668	647	7,735	4,710	3,497	0	1,896
155	643	1,110	2,982	3,133	2,693	0	1,570
156	521	1,673	2,416	4,443	3,797	0	2,143
157	381	445	1,765	1,662	1,325	0	743
158	302	73	1,401	514	394	0	255
159	589	159	2,733	1,015	798	0	512
160	225	108	1,044	760	560	0	291
161	456	226	2,113	1,409	1,060	0	574
162	386	212	1,789	1,540	1,116	0	558

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
163	424	63	1,968	701	533	0	327
164	419	166	1,943	968	759	0	444
165	343	451	1,590	1,457	1,250	0	704
166	478	132	2,216	1,057	791	0	456
167	154	170	715	973	734	0	346
168	603	255	2,794	1,194	997	0	619
169	1,754	634	8,134	3,158	2,604	0	1,667
170	1,536	222	7,123	1,881	1,478	0	1,067
171	1,664	435	7,716	2,656	2,170	0	1,406
172	1,204	323	5,581	2,060	1,650	0	1,045
173	1,561	488	7,236	3,542	2,715	0	1,550
174	1,919	1,722	8,896	10,233	7,635	0	3,693
175	1,466	4,696	6,799	15,236	13,132	0	6,562
176	1,265	553	5,867	4,673	3,384	0	1,668
177	1,061	656	4,920	3,220	2,604	0	1,429
178	2,973	1,633	13,785	28,710	6,408	0	5,754
179	441	52	2,047	520	411	0	295
180	416	155	1,928	1,011	808	0	445
181	673	95	3,118	1,010	779	0	499
182	625	135	2,898	774	659	0	470
183	927	246	4,299	2,239	1,634	0	908
184	367	67	1,700	628	473	0	295
185	328	335	1,520	1,153	935	0	558
186	1,142	513	5,295	2,822	2,201	0	1,282
187	997	322	4,624	2,250	1,698	0	992
188	242	105	1,124	547	428	0	260
189	480	302	2,223	1,533	1,184	0	658
190	63	80	291	263	229	0	127
191	176	336	818	1,270	1,020	0	523
192	449	323	2,080	1,928	1,420	0	725
193	568	1,217	2,632	8,833	6,066	0	2,549
194	844	647	3,913	3,662	2,716	0	1,399
195	1,079	202	5,000	1,399	1,111	0	795
196	1,003	491	4,652	2,075	1,695	0	1,086
197	25	476	114	838	773	0	488
198	261	415	1,208	1,449	1,217	0	645
199	91	324	422	2,765	1,857	0	724
200	52	1,155	241	3,328	2,674	0	1,397
201	944	340	4,375	1,997	1,565	0	944
202	2,853	2,236	13,227	14,908	10,819	0	5,191
203	1,570	1,233	7,280	12,019	8,111	0	3,475
204	1,082	303	5,017	2,356	1,750	0	1,027
205	782	189	3,624	1,123	914	0	627
206	1,210	683	5,609	4,539	3,298	0	1,710
207	684	137	3,172	1,074	820	0	541
208	466	180	2,162	1,097	833	0	492
209	460	634	2,131	3,175	2,415	0	1,165
210	44	2,445	202	17,210	11,755	0	4,612
211	767	741	3,557	2,162	1,854	0	1,187
212	61	1,168	283	2,658	2,270	0	1,298
213	115	1,063	533	2,515	2,181	0	1,225
214	315	735	1,458	2,391	1,954	0	1,049
215	244	201	1,131	613	518	0	340
216	391	622	1,815	2,699	2,055	0	1,045

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
217	202	827	934	3,032	2,321	0	1,171
218	0	1,084	0	3,203	2,524	0	1,302
219	638	1,431	2,956	4,385	3,554	0	1,997
220	274	471	1,272	1,666	1,338	0	722
221	1,242	696	5,759	3,013	2,445	0	1,485
222	276	161	1,280	854	657	0	365
223	967	217	4,483	1,388	1,128	0	764
224	1,399	682	6,488	3,504	2,805	0	1,622
225	991	626	4,595	4,399	3,153	0	1,561
226	392	341	1,816	1,741	1,301	0	684
227	367	571	1,701	2,472	1,874	0	960
228	891	576	4,130	3,515	2,624	0	1,345
229	994	515	4,606	3,789	2,753	0	1,385
230	694	200	3,218	1,036	839	0	584
231	152	134	707	302	281	0	205
232	3,054	197	14,158	3,209	2,461	0	1,856
233	367	132	1,702	887	663	0	384
234	488	491	2,264	2,064	1,648	0	888
235	1,106	218	5,129	1,520	1,199	0	837
236	904	282	4,190	1,648	1,301	0	827
237	317	178	1,468	773	607	0	378
238	241	66	1,118	553	407	0	233
239	1,704	181	7,900	1,881	1,493	0	1,104
240	1,469	188	6,812	2,097	1,560	0	1,050
241	2,017	109	9,353	1,786	1,400	0	1,154
242	1,091	326	5,058	2,901	2,067	0	1,135
243	405	305	1,878	1,386	1,077	0	606
244	552	284	2,560	1,355	1,097	0	646
245	450	47	2,085	529	412	0	296
246	817	463	3,787	1,944	1,641	0	980
247	372	6	1,726	299	238	0	198
248	539	33	2,498	565	439	0	327
249	945	225	4,382	1,338	1,064	0	749
250	423	115	1,962	545	463	0	338
251	402	1,066	1,866	2,844	2,639	0	1,417
252	261	40	1,208	238	202	0	169
253	57	29	263	126	102	0	64
254	308	47	1,430	642	455	0	259
255	66	5	308	61	50	0	39
256	155	126	718	343	294	0	206
257	63	35	291	168	134	0	78
258	541	653	2,506	3,329	2,484	0	1,231
259	509	257	2,362	4,093	1,097	0	888
260	0	88	0	222	193	0	101
261	12	602	58	4,830	3,253	0	1,234
262	614	455	2,849	2,701	2,008	0	1,014
263	522	856	2,420	4,648	3,426	0	1,591
264	316	306	1,464	2,825	1,923	0	809
265	363	308	1,682	2,025	1,472	0	699
266	415	393	1,922	2,241	1,676	0	818
267	215	39	999	237	203	0	151
268	0	1,078	0	7,257	4,915	0	1,964
269	545	419	2,526	1,270	1,141	0	728
270	493	495	2,285	2,010	1,613	0	883

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
271	556	650	2,576	3,945	2,837	0	1,335
272	1,180	269	5,469	1,791	1,385	0	945
273	172	279	798	1,559	1,112	0	523
274	339	80	1,572	544	424	0	279
275	460	120	2,132	581	481	0	360
276	120	2	557	91	73	0	63
277	232	189	1,074	481	443	0	306
278	252	330	1,167	875	769	0	480
279	622	518	2,885	1,379	1,208	0	839
280	55	1,041	254	717	975	0	877
281	8	43	37	33	43	0	39
282	167	153	774	374	360	0	239
283	462	556	2,144	1,638	1,414	0	853
284	0	261	0	485	470	0	270
285	130	398	604	1,195	1,067	0	544
286	483	185	2,240	1,446	1,042	0	559
287	248	751	1,149	4,240	3,115	0	1,345
288	207	1,111	962	2,324	2,114	0	1,264
289	583	125	2,703	1,071	804	0	494
290	499	109	2,315	916	682	0	423
291	517	322	2,398	2,023	1,463	0	764
292	318	125	1,475	671	511	0	323
293	369	211	1,711	807	695	0	432
294	508	41	2,357	642	478	0	332
295	337	93	1,562	726	529	0	316
296	264	133	1,222	1,618	1,079	0	464
297	127	163	588	1,555	1,046	0	423
298	289	425	1,342	2,531	1,857	0	840
299	227	178	1,050	1,244	898	0	423
300	409	112	1,895	541	465	0	330
301	396	94	1,837	491	420	0	304
302	587	163	2,723	794	679	0	479
303	435	782	2,015	2,869	2,265	0	1,206
304	237	656	1,098	1,126	1,082	0	747
305	316	474	1,465	1,644	1,335	0	737
306	83	328	383	1,133	907	0	457
307	233	461	1,083	3,025	2,095	0	918
308	74	58	343	159	141	0	97
309	109	21	507	165	129	0	85
310	190	58	880	234	198	0	154
311	589	192	2,729	702	635	0	484
312	45	502	210	2,147	1,632	0	737
313	0	0	0	0	0	0	0
314	0	0	0	0	0	0	0
315	0	0	0	0	0	0	0
316	0	0	0	0	0	0	0
317	0	0	0	0	0	0	0
318	0	0	0	0	0	0	0
319	0	0	0	0	0	0	0
320	0	0	0	0	0	0	0
321	0	0	0	0	0	0	0
322	0	0	0	0	0	0	0
323	0	0	0	0	0	0	0
324	0	0	0	0	0	0	0

Zone	Home Based Work		Home Based Other		Non-Home Based	Internal External	
	Productions	Attractions	Productions	Attractions	P & A	Productions	Attractions
325	0	0	0	0	0	15,600	0
326	0	0	0	0	0	59,325	0
327	0	0	0	0	0	26,930	0
328	0	0	0	0	0	8,100	0
329	0	0	0	0	0	3,510	0
330	0	0	0	0	0	9,470	0
331	0	0	0	0	0	32,334	0
332	0	0	0	0	0	1,500	0
333	0	0	0	0	0	9,776	0
334	0	0	0	0	0	4,300	0
335	0	0	0	0	0	2,300	0
336	0	0	0	0	0	6,120	0
337	0	0	0	0	0	6,550	0
338	0	0	0	0	0	9,675	0
339	0	0	0	0	0	9,000	0
340	0	0	0	0	0	6,750	0
341	0	0	0	0	0	6,100	0
342	0	0	0	0	0	18,750	0
343	0	0	0	0	0	16,120	0

Appendix A6 MATS Link Codes, Capacities, and Coded Speeds

MATS Link Codes, Capacities, and Coded Speeds

Link Group 1 = Functional Classification and Cross-section (# lanes)

Link Group 2 = Land Use Code
- 1 = Undeveloped (Activity Index < .5/Ac.)
- 2 = Suburban (Activity Index >= .5 and < 2.5/Ac.)
- 3 = Urban (Activity Index >= 2.5 and < 10.0/Ac.)
- 4 = Activity Center (Activity Index >= 10.0 and < 30.0/Ac.)
- 5 = CBD (Activity Index >= 30.0/Ac.)

Link Group 3 = Capacity Flag
- Indicates Lane Width for Arterials: 1 = lanes >= 10' wide; 2 = lanes < 10' wide
- Indicates Posted Speed for Freeways: 0 = 55 mph; 1 = 65 mph; 2 = 70 mph

LOS D Directional Capacity (vpd) and Coded Speeds

	Posted Speed (LG3)	Coded Speed	# Lanes (each direction) 1	2	3	4	5	6	
				12	13	14	15	16	<-- LG1
Freeway	55	52		27800	40200	53700	67100	80500	
	60	57		28900	41300	55100	68800	82500	
	65	61		31000	44400	59300	74000	88700	
	70	67		32000	46000	61400	76600	91800	
			91	92	93				<-- LG1
Ramps		45	11000	22000	33000				

Arterials (LG1/standard/narrow lanes)

Undeveloped areas (LG2 = 1)					
Divided or center turn lane-					
Prin Arterial w/ Access Control	52		25/23500/ NA	27/35300/ NA	29/47000/ NA
Principal Arterial	45	33/10300/9600	35/20500/19000	37/30800/28600	39/41000/38100
Minor Arterial	40	43/9200/8500	45/18200/16900	47/27400/25500	49/36400/33900
Collector	37	53/8100/7500	55/16000/14800	57/23900/22300	
Undivided-					
Principal Arterial	45	32/9300/8700	34/18700/17400	36/28000/26000	
Minor Arterial	40	42/8300/7700	44/16700/15500	46/24900/23200	
Collector	37	52/7200/6700	54/14600/13500	56/21800/20200	
One Way-					
Principal Arterial	45		62/22700/21000	63/34000/31500	
Minor Arterial	40		72/20200/18600	73/30200/28000	
Collector	37		82/17600/16400	83/26500/24500	
Intrazonal/TAZ Connectors	30				
Suburban areas (LG2 = 2)					
Divided or center turn lane-					
Prin Arterial w/ Access Control	47		25/21100/ NA	27/31700/ NA	29/42200/ NA
Principal Arterial	42	33/9200/8600	35/18300/17000	37/27500/25600	39/36600/34000
Minor Arterial	37	43/8200/7600	45/16300/15100	47/24400/22800	49/32500/30300
Collector	32	53/7200/6700	55/14300/13300	57/21400/19900	
Undivided-					
Principal Arterial	42	32/8300/7800	34/16700/15500	36/25000/23300	
Minor Arterial	37	42/7400/6900	44/14900/13800	46/22300/20700	
Collector	32	52/6400/6000	54/13000/12100	56/19400/18100	
One Way-					
Principal Arterial	42		62/20300/18800	63/30400/28100	
Minor Arterial	37		72/18000/16600	73/27000/25000	
Collector	32		82/15800/14600	83/23600/21900	
Intrazonal/TAZ Connectors	27				
Urban areas (LG2 = 3)					
Divided or center turn lane-					
Prin Arterial w/ Access Control	38		25/21100/ NA	27/31700/ NA	29/42200/ NA
Principal Arterial	33	33/9200/8600	35/18300/17000	37/27500/25600	39/36600/34000
Minor Arterial	30	43/8200/7600	45/16300/15100	47/24400/22800	49/32500/30300
Collector	27	53/7200/6700	55/14300/13300	57/21400/19900	

	Coded Speed	# Lanes (each direction) 1	2	3	4
Urban areas (continued)					
Undivided-					
Principal Arterial	33	32/8300/7800	34/16700/15500	36/25000/23300	
Minor Arterial	30	42/7400/6900	44/14900/13800	46/22300/20700	
Collector	27	52/6400/6000	54/13000/12100	56/19400/18100	
One Way-					
Principal Arterial	33		62/20300/18800	63/30400/28100	
Minor Arterial	30		72/18000/16600	73/27000/25000	
Collector	27		82/15800/14600	83/23600/21900	
Intrazonal/TAZ Connectors	24				
Activity Centers (LG2 = 4)					
Divided or center turn lane-					
Prin Arterial w/ Access Control	32		25/18500/ NA	27/27800/ NA	29/37000/ NA
Principal Arterial	27	33/8100/7500	35/16100/15000	37/24200/22500	39/32200/29900
Minor Arterial	24	43/7200/6700	45/14300/13300	47/21500/20000	49/28600/26600
Collector	21	53/6300/5900	55/12500/11700	57/18800/17500	
Undivided-					
Principal Arterial	27	32/7300/6800	34/14700/13600	36/22000/20500	
Minor Arterial	24	42/6500/6100	44/13100/12200	46/19600/18200	
Collector	21	52/5700/5300	54/11400/10600	56/17100/15900	
One Way-					
Principal Arterial	27		62/17800/16500	63/26700/24800	
Minor Arterial	24		72/15800/14600	73/23800/22000	
Collector	21		82/13900/12900	83/20800/19300	
Intrazonal/TAZ Connectors	18				
Central Business District (LG2 = 5)					
Divided or center turn lane-					
Prin Arterial w/ Access Control	27		25/16700/ NA	27/25100/ NA	29/33400/ NA
Principal Arterial	21	33/7300/6800	35/14500/13500	37/21800/20200	39/29000/26900
Minor Arterial	18	43/6500/6000	45/12900/12000	47/19400/18000	49/25700/24000
Collector	15	53/5700/5300	55/11300/10500	57/16900/15700	
Undivided-					
Principal Arterial	21	32/6600/6100	34/13200/12300	36/19800/18400	
Minor Arterial	18	42/5800/5400	44/11800/10900	46/17600/16400	
Collector	15	52/5100/4800	54/10300/9600	56/15400/14300	
One Way-					
Principal Arterial	21		62/16000/14900	63/24100/22300	
Minor Arterial	18		72/14300/13200	73/21400/19800	
Collector	15		82/12500/11600	83/18700/17300	
Intrazonal/TAZ Connectors	12				

Appendix A7 Friction Factors

Friction Factors

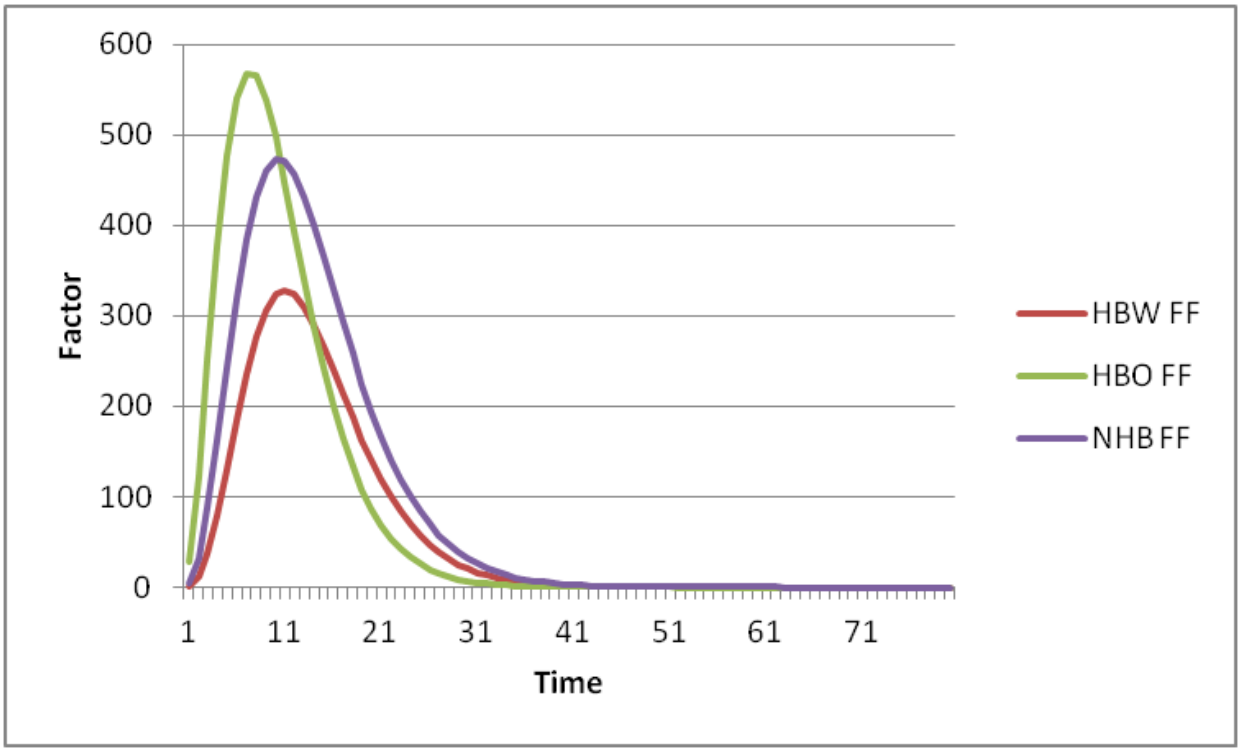
TIME	HBW	HBO	NHB	IN/EX
1	1.09E+000	27.79801	4.771906	0
2	11.00755	122.5766	32.45671	0
3	36.80255	251.4573	87.52136	165000
4	78.27798	377.0989	161.591	140000
5	129.9484	476.3102	242.4264	125000
6	184.4268	539.7168	318.9531	112500
7	234.9073	567.4118	383.2904	105000
8	276.4283	564.6911	431.0524	97000
9	306.2	538.9279	460.8258	92000
10	323.3783	497.622	473.3615	86000
11	328.591	447.361	470.7734	81000
12	323.4154	393.3957	455.869	78000
13	309.9161	339.5868	431.6534	72000
14	290.2888	288.5467	400.9971	68000
15	266.6158	241.8646	366.4402	65000
16	240.7206	200.3469	330.0985	62000
17	214.0983	164.2372	293.6416	59000
18	187.9026	133.4001	258.3154	56000
19	162.966	107.4657	224.9913	54000
20	139.8413	85.93681	194.2257	52000
21	118.85	68.26479	166.3227	50000
22	100.133	53.90037	141.3923	49000
23	83.69622	42.32505	119.4019	47000
24	69.45109	33.06871	100.2199	45000
25	57.24723	25.71756	83.65075	43000
26	46.89855	19.91556	69.46231	41000
27	38.20283	15.3619	57.40648	39000
28	30.95583	11.80624	47.23407	36500
29	24.96094	9.042822	38.70501	34000
30	20.03527	6.904335	31.59493	31000
31	16.0131	5.256	25.69891	28000
32	12.74733	3.990122	20.8333	24500
33	10.1096	3.021262	16.83591	20500
34	7.989438	2.282071	13.56538	16500
35	6.292967	1.719769	10.89981	13500
36	4.941203	1.293206	8.735041	11000
37	3.868322	0.970451	6.982854	9000
38	3.01991	0.726835	5.569041	7400
39	2.35131	0.543372	4.431597	6000
40	1.826119	0.405507	3.519018	5000
41	1.414835	0.302119	2.78875	4250
42	1.093679	0.224735	2.205802	3500
43	0.843584	0.16692	1.741532	3050
44	0.649329	0.1238	1.37259	2600
45	0.498815	0.091693	1.080012	2250
46	0.382464	0.067823	0.848451	1900
47	0.29272	0.050105	0.665525	1650
48	0.223646	0.03697	0.521278	1400
49	0.170586	0.027247	0.407726	1230
50	1.30E-001	0.020059	0.318482	1050

51	9.88E-002	1.48E-002	0.248453	930
52	7.50E-002	1.08E-002	0.193582	800
53	5.69E-002	7.95E-003	0.15065	700
54	4.30E-002	5.83E-003	0.117105	610
55	3.26E-002	4.27E-003	0.09093	540
56	2.46E-002	3.13E-003	0.07053	480
57	1.85E-002	2.29E-003	0.05465	430
58	1.40E-002	1.67E-003	0.042304	380
59	1.05E-002	1.22E-003	0.032716	340
60	7.90E-003	8.90E-004	0.025277	300
61	5.93E-003	6.49E-004	0.019513	260
62	4.45E-003	4.73E-004	0.01505	230
63	3.33E-003	3.44E-004	0.011598	200
64	2.50E-003	2.50E-004	0.00893	170
65	1.87E-003	1.82E-004	0.006871	140
66	1.40E-003	1.32E-004	0.005283	120
67	1.04E-003	9.61E-005	0.004058	100
68	7.77E-004	6.97E-005	0.003116	80
69	5.79E-004	5.06E-005	0.00239	60
70	4.31E-004	3.67E-005	0.001832	50
71	3.21E-004	2.66E-005	0.001404	40
72	2.39E-004	1.92E-005	0.001075	30
73	1.77E-004	1.39E-005	0.000823	20
74	1.32E-004	1.01E-005	0.000629	10
75	9.77E-005	7.28E-006	0.000481	5
76	7.24E-005	5.26E-006	0.000367	5
77	5.37E-005	3.80E-006	0.00028	5
78	3.97E-005	2.74E-006	0.000214	5
79	2.94E-005	1.98E-006	0.000163	5
80	2.17E-005	1.43E-006	0.000124	5

MATS Friction Factors

These friction factors are the results of the Origin-Destination Study Using Cellular Data,

see Appendix A-10



Appendix A8 Screenline Error

Screen Line Errors

Screenline	Count 2,924,040	Restrained 2,951,294	Diff 0.9%	AoN 2,998,259	Diff 2.5%
A	77,770	77,723	-0.1%	79,223	1.9%
B1	92,440	115,573	25.0%	115,063	24.5%
B	88,060	100,672	14.3%	102,802	16.7%
C	153,090	132,604	-13.4%	131,470	-14.1%
C1	158,510	141,027	-11.0%	142,264	-10.2%
D	59,350	65,399	10.2%	67,551	13.8%
E1	130,500	132,935	1.9%	137,471	5.3%
E2	146,400	137,514	-6.1%	131,859	-9.9%
F1	93,380	92,707	-0.7%	91,225	-2.3%
F2	46,630	45,084	-3.3%	45,540	-2.3%
F3	155,700	156,953	0.8%	169,434	8.8%
G1	42,550	42,851	0.7%	43,033	1.1%
G2	9,360	11,483	22.7%	10,606	13.3%
H	93,670	108,628	16.0%	110,285	17.7%
I	189,770	176,864	-6.8%	195,319	2.9%
J	159,650	158,580	-0.7%	159,627	0.0%
K1	132,760	123,490	-7.0%	125,324	-5.6%
K2	38,090	35,625	-6.5%	35,049	-8.0%
L	77,380	78,692	1.7%	78,357	1.3%
M	33,450	40,237	20.3%	38,567	15.3%
N	128,460	115,603	-10.0%	116,832	-9.1%
O	96,310	96,572	0.3%	102,075	6.0%
P	137,610	157,768	14.6%	162,866	18.4%
Q	84,750	85,346	0.7%	87,044	2.7%
R	47,620	43,121	-9.4%	44,108	-7.4%
S	38,360	40,232	4.9%	37,216	-3.0%
T	40,310	42,550	5.6%	39,627	-1.7%
U	106,950	114,018	6.6%	120,953	13.1%
V	98,760	95,688	-3.1%	91,819	-7.0%
W	47,770	59,879	25.3%	59,785	25.2%
X	70,720	72,460	2.5%	72,359	2.3%
Y	26,540	33,291	25.4%	33,397	25.8%
Z	21,370	20,123	-5.8%	20,106	-5.9%

Screen	Road	A	B	Count	Restrained	Error	Free	Error
A				**77,770**	**77,723**	**-0.1%**	**79,223**	**1.9%**
	Celeste Rd	1420	1420	6,500	6,528	0.4%	6,434	-1.0%
	I-65	1401	1401	40,190	44,806	11.5%	45,955	14.3%
	Lott Rd	1435	1435	6,160	8,946	45.2%	8,946	45.2%
	US 43	1404	1404	18,240	6,461	-64.6%	6,906	-62.1%
	US 45	1427	1427	6,680	10,982	64.4%	10,982	64.4%
B				**88,060**	**100,672**	**14.3%**	**102,802**	**16.7%**
	Craft Hwy	901	901	6,950	5,578	-19.7%	3,345	-51.9%
	I65	866	866	69,560	77,455	11.4%	81,656	17.4%
	Iroquois St	890	890	1,180	319	-72.9%	333	-71.8%
	US 43	911	911	7,860	9,799	24.7%	9,877	25.7%
	Wasson Ave	1140	1140	2,510	7,520	199.6%	7,592	202.5%
B1				**92,440**	**115,573**	**25.0%**	**115,063**	**24.5%**
	College Pkwy	1146	1146	3,280	4,881	48.8%	4,965	51.4%
	I-65	1148	1148	64,360	72,656	12.9%	78,215	21.5%
	Shelton Beach Rd	1145	1145	4,270	6,968	63.2%	4,192	-1.8%
	US 43	1152	1152	11,800	21,218	79.8%	17,543	48.7%
	US45	1118	1118	8,730	9,850	12.8%	10,148	16.2%
C				**153,090**	**132,604**	**-13.4%**	**131,470**	**-14.1%**
	Cochrane Causeway	926	926	16,250	20,504	26.2%	19,122	17.7%
	Conception St	860	860	1,950	170	-91.3%	170	-91.3%
	I-165	586	586	27,200	25,561	-6.0%	24,688	-9.2%
	I-65	835	835	69,000	63,189	-8.4%	66,466	-3.7%
	I-65 E Srvc Rd	1231	1231	4,000	1,832	-54.2%	1,843	-53.9%
	I-65 W Srvc Rd	1232	1232	4,630	1,809	-60.9%	1,767	-61.8%
	Mobile St	1297	1297	4,820	3,598	-25.4%	2,940	-39.0%
	Stanton Rd	829	829	3,160	3,649	15.5%	3,580	13.3%
	Summerville St	830	830	3,730	3,029	-18.8%	2,846	-23.7%
	US 43	921	921	2,020	284	-85.9%	280	-86.1%
	US 45	846	846	16,330	8,978	-45.0%	7,767	-52.4%
C1				**158,510**	**141,027**	**-11.0%**	**142,264**	**-10.2%**
	Bayshore Ave	783	783	5,610	6,932	23.6%	6,856	22.2%
	Conception St	1282	1282	1,800	60	-96.7%	50	-97.2%
	I-165	584	585	27,200	25,561	-6.0%	24,688	-9.2%
	I-65	1224	1223	77,080	63,189	-18.0%	66,466	-13.8%
	I-65 E Srvc Rd	1229	1229	4,000	2,504	-37.4%	2,517	-37.1%
	I-65 W Srvc Rd	1222	1222	1,240	273	-78.0%	0	-100.0%
	Martin Luther King	849	849	7,000	6,219	-11.2%	6,137	-12.3%
	Mobile St	784	784	11,050	15,310	38.6%	14,920	35.0%
	Stanton Rd	810	810	11,070	9,813	-11.4%	9,493	-14.2%
	US 45	807	807	12,460	11,166	-10.4%	11,136	-10.6%

Screen	Road	A	B	Count	Restrained	Error	Free	Error
D				**59,350**	**65,399**	**10.2%**	**67,551**	**13.8%**
	Congress St	517	517	2,760	898	-67.5%	798	-71.1%
	Dauphin St	742	742	13,300	12,100	-9.0%	10,386	-21.9%
	Martin Luther King	525	525	5,450	9,247	69.7%	8,931	63.9%
	US 90	439	439	21,970	20,894	-4.9%	25,560	16.3%
	US 98	797	797	15,870	22,260	40.3%	21,875	37.8%
E1				**130,500**	**132,935**	**1.9%**	**137,471**	**5.3%**
	Halls Mill Rd	706	706	8,860	9,205	3.9%	8,219	-7.2%
	I-10	632	632	93,900	87,189	-7.1%	94,920	1.1%
	US 90	710	710	27,740	36,541	31.7%	34,333	23.8%
E2				**146,400**	**137,514**	**-6.1%**	**131,859**	**-9.9%**
	Airport Blvd	735	735	28,400	27,150	-4.4%	28,636	0.8%
	Cottage Hill Rd	765	765	10,000	7,956	-20.4%	5,741	-42.6%
	Dauphin St	759	759	28,880	24,305	-15.8%	23,092	-20.0%
	Emogene St	732	732	3,900	194	-95.0%	0	-100.0%
	Old Shell Rd	776	776	12,320	11,437	-7.2%	10,712	-13.1%
	Pleasant Valley	711	711	10,690	19,077	78.5%	16,044	50.1%
	Springhill Ave	779	779	31,310	25,306	-19.2%	25,140	-19.7%
	US 98	781	781	20,900	22,089	5.7%	22,495	7.6%
F1				**93,380**	**92,707**	**-0.7%**	**91,225**	**-2.3%**
	Broad St	400	400	9,180	3,850	-58.1%	2,954	-67.8%
	Claiborne St	934	614	1,000	0	100.0%	0	100.0%
	I-10 E	612	932	40,080	42,536	6.1%	41,412	3.3%
	I-10 W	933	613	40,080	42,723	6.6%	43,564	8.7%
	Royal St	610	610	740	2,188	195.6%	2,107	184.7%
	Washington Ave	682	682	2,300	1,410	-38.7%	1,188	-48.3%
F2				**46,630**	**45,084**	**-3.3%**	**45,540**	**-2.3%**
	Ann St	1439	1439	8,160	4,649	-43.0%	4,721	-42.1%
	Broad St	440	440	23,330	26,403	13.2%	29,389	26.0%
	Catherine St	1440	1440	9,100	7,109	-21.9%	5,713	-37.2%
	Houston St	738	738	4,060	6,766	66.6%	5,717	40.8%
	Willliams St	737	737	1,980	155	-92.1%	0	100.0%
F3				**155,700**	**156,953**	**0.8%**	**169,434**	**8.8%**
	Florida St	721	721	11,880	9,439	-20.5%	7,261	-38.9%
	I-65	726	726	92,680	93,692	1.1%	109,077	17.7%
	I-65 E Srvc Rd	975	975	9,240	12,872	39.3%	16,288	76.3%
	I-65 W Srvc Rd	987	987	6,630	6,799	2.6%	6,009	-9.4%
	McGregor Ave	1039	1039	20,700	16,124	-22.1%	14,842	-28.3%
	Sage Ave	728	728	14,570	18,026	23.7%	15,956	9.5%

Screen	Road	A	B	Count	Restrained	Error	Free	Error
G1				**42,550**	**42,851**	**0.7%**	**43,033**	**1.1%**
	Highpoint Blvd	1248	1248	10,400	10,905	4.9%	9,220	-11.3%
	Shelton Beach Rd	1104	1104	3,020	995	-67.0%	749	-75.2%
	US98	1106	1106	24,320	28,225	16.1%	30,346	24.8%
	Wolf Ridge Rd	1096	1096	4,810	2,726	-43.3%	2,717	-43.5%
G2				**9,360**	**11,483**	**22.7%**	**10,606**	**13.3%**
	Bear Fork Rd	1109	1109	4,060	4,747	16.9%	4,134	1.8%
	Lott Rd	1113	1113	5,300	6,736	27.1%	6,472	22.1%
H				**93,670**	**108,628**	**16.0%**	**110,285**	**17.7%**
	Airport Blvd	1062	1062	34,940	40,533	16.0%	48,488	38.8%
	Old Shell Rd	1061	1061	20,940	19,529	-6.7%	12,385	-40.9%
	US 98	1109	1109	23,140	32,972	42.5%	34,480	49.0%
	Zeigler Blvd	1077	1077	14,650	15,595	6.5%	14,932	1.9%
I				**189,770**	**176,864**	**-6.8%**	**195,319**	**2.9%**
	Airport Blvd	726	726	82,110	60,661	-26.1%	77,557	-5.5%
	Dauphin St	1029	1029	23,800	20,500	-13.9%	20,811	-12.6%
	Old Shell Rd	1052	1052	15,670	18,230	16.3%	16,686	6.5%
	Springhill Ave	1069	1069	24,490	31,459	28.5%	28,124	14.8%
	US 98	1093	1093	43,700	46,013	5.3%	52,141	19.3%
J				**159,650**	**158,580**	**-0.7%**	**159,627**	**0.0%**
	Dauphin Island P	600	600	27,800	31,704	14.0%	32,127	15.6%
	Halls Mill Rd	1001	1001	9,730	4,843	-50.2%	3,294	-66.1%
	I-10	633	633	96,050	91,189	-5.1%	94,972	-1.1%
	US 90	1003	1003	26,070	30,844	18.3%	29,234	12.1%
K1				**132,760**	**123,490**	**-7.0%**	**125,324**	**-5.6%**
	Halls Mill Rd	1333	1333	8,860	6,686	-24.5%	1,595	-82.0%
	I-10	1511	1511	98,200	91,189	-7.1%	94,972	-3.3%
	US 90	1513	1513	25,700	25,615	-0.3%	28,757	11.9%
K2				**38,090**	**35,625**	**-6.5%**	**35,049**	**-8.0%**
	Cody Rd	1465	1465	6,170	9,693	57.1%	8,601	39.4%
	Hillcrest Rd	1514	1514	18,030	11,804	-34.5%	10,636	-41.0%
	Schillinger Rd	1171	1171	13,890	14,128	1.7%	15,812	13.8%
L				**77,380**	**78,692**	1.7%	**78,357**	1.3%
	Airport Blvd	1176	1176	27,880	31,899	14.4%	34,206	22.7%
	Cottage Hill	1173	1173	21,570	14,929	-30.8%	14,956	-30.7%
	Howell's Ferry R	1195	1195	8,930	14,803	65.8%	13,183	47.6%
	Old Shell Rd	1188	1188	10,980	11,139	1.4%	10,356	-5.7%
	Zeigler Blvd	1271	1271	8,020	5,922	-26.2%	5,655	-29.5%

Screen	Road	A	B	Count	Restrained	Error	Free	Error
M				**33,450**	**40,237**	**20.3%**	**38,567**	**15.3%**
	Howell's Ferry R	1105	1105	7,960	5,608	-29.6%	4,803	-39.7%
	Overlook Rd	1084	1084	8,090	17,405	115.1%	16,686	106.3%
	Zeigler Blvd	1074	1074	17,400	17,225	-1.0%	17,078	-1.9%
N				**128,460**	**115,603**	**-10.0%**	**116,832**	**-9.1%**
	Airport Blvd	1043	1043	47,620	54,489	14.4%	61,264	28.7%
	Cottage Hill Rd	1021	1021	27,950	22,205	-20.6%	19,998	-28.5%
	Grelot Rd	1033	1033	24,540	27,251	11.0%	28,136	14.7%
	Old Shell Rd	1059	1059	28,350	11,658	-58.9%	7,435	-73.8%
O				**96,310**	**96,572**	**0.3%**	**102,075**	**6.0%**
	Cody Rd	1062	1062	12,200	9,779	-19.8%	10,256	-15.9%
	Hillcrest Rd	1044	1044	26,490	27,378	3.4%	26,015	-1.8%
	Schillinger Rd	1175	1175	27,200	25,867	-4.9%	25,558	-6.0%
	University Blvd	1041	1041	30,420	33,549	10.3%	40,246	32.3%
P				**137,610**	**157,768**	**14.6%**	**162,866**	**18.4%**
	Azalea Rd	1039	1039	19,100	22,874	19.8%	18,050	-5.5%
	Bel Air Blvd	951	951	14,520	20,213	39.2%	18,299	26.0%
	I-65	725	725	78,680	83,757	6.5%	94,155	19.7%
	I-65 E Srvc Rd	804	804	6,800	8,016	17.9%	7,263	6.8%
	Montlimar Dr	995	995	14,860	20,619	38.8%	22,595	52.0%
	Sage Ave	729	729	3,650	2,289	-37.3%	2,504	-31.4%
Q				**84,750**	**85,346**	**0.7%**	**87,044**	**2.7%**
	Cody Rd	1062	1062	13,820	14,635	5.9%	18,210	31.8%
	Hillcrest Rd	1044	1044	15,680	7,976	-49.1%	3,500	-77.7%
	Schillinger Rd	1176	1176	30,420	34,529	13.5%	33,757	11.0%
	University Blvd	1045	1045	24,830	28,206	13.6%	31,577	27.2%
R				**47,620**	**43,121**	**-9.4%**	**44,108**	**-7.4%**
	Cody Rd	1221	1221	9,260	7,959	-14.1%	6,959	-24.9%
	Hillcrest Rd	1022	1022	22,860	17,494	-23.5%	17,908	-21.7%
	Schillinger Rd	1171	1171	15,500	17,668	14.0%	19,242	24.1%
S				**38,360**	**40,232**	**4.9%**	**37,216**	**-3.0%**
	Azalea Rd	1011	1011	13,400	9,290	-30.7%	8,113	-39.5%
	Demetropolis Rd	1017	1017	3,360	5,131	52.7%	4,550	35.4%
	Knollwood Dr	1020	1020	8,800	6,540	-25.7%	6,430	-26.9%
	University Blvd	1018	1018	12,800	19,271	50.6%	18,123	41.6%
T				**40,310**	**42,550**	**5.6%**	**39,627**	**-1.7%**
	Azalea Rd	1004	1004	13,930	18,187	30.6%	16,139	15.9%
	Demetropolis Rd	1008	1008	11,640	10,148	-12.8%	10,360	-11.0%
	Knollwood Dr	1609	1609	14,740	14,215	-3.6%	13,128	-10.9%

Screen	Road	A	B	Count	Restrained	Error	Free	Error
U				**106,950**	**114,018**	**6.6%**	**120,953**	**13.1%**
	Airport Blvd	1039	1039	52,800	58,442	10.7%	69,689	32.0%
	Cottage Hill Rd	1015	1015	32,210	33,537	4.1%	30,008	-6.8%
	Old Shell Rd	1053	1053	21,940	22,040	0.5%	21,256	-3.1%
V				**98,760**	**95,688**	**-3.1%**	**91,819**	**-7.0%**
	Azalea Rd	1015	1015	14,510	9,002	-38.0%	6,938	-52.2%
	Cody Rd	1221	1221	11,040	9,862	-10.7%	8,941	-19.0%
	Hillcrest Rd	1022	1022	22,210	20,854	-6.1%	19,252	-13.3%
	Knollwood Dr	1020	1020	9,990	4,814	-51.8%	4,330	-56.7%
	Schillinger Rd	1173	1173	20,510	28,734	40.1%	30,023	46.4%
	University Blvd	1018	1018	20,500	22,423	9.4%	22,335	9.0%
W				**47,770**	**59,879**	**25.3%**	**59,785**	**25.2%**
	Airport Blvd	1186	1186	13,940	15,756	13.0%	15,967	14.5%
	Cottage Hill Rd	1458	1458	4,690	6,377	36.0%	6,399	36.4%
	Jeff Hamilton Rd	1457	1457	2,850	4,656	63.4%	4,329	51.9%
	Old Shell Rd	1456	1456	8,330	10,212	22.6%	10,212	22.6%
	US98	1209	1209	17,960	22,878	27.4%	22,878	27.4%
X				**70,720**	**72,460**	**2.5%**	**72,359**	**2.3%**
	I-10	1357	1357	58,020	57,311	-1.2%	62,427	7.6%
	Old Pascagoula R	1359	1359	5,500	10,473	90.4%	6,652	20.9%
	US90	1355	1355	7,200	4,676	-35.1%	3,280	-54.4%
Y				**26,540**	**33,291**	**25.4%**	**33,397**	**25.8%**
	Bellingrath Rd	1318	1318	5,810	5,915	1.8%	5,610	-3.4%
	DIP	1302	1302	6,970	9,744	39.8%	9,732	39.6%
	Irvington-Bayou	1352	1352	5,890	5,980	1.5%	6,237	5.9%
	Padgett Switch R	1347	1347	7,870	11,652	48.1%	11,818	50.2%
Z				**21,370**	**20,123**	**-5.8%**	**20,106**	**-5.9%**
	AL188	1665	1665	5,170	6,747	30.5%	6,323	22.3%
	Bellingrath Rd	1315	1315	3,400	4,397	29.3%	4,130	21.5%
	Irvington-Bayou	1351	1351	5,940	6,494	9.3%	5,413	-8.9%
	Padgett Switch R	1349	1349	6,860	2,485	-63.8%	4,240	-38.2%

Appendix A9 Trucks

Figure A9- 1 Freight Analysis Zones

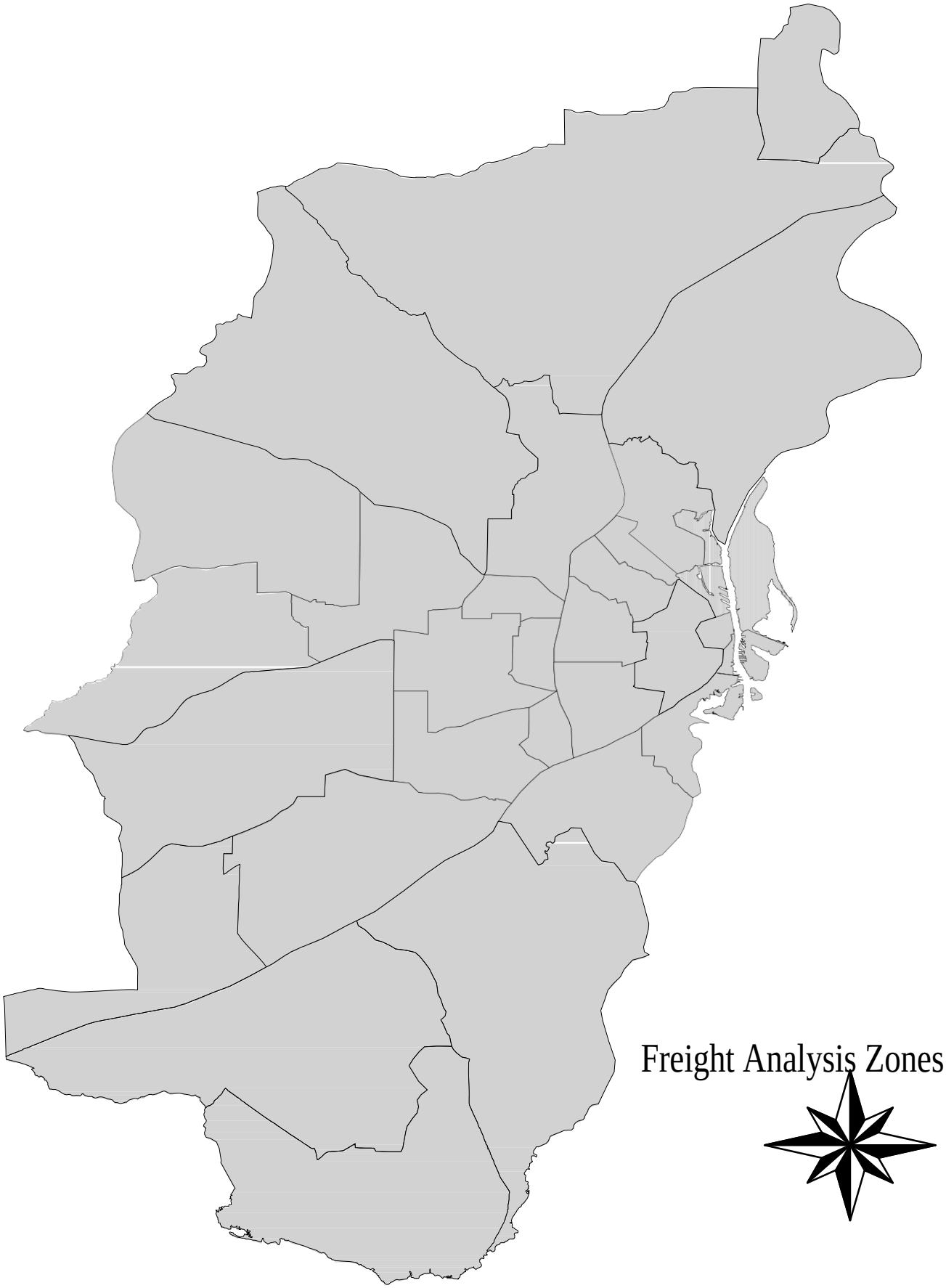


Table A9- 1 TAZs contained within FAZs

FAZ	TAZ Equivalent																			
1	157	158	159	160	161	162	163	164	165	166	167	211								
2	19	20	21	49																
3	212	213	214	215	216	217	218	219	220	221	222	232	233	282	286	288	309			
5	226	227	228	229	230	293	297	298	299	300	301	302								
6	231	303	304	305	306	307	308													
7	136	137	138	140	283															
9	179	180	181	182	183	185	186	197	198	199	200	312								
10	139	144	145	146	147	150	172	173	174	175	176	177	178							
11	141	142	143	148	149	151	156													
14	152	153	154	155	168	169	170	171												
15	193	194	195	196	245	246	247													
16	201	202	203	204	205	206	238	239	240	241	311									
17	242	243	244	310	207															
18	207	208	209	210	223	224	225	234	235	237	287									
19	236	291	294	296																
20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	119	
22	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
23	86	87	88	89	90	91	92	93	94	95	96	97								
24	98	99	100	101	102	109	110	111	112											
26	67	68	69	70	72	73	74	75	76	77	78	79	80	81	82	83	84	85		
29	48	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	66	284	285	
30	123	124	125	126	127	128	129	132	133	134	135	257	259	260						
32	130	131	184	187	188	189	190	191	192	248	249	250	251	289	290					
33	252	253	254	255	256	258	274	275	276	277	278	279	292	295						
35	280	281																		
36	103	105	106	107	108	113	114	115	116	117	118	120	122							
37	22	23	24	104	121															
38	261	262	263	264	265	266	267	268	269	270	271	272	273							

Table A9- 2 2015 External Trucks and Vehicles

ALDOT Truck Count Percentage	trucksOrig	trucksDest	zne	TOTCNT	EECAR	EETRUCKS		% Thru	2015EECar	Cordon
10.60%	4000	4000	326	75500	27000	8000	13500	40	27000	40500
0.00%	0	0	327	16580	0	0	0	0	0	16580
0.00%	0	0	328	5641	564	0	282	10	564	5077
0.00%	0	0	329	2873	287	0	144	10	287	2586
0.00%	0	0	330	5830	0	0	0	0	0	5830
16.75%	3700	3700	331	44170	14708	7400	7354	40	14708	22062
0.00%	0	0	332	1100	0	0	0	0	0	1100
0.00%	0	0	333	7290	729	0	365	10	729	6561
0.00%	0	0	334	3200	0	0	0	0	0	3200
0.00%	0	0	335	1720	0	0	0	0	0	1720
0.00%	0	0	336	5070	507	0	254	10	507	4563
0.00%	0	0	337	4850	0	0	0	0	0	4850
13.75%	1100	1100	338	16000	3450	2200	1725	25	3450	10350
0.00%	0	0	339	6160	0	0	0	0	0	6160
8.64%	350	350	340	8100	1850	700	925	25	1850	5550
0.00%	0	0	341	4520	0	0	0	0	0	4520
9.11%	860	860	342	18890	4293	1720	2147	25	4293	12877
19.46%	2100	2100	343	21580	6083	4200	3042	35	6083	11297

Table A9-3 2045 External Trucks

trucksOrig	trucksDest	zne	2010 Count	45Count	EECAR	EETRUCKS	EECAR	% Thru	2045	Cordon
1500	1500	325	newroad	23800	5200	3000	2600	25	5200	15600
5850	5850	326	75500	110575	39550	11700	19775	40	39550	59325
0	0	327	16580	26930	0	0	0	0	0	26930
0	0	328	5641	9000	900	0	450	10	900	8100
0	0	329	2873	3900	390	0	195	10	390	3510
0	0	330	5830	9470	0	0	0	0	0	9470
5400	5400	331	44170	64690	21556	10800	10778	40	21556	32334
0	0	332	1100	1500	0	0	0	0	0	1500
0	0	333	7290	9825	49	0	25	10	983	9776
0	0	334	3200	4300	0	0	0	0	0	4300
0	0	335	1720	2300	0	0	0	0	0	2300
0	0	336	5070	6800	680	0	340	10	680	6120
0	0	337	4850	6550	0	0	0	0	0	6550
1050	1050	338	16000	15000	3225	2100	1613	25	3225	9675
0	0	339	6160	9000	0	0	0	0	0	9000
400	400	340	8100	9800	2250	800	1125	25	2250	6750
0	0	341	4520	6100	0	0	0	0	0	6100
1250	1250	342	18890	27500	6250	2500	3125	25	6250	18750
3000	3000	343	21580	30800	8680	6000	4340	35	8680	16120

Table A9- 4 Streetlight Traffic Index to Create Matrix

Zone ID	Zone Type	TAZ	Zone Name	Zone Traffic (StL Index)	AADT Counts for Heavy	AADT/StL Index Ratio
1	Origin	343	I-65 (External)_in	114713	2100	0.018307
2	Origin	342	US 43 (External)_in	19063	860	0.045114
3	Origin	340	US 45 (External)_in	11941	350	0.029311
4	Origin	338	US 98 (External)_in	34706	1100	0.031695
5	Origin	336	Airport Blvd (External)_in	305	0	0
6	Origin	331	I-10 (External)_in	171791	3700	0.021538
7	Origin	329	SR 188 (External)_in	115	0	0
8	Origin	326	1-10 Bayway (External)_in	123611	4000	0.03236
10	Middle Filter	61	I-65 b/t US 90 & Airport Blvd	269855	4700	0.017417
11	Middle Filter	149	Rangeline Rd b/t Hamilton and I-10	43842	1950	0.044478
12	Middle Filter	214	Cochrane Causeway on bridge	67830	3250	0.047914
13	Middle Filter	213	I-165 b/t Water St & Bay Bridge Rd	50100	1550	0.030938
14	Middle Filter	22	Water St b/t Government & Dauphin St	57226	1000	0.017475
15	Middle Filter	24	Broad St b/t 1-10 & Virginia St	412	0	0
9	Middle Filter	283	Moffet Rd b/t Wolf Ridge & I-65	51921	1700	0.032742
1	Destination	135	I-65 (External)_out	123049	2100	0.017066
2	Destination	45	US 43 (External)_out	22255	860	0.038643
3	Destination	46	US 45 (External)_out	12233	350	0.028611
4	Destination	338	US 98 (External)_out	29280	1100	0.037568
5	Destination	336	Airport Blvd (External)_out	321	0	0
6	Destination	331	I-10 (External)_out	176775	3700	0.020931
7	Destination	329	SR 188 (External)_out	110	0	0
8	Destination	326	1-10 Bayway (External)_out	83538	4000	0.047882

Origin Destination Study for Mobile County - SARPC

December 31, 2012
Mr. Kevin Harrison, P.T.P.
Director, Transportation Planning
South Alabama Regional Planning Comm.
www.sarpc.org
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1.0 INTRODUCTION

AirSage, an Atlanta based wireless information and data provider, has developed a new approach to gathering data about population mobility throughout a region. AirSage analyzes anonymous location and movement of mobile devices, which is derived from wireless signaling data, to provide new insights into where populations, are, were or will be, and how they move about over time and in response to special events or disruptions to the roadway network.

With increasing fiscal constraints, limited resources, and growing management challenges, the need to prioritize investments has never been more pressing. Agencies must undertake extensive planning activities to better understand, among other things, travel demand and visitor demographics. This information provides a framework to guide decisions for actions, approve uses, and funding.

The purpose of this document is to describe the methodology used by AirSage to determine Origin and Destination and to calibrate the SARPC Travel demand model and to present the results in Summary.

2.0 AIRSAGE TECHNOLOGY

AirSage provides population location, movement, and traffic information derived from analysis of wireless (and in particular, cellular phone) signaling data. Combining patented and proprietary data collection and analysis technologies with signaling data from wireless carriers, AirSage has developed and deployed a secure data collection and reporting network with over 100 million mobile “sensors” that provide unprecedented visibility into where groups of people are, where they were, where they are likely to be, and how they move from one area to another.

AirSage’s WiSE (Wireless Signal Extraction) technology extracts data from wireless carrier networks, as generated by devices in the normal course of operation. Mobile devices frequently communicate with the network through control channel messages, both during use and when the mobile is in idle mode. The frequency and nature of the signaling data varies based on the network equipment used to provide cellular service to the area. The WiSE technology anonymizes the data stream (ensuring user privacy) and performs multiple stages of analysis to monitor the location and movement of the mobile devices (and thus the population of mobile users).

3.0 AIRSAGE STUDY METHODOLOGY

AirSage uses a modular, multi-step methodology to derive useful information and analytics from wireless signaling data provided by its wireless carrier partners.

The core functional components are listed below, and further described throughout the remainder of this document.

AirSage PDE + Post-Process: Generates time-stamped locations (lat/long) for each mobile device (e.g. a cellphone), utilizing the network signaling data generated each time a mobile device interacts with the mobile network. Post-processing is applied to refine the raw location data, yielding Processed Sightings.

Activity Point Generation: Processed Sightings are grouped into uniform "grid cells" or "Grids" (rectangles typically 1000 meters on a side), which are the basic geographical unit used by AirSage to analyze movement of mobile devices over time. Collectively, a series of one or more time-consecutive sightings within a single Grid represent a single Activity Point. Additional attributes assigned to the Activity Point characterize the device's movement (or "Activity") relative to that Grid. For example, has the device just completed a trip? Is it just passing through?

TAZ Assignment: For each particular study, one or more Traffic Analysis Zones (TAZ) are defined by geographical boundaries that define a particular area (e.g. a neighborhood) or venue (e.g. a sports stadium, a park, etc.). In TAZ Assignment, each Activity Point is assigned to a that contains it.

Data Expansion: Using several factors, such as the relative mobile device penetration of AirSage partner carriers vs. the full population, US Census data, visibility (subscriber sighting frequency), and others, the TAZ Count sample data is expanded to reflect the actual Trip Count that would be expected to be observed in the field (i.e. for the total population).

Post Analysis: To meet specific project requirements, additional analysis may be applied to further characterize the Trips to a given TAZ. Examples include Origin (determined using subscriber Home/Work Tables), visit duration (how long did a given Visitor dwell in the TAZ?), and visit frequency (over a given time period, how often did a given Visitor visit the TAZ?). The extent and granularity of these insights depends on a variety of factors including the time period studied, sample size relative to the universe of potential trips, and others.

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3.1 ANALYSIS COMPONENTS

Each time a mobile device on one of AirSage's carrier partner networks engages with the network (e.g. to send or receive a call), AirSage receives network signaling data.

The role of the AirSage PDE (Position Determining Entity) is to analyze the signaling data, which includes data elements such as:

- Encrypted Device ID associated with the signaling data (i.e. an encrypted version of the mobile device's unique MEID).
- Cell tower(s) visible to the device when the network event occurred
- Other proprietary signal information

Using this data, the PDE uses advanced "triangulation" and other proprietary analysis to yield a time-stamped location (lat/long) – i.e. a Raw Sighting – for the encrypted Device ID. The PDE also provides additional data regarding the estimated accuracy and validity of each location.

PDE Data Output and Post-Processing

The raw time-stamped lat/long data output by the PDE is prone to small variances due to specific characteristics of the original network signaling data, or artifacts of the triangulation process itself.

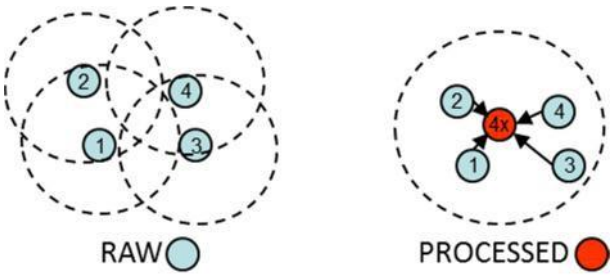

Fig. 2 – Removing spatial "jitter"

These variances are commonly seen as "spatial jitter," which occurs when a series of consecutive sightings from a mobile device which is actually stationary generate slightly different lat/long locations. See **Figure 2**. Noise reduction techniques are applied to converge these sightings onto a single lat/long point location, i.e. each of the sightings is assigned the same "converged" lat/long. The degree of noise reduction applied is based on the quality of the network signaling data, overall performance capabilities of the PDE, the relative time intervals between the Raw Sightings, and other factors.

Activity Points

Activity Points are thus comprised of time-adjacent Processed Sightings within a single Grid. When a device enters a new Grid, thus begins a new Activity Point.

Activity Points are assigned to a TAZ, rather than to a specific lat/long point. This is necessary for efficient analysis of movement. In other words, an Activity Point indicates:

i) the mobile device was located in this TAZ,
ii) in this time window, and

iii) the device was either stationary or moving (or "uncertain") in this TAZ and time window.

3.1.1 Data Output

Because they encompass multiple Processed Sightings, the output for Activity Points includes time duration, i.e. the difference between when the device entered that Grid, and when it left the Grid. These durations can be quite long, for example, when the device goes home after work and remains there overnight.

While not required specifically to derive Trip Counts, additional attributes are assigned to the Activity Point to characterize the device's status or movement (i.e. "Activity") relative to that Grid. For example, has the device just completed a trip (i.e. an "End Point")? Is the device in motion, pasting through this Grid on the way to a different destination (i.e. a "Transient Point")?

3.1.2 Subscriber Visibility

Also generated with Activity Points are Subscriber Visibility statistics. These stats deal with how frequently (or not) a given mobile device is visible to AirSage during the course of a day. Visibility tables are generally built using 15-minute intervals. This information becomes an input for Data Expansion.

3.1.3 Subscriber Home & Work Assignments

Also generated with Activity Points are the Home and Work census block groups for each mobile device. These are determined by observing device movement patterns over time. This information becomes an input for Data Expansion and other analysis.

3.2 TAZ (Traffic Analysis Zone) Assignment

3.2.1 Overview

A TAZ is simply a defined geographical boundary, usually associated with an area of interest (e.g. a neighborhood) or a business district (e.g. a sports stadium, a park, a retail location and surrounding buffer zone, etc.). TAZ definitions are typically provided via a GIS shapefile.

In TAZ Assignment, each Activity Point record is assigned, based on its Grid or raw location, to the TAZ boundary that contains that location.

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3.3 Data Expansion

As indicated, the Trip Count output (across all mobile devices available on AirSage carrier partner networks) represents a sample Trip Count. This sample count represents only a portion of the total population of mobile devices and visitors to the TAZ.

To provide a full population Trip Counts, the sample data must be expanded. This expansion is accomplished using the following:

3.3.1 Determining the mobile devices' "Home Location" Dividing the mobile device counts for a given "Home" census block group into US Census Population data for the same area yields a "Penetration Factor" – essentially a multiplier to apply to the sample data.

3.3.2 Optional: If the Trip Count is to report "vehicle" visits, rather than "people" visits, the count must be scaled to reflect average per-vehicle occupancy. Because AirSage counts mobile devices rather than vehicles, multiple occupants present in a vehicle will skew the count numbers higher. Dividing the AirSage mobile device counts by the average vehicle occupancy translates the output to vehicle counts.

3.3.3 Visibility Factors – how often, and at what intervals, a given device is "seen" by AirSage – are used to tune the expansion algorithms.

3.4 Post-Processing

Post-processing of Visitor Count data can yield valuable additional insights for a TAZ. Examples include Trip Origin (determined using subscriber Home/Work Tables), visit duration (how long did a given Visitor dwell in the TAZ?), and visit frequency (over a given time period, how often did a given Visitor visit the TAZ?).

The extent and granularity of these insights can only be determined after the Trip Count analysis is complete, as they depend on output data characteristics including the time period studied, and the effective sample size relative to the universe of potential Trips. The "density" of visitor Home locations is also an important consideration. For example, do Trips come from all over the country (as they might for a tourist destination), or do they come primarily from a local area (as they might for a shopping mall).

4.0 PROJECT SPECIFICS

AirSage partnered with Alliance Transportation Group for the actual calibration process. Their report is included herein in Appendix A

ALLIANCE TRANSPORTATION GROUP

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TECHNICALMEMORANDUM

DATE: December 28, 2012

TO: Kevin Harrison, SARPC

CC: JD Allen

FROM: Jim Harvey

RE: SARPC Trip Distribution Model Calibration and Validation

This memorandum provides a description of the methodology and outcomes of the calibration of the SARPC trip distribution model using trip ends derived from cell phone data for June 2012. Although the scope only called for calibration of the trip distribution model, Alliance also validated the traffic assignment model as a quality assurance check that the trip distribution tables produced by the calibrated model were not only statistically reasonable, but also provided realistic inputs to support performance of downstream model components. The following sections provide a description of the data inputs and methodology used in calibrating and validating of the selected components of the SARPC travel demand model (TDM) along with a summary of the outcomes of the process.

Data Inputs

This section provides a summary description of the cell phone data used in the calibration effort. A more complete technical description of the data collection methodology, sampling plan, data reduction and sample expansion is contained in the technical memorandum on cell phone data development prepared by Airsage, the data vendor.

Airsage assembled sample cell phone transaction data from participating cell phone service providers for the month of June 2012, and identified transactions being carried out by likely trip makers in the SARPC study area. From this data, Airsage aggregated estimated linked trip origin destination zonal pairs for each of the trips identified.

Airsage then used proprietary data analysis algorithms to impute a trip purpose for each of the identified trips in the sample. Primary trip purposes defined in this manner included Home-Based Work (HBW); Home-Based Other (HBO); and Non Home-Based (NHB). Table 1 shows a comparison of the trips obtained to the previous Mobile MPO TDM and the proportion of trips by purpose compared to NCHRP reported typical ranges.

Table 1 – Total Trips by Purpose

TRIP MATRIX: PURPOSE (Internal Trips)						
	MATS 2007		**AirSage 2012**		**NCHRP 2009 Ranges**	
	Trips	Percent	Trips	Percent	Low	High
HBW	279,300	26.13%	124,403	11.0%	14.0%	15.0%
HBO	563,900	52.76%	582,190	51.3%	54.0%	56.0%
NHB	225,600	21.11%	427,636	37.7%	30.0%	31.0%
Total	1,068,800	100.0%	1,134,229	100.0%	-	-

Source: Airsage (November 2012)

In each case, the cell phone data is close to, but somewhat outside of the ranges defined in the NCHRP. The variance may be explainable based on some expected differences in data collected using the new technology. A slightly lower number of HBW trips and higher total HBO and NHB trips could be explained by the fact that the cell phone data identifies trip chaining behavior, and, therefore, portions of the home-to-work tour would show up as a higher level of HBO and NHB trips. In addition, visitor trips not normally captured in a HH travel survey would be captured in the cell phone sample as NHB trips. It is hard to say whether such differences in data collection technique can account for all of the reduction in the share of HBW trips, but in the aggregate, the data appear reasonable and the observed anomalies at least partially explainable. The same is not necessarily true at the sub-regional level. The Table below shows cell phone based county-to-county and intra-county trip interchanges compared to the US Census Longitudinal Origin-Destination Employment Statistics (LODES) data for the Mobile metropolitan area.

Table 2– Employment Trip Ends

Difference (AirSage 2012 - Census LODES)					
County	**Mobile**	**Baldwin**	**George**	**Jackson**	**Total**
Mobile	-4,705	-3,206	206	2,836	-4,240
Baldwin	-9,105	6,325	-14	265	-2,528
George	926	8	3,576	-1,171	3,338
Jackson	2,117	179	5	3,504	5,805
Total	-10,137	3,306	3,773	5,433	2,375

Source: Airsage (November 2012)

Although the variance in the total is only about1% of the total trips, the deficit related to trips destined for Mobile County is significant because Mobile County is the core of the study area.

When compared to data about household travel, the discrepancies at the subarea level are more significant. The table below shows the cell phone data sample compared to the three year American Community Survey (ACS).

Table 3 – Household Trip Ends

Difference (AirSage 2012 - ACS 3 YR)					
County	Mobile	Baldwin	George	Jackson	Total
Mobile	-35,566	546	390	-1,952	-36,583
Baldwin	-5,761	-13,216	9	-108	-19,075
George	2,106	153	1,316	-1,138	2,436
Jackson	1,447	216	564	-5,721	-3,494
Total	-37,774	-12,301	2,279	-8,920	-56,716

Source: Airsage (November 2012)

The 25% variance shown in Table 3 demonstrated an apparent bias in the cell phone data at the subarea level that led Alliance to the conclusion that the expanded cell phone data sample should not be used to establish a total number of trips generated in the region. Therefore, the use of the cell phone data sample was restricted to developing regional trip distribution parameters from the pattern of trip travel time and distance depicted in the sample at the regional level.

Another data component needed for calibration is zone-to-zone travel time data, which was also originally anticipated to come from the cell phone data. However, during data development, Airsage determined that the cell phone data sample was not of sufficient size or density to develop link level travel times.

To address the unavailability of travel data from the cell phone sample, Alliance substituted more conventional data from available MPO travel time and delay studies collected using geographic positioning system (GPS) data. This travel time data combined with the weighted sample of internal trips by trip purpose derived from observed cell phone transactions at traffic analysis zones (TAZ) in the study area was used to perform the trip distribution calibration.

Calibration of the Trip Distribution Model

The cell phone data and the supplemental travel time data were analyzed to produce values for average trip length by trip purpose; to develop trip length frequency distributions; and to calculate friction factors (FF) for use in the calibration of the model. The resulting trip distribution parameters were then tested in the model to determine reasonableness against observed travel behavior.

One of the principle mechanisms for developing these trip distribution parameters is the use of trip length frequency distribution (TLFD) curves. Alliance analyzed the available cell phone data to estimate a gamma distribution function describing the shape of the TLFD curve for each trip purpose. The parameters of the gamma distribution functions derived from the reported cell phone records are shown below in Table 4.

Table 4 - Trip Length Frequency Distribution Curves

Trip Length Frequency Distribution Curves (gamma distribution function)			
	HBW	HBO	NHB
Trip Length	18.1924	15.868876	17.19881006
a	0.0000	0.0004	0.0001
b	4.8049	3.3254	4.0215
c	-0.3190	-0.2725	-0.2919

The gamma distribution functions were used to develop friction factors (FF) for each trip purpose. The role of the FFs is to provide a mathematical interpretation of how trip makers in the trip market perceive and react to differences in travel impedances (such as travel time) among available destinations. The iterative process of developing and adjusting FFs until the TLFD curves produced by the trip distribution model match the target TLFD curve from the observed trip data comprises the primary objective of the trip distribution model calibration process.

Alliance used the TLFD curves from the cell phone data to develop and test FF for use in the distribution model. These friction factors were then applied in the model using the production and attraction trip tables from trip generation to produce a set of distributed trips. The TLFD curves for the distributed trips were then calculated and compared to the observed TLFD curves. The Alliance travel demand model development staff repeated this process of adjusting and testing FF values in an iterative fashion until an acceptable match between observed and modeled TLFD had been achieved. Table 5 shows a summary of the average trip lengths (in minutes) derived from the observed zone-to-zone cell phone activity.

Table 5 - Average Trip Lengths and Coincidence Ratios

Purpose	Average Trip Length in Minutes (Cell phone data)	Average Trip Length In Minutes (Modeled)	Coincidence Ratio*
HBW	18.19	18.16	0.81
HBO	15.87	15.79	0.76
NHB	17.20	17.09	0.80

**coincidence values above 0.70 are typically considered to reflect effective calibration*

The average trip lengths derived from the data and produced by the model compare favorably to published ranges of reasonable values for an urban area the size of metropolitan Mobile, and the modeled trip lengths compare reasonably well to the observed trip lengths with all coincidence values above 0.7.

Although average trip length is a useful parameter for evaluation of model performance, the distribution of trips around the mean value is actually more descriptive of travel behavior. The following three figures depict the shape of the TLFD curves for each of the three internal trip purposes.

Figure 1 - Home Based Work Trip Length Frequency Distribution Curves

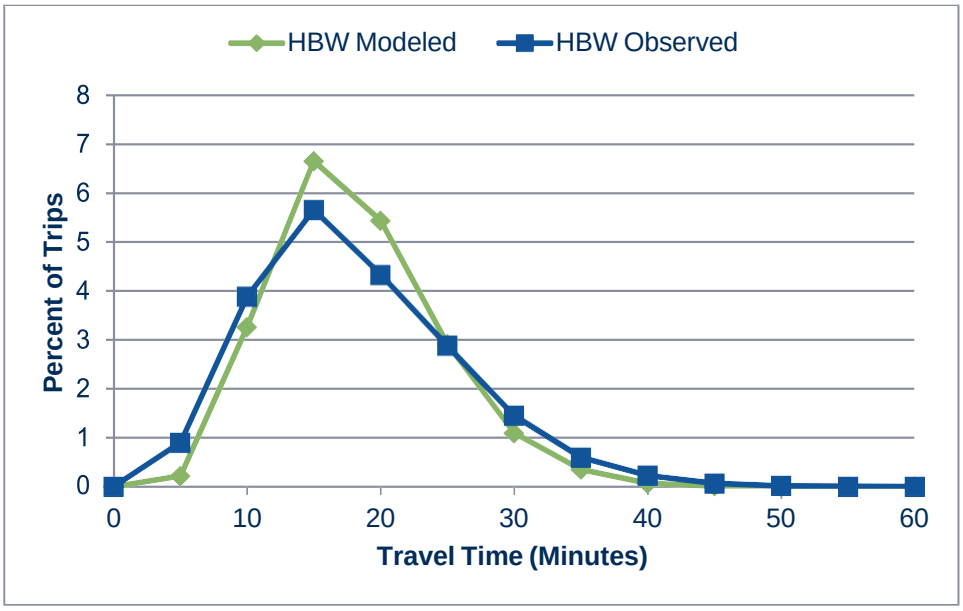


Figure 2 - Home Based Other Trip Length Frequency Distribution Curve

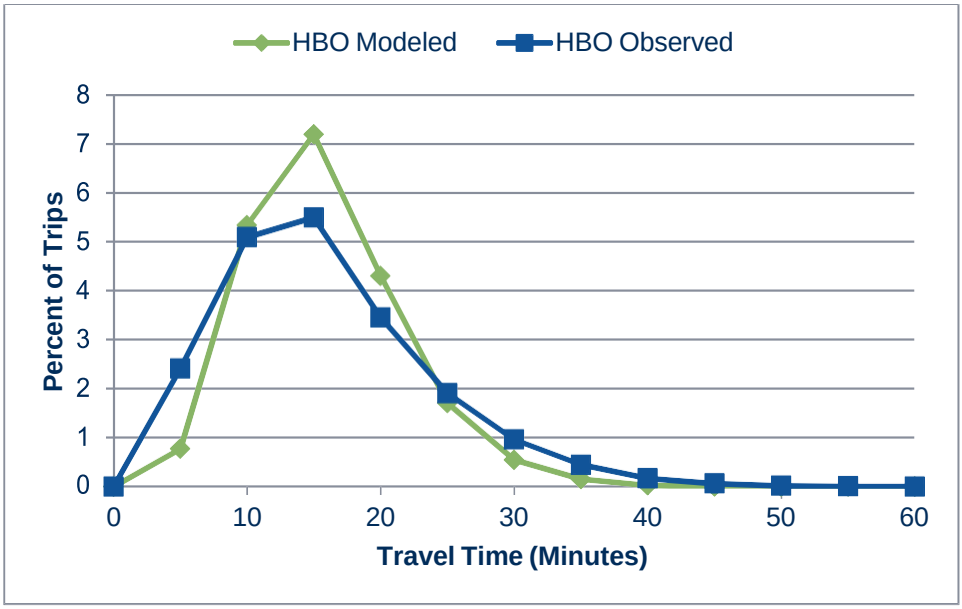
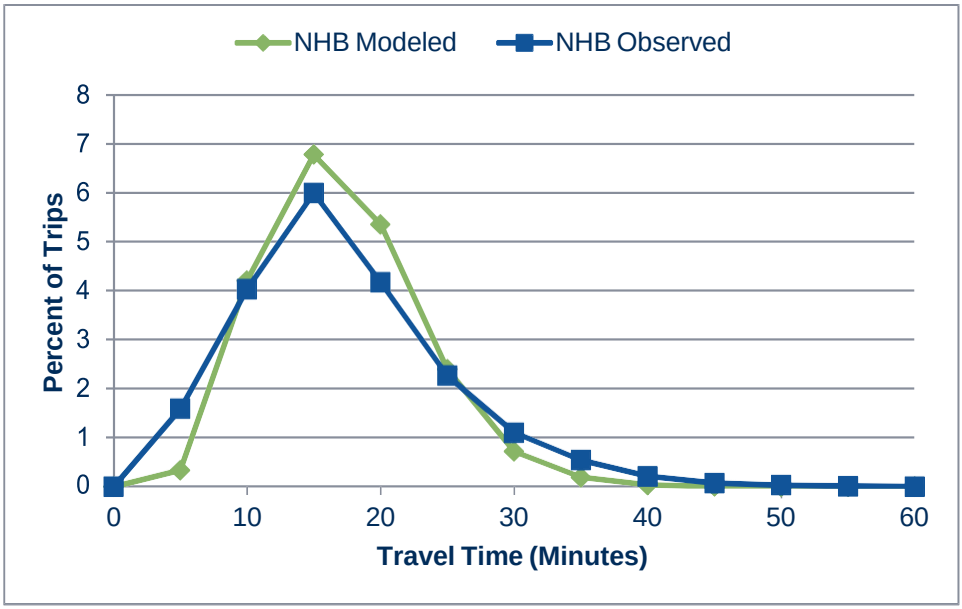


Figure 3 - Non-Home Based Trip Length Frequency Distribution Curve



The iterative calibration process resulted in a set of friction factors by trip purpose. The FF tables represent the actual trip distribution parameter data inputs used in travel demand model application. The complete list of friction factors is shown in tabular form in Appendix A.

Model Validation

Alliance applied the calibrated trip distribution model using the new parameters, and input the results into the new 2010 base year traffic assignment model. The results were then compared to Alabama DOT 2010 traffic counts by functional class. Table 6 shows the final base year 2010 traffic assignment results by Link Group 1 nested categories (e.g., 10's = interstate, etc.). The overall match against counts is within -0.6% at 99.4% of total counted volume and the overall match against VMT is within 0.1% at 100.1% of total counted volume. The RMSE% overall is at 33% which is reasonable, but more importantly the RMSE by category is within acceptable ranges for each classification.

These statistics reflect an adequately validated model at the systems level that should have solid predictive capabilities when testing future scenarios.

Table 6 – Validation Comparison

LG 1	Total Assigned Volume	Total Counted Volume	No. of links	Center Line Miles	% Count	% RMSE	Modeled VMT	Counted VMT	% VMT
10	3,072,146	3,208,200	71	68.34	95.8%	13.5%	3,241,079	3,314,192	97.8%
20	513,907	470,400	19	13.79	109.2%	32.1%	315,919	322,915	97.8%
30	6,562,834	6,577,100	321	148.85	99.8%	26.8%	2,761,935	2,687,918	102.8%
40	5,713,646	5,754,400	487	249.14	99.3%	34.9%	2,562,983	2,530,926	101.3%
50	1,804,660	1,823,400	396	164.95	99.0%	62.6%	771,910	788,969	97.8%
70	299,140	243,400	116	12.09	122.9%	70.3%	29,812	26,146	114.0%
60	13,273	13,000	2	0.18	102.1%	5.4%	1,195	1,170	102.1%
80	19,470	17,000	2	0.16	114.5%	108.0 %	1,558	1,360	114.5%
90	68,392	68,600	6	0.73	99.7%	36.2%	9,421	10,780	87.4%
Tot	18,067,468	18,175,500	1420	658.23	99.4%	33.0%	9,695,811	9,684,376	100.1%

Volume Groupings

In addition to the match by functional class, the model also provides a reasonable match to observed traffic by volume grouping. The Table 7 shows a comparison of the assigned base year volumes to observed 2010 traffic by volume group. In each case the amount of variance between counts and the modeled traffic assignment is well within the maximum allowable RMSE.

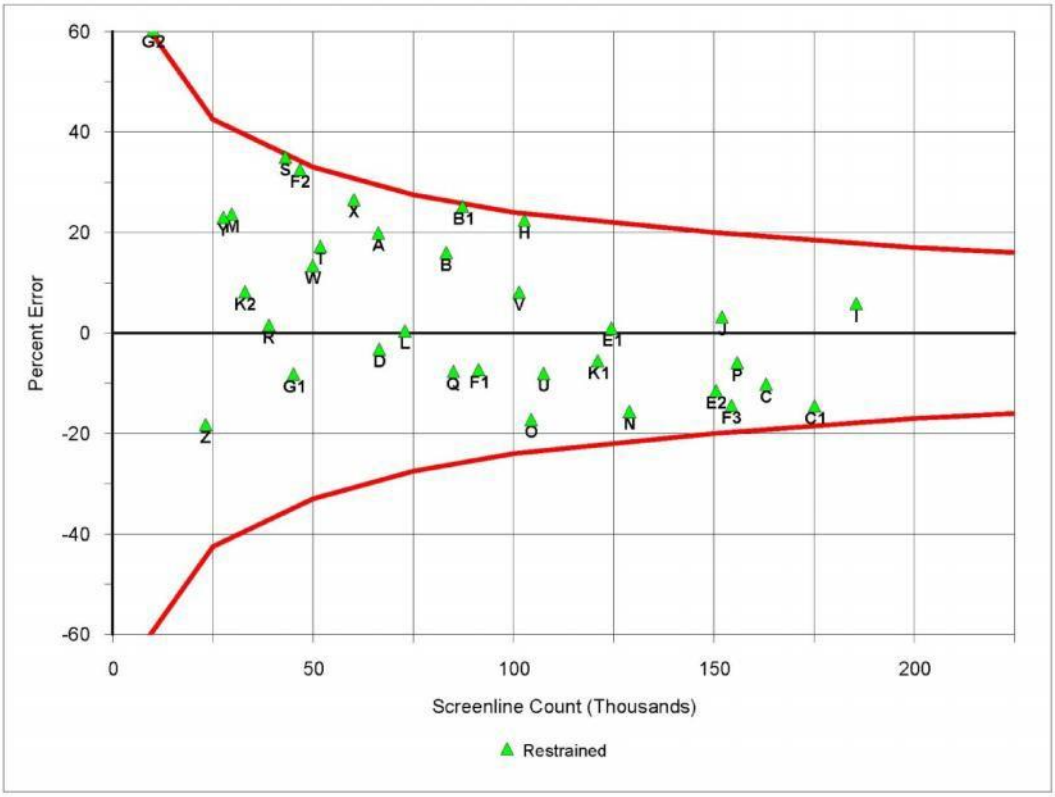
Table 7 – Validation Comparison by Volume Group

Volume Range	Max Error	# Links	Counted Volume	Assigned Volume	% Diff	RMS Error	
< 5 000	>47%	1459	2561	2934	14.6%	1504	58.7%
5 - 9 999	35-47%	657	6885	6756	-1.9%	2135	31.0%
10 - 19999	27-35%	495	13264	12755	-3.8%	3090	23.3%
20 - 29 999	24-27%	36	25178	21969	-12.7%	5425	21.5%
30 - 39 999	22-24%	37	34795	31597	-9.2%	5115	14.7%
40 - 49 999	20-22%	15	43780	39791	-9.1%	5121	11.7%

Screenlines

In addition to a reasonable match at the regional level, the model demonstrates comparable results at the corridor level as well. Figure 4 shows how the traffic volumes assigned by the travel demand model compare to traffic counts at selected screenlines within the study area. In general, the figure shows that the match between traffic assignment and total count volume at the screenlines falls within acceptable error ranges for their respective volume groups.

Figure 4- Screenline Volumes Graphed Against % Error



Conclusion

Although hampered somewhat by some unavailable data items and some perceived bias in the cell phone sample, Alliance was able to use the available cell phone sample data to develop reasonable trip distribution parameters and to calibrate a set of friction factors that meet acceptable statistical benchmarks. When the trip distribution model was applied and the results input into the new 2010 base year model, the traffic assignment validated well at both the regional and corridor level.

Based on the demonstrated performance of the Mobile MPO TDM 2010 base year model, SARPC can be confident in the model's predictive value for forecasting transportation system conditions on alternative metropolitan transportation plan scenarios.

Appendix A – Friction Factors

Table 8 below lists the TLFD curve value and resulting friction factors by trip purpose.

Table 8 - Final Friction Factors

Friction Factors by Trip Purpose						
Time	HBW TLFD	HBW FF	HBO TLFD	HBO FF	NHB TLFD	NHB FF
1	1.09E-09	1.090783	2.78E-08	27.79801	4.77E-09	4.77
2	1.10E-08	11.00755	1.23E-07	122.5766	3.25E-08	32.46
3	3.68E-08	36.80255	2.51E-07	251.4573	8.75E-08	87.52
4	7.83E-08	78.27798	3.77E-07	377.0989	1.62E-07	161.59
5	1.30E-07	129.9484	4.76E-07	476.3102	2.42E-07	242.43
6	1.84E-07	184.4268	5.4E-07	539.7168	3.19E-07	318.95
7	2.35E-07	234.9073	5.67E-07	567.4118	3.83E-07	383.29
8	2.76E-07	276.4283	5.65E-07	564.6911	4.31E-07	431.05
9	3.06E-07	306.2	5.39E-07	538.9279	4.61E-07	460.83
10	3.23E-07	323.3783	4.98E-07	497.622	4.73E-07	473.36
11	3.29E-07	328.591	4.47E-07	447.361	4.71E-07	470.77
12	3.23E-07	323.4154	3.93E-07	393.3957	4.56E-07	455.87
13	3.10E-07	309.9161	3.4E-07	339.5868	4.32E-07	431.65
14	2.90E-07	290.2888	2.89E-07	288.5467	4.01E-07	401.00
15	2.67E-07	266.6158	2.42E-07	241.8646	3.66E-07	366.44
16	2.41E-07	240.7206	2E-07	200.3469	3.30E-07	330.10
17	2.14E-07	214.0983	1.64E-07	164.2372	2.94E-07	293.64
18	1.88E-07	187.9026	1.33E-07	133.4001	2.58E-07	258.32
19	1.63E-07	162.966	1.07E-07	107.4657	2.25E-07	224.99
20	1.40E-07	139.8413	8.59E-08	85.93681	1.94E-07	194.23
21	1.19E-07	118.85	6.83E-08	68.26479	1.66E-07	166.32
22	1.00E-07	100.133	5.39E-08	53.90037	1.41E-07	141.39
23	8.37E-08	83.69622	4.23E-08	42.32505	1.19E-07	119.40
24	6.95E-08	69.45109	3.31E-08	33.06871	1.00E-07	100.22
25	5.72E-08	57.24723	2.57E-08	25.71756	8.37E-08	83.65
26	4.69E-08	46.89855	1.99E-08	19.91556	6.95E-08	69.46

27	3.82E-08	38.20283	1.54E-08	15.3619	5.74E-08	57.41
28	3.10E-08	30.95583	1.18E-08	11.80624	4.72E-08	47.23
29	2.50E-08	24.96094	9.04E-09	9.042822	3.87E-08	38.71
30	2.00E-08	20.03527	6.9E-09	6.904335	3.16E-08	31.59
31	1.60E-08	16.0131	5.26E-09	5.256	2.57E-08	25.70
32	1.27E-08	12.74733	3.99E-09	3.990122	2.08E-08	20.83
33	1.01E-08	10.1096	3.02E-09	3.021262	1.68E-08	16.84
34	7.99E-09	7.989438	2.28E-09	2.282071	1.36E-08	13.57
35	6.29E-09	6.292967	1.72E-09	1.719769	1.09E-08	10.90
36	4.94E-09	4.941203	1.29E-09	1.293206	8.74E-09	8.74
37	3.87E-09	3.868322	9.7E-10	0.970451	6.98E-09	6.98
38	3.02E-09	3.01991	7.27E-10	0.726835	5.57E-09	5.57
39	2.35E-09	2.35131	5.43E-10	0.543372	4.43E-09	4.43
40	1.83E-09	1.826119	4.06E-10	0.405507	3.52E-09	3.52
41	1.41E-09	1.414835	3.02E-10	0.302119	2.79E-09	2.79
42	1.09E-09	1.093679	2.25E-10	0.224735	2.21E-09	2.21
43	8.44E-10	0.843584	1.67E-10	0.16692	1.74E-09	1.74
44	6.49E-10	0.649329	1.24E-10	0.1238	1.37E-09	1.37
45	4.99E-10	0.498815	9.17E-11	0.091693	1.08E-09	1.08
46	3.82E-10	0.382464	6.78E-11	0.067823	8.48E-10	0.85
47	2.93E-10	0.29272	5.01E-11	0.050105	6.66E-10	0.67
48	2.24E-10	0.223646	3.7E-11	0.03697	5.21E-10	0.52
49	1.71E-10	0.170586	2.72E-11	0.027247	4.08E-10	0.41
50	1.30E-10	0.129907	2.01E-11	0.020059	3.18E-10	0.32
51	9.88E-11	0.098777	1.48E-11	0.014752	2.48E-10	0.25
52	7.50E-11	0.074995	1.08E-11	0.010838	1.94E-10	0.19
53	5.69E-11	0.056859	7.95E-12	0.007954	1.51E-10	0.15
54	4.30E-11	0.043049	5.83E-12	0.005832	1.17E-10	0.12
55	3.26E-11	0.032551	4.27E-12	0.004273	9.09E-11	0.09
56	2.46E-11	0.024582	3.13E-12	0.003127	7.05E-11	0.07
57	1.85E-11	0.018541	2.29E-12	0.002287	5.47E-11	0.05
58	1.40E-11	0.013968	1.67E-12	0.001671	4.23E-11	0.04
59	1.05E-11	0.010511	1.22E-12	0.00122	3.27E-11	0.03
60	7.90E-12	0.007901	8.9E-13	0.00089	2.53E-11	0.03

61	5.93E-12	0.005932	6.49E-13	0.000649	1.95E-11	0.02
62	4.45E-12	0.00445	4.73E-13	0.000473	1.50E-11	0.02
63	3.33E-12	0.003334	3.44E-13	0.000344	1.16E-11	0.01
64	2.50E-12	0.002496	2.5E-13	0.00025	8.93E-12	0.01
65	1.87E-12	0.001867	1.82E-13	0.000182	6.87E-12	0.01
66	1.40E-12	0.001395	1.32E-13	0.000132	5.28E-12	0.01
67	1.04E-12	0.001042	9.61E-14	9.61E-05	4.06E-12	0.00
68	7.77E-13	0.000777	6.97E-14	6.97E-05	3.12E-12	0.00
69	5.79E-13	0.000579	5.06E-14	5.06E-05	2.39E-12	0.00
70	4.31E-13	0.000431	3.67E-14	3.67E-05	1.83E-12	0.00
71	3.21E-13	0.000321	2.66E-14	2.66E-05	1.40E-12	0.00
72	2.39E-13	0.000239	1.92E-14	1.92E-05	1.07E-12	0.00
73	1.77E-13	0.000177	1.39E-14	1.39E-05	8.23E-13	0.00
74	1.32E-13	0.000132	1.01E-14	1.01E-05	6.29E-13	0.00
75	9.77E-14	9.77E-05	7.28E-15	7.28E-06	4.81E-13	0.00
76	7.24E-14	7.24E-05	5.26E-15	5.26E-06	3.67E-13	0.00
77	5.37E-14	5.37E-05	3.8E-15	3.8E-06	2.80E-13	0.00
78	3.97E-14	3.97E-05	2.74E-15	2.74E-06	2.14E-13	0.00
79	2.94E-14	2.94E-05	1.98E-15	1.98E-06	1.63E-13	0.00
80	2.17E-14	2.17E-05	1.43E-15	1.43E-06	1.24E-13	0.00

Appendix A11 S.L.U.E.T.H. Methodology

SLEUTH

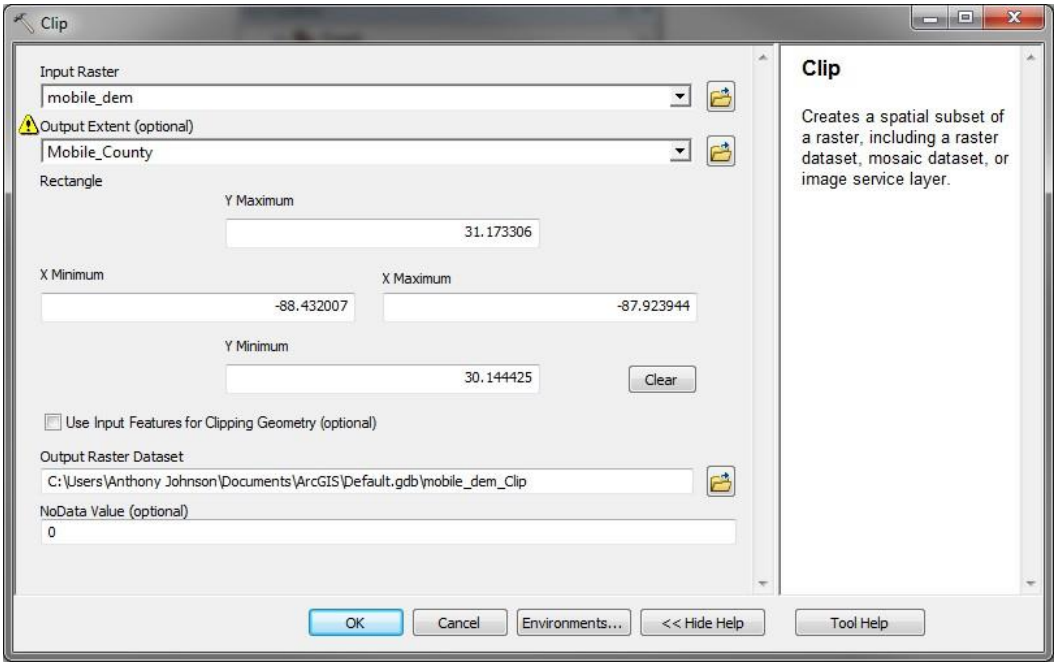
Background:

SLEUTH model is a method in predicting the urban extent is the; slope, land use, exclusion, urban, transportation, and hillshade. The SLEUTH model will be applied the projects study area of Mobile, AL. This document will now explain each of the variables, how they were derived and how to implement them to obtain the outcome that is sought after.

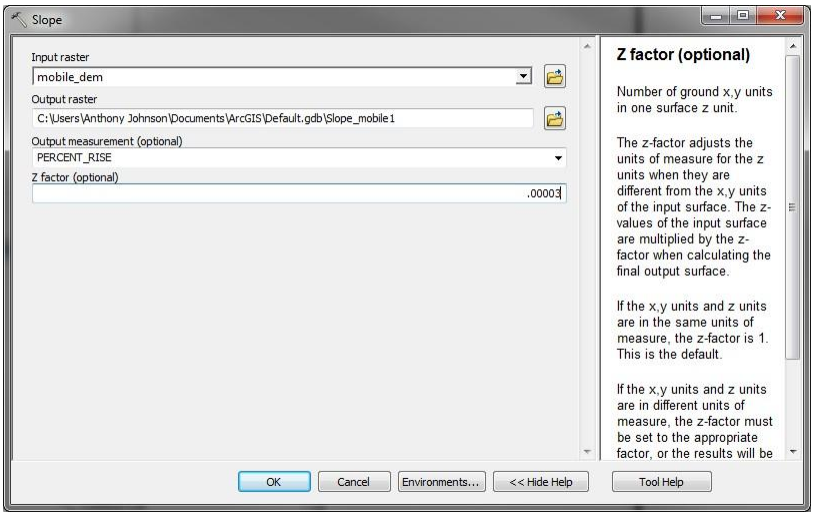
Step 1: Data Set Preparation

1.1 Slope:

The slope of the land is calculated to understand where urban expansion will be able to develop. For instance, it is not typically an option to build on a ninety-degree cliff. In Mobile, we need not worry since there are not many areas that would restrict development because of the degree of slope. To determine the percent slope of the landscape we must first obtain the digital elevation map from the USGS and also a shapefile of Mobile County from the Census Tigerline Files. Then make sure the data frame, raster, and shapefile's projection is set to NAD 1983 by using the projection tool. After that, clip the DEM raster to the extent of the Mobile County shapefile with the Clip tool in the toolbox.

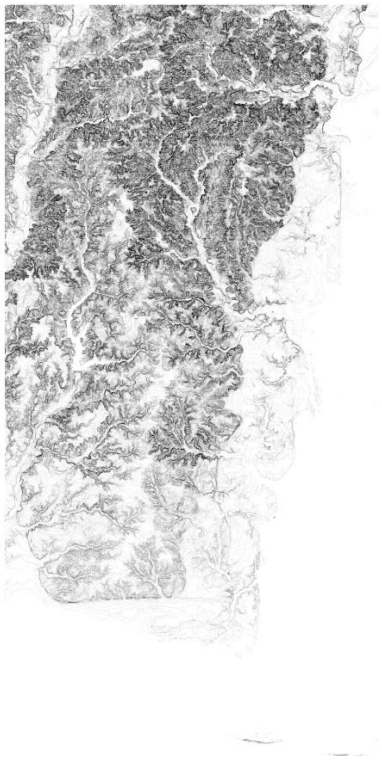


Now select the slope tool and input the DEM, set the output measurement to "percent" and the Z factor to 0.00003.



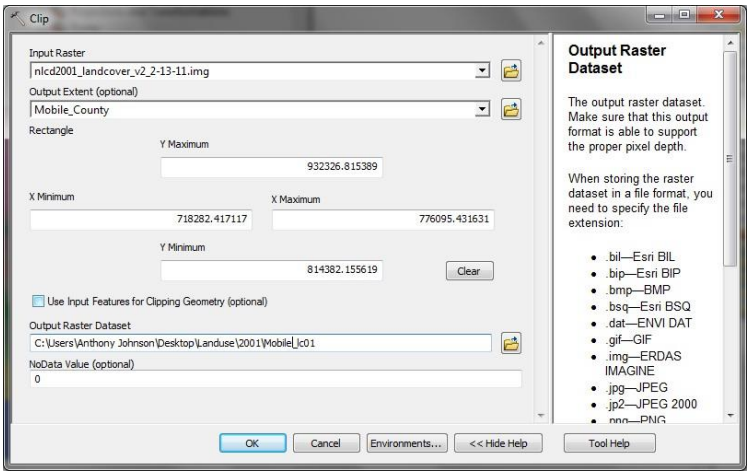
Select the reclassify tool in spatial analyst to categorize the values of the slope raster to whole numbers, 0 – 100. Then select the copy raster tool to change to pixel type to an 8_BIT_UNASSIGNED of the reclassified slope raster. This will allow the raster to be exported to a GIF format. To export the data as a GIF, select the export data tool, change no values to 0, set the size to be 955X1932, and save as demo200.slope.gif.

Slope



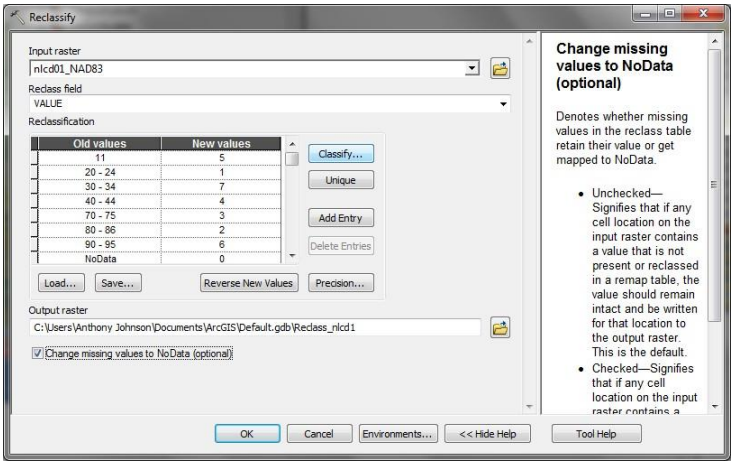
1.2 Land use:

The SLEUTH model will use land use data to better understand the historical terrain of the study area, whether it be wetland, agriculture, or forests. This data will be created by first obtaining National Land Cover Data for the years 1992, 2006, and 2011 from the United States Geological Survey. Then make sure both rasters are projected in NAD 1983. Clip both NLCD rasters to the extent of the Mobile County shapefile with the Clip.



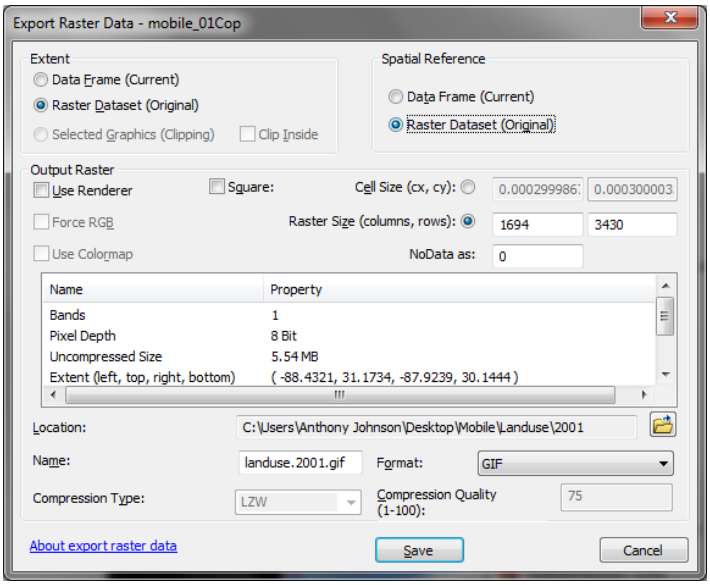
Select the reclassify tool in spatial analyst to categorize each of the rasters:

- 11 to 5 ;Water
- 20-24 to 1 ;Urban
- 30-34 to 7 ;Barren
- 40-44 to 4 ;Forest
- 50-75 to 3 ;Rangeland
- 80-86 to 2 ;Agriculture
- 90-95 to 6 ;Wetlands
- Nodata to 0 ;Unknown

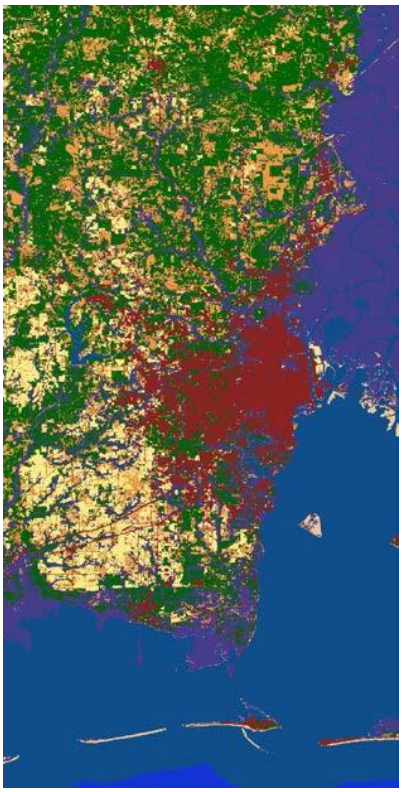


This has set each pixel in the raster to a value that defines the type of land that occupies that spot. Again select the copy raster tool to change to pixel type to an 8_BIT_UNASSIGNED of the reclassified of each

raster. Then export the data as a GIF, change no values to 0, change the size to 955X1932, save as demo200.landuse.1992.gif, demo200.landuse.2006.gif, demo200.landuse.2011.gif.



2011 Land use



1.3 Exclusion:

Since most places are not going to expand into water or environmentally protected wetlands, the sleuth model requires a raster image of these excluded perimeters. First, obtain National Land Cover Data for the year 2011 from the USGS and make sure it is in NAD 1983. Clip the raster to the extent of the Mobile County with the Clip tool. Choose the reclassify tool in spatial analyst to categorize the raster to the following:

- 0-10 to 0 ;Not Excluded
- 11 to 100 ;Excluded
- 12-93 to 0 ;Not Excluded
- 95 to 100 ;Excluded
- Nodata to 100 ;Excluded

Doing this has established water and wetlands to be excluded from development. Select the copy raster tool to change to pixel type to an 8_BIT_UNASSIGNED of the reclassified raster. Do an union on any shapefiles that need to be excluded, such as flood plains, graveyards, protected lands, etc….Then export the data as a GIF, change no values to 0, change size to 955X1932, save as demo200.Excluded.gif.

Exclusion

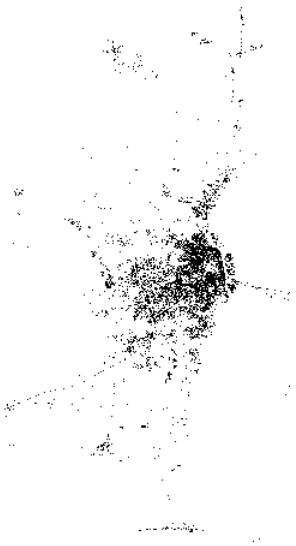
1.4 Urban:

The SLEUTH model requires four historical raster images that only show the urban area. The four separate years gives the input needed for the SLEUTH model to calculate the rate of growth. Also, the most recent urban raster will serve as the base at which it will append future urban clusters to, determined by the rate of growth. First, obtain National Land Cover Data for the years 1992, 2001, 2006, and 2011 from the USGS and make sure they are in NAD 1983. Clip the rasters to the extent of the Mobile County shape file with the Clip tool. Choose the reclassify tool in spatial analyst to categorize the rasters to the following:

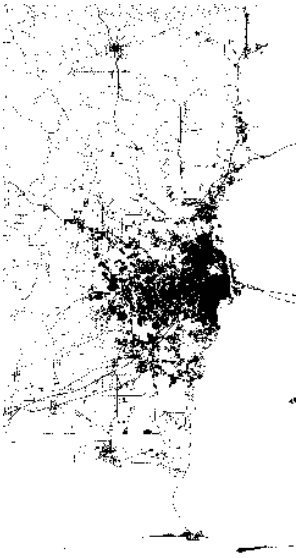
- 0-19 to 0 ;Not Urban
- 20-24 to 1 ;Urban
- 30-95 to 0 ;Not Urban
- Nodata to 0 ;Not Urban

Select the copy raster tool to change to pixel type to an 8_BIT_UNASSIGNED of the reclassified rasters. Then export the data as a GIF, change no values to 0, change size to 955X1932, save as demo200.urban.1992.gif, demo200.urban.2001.gif, demo200.urban.2006.gif or demo200.urban.2011.gif.

1992 Urban Area



2011 Urban Area



1.5 Transportation:

Transportation is one of the most important variables in this project, in that urban areas tend to develop around them for ease of access. Start by locating road shapefiles for the years 1992, 2000, and 2010 from Census Tigerline and make sure they are in NAD 1983. If there are any other future road shapefiles accessible be sure to use them. This project used roads from 2012 and 2020 that were on hand from other projects. This will help predict new areas that will develop that may not have ever been projected in the SLEUTH model. Now, in each shapefile create a new field called “Weight”. Then populate the field in accordance to the CFCC or MTFCC field:

1992 and 2000

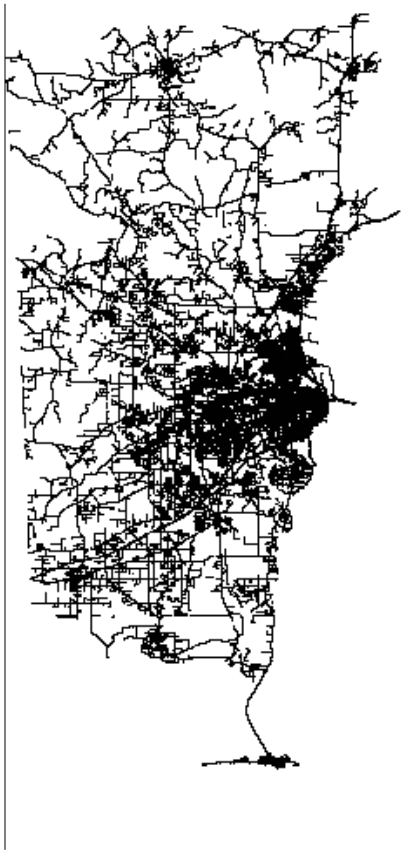
- A1x and A2x 4 Primary
- A3x 2 Secondary
- A4x 1 Local
- Other 0 Other

2010, 2012, 2020 delete all RoadsFlags = NO

- S1100 4 Primary
- S1200 2 Secondary
- S1400 1 Local
- Other 0 Other

The weight assigned is based on road type which decides how much gravitational pull the road has on attracting future development. Primary and Secondary roads tend to have a higher capacity and more traffic load than local roads, so they will be weighted higher. Since the Sleuth model requires raster gif images the shape file need to be converted to raster images. Select the Feature Class to Raster conversion tool based on "Weight", do this for each road shapefile. Clip the rasters to the extent of the Mobile County shapefile with the Clip tool. Select the copy raster tool to change to pixel type to an 8_BIT_UNASSIGNED of the newly clipped rasters. Then export the data as a GIF, change no values to 0, change size to 955X1932, save as demo200.roads.1992.gif, demo200.roads.2000.gif, demo200.roads.2010.gif, demo200.roads.2012.gif, or demo200.roads.2020.gif.

2020 Roads



1.6 Hillshade:

Hillshade adds a sense of depth and texture to the outputted images. Start by getting digital elevation map that was already used earlier and make sure it is in NAD 1983. Clip the raster to the extent of the Mobile County with the Clip. Select the Hillshade tool and input the DEM. Use the copy raster tool to change to pixel type to an 8_BIT_UNASSIGNED of the hillshade output. Then export the data as a GIF, change no values to 0, change size to 955X1932, save as demo200.Hillshade.gif.

Step 2: Download and verify model functions

2.1 Download directory structure

In this documentation path names to executable and data files will occasionally be used. Unless otherwise indicated, these names will be relative to the Scenarios directory, which is assumed to be the working directory, and the downloaded directory structure. The SLEUTH3.0beta directory is assumed to be the root directory. For a diagram and brief explanation of directory contents see directory structure.

2.2 Download UGM3.0beta

The SLEUTH code may be acquired from the download page on this site. If an internet browser is used to download the file, be sure the filename extensions are not altered by the software.

2.2.1. Decompress file

To decompress the downloaded file from a command line interface:

prompt% unzip SLEUTH3.0beta.tar.gz

prompt% tar xvf SLEUTH3.0beta.tar

2.2.2. Compile code

Specifications for compiling SLEUTH3.0beta are set in the Makefile in the root directory. Variables include parallel processing and debug assert flags. Review the Makefile before compiling. The Makefiles in the three code directories (SLEUTH3.0beta, GD, and Whirlgif) all use the gcc C library compiler

To compile all libraries used by SLEUTH3.0beta:

(pathnames relative to the root directory SLEUTH3.0beta)

change directories into GD

prompt% cd GD

compile gd libraries

prompt% make

from GD change directories into Whirlgif

prompt% cd ../Whirlgif

compile whirlgif libraries

prompt% make

from Whirlgif change directories into the root directory

prompt% cd ..

compile SLEUTH3.0beta

prompt% make

2.3. Verify model execution

The downloaded scenario files will be set to run on a provided sample data set, demo_city. The scenario.demo200_test file is set to run in test mode, modeling urban land cover only. (To execute a test run modeling Anderson Level I land class types use the scenario.demo200_land_test file.) Many of the output image and statistic file flags are set to "YES". This is helpful to see what affect a certain set of coefficients is having upon the data, or simply confirm that the model is functioning properly. Examine the file scenario.demo200_test in the Scenarios directory. Note how the input and output path names, and input file names are set. This is how input and output is located for an application. Notice also the coefficient value settings. The *_START coefficient values will initialize the run. See also that the flags to write the average, standard deviation, and coefficient files are all set the "YES". These files will all be written to the output directory.

usage:

prompt% grow.exe <mode> <scenario file>

Allowable modes are:

calibrate

restart

test

predict

execute a test run: (from the Scenarios directory)

prompt% ../grow.exe test scenario.demo200_test

Data will be written to the screen showing application progress.

2.4. Check model output

All output files from a model execution will be written to the directory defined by the OUTPUT_DIR flag in the scenario.demo200_test file. In this case, the demo200_test directory located within the Output directory. The results from a test run on your machine and platform may be compared with ours to verify functionality and test performance. Results may vary slightly.

2.0 Calibration:

Calibration comes in three different stages. First is the coarse stage. The second stage is the fine stage. Lastly the final stage. Each one of these will have outputs that determine the values used for the

Step 2: Download and verify model functions

Step 3: Calibration

Five coefficient values affect modeled urban growth of a study area. Known historical data is compared to simulated land cover in an effort to find the coefficient values that best model urban and related land cover change through time. These are measured using several Pearson r2 statistics, comparing measurements such as total number of urban pixels, edges, clusters and a spatial match comparison. For a more complete explanation see output statistic files.

Running SLEUTH in calibrate mode will perform brute force monte carlo runs through the historical data using every combination of the model coefficient values indicated. The CALIBRATION_*_START coefficient values (where "*" represents a coefficient type) will initialize the first simulation. A coefficient will then be increased by its _STEP value, and another simulation performed. This will continue until the coefficient _STOP value has been reached or exceeded. The incrementation will be repeated for all possible permutations of given ranges.

Calibration requires many (often thousands) of single simulations of land cover change. Because of this, output requirements can greatly add to the total application time. Many options are available for log and image file output during calibration. However, the fewer output files written, the more efficiently the code will run. It is important to understand the scenario file options to optimize it for your applications. To prevent overwriting, it is recommended to create, and in the scenario file point to, a unique output directory for each phase of model calibration and prediction.

Since the urban growth module of SLEUTH is its most basic component, the following instructions on how to calibrate the model will use urban growth only. The steps of calibration are the same when the Deltatron module is incorporated, but the output file control_stats.log will vary slightly. (For more information see: SLEUTH functions.

3.1 Set constants and verify

3.1.1 Create a scenario file for your data

The scenario.demo50_calibrate file is an example of how a file could be set up for first phase, or coarse, calibration. In order to make the code run more efficiently and, cut down on i/o requirements, all of the output file flags are set to "NO" except for the LOGGING(YES/NO) flag. If statistics for a few specific calibration runs are desired, these can be run independently of the calibration step in calibration or test mode with the desired flags set to "YES". (Test mode will produce annual images of land cover change, calibration mode will not.)

The easiest way to create a scenario file for your data set is to edit the scenario.demo50_calibrate file included with SLEUTH3.0beta. A scenario file must begin with the keyword "scenario.". Customizing this file will require, at the very least, editing the input and output path names and input file name flags to represent your data. Be sure to become familiar with the different functions and output controlled by the scenario file. This can be done by reading the comments contained in the provided scenario file. In addition, intelligently altering the variables and flags contained in the file, and examining the results, is recommended in order to become familiar with how SLEUTH functionality and output is controlled.

Create a copy of scenario.demo50_calibrate using a unique name

Filename example: scenario.mydata_coarse

Edit INPUT_DIR flag to point to your input data directory

Edit OUTPUT_DIR flag to point to a desired output directory

Edit input image flags to represent your file names

3.1.2 Run a test on your data

Execute a test run

prompt% ../grow test scenario.mydata_coarse

Monitor progress

If the ECHO flag is set to "YES" growth years should be printed to the screen as the model executes.

The NUMBER_OF_ITERATIONS flag may be set to one (1)

Examine output

SLEUTH output should make sense relative to its input. For example, the output images will not necessarily look realistic because the coefficients used were not calibrated for the data set. However, growth should be logical - not occurring in excluded areas but spreading from existing urban edges, etc. The LOG_0 file will record what was contained in the scenario file used for the application, what files were read in, what their values were, and some basic calculations on the data.

Repeat steps 1-3 as many times as desired, changing the scenario file flags between runs

if more growth is desired increase the coefficient *_START values

test will always use only the *_START values

the *_START values must be less than the *_STOP values

3.2 Coarse calibration

3.2.1 Modify scenario file for coarse calibration

Set all resolution of inputs to 1/4 of its full size.

Create a copy of, or modify the scenario file used for testing in the previous step

Filename example: scenario.mydata_coarse

Check MONTE_CARLO_ITERATIONS flag setting

This should be set to a low number (~4-5)

Set initial coefficient settings for calibration

Coefficient value ranges: {0-100}.

For coarse calibration it is recommended to set all coefficients to {0-100,25} where the first number (0) is the _START value, the second number (100) is the _STOP value, and the third (25) is the _STEP

The downloaded scenario.demo50_calibrate file calibration coefficient settings are set for a coarse calibration and may be used as an example.

3.2.2 Run a coarse calibration on your data

Execute a calibration run

prompt% ../grow calibrate scenario.mydata_coarse

Monitor progress

If ECHO flag is set to "YES" growth years should be printed to the screen as the model executes.

Time passes...

Examine output

The primary file used for coefficient range selection is the control_stats.log file. For more information on how ranges are selected see selecting ranges.

3.3 Fine calibration

3.3.1 Modify scenario file for fine calibration

Create a copy of, or modify, the scenario file used in the previous step

Filename example: scenario.mydata_fine

Edit INPUT_DIR flag to point to the directory of your 1/2 resolution images

Edit OUTPUT_DIR flag to point to a desired output directory

Edit input image flags to represent your file names

Check MONTE_CARLO_ITERATIONS flag setting

This should be set to a low number (~7-8)

Set coefficient settings for fine calibration – The following are the coefficients this project produced

```
CALIBRATION_DIFFUSION_START= 0
CALIBRATION_DIFFUSION_STEP=  25
CALIBRATION_DIFFUSION_STOP=  100

CALIBRATION_BREED_START=     0
CALIBRATION_BREED_STEP=      25
CALIBRATION_BREED_STOP=      100

CALIBRATION_SPREAD_START=    1
CALIBRATION_SPREAD_STEP=     5
CALIBRATION_SPREAD_STOP=     20

CALIBRATION_SLOPE_START=     1
CALIBRATION_SLOPE_STEP=      5
CALIBRATION_SLOPE_STOP=      25

CALIBRATION_ROAD_START=      75
CALIBRATION_ROAD_STEP=       5
CALIBRATION_ROAD_STOP=       100
```

These values should define a narrowed coefficient range derived from the coarse phase of calibration.

3.3.2 Run a fine calibration on your data

Execute a calibration run

prompt% ../grow calibrate scenario.mydata_fine

Monitor progress

If ECHO flag is set to "YES" growth years should be printed to the screen as the model executes.

More time passes...

Examine output

The primary file used for coefficient range selection is the control_stats.log file. For more information on how ranges are selected see selecting coefficients.

3.4. Final calibration

3.4.1. Modify scenario file for final calibration

Create a copy of or modify the scenario file used in the previous step

Filename example: scenario.mydata_final

Edit INPUT_DIR flag to point to the directory of your full resolution images

Edit OUTPUT_DIR flag to point to a desired output directory

Edit input image flags to represent your file names

Check MONTE_CARLO_ITERATIONS flag setting

This should be set to ~8-10

Set coefficient settings for final calibration – The following are the coefficients this project produced

```
CALIBRATION_DIFFUSION_START= 1
CALIBRATION_DIFFUSION_STEP=  1
CALIBRATION_DIFFUSION_STOP=  5

CALIBRATION_BREED_START=     75
CALIBRATION_BREED_STEP=      5
CALIBRATION_BREED_STOP=      100

CALIBRATION_SPREAD_START=    13
CALIBRATION_SPREAD_STEP=     1
CALIBRATION_SPREAD_STOP=     18

CALIBRATION_SLOPE_START=     16
CALIBRATION_SLOPE_STEP=      1
CALIBRATION_SLOPE_STOP=      21

CALIBRATION_ROAD_START=      75
CALIBRATION_ROAD_STEP=       2
CALIBRATION_ROAD_STOP=       85
```

These values should define a narrowed coefficient range derived from the fine phase of calibration.

3.4.2 Run a final calibration on your data

Execute a calibration run

prompt% ../grow calibrate scenario.mydata_final

Monitor progress

If ECHO flag is set to "YES" growth years should be printed to the screen as the model executes.

A lot more time passes...

Examine output

The primary file used for coefficient range selection is the control_stats.log file. For more information on how ranges are selected see selecting coefficients.

3.5. Derive forecasting coefficients

The calibration process produces initializing coefficient values that best simulate historical growth for a region. However, due to SLEUTH's self-modification qualities, coefficient values at the START_DATE of a run may be altered by the STOP_DATE. For forecast initialization, the STOP_DATE values from the best calibrated coefficients are desired. Using the best coefficients derived from calibration and running SLEUTH for the historical time period will produce a single set of STOP_DATE coefficients to initialize forecasting. However, due to the random variability of the model, averaged coefficient results of many monte carlo iterations will produce a more robust forecasting coefficient set.

3.4.1. Modify scenario file

Create a copy of or modify the scenario file used in the previous step

Filename example: scenario.mydata

The INPUT_DIR flag should point to the directory of your full resolution images

The OUTPUT_DIR flag should point to a desired output directory

The input image flags should represent your full size file names

Check MONTE_CARLO_ITERATIONS flag setting

This should be set very high (e.g.; 100 or greater))

Set initializing coefficient settings

These values should define a single set of best coefficient values derived from the final phase of calibration. The _START and _STOP values should be equal, and the _STEP value should be one (1).

Set the WRITE_AVG_FILE(YES/NO) flag to "YES"

(The coeff.log file may also be used to find the STOP_DATE coefficient values.)

3.4.2. Find forecasting coefficients

Execute a calibration run

prompt% ../grow calibrate scenario.mydata

Monitor progress

If ECHO flag is set to "YES" growth years should be printed to the screen as the model executes.

Examine output

The file used to store coefficient values is the avg.log file. For more information on how to use this file see selecting coefficients.

Step 4: Selecting Coefficient Ranges

The control_stats.log file is the primary file used to score the many runs executed during a calibration phase. By sorting on one or more of the metrics contained in the control_stats.log file, coefficient sets that performed best may be found. Using this information, the user must decide what coefficient ranges will be used for the subsequent phase of calibration.

The algorithm for narrowing these ranges is an area of continuous discussion among users, and so far no definitive "right" way has been agreed upon. Examples of approaches used thus far include: sorting on all metrics equally, weighting some metrics more heavily than others, and sorting only on one metric. Ron Matheny of the Environmental Protection Agency wrote a simple SAS script to sort the control_stats.log file that may be downloaded here. For the sake of clarity in this example, the last method, sorting on one metric, is applied. Simulations are scored on their performance for the spatial match, or lee sallee, metric.

Another disputed issue associated with this process is how many of the best scores should influence the range selection: the top 5, 10, 50? This too is an area that is ripe for more research. The pragmatic answer is enough to capture good results, while substantially reducing the values' spread.

4.1 Selecting coefficients with Optimum SLEUTH Metric (OSM)

Optimum SLEUTH Metric (Dietzel and Clarke, 2007) code is provided in the Download page. After each phase of calibration OSM code can be run using the control_stats.log file to find out the 'top 50' best fit values.

1. Download the OSM code, unzip and place it in the 'Output' directory.

2. Execute the OSM run

    prompt% ./readdata2

    autoprompt 'Enter the input file name:' % control_stats.log

3. This generates 'top50.txt' which stores the top 50 best fit set of coefficient values.

4. For the top three rankings: take high and low values of each of the coefficients.It is possible for more than one run to have the same score, creating a tie

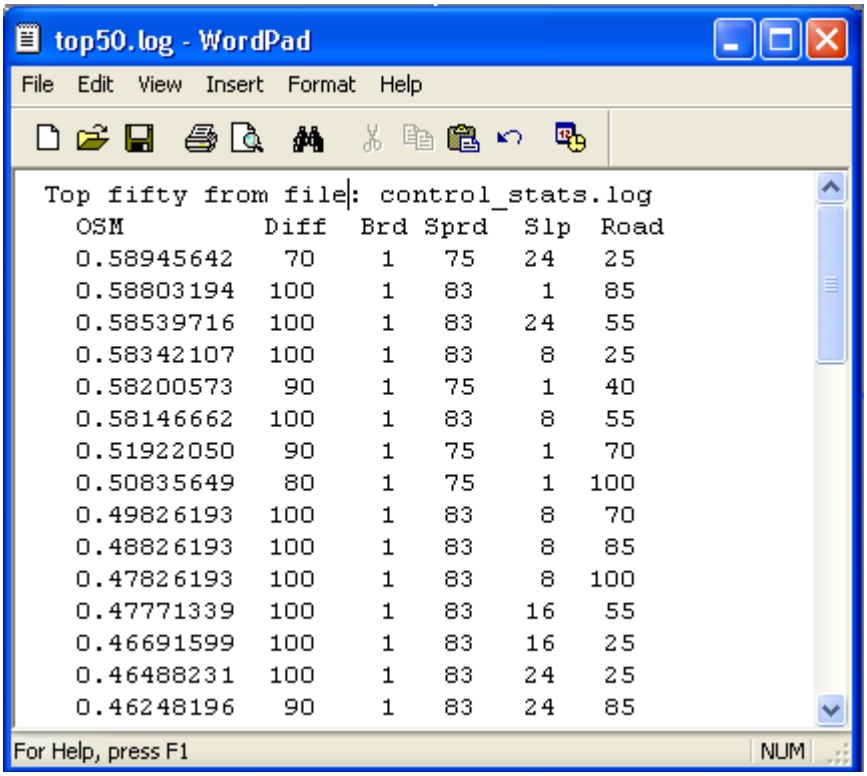
5. For each coefficient: in the scenario file to be used for fine calibration, low values are set to _START

6. For each coefficient: in the scenario file to be used for fine calibration, high values are set to _STOP

7. A _STEP value is selected that will increment between the _START and _STOP values 4-6 times

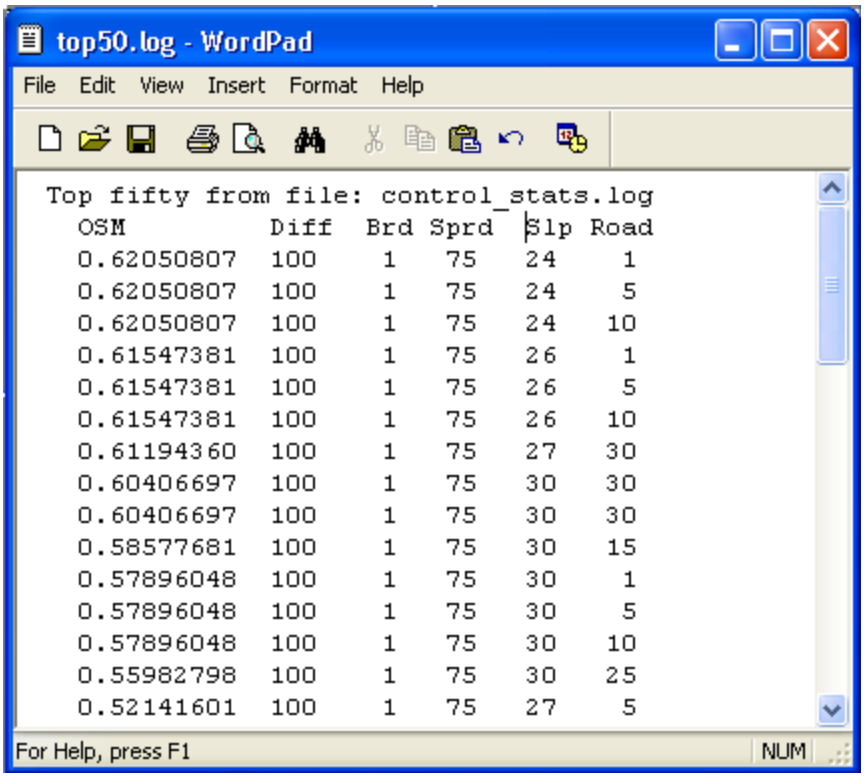
If only one coefficient value sorts into the top 10 (e.g.; "1" for dispersion and spread) select _START, _STEP, and _STOP values that will explore a finer coefficient space around the value

Top 5 scores from an example study coarse calibration, sorting only on the OSM:



dispersion	{70 - 100, 8}
breed	{1 - 1, 1}
spread	{75 - 83, 5}
slope	{1 - 24, 5}
road gravity	{25 - 85, 10}

Top 5 scores from an example study final calibration, sorting only on the OSM:



Coefficient values used to predict growth:

to dispersion	100
breed	1
spread	75
slope	24
road gravity	1

Step 5: Model Prediction

This documentation will show how to use the coefficient set acquired through calibration to initialize future land cover change in a region. However, SLEUTH will execute in predict mode with any set of coefficients with values between 0 - 100 (not necessarily derived through calibration.)

5.1 Set constants

5.1.1 Update input data

This step is optional. SLEUTH maybe used to run alternative scenarios of regional growth by altering the input data used to initialize multiple prediction runs. Otherwise, the same input used for calibration maybe used. For more information on generating alternative scenarios click here.

5.1.2 Modify scenario file for prediction

Create a copy of, or modify the scenario file used to derive forecasting coefficients, or modify the scenario.demo200_predict file contained in the downloaded Scenarios directory.

New filename example: scenario.<mydata>_predict

Edit INPUT_DIR flag to point to the directory of your full resolution images:

```
INPUT_DIR=../Input/prediction/
```

Edit OUTPUT_DIR flag to point to a desired output directory:

```
OUTPUT_DIR=../Output/prediction/
```

Set Output file flags to "YES" in order to create desired statistic files (at least avg.log is recommended)

The NUM_WORKING_GRIDS flag might have to be increased. If the setting is too low an error message will be printed to the screen upon execution:

```
NUM_WORKING_GRIDS=5
```

Set the MONTE_CARLO_ITERATIONS flag to a high number (100 or greater):

```
MONTE_CARLO_ITERATIONS=100
```

Set coefficient settings for prediction – The following are the coefficients this project produced

```
CALIBRATION_DIFFUSION_START= 1
CALIBRATION_DIFFUSION_STEP=  1
CALIBRATION_DIFFUSION_STOP=  1

CALIBRATION_BREED_START=     95
CALIBRATION_BREED_STEP=      95
CALIBRATION_BREED_STOP=      95

CALIBRATION_SPREAD_START=    14
CALIBRATION_SPREAD_STEP=     14
CALIBRATION_SPREAD_STOP=     14

CALIBRATION_SLOPE_START=     18
CALIBRATION_SLOPE_STEP=      18
CALIBRATION_SLOPE_STOP=      18

CALIBRATION_ROAD_START=      81
CALIBRATION_ROAD_STEP=       81
```

```
CALIBRATION_ROAD_STOP=       81
```

Enter the coefficient set derived from calibration into the PREDICTION_*_BEST_FIT flags, where (*) represents each coefficient type – The following are the coefficients this project produced.

```
PREDICTION_DIFFUSION_BEST_FIT=  1
PREDICTION_BREED_BEST_FIT=  100
PREDICTION_SPREAD_BEST_FIT=  16
PREDICTION_SLOPE_BEST_FIT=  1
PREDICTION_ROAD_BEST_FIT=  89
```

Set prediction date range:

```
PREDICTION_START_DATE=2011
PREDICTION_STOP_DATE=2045
```

Edit input image flags to represent your desired files for this prediction scenario

```
# Urban data GIFs
#  format:  <location>.urban.<date>.[<user info>].gif
#
#
URBAN_DATA= demo200.urban.1992.gif
URBAN_DATA= demo200.urban.2001.gif
URBAN_DATA= demo200.urban.2006.gif
URBAN_DATA= demo200.urban.2011.gif
#
# Road data GIFs
#  format:  <location>.roads.<date>.[<user info>].gif
#
ROAD_DATA= demo200.roads.1992.gif
ROAD_DATA= demo200.roads.2000.gif
ROAD_DATA= demo200.roads.2010.gif
ROAD_DATA= demo200.roads.2012.gif
ROAD_DATA= demo200.roads.2020.gif
#
# Land use data GIFs
#  format:  <location>.landuse.<date>.[<user info>].gif
#
LANDUSE_DATA= demo200.landuse.1992.gif
LANDUSE_DATA= demo200.landuse.2006.gif
LANDUSE_DATA= demo200.landuse.2011.gif
# Excluded data GIF
#  format:  <location>.excluded.[<user info>].gif
#
EXCLUDED_DATA= demo200.excluded.gif
#
# Slope data GIF
#  format:  <location>.slope.[<user info>].gif
#
SLOPE_DATA= demo200.slope.gif
```

```
#
# Background data GIF
#  format:    <location>.hillshade.[<user info>].gif
#
BACKGROUND_DATA= demo200.hillshade.gif
```

Alter color table values if desired

5.2 Run a prediction

Execute a calibration run

prompt% ../grow.exe predict scenario.<mydata>_predict

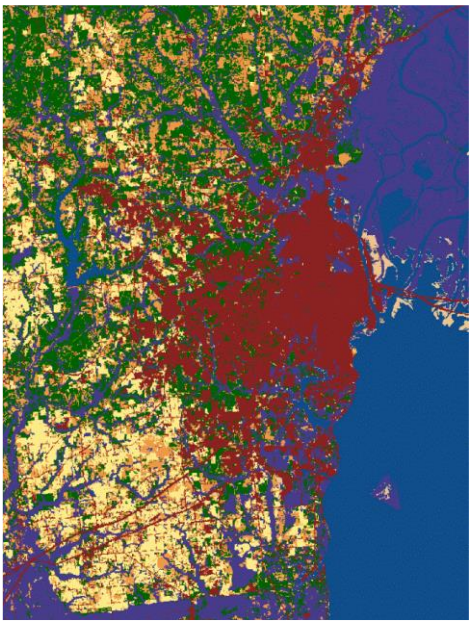
Monitor progress

If ECHO flag is set to "YES" growth years should be printed to the screen as the model executes.

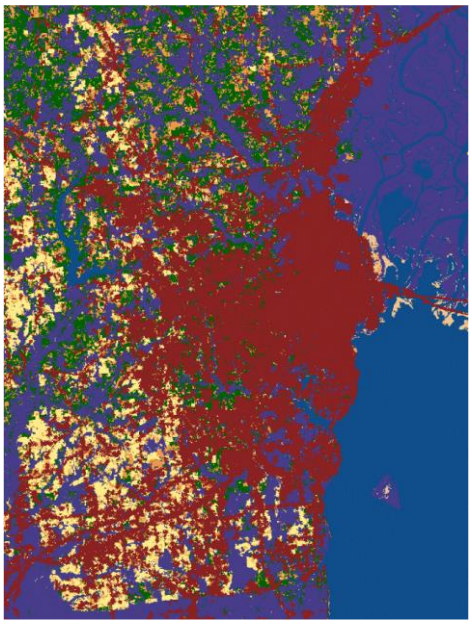
5.3 Examine Output

The output includes a raster image of each year from start year to end year. Here are the beginning year and end year.

2011



2045

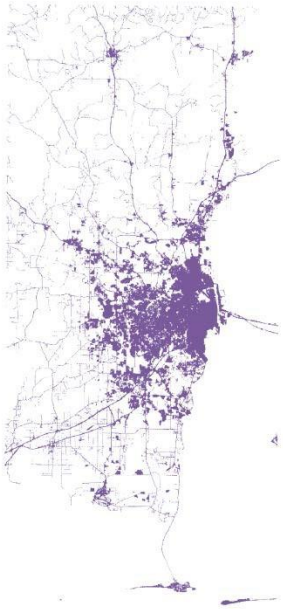


Step 6: Determine the Percent Urban Change for Each TAZ

Acquire the TAZ shape file of the study area.

Take the 2045 and 2011 outputs that would have been obtained from the running of the prediction and reclassify them to where only the urban area is a value.

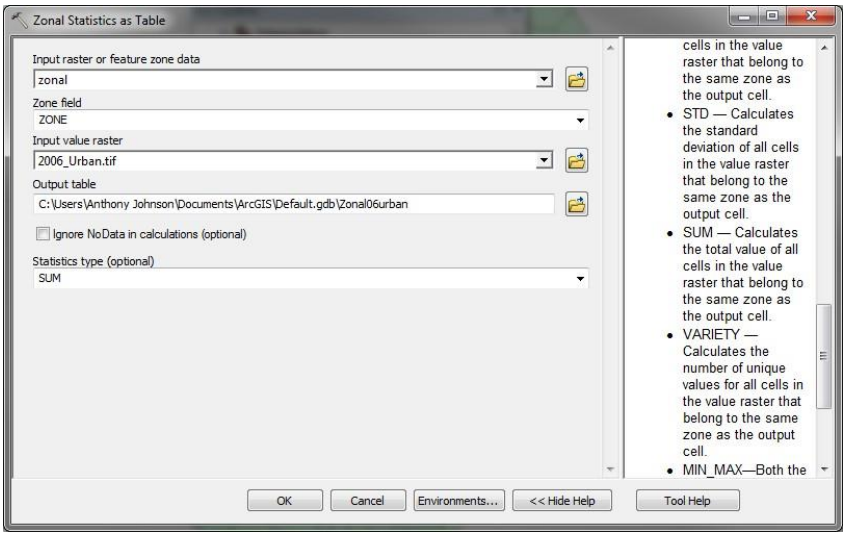
2011 Urban Area



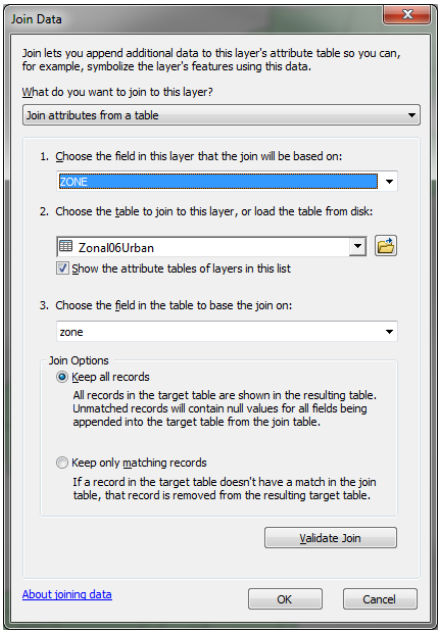
2045 Urban Area

The Georeference tool was then used to stretch out the rasters so they overlay the TAZ shapefile correctly. Then utilize the Zonal Statics as Table tool and input the TAZs as the zone data and use the

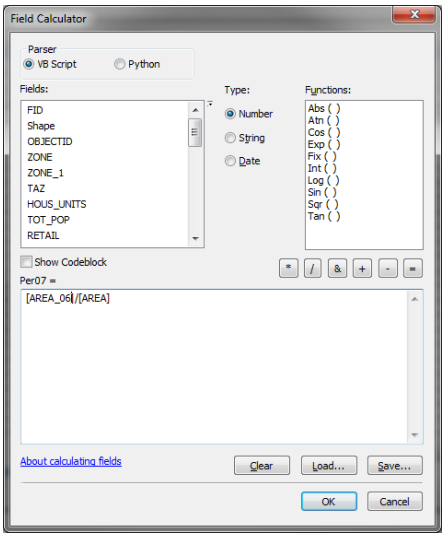
field zone. Input the 2011 urban raster and later the 2045 as the value. Select sum so it will output the total area of the urban extent into each zone. This will be in dbf format, but the amount of urban area will be tied to each zone.



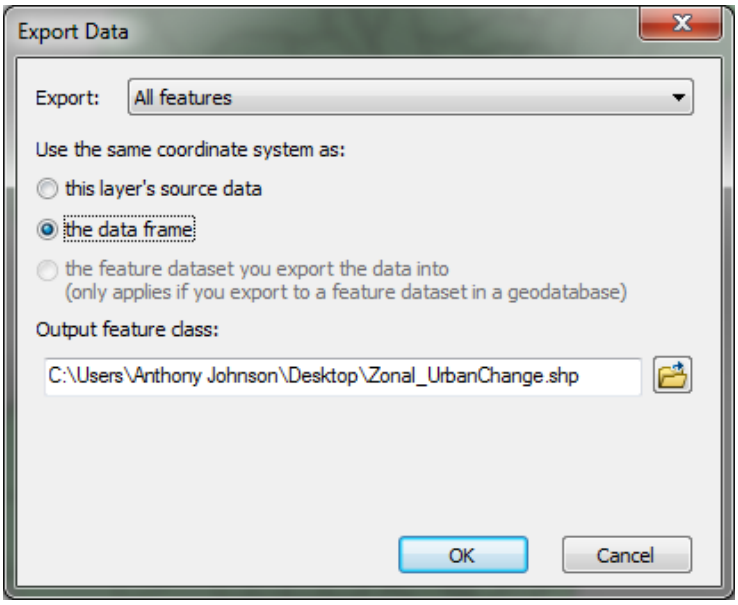
Using the Join tool, join both the 2011 and 2045 urban dbf's to the TAZ shapefile.



So now there is a TAZ shapefile that contains both the 2011 and 2045 urban area total within each zone. Create two new fields called Percent06 and Percent40 and in field calculator divide 2011, later 2045, total urban area by the total area of the TAZ zone.



This will output the percentage of urban area that covers the TAZ for each zone. Create a new field called PercentChange and in field calculator subtract Percent11 from Percent45. This will provide a field with the percent change from the year 2011 to 2045 for each individual zone. Export the shapefile to have a specific shape file for the zonal urban change]



Appendix A12 2015-2045 Volume Plots

Figure A12- 1 2015 Volume

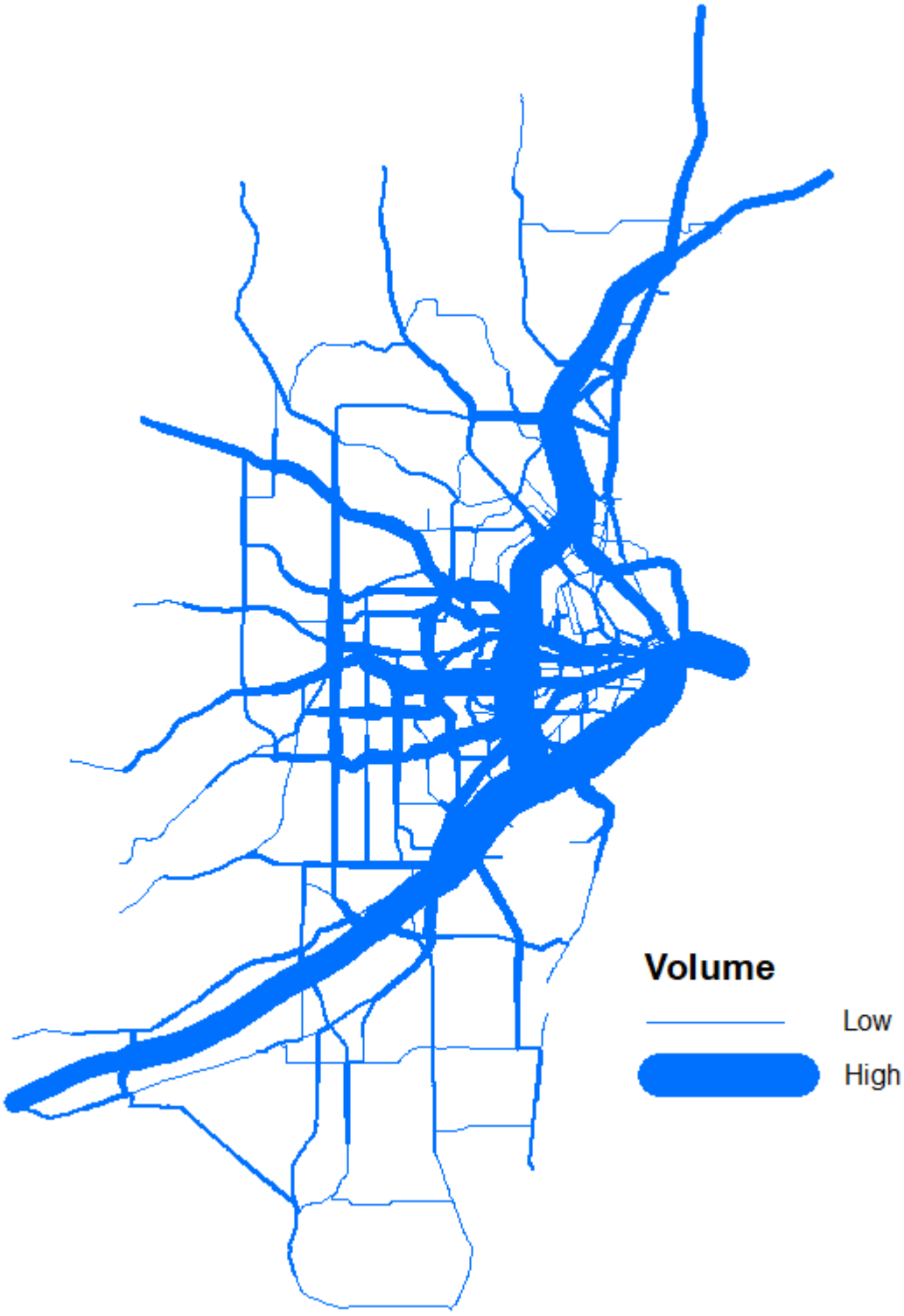


Figure A12- 2 2015 Volume/Capacity

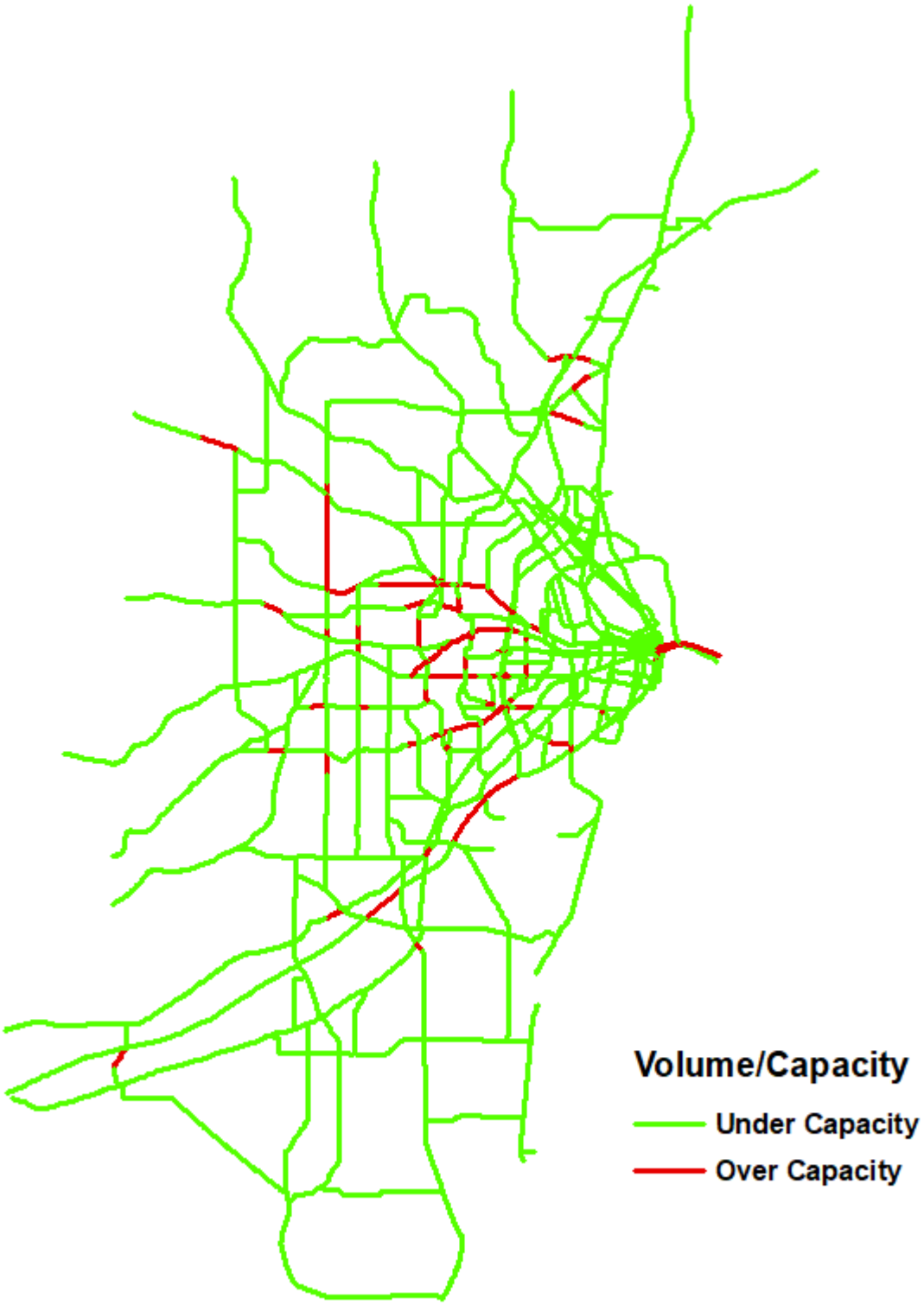


Figure A12- 3 2045 E+C Volumes

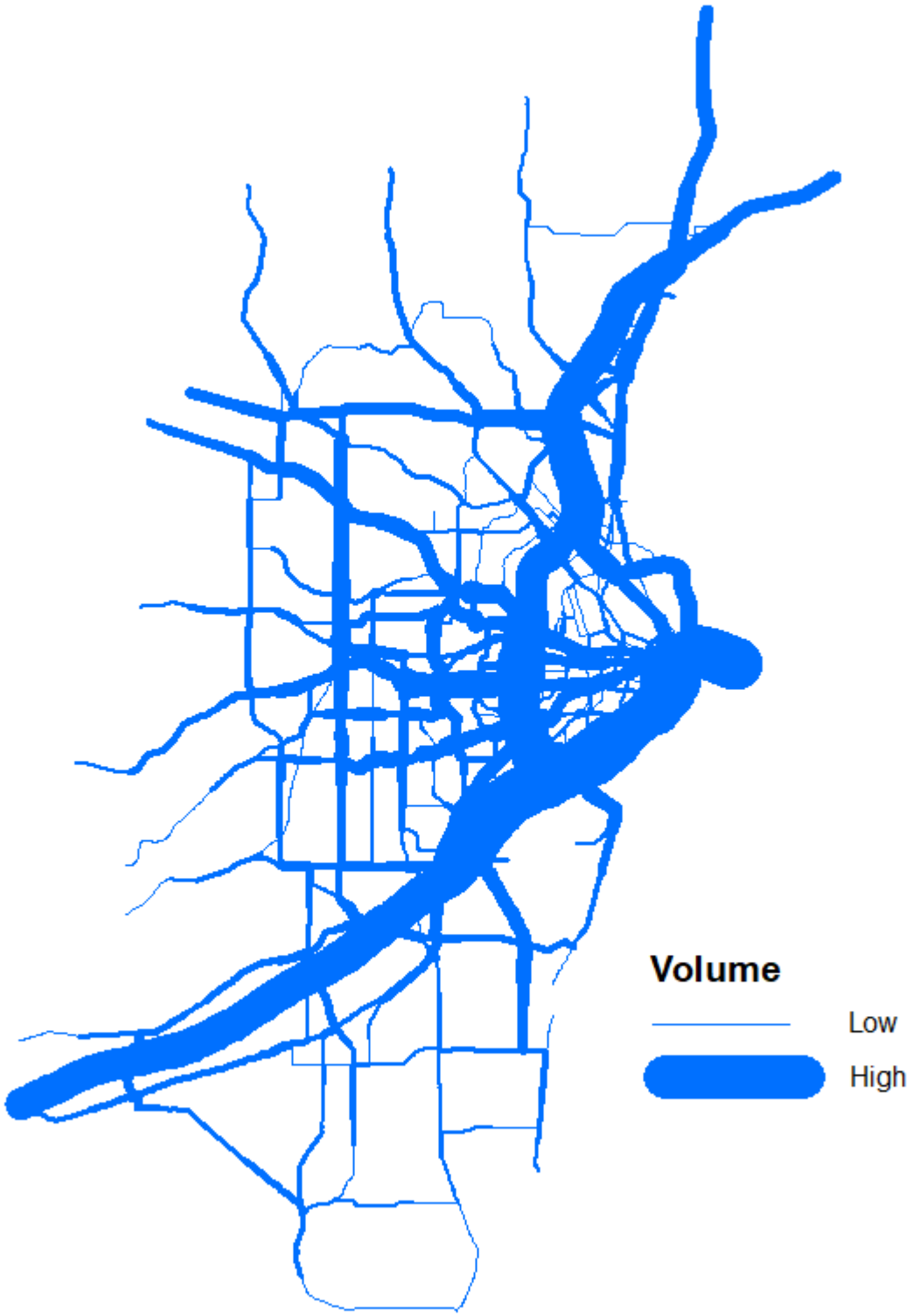


Figure A12- 4 2045 E+C Volume/Capacity

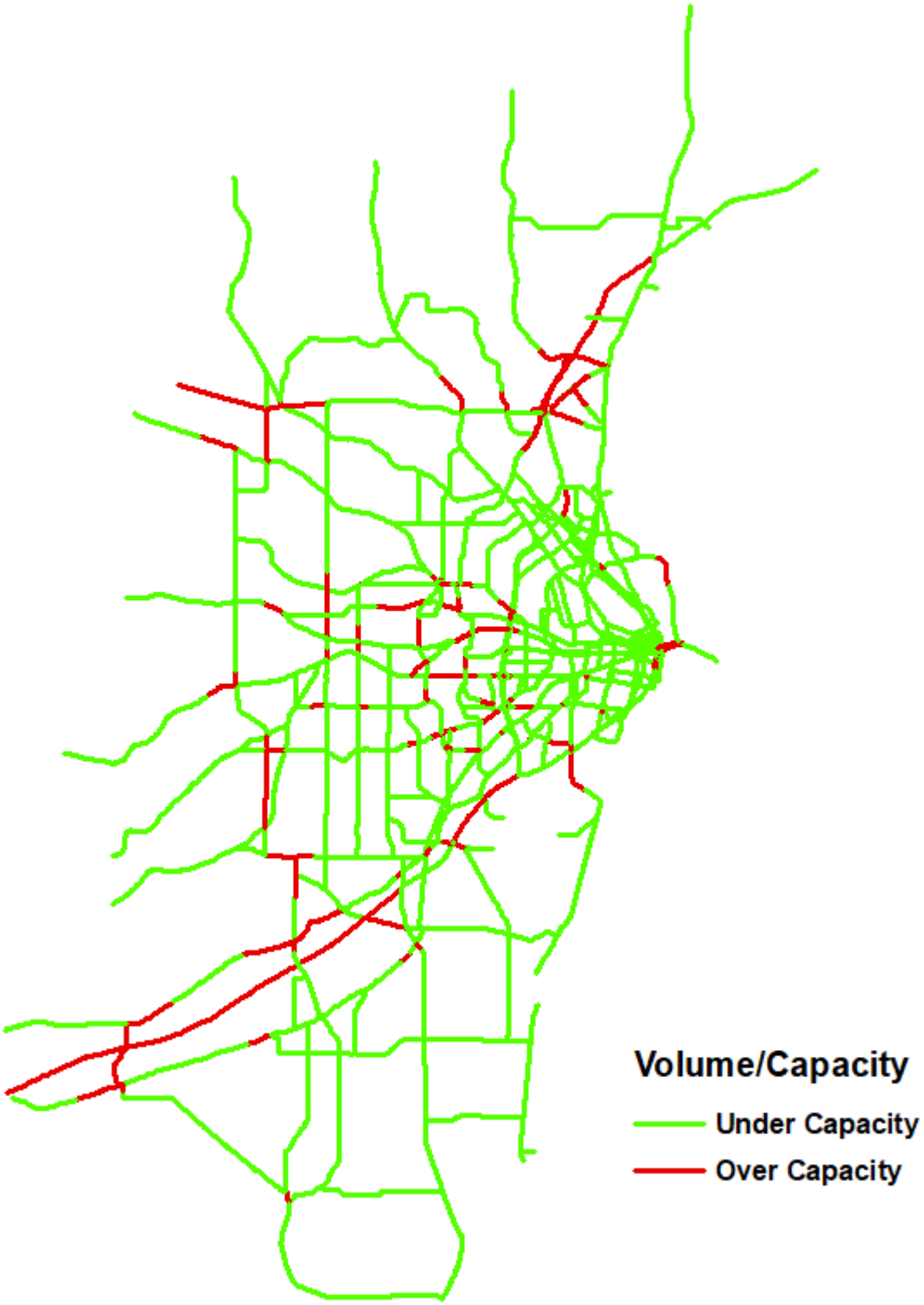


Figure A12- 5 2045 Plan Volume

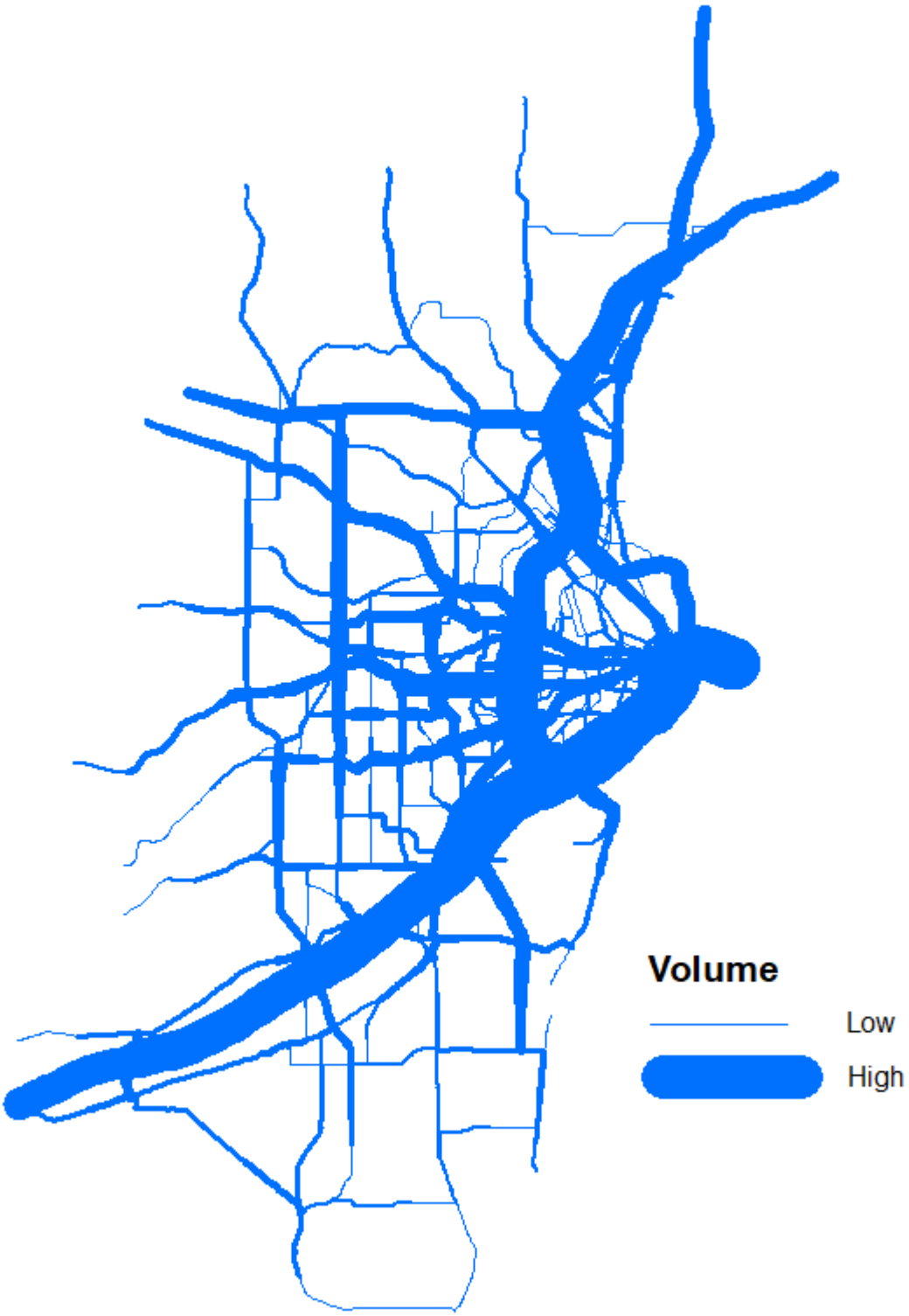
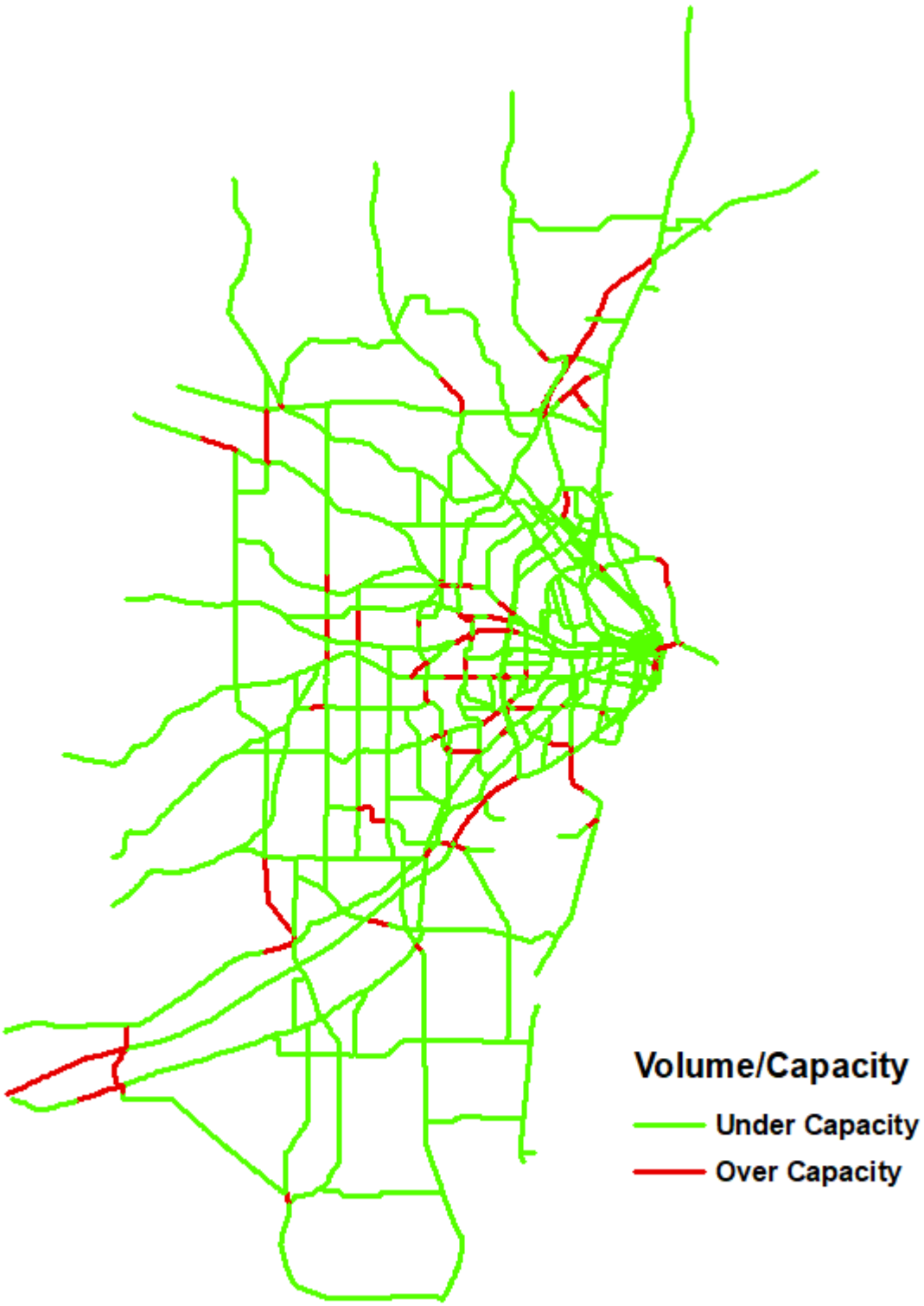



Figure A12- 2045 Plan Volume/Capacity