Travel Demand Model Update

Travel Model Development Report

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AMATS Travel Demand Model Development Report

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1.0 INTRODUCTION

This report describes the development of a new modeling system for the Anchorage region. The modeling system has been completely updated from previous versions, and contains a number of enhancements due to the need to keep the travel models current and to add sensitivities to the model system for analysis of upcoming Metropolitan Transportation Plan and Transportation Improvement Program policies and projects. The model was calibrated to match observed travel patterns from recently-collected household and transit on-board survey data, and Bluetooth survey data, and utilizes an updated base year for calibration (2013). The enhancements include the following:

- A more refined Transportation Analysis Zone (TAZ) system covering the Municipality of Anchorage and Matanuska-Susitna Borough
- Updated TAZ data inputs including NAICS-based employment categories
- Updated socio-economic distributions and household sub-models based on recent census data and using more disaggregate income categories for greater sensitivity to cost variables
- A set of continuous buffered density measures used in various model components to represent accessibilities to activities of different types by different modes
- Replacement of traditional ‘gravity’ formulation for trip distribution with logit-based destination choice models to better reflect sensitivity to various travel modes (including non-motorized) on trip length and to better differentiate travel patterns for residents of the Municipality of Anchorage versus residents of outlying areas of the region.
- Development of a fully-segmented and nested logit mode choice model with auto travel modes by occupancy, walk and bike modes, and transit walk and drive access. The model utilizes auto sufficiency as the primary method of segmentation to better represent “choice” versus “captive” transit riders and four income bins for improved cost sensitivities to toll facilities.
- Implementation of a new method for treatment of non-home-based trips that represents a partial move towards tour-based modeling.
- Development of a set of commercial vehicle models including a freight model based upon ATRI data and a state-of-the-practice non-goods movement commercial vehicle model.
- Implementation using the TransCAD software platform: all model steps are implemented in the TransCAD scripting language GISDK. A graphical model user interface (GUI) was also coded in GISDK and the model outputs a number of summaries useful for comparing scenario results.

This document covers model specification, estimation and calibration\validation of the model system. It is accompanied by a Model User’s Guide that describes how to set up and use the new model, including network and TAZ data coding, running the model, model outputs and reports.

2.0 DATA FOR MODEL DEVELOPMENT

2.1 REGIONAL HOUSEHOLD TRAVEL SURVEY

The recently completed household and transit on-board surveys form the basis for most of the model development activities described below. The regional household travel survey (RHTS) was conducted in 2014 in order to collect current information about household and individual travel patterns for residents throughout the greater Anchorage area, including residents in Chugiak-Eagle River and the Mat-Su Valley, as well as in the Anchorage Bowl. The survey was designed to get the core information required for travel demand modeling process. The primary goal of the RHTS was to collect complete travel information for a 24-hour weekday period from a representative sample of households in the region; the survey also sought to collect a sufficient sample of households that may be more difficult to reach or are important to transportation policies and plans. This includes (but is not limited to) low-income households, low- or no-vehicle households and households in rapidly growing parts of the region. The survey collected the full range of household travel information, including detailed trip purposes, all types of trip modes (e.g., driving, walking, bicycling, riding transit, etc.) and trips made by every household member (both individually and jointly with other household members). In addition, supplemental questions were asked to capture commuting behaviors and other travel preferences.

The households invited to the survey were assigned to one of 21 “travel dates” over seven weeks in September and October 2014. All members of each household were asked to report all the trips they made (i.e., places they went) during their pre-assigned 24-hour travel date. All travel dates were on a Tuesday, Wednesday or Thursday. The survey resulted in a total of 3,104 complete household records and 28,362 travel day trips. For further information on the household survey, see the final report (Regional Household Travel Survey Report, Anchorage Metropolitan Area Transportation System, December 23, 2014).

The survey sample was further post-processed to be used for model development and other analysis. Details of the various post-processing steps for the RHTS are below:

- Identification of external trip ends: Any trip with one end external or internal to the region are identified as either external-external, internal-external or external-internal based on origin and destination. Trips with one end at the airport are identified as an airport trip.
- Trip linking: Trips with change of mode as a purpose in between are linked into a single trip. The origin information for the newly formed linked trip is taken from the first trip. Destination information is copied from the last non-change-of-mode trip in the trip sequence. Transit boarding, transfer, and alighting locations and parking locations are retained while an aggregated mode code is generated.
- Production attraction format: Trips are reported by respondents in the order in which they take place, from origins to destinations. Trip-based models use a convention known as production and attraction format for many steps of the modeling process[1]. Production and attraction fields are created for each trip containing information about place, purpose, coordinates, modes, etc. Fields are swapped for the trips going back home.

[1] The trip production end of the trip is the home end for trips that begin or end at home, or the origin end of trips where neither end is at home. The attraction end of the trip is the non-home end for trips that begin or end at home, or the destination end of trips where neither end is at home.

- Trip purpose definitions: Production and attraction purpose fields are collapsed into equivalent trip purpose as used in the travel demand model.
- Mode codes: Mode codes are made consistent with those used in the model.
- Miscellaneous: A final trip file is created by adding household and person data along with trip distance, distance to usual workplace and school location.

2.2 TRANSIT ON-BOARD SURVEY

The transit on-board survey (OBS) was conducted in 2014 to understand ridership patterns in the modeling region. The survey collected information on origin/destination location and activity purpose, trip purpose, boarding/ alighting stations, access and egress modes, fare paid, and a range of socio-economic variables. Surveys were taken from riders on board the People Mover and Eagle River Connect buses. After data cleaning, a total of 2,070 completed survey records were obtained for different transit routes. Out of these, 1,473 completed records are for weekday travel, which were used for travel model development. For further information on the transit on board survey, see the final report (Onboard Origin-Destination Study Report, Anchorage Metropolitan Area Transportation System, December 23, 2014).

The completed survey records were also subjected to post-processing to make them ready for AMATS model update.

- Data coding: This involved coding the raw variables and values. Trip purposes, income segment and auto sufficiency groups are coded consistently with the AMATS model.
- Production attraction format: All origin/boarding and destination/alighting fields are converted to production and attraction fields.
- Access mode coding: Access modes are identified as either “Walk” or “Park and Ride (driving and parking)” or “Kiss and Ride (dropped off or picked up at transit station)”.
- Data expansion: The data delivered as part of the survey effort are expanded to total boardings by route. Weights are computed which expand the data to total “linked” trips[2]. The trip weights are computed as follows:
    - tripWeight=boardingWeight/((Total_Transfers+1))

2.3 BLUETOOTH ORIGIN-DESTINATION SURVEY

RSG CONDUCTED AN ORIGIN-DESTINATION SURVEY (ODS) ALONG ROUTE 1 (SEWARD HIGHWAY) IN THE SUMMER OF 2014 IN ORDER TO SUPPORT VALIDATION OF THE UPDATED AMATS TRAVEL DEMAND MODEL. THE ODS WAS PERFORMED BY DEPLOYING BLUETOOTH SENSORS AT LOCATIONS SELECTED TO ISOLATE THE MODELED GEOGRAPHY FROM EXTERNAL TRAVEL AND TO ISOLATE THE LIMITED- ACCESS INTERCHANGES OF SEWARD HIGHWAY IN AND NEAR THE CITY OF ANCHORAGE. THE DATA COLLECTION EFFORT STARTED THURSDAY, AUGUST 14, 2014 AT ABOUT 7 P.M., AND ENDED WEDNESDAY, AUGUST 20, 2014 AT ABOUT 8 P.M. DETECTORS WERE DEPLOYED AT 19 LOCATIONS AS SHOWN IN TABLE 1. TEN LOCATIONS WERE ALONG SEWARD HIGHWAY IN ANCHORAGE MUNICIPALITY (

[2] A linked trip is a trip from an origin to a destination, including all access from the trip origin to the first transit boarding location, riding on one or more transit vehicles (including transfers), and egress from the last transit stop to the final destination. Therefore if a given respondent reports transferring as part of their transit trip, they will be counted as two boardings, but only one linked trip.

Figure 1). The remaining nine locations were within or near Mat-Su Borough (Figure 2). Not shown is detector station 99-12 on Parks Highway west of Big Lake. The Bluetooth data was cleaned, expanded to observe Average Annual Daily Traffic Counts, and analyzed.

The advantage of Bluetooth data collection is that it is a relatively inexpensive and completely passive method to collect origin-destination data. The disadvantage of Bluetooth data collection is that it is not possible to determine the ultimate origin and destination of each trip (activity locations), the trip purpose or the socio-economic segment of the traveler from the data. For further information on the Bluetooth survey including data collection, cleaning, expansion and analysis, see the final memorandum (Anchorage Bluetooth Origin-Destination Survey, from RSG Project Team to Teresa Brewer, Anchorage Metropolitan Area Transportation System, July 7, 2015).

Table 1. Detector Location Descriptions

		EB/NB			SB/WB			
Location	**Description**	**AM**	**PM**	**Daily**	**AM**	**PM**	**Daily**	**Source**
99-12	Parks Highway West of Big Lake Road	734	666	3796	259	1086	3796	ADOT*
99-09	West Big Lake Road West of Parks Highway	226	947	3311	640	581	3311	ADOT*
99-21	South Knik Goose Bay Road West of South Vine Road	450	1890	6611	1279	1160	6611	ADOT*
99-16	East Parks Highway West of South Seward Meridian Parkway	2226	3654	18511	1397	5205	18550	PTR
99-08	Glenn Highway North of Buffalo Mine Road	181	441	2033	170	440	1825	PTR
99-10	Glenn Highway East of South Colleen Street	884	2037	7932	1006	1779	7944	PTR
99-13	Old Glenn Highway at Knik River Bridge	91	502	1520	251	244	1520	ADOT*
99-19	Glenn Highway at Knik River Bridge	958	5275	15979	2633	2561	15979	ADOT*
99-20	Glenn Highway South of Eklutna Village Road	1195	6580	19932	3230	3141	19601	PTR
99-01	Seward Highway South of East 15th Avenue	3985	7025	31920	2950	5973	26385	PTR
99-04	Seward Highway South of East 36th Avenue	4827	5908	32448	2498	7838	28825	MOA
99-07	Seward Highway South of East Tudor Road	5260	6772	37619	3218	10297	37619	MOA
99-14	Seward Highway at East 68th Avenue	5347	6884	38243	3364	10555	37730	MOA
99-02	Seward Highway at Lore Road	5609	5382	28961	2808	10190	35425	PTR
99-03	Seward Highway South of Abbott Road	4247	4434	26504	1805	6728	22054	MOA
99-17	Seward Highway South of O'Malley Road	4494	4075	23232	1185	4974	17395	MOA
99-18	Seward Highway South of Huffman Road	2258	3158	17126	1196	4011	14270	MOA
99-11	Seward Highway South of De Armoun Road	1272	1977	10366	887	2477	9800	MOA
99-05	Seward Highway South of Old Seward Highway	507	1377	6252	487	1371	6032	PTR
***Directionality and peak period counts were synthesized**								

FIGURE 1. ANCHORAGE DETECTOR LOCATIONS

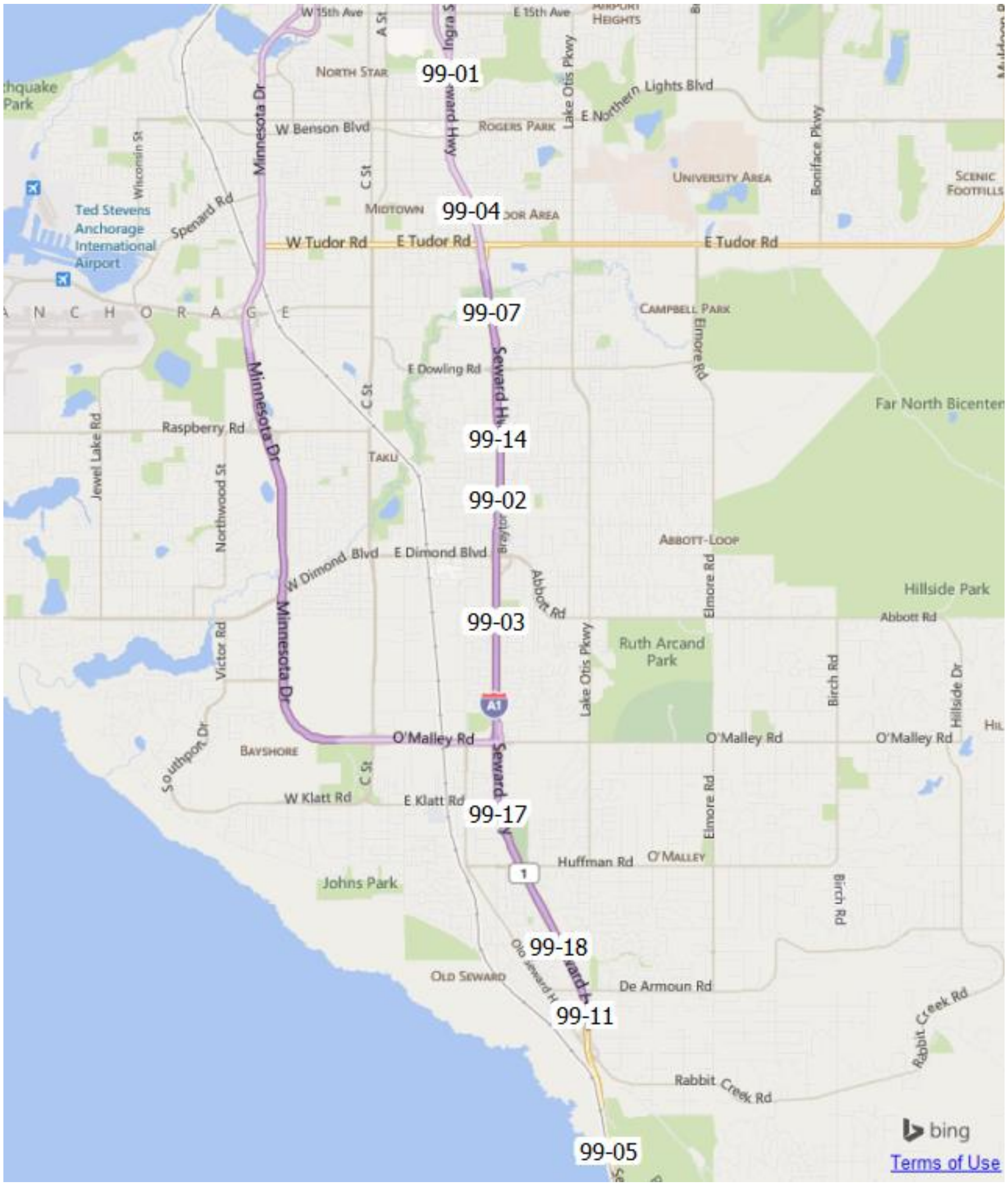
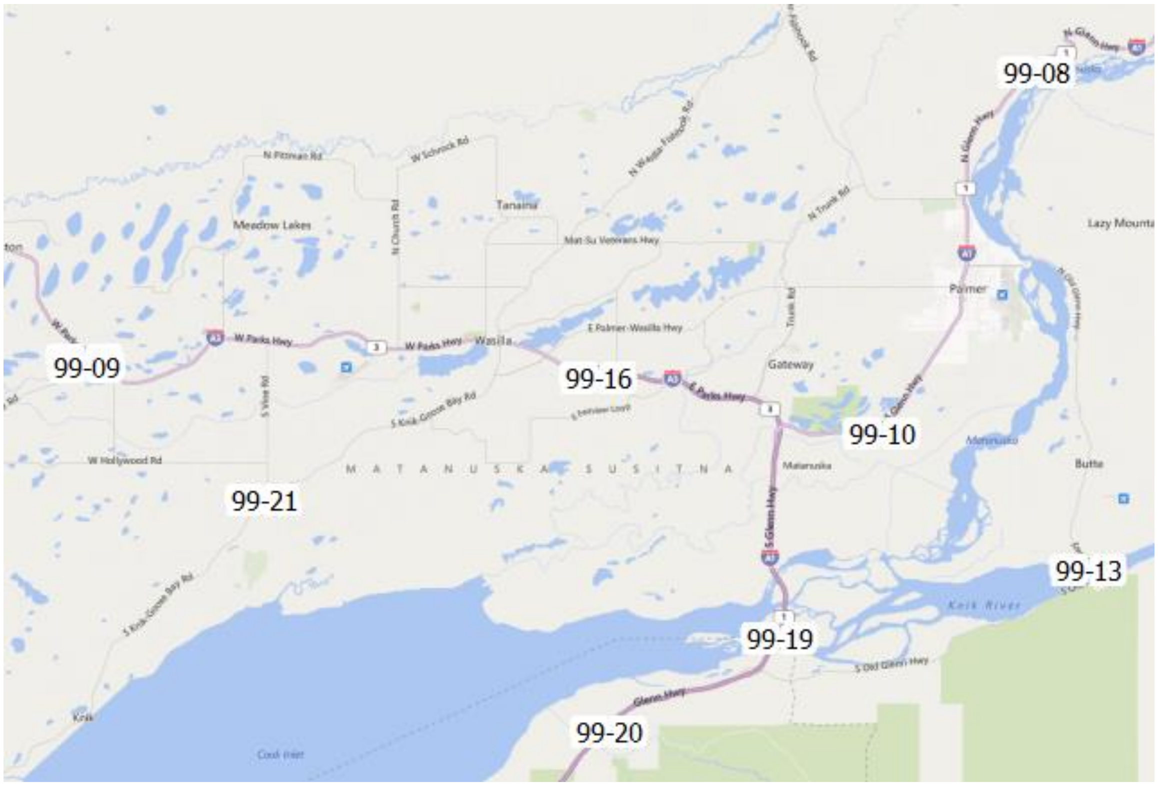


FIGURE 2. MAT-SU DETECTOR LOCATIONS



2.4 TRANSPORTATION ANALYSIS ZONE (TAZ) SYSTEM AND SOCIO-ECONOMIC DATA

Travel demand models rely upon a spatial aggregation of the model region into areas commonly referred to as transportation analysis zones (TAZs). A TAZ system for the model region with the following guiding principles:

- Provide TAZs sized appropriately for forecasting purposes to the latest observed population and employment distribution in the region. "Appropriate" means:
  - Range of TAZ population and employment totals is reasonably small across all TAZ
  - TAZs permit realistic loading points for centroid connectors onto the modeled street network
- Provide TAZs that nest productively with census geographies (block groups or blocks)
- Provide sufficient zonal detail to forecast travel in expected high-growth subareas
- Enable sufficient network density for calibrating subareas that have historically been challenging to calibrate
- Provide sufficient detail to support potential applications of the model to transit analyses

There are 914 "internal" zones (representing demand with an origin and/or destination in the model region) and three "external station" zones (representing demand with an origin and/or destination outside the model region). Figure 3 illustrates the model space (the red outline indicates the AMATS Planning Boundary, while the green represents the area covered by the model). There are 604 zones defined for the

Municipality of Anchorage; 60 zones for Chugiak-Eagle River, 91 zones for the Palmer area, 52 zones for the Mat-Su area and 106 zones for Knik Arm (not including the three external stations). The three external stations are numbered as follows:

- Zone 970: Seward Highway south of Anchorage
- Zone 971: Seward Highway east of Palmer
- Zone 972: Highway 3 north of Wasilla

THE ZONE SYSTEM FOR THE MODEL REGION IS SHOWN IN

Figure 4. The zone system for the Anchorage Bowl is shown in Figure 5.

FIGURE 3: MODEL REGION

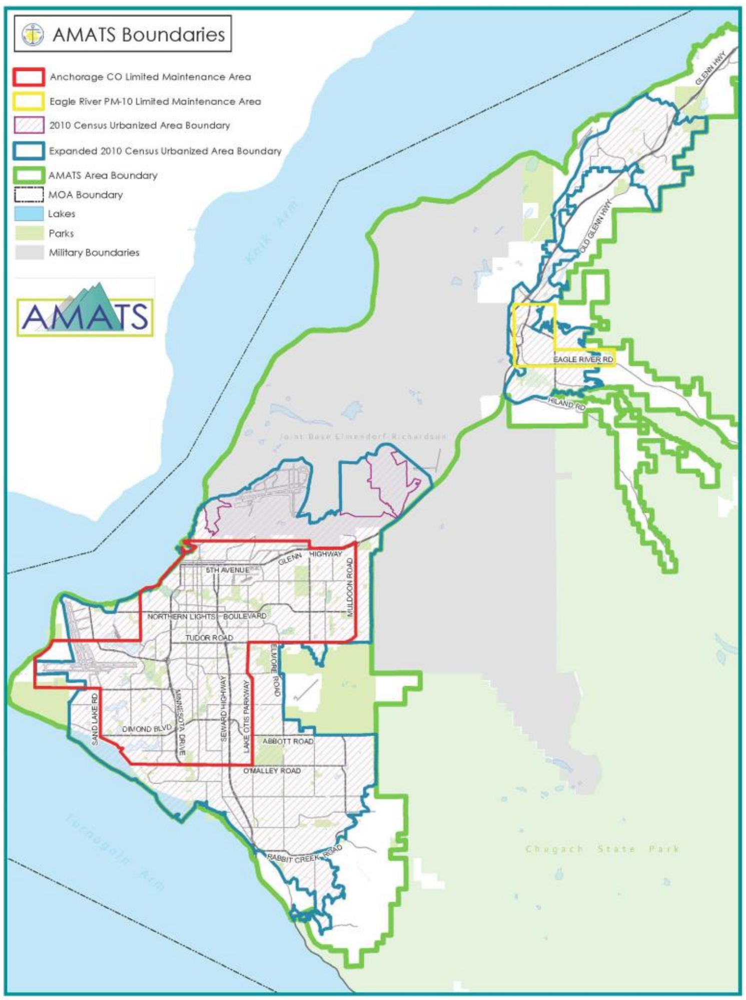


Figure 2. AMATS Boundary Map, 2014

Public Participation Plan

FIGURE 4: TRANSPORTATION ANALYSIS ZONE SYSTEM – MODEL REGION

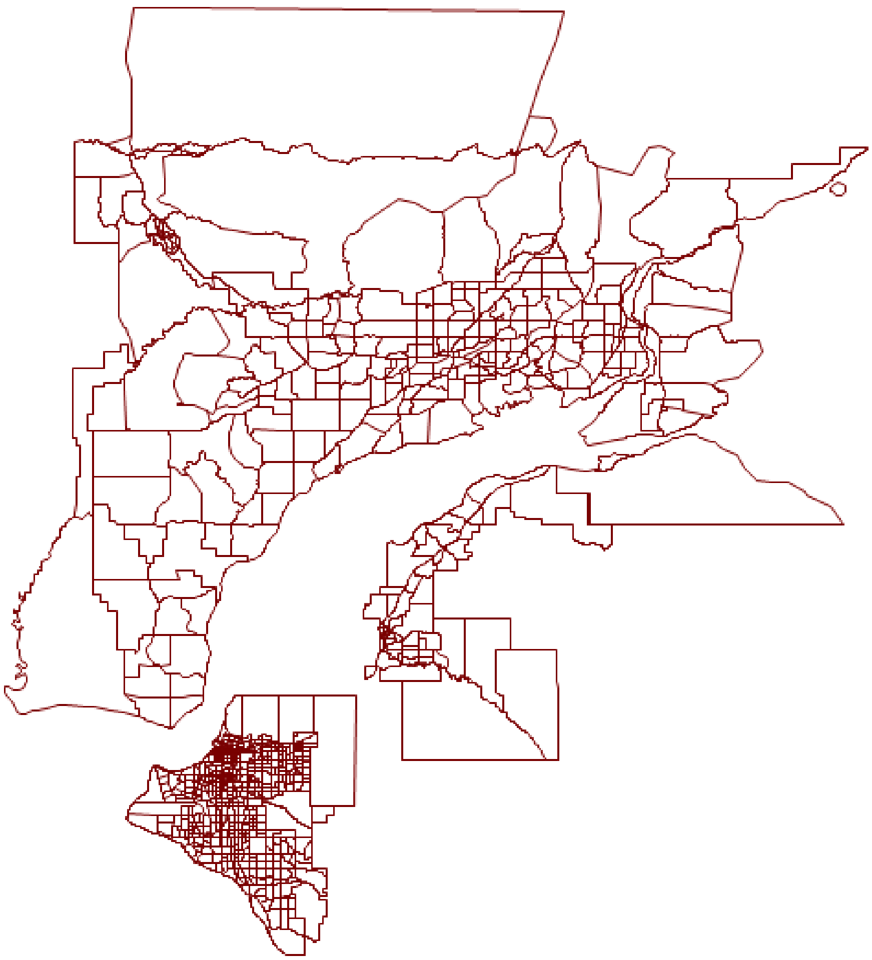
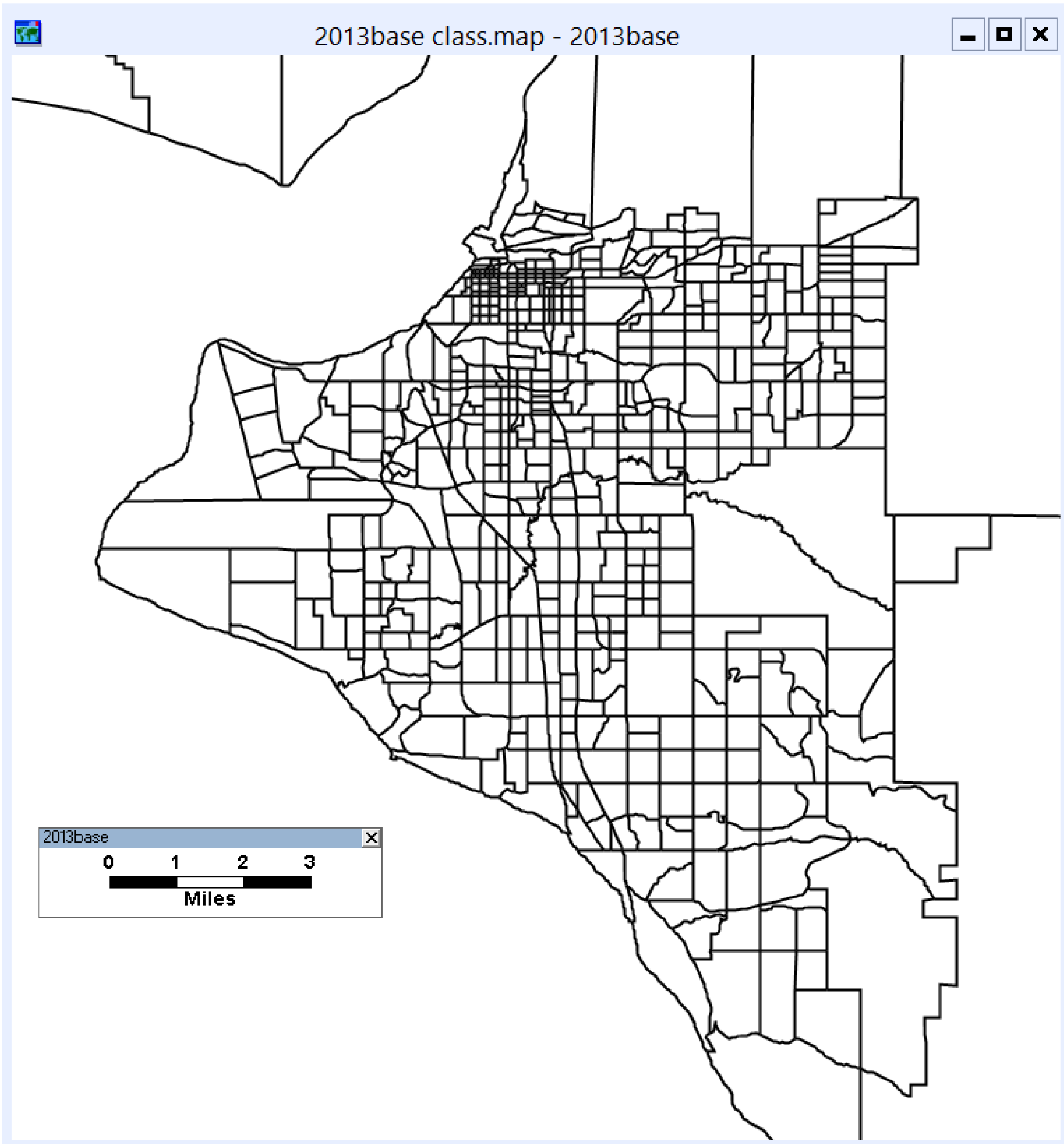


FIGURE 5: TRANSPORTATION ANALYSIS ZONE SYSTEM – ANCHORAGE BOWL



A set of socio-economic data was prepared for the base-year (2013) and future-year (2040) model zone system. Base-year data was used for model estimation, calibration and validation. For a full description of all socio-economic data used in the model, and the methodology for allocation from regional controls to TAZs, see the final report on socio-economic projections and zonal allocation (AMATS Travel Model

Update: Socio-economic Projections and Land Use Allocation Report, Anchorage Metropolitan Area Transportation Study, February 2, 2016). The input data includes the following general categories; the full input zonal data table is described in Table 2. There are also files for hotel rooms and military base households\employment, described below.

- Households and population, created as described in the report cited above.
- Employment data by 2-digit North American Industry Classification system (NAICS) code, created as described in the report cited above.
- The following socio-economic household classifications:
  - Average household size and households by size bin (1, 2, 3, and 4+). The source of this data is 2013 American Community Survey (ACS) 5-Year Estimate Table B11016 (Block Group Data). Note that households by size bin are used for development of the household size model described below, but are not used for forecasting.
  - Average household income and households by income group (0-$30k, $30k-$50k, $50k-$100k, $100k+). The source of this data is 2013 ACS 5-Year Estimate Table B19001 (Block Group Data). Note that households by income group bin are used for development of the household size model described below, but are not used for forecasting.
  - Households by number of workers per household (0, 1, 2, 3+). The source of this data is 2013 ACS 5-Year Estimate Table B08203 (Census Tract Data). Note that this data was not used in model development or forecasting.
  - Households by number of vehicles available per household (0, 1, 2, 3, 4+). The source of this data is 2013 ACS 5-Year Estimate Table B08203 (Census Tract Data). Note that this data was not used in model development or forecasting.
- School enrollment data for the following categories, created as described in the report cited above:
  - K-12 public schools
  - K-12 private schools
  - Colleges\universities (see description below and data in Table 3)
- Hourly parking cost data for 2013, obtained from University of Alaska at Anchorage and Anchorage Community Development Authority.
- Number of hotel rooms and occupancy rate for each hotel. This data was updated from the old 2007 AMATS model hotel room inventory.
- Military base population and employment. This data was updated from the old 2007 AMATS model military base special generator input file.

TABLE 2: TAZ SOCIO-ECONOMIC DATA FILE FIELDS

Field Name	Description
ZONE	TAZ number
GQPOP	Total population in non-institutional group quarters
GQTYPE	Type of non-inst. group quarters (1=military, 2=college\university, 3=other)
HHPOP	Total population in households
TOTALHH	Total households
Special_Freight_Zone	1 if special freight zone
Mat-Su	1 if Mat-Su Borough zone
HBS_ATTR_FACTOR	Home-based shop trip attraction factor
HBO_ATTR_FACTOR	Home-based other trip attraction factor
Special Factor Description	Description of land-use requiring factor (not used by model)
AVHHS	Average household size
AVINC	Average household income
AVAO	Average autos owned (not used by model)
AVWHH	Average workers per household (not used by model)
AVCHH	Average children per household (not used by model)
SENROLL	Public K-12 school enrollment
COLLENROLL	College enrollment
Cat 1	Natural Resources Employment (NAICS 11 & 21)
Cat 2	Wholesale Trade, Manufacturing and Utilities Employment (NAICS 22,31,32,33,42)
Cat 3	Construction Employment (NAICS 23)
Cat 4	Retail Trade Employment (NAICS 44 & 45)
Cat 5	Transportation & Warehousing Employment (NAICS 48 & 49)
Cat 6	FIRE, Professional Services and Other Employment (NAICS 51-56 & 81)
Cat 7	Educational Services Employment (NAICS 61)

Cat 8	Health Care & Social Assistance Employment (NAICS 62)
Cat 9	Accommodation, Food Services, & Entertainment Employment (NAICS 71 & 72)
Cat 10	Government Employment (NAICS 92)
TOTEMP	Total employment
HHS1	Number of 1 person households
HHS2	Number of 2 person households
HHS3	Number of 3 person households
HHS4	Number of 4+ person households
INC1	Number of households Under $10,000
INC2	Number of households $10-24,999
INC3	Number of households $25-34,999
INC4	Number of households $35-39,999
INC5	Number of households $40-49,999
INC6	Number of households $50-59,999
INC7	Number of households $60-74,999
INC8	Number of households $75-99,999
INC9	Number of households $100,000 and Over
AO0	Number of 0-auto households (not used by model)
AO1	Number of 1-auto households (not used by model)
AO2	Number of 2-auto households (not used by model)
AO3	Number of 3-auto households (not used by model)
AO4	Number of 4+ auto households (not used by model)
WHH0	Number of 0-worker households (not used by model)
WHH1	Number of 1-worker households (not used by model)
WHH2	Number of 2-worker households (not used by model)
WHH3	Number of 3+ worker households (not used by model)
PKCOST	Parking cost
DUMCBD	CBD Dummy

PSENROLL	Private K-12 School enrollment
Pct Korean	Percent households that speak Korean as primary language (not used)
Pct Spanish	Percent households that speak Spanish as primary language (not used)
Pct Hmong	Percent households that speak Hmong as primary language (not used)
Pct Tagalog	Percent households that speak Tagalog as primary language (not used)
Pct Minority	Percent of households that are minorities (not used)
WHH2	Number of 2-worker households (not used by model)
WHH3	Number of 3+ worker households (not used by model)
PKCOST	Parking cost
PSENROLL	Private School enrollment
Pct Korean	Percent households that speak Korean as primary language (not used)
Pct Spanish	Percent households that speak Spanish as primary language (not used)
Pct Hmong	Percent households that speak Hmong as primary language (not used)
Pct Tagalog	Percent households that speak Tagalog as primary language (not used)
Pct Minority	Percent of households that are minorities (not used)

2.4.1 COLLEGE ENROLLMENT DATA

The National Center for Education (NCE) was used as the main source to create a database of colleges and universities in the study area that offer a bachelor's degree or higher. Information extracted from NCE include institution name, location (latitude and longitude), and total enrollment (for example, Figure 6 shows location of University of Alaska Anchorage when overlaid by TAZ layer). Once this database (Table 3) was created, number of college/university trips attracted to each zone and other trip-level information available from the household travel survey data (such as description of attraction place) was used to allocate college/university enrollment numbers to a set of TAZs.

FIGURE 6 LOCATION OF UNIVERSITY OF ALASKA ANCHORAGE OVERLAID BY TAZ LAYER

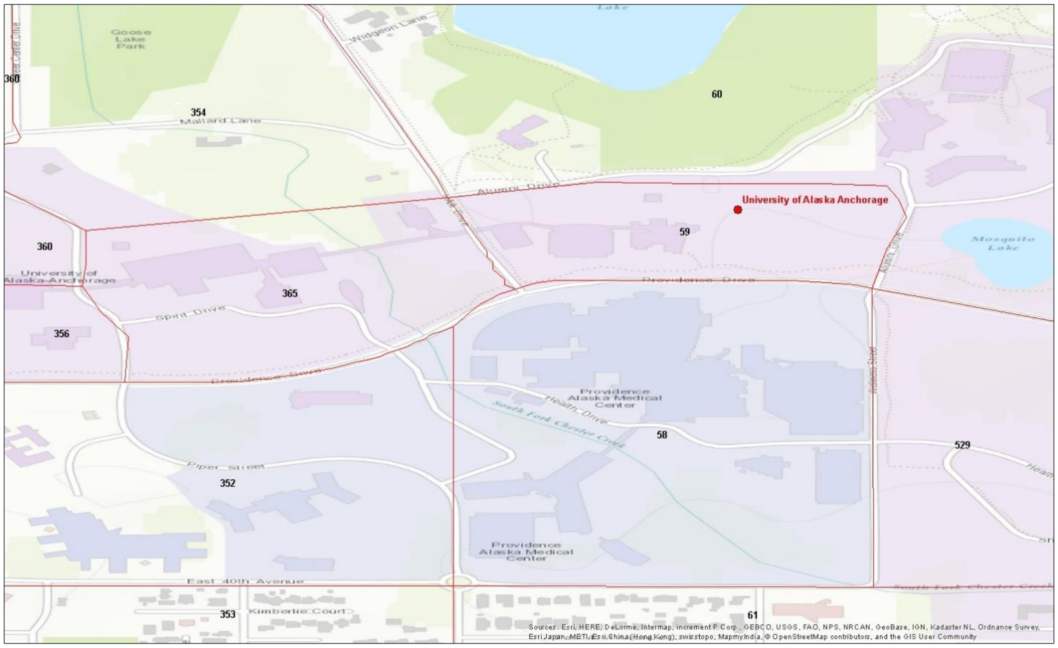


TABLE 3 LIST OF COLLEGES AND UNIVERSITIES IN THE STUDY AREA

College/university	Enrollment
University of Alaska Anchorage	15,501
Charter College	3,267
Alaska Career College	479
Alaska Pacific University	579
AVTEC - Alaska's Institute of Technology	889
Alaska Bible College	46
Matanuska-Susitna College	1,650
Alaska Northern Industrial Training School	50
Total	**22,461**

2.5 TRANSPORTATION NETWORKS

The transportation network represents the supply of transport infrastructure available for travelers. The AMATS travel demand model represents auto, walking, biking and fixed-route transit modes specifically. Other modes, such as air and water travel, are not represented in the model due to low observed intra-region demand for these modes in the household travel survey data.

There are two components of the transportation network; an auto (street) network and a transit network. The auto network consists of a set of nodes which define start and end points of road segments, and links which represent travel paths through the street system. The transit network consists of transit routes and transit stops. Transit routes are mostly coded along the street system so that transit time takes into account congestion and delay due to vehicle traffic.

2.5.1 AUTO NETWORK

The auto network was updated from the old 2007 AMATS travel demand model network to represent the facilities and characteristics that existed in 2013. Each TAZ is associated with a special node in the transportation network called a “centroid”; all demand is loaded onto the transportation network to and from centroids using links called “centroid connectors.” These are not real streets--rather they are aggregations of streets used to access the land-uses defined by the zonal boundary.

FIGURE 7: BASE-YEAR AUTO NETWORK – MODEL REGION

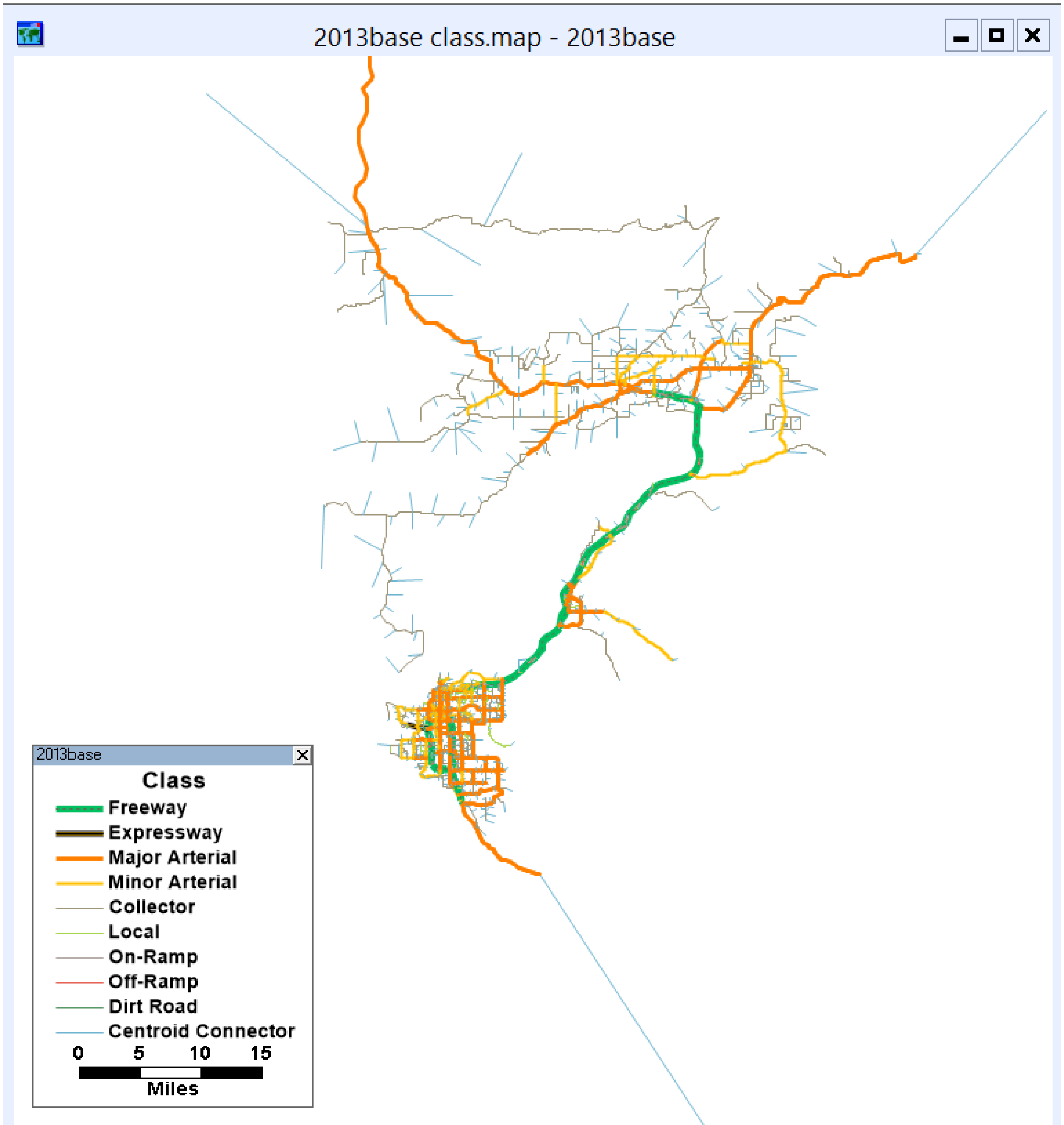
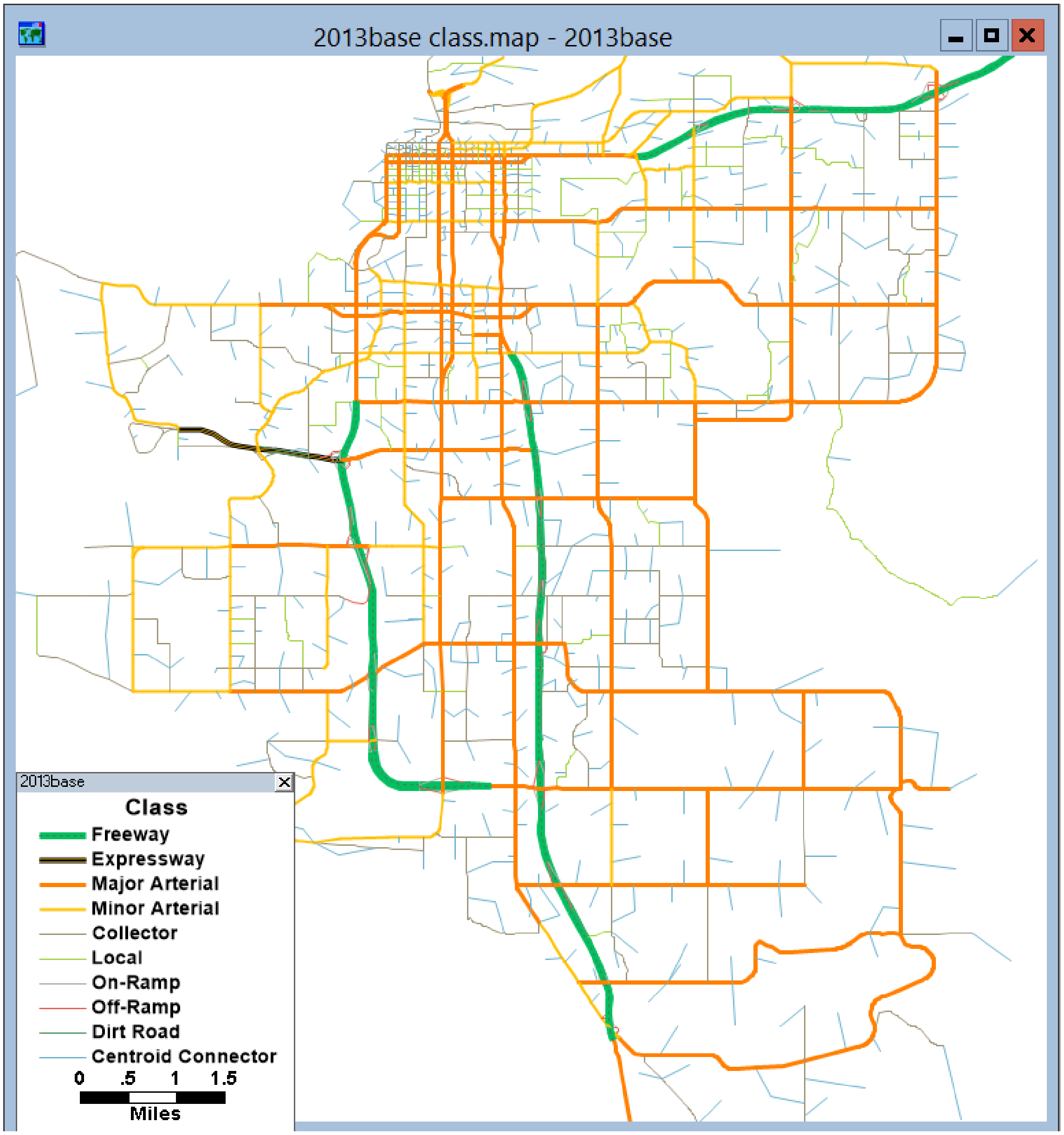


FIGURE 8: BASE-YEAR AUTO NETWORK – ANCHORAGE BOWL



Input node table fields are shown in Table 4. Each node in the auto network is coded with an ID, an XY coordinate that identifies its location, the intersection control type (signalized, all-way stop or roundabout), and an indicator used to identify park-and-ride lots. Intersection control type is used to calculate delay on approaches to signal-controlled intersections. The park-and-ride lot indicator is used to determine locations for the park-and-ride access to transit mode.

TABLE 4: NODE TABLE FIELDS

Field Name	Description
ID	Node ID
Longitude	Longitude
Latitude	Latitude
Control	Intersection Control type (Table 5)
Parking	Park-and-ride lot indicator
TEMP	TEMP (Not used by model)

TABLE 5: NODE INTERSECTION CONTROL CODES

Code	Control Type
1	Signalized
2	All way stop signs
3	Roundabouts

Input link table fields are shown in Table 6. Each link in the auto network is coded with the link ID, a link classification field (Table 7), the link speed limit, the number of lanes by direction, the area type (Table 8), whether there is a bus lane on the link by direction, a signal progression factor by direction, whether the link is a CBD transit indicator (for slower transit speeds in downtown) and a series of toll costs which can be set by time period, mode and direction. Time periods in the network are:

- AM Peak (AM): Between 7 a.m. and 9 a.m. (2 hours)
- PM Peak (PM): Between 3 p.m. and 6 p.m. (3 hours)
- Off-Peak (OP): Between 6 p.m. and 7 a.m., and between 9 a.m. and 3p.m. (19 hours)

Toll costs can be specified for the following auto modes (note that there are no tolls in the base-year network):

- Drive-alone (DA)
- Shared-ride 2 occupants (S2)
- Shared-ride 3+ occupants (S3)
- Light trucks and commercial vehicles (LT)
- Heavy trucks (HT)

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TABLE 6: LINK TABLE FIELDS

Field Name	Description
ID	Link ID
Length	Link length (Miles)
Dir	Direction (-1= oneway B to A, 0 = two-way, 1 = oneway A to B)
PRJNUM	Project name (not used by model)
FEANME	Feature name (not used by model)
RoadName	Road name (not used by model)
MPH	Miles per hour
Lane_Num	Number of lanes (not used by model)
AB_Lanes	Lanes in A to B direction
BA_Lanes	Lanes in B to A direction
AB_BusLane	Bus-only lanes in A to B direction
BA_BusLane	Bus-only lanes in B to A direction
Median	Median indicator (Table 9Table 9)
AB_PF	Signal progression factor in A to B direction (0.6->1.2)
BA_PF	Signal progression factor in B to A direction (0.6->1.2)
Area_Type	Area type (Table 8)
Class	Link Class (Table 7)
ClassDesc	Link Class description (not used by model)
CBDTransit	CBD Transit indicator (slower bus speeds due to more frequent stops)
NTMode	Non-transit mode
AB_NAME	Name of link in AB direction (not used)
BA_NAME	Name of link in BA direction (not used)
AB_AMDATOLL	AM Period Toll for SOV in AB direction
BA_AMDATOLL	AM Period Toll for SOV in AB direction
AB_AMS2TOLL	AM Period Toll for 2-occupant vehicles in AB direction
BA_AMS2TOLL	AM Period Toll for 2-occupant vehicles in AB direction
AB_AMS3TOLL	AM Period Toll for 3+ occupant vehicles in AB direction
BA_AMS3TOLL	AM Period Toll for 3+ occupant vehicles in AB direction
AB_AMLTTOLL	AM Period Toll for commercial vehicles\light trucks in AB direction
BA_AMLTTOLL	AM Period Toll for commercial vehicles\light trucks in BA direction
AB_AMHTTOLL	AM Period Toll for heavy trucks in AB direction
BA_AMHTTOLL	AM Period Toll for heavy trucks in BA direction
AB_PMDATOLL	PM Period Toll for SOV in AB direction

BA_PMDATOLL	PM Period Toll for SOV in AB direction
AB_PMS2TOLL	PM Period Toll for 2-occupant vehicles in AB direction
BA_PMS2TOLL	PM Period Toll for 2-occupant vehicles in AB direction
AB_PMS3TOLL	PM Period Toll for 3+ occupant vehicles in AB direction
BA_PMS3TOLL	PM Period Toll for 3+ occupant vehicles in AB direction
AB_PMLTTOLL	PM Period Toll for commercial vehicles\light trucks in AB direction
BA_PMLTTOLL	PM Period Toll for commercial vehicles\light trucks in BA direction
AB_PMHTTOLL	PM Period Toll for heavy trucks in AB direction
BA_PMHTTOLL	PM Period Toll for heavy trucks in BA direction
AB_OPDATOLL	Off-peak Period Toll for SOV in AB direction
BA_OPDATOLL	Off-peak Period Toll for SOV in AB direction
AB_OPS2TOLL	Off-peak Period Toll for 2-occupant vehicles in AB direction
BA_OPS2TOLL	Off-peak Period Toll for 2-occupant vehicles in AB direction
AB_OPS3TOLL	Off-peak Period Toll for 3+ occupant vehicles in AB direction
BA_OPS3TOLL	Off-peak Period Toll for 3+ occupant vehicles in AB direction
AB_OPLTTOLL	Off-peak Period Toll for commercial vehicles\light trucks in AB direction
BA_OPLTTOLL	Off-peak Period Toll for commercial vehicles\light trucks in BA direction
AB_OPHTTOLL	Off-peak Period Toll for heavy trucks in AB direction
BA_OPHTTOLL	Off-peak Period Toll for heavy trucks in BA direction
HOV2	Indicator for HOV 2+ lane
HOV3	Indicator for HOV 3+ lane
AB_AM_LightComm	AM Period Light Commercial Vehicle Count in AB direction
BA_AM_LightComm	AM Period Light Commercial Vehicle Count in BA direction
AB_PM_LightComm	PM Period Light Commercial Vehicle Count in AB direction
BA_PM_LightComm	PM Period Light Commercial Vehicle Count in BA direction
AB_OP_LightComm	Off-peak Period Light Commercial Vehicle Count in AB direction
BA_OP_LightComm	Off-peak Period Light Commercial Vehicle Count in BA direction
AB_24H_LightComm	24-Hour Period Light Commercial Vehicle Count in AB direction
BA_24H_LightComm	24-Hour Period Light Commercial Vehicle Count in BA direction

AB_AM_HeavyComm	AM Period Heavy Commercial Vehicle Count in AB direction
BA_AM_HeavyComm	AM Period Heavy Commercial Vehicle Count in BA direction
AB_PM_HeavyComm	PM Period Heavy Commercial Vehicle Count in AB direction
BA_PM_HeavyComm	PM Period Heavy Commercial Vehicle Count in BA direction
AB_OP_HeavyComm	Off-peak Period Heavy Commercial Vehicle Count in AB direction
BA_OP_HeavyComm	Off-peak Period Heavy Commercial Vehicle Count in BA direction
AB_24H_HeavyComm	24-Hour Period Heavy Commercial Vehicle Count in AB direction
BA_24H_HeavyComm	24-Hour Period Heavy Commercial Vehicle Count in BA direction
AB_AM_COUNT	AM Period Vehicle Count in AB direction
BA_AM_COUNT	AM Period Vehicle Count in BA direction
AB_PM_COUNT	PM Period Vehicle Count in AB direction
BA_PM_COUNT	PM Period Vehicle Count in BA direction
AB_OP_COUNT	Off-Peak Period Vehicle Count in AB direction
BA_OP_COUNT	Off-Peak Period Vehicle Count in BA direction
AB_24H_COUNT	24-hour Vehicle Count in AB direction
BA_24H_COUNT	24-hour Vehicle Count in BA direction
ABBA_24H_COUNT	Total 24-hour Vehicle Count in both directions
Subarea	Subarea indicator (Not used by model)
Screenline	Screenline
MSB	MSB indicator (Not used by model)
TEMP	Temp field (Not used by model)
REPORT_FAC	Report Facility (code to summarize time in SummaryReport.xml

TABLE 7: LINK CLASS CODES

Class	Description
1	Freeway
2	Expressway
3	Major Arterial
4	Minor Arterial
5	Collector
6	Local
7	On Ramp
8	Off-Ramp
9	Reserved
10	Frontage Road
11	Dirt Road (only used in the MSB)
99	Centroid Connector

TABLE 8: AREA TYPE CODES

Area Type	Definition
1	Urban-CBD
2	Central City
3	Suburban
4	Rural
5	Expressways (special cases)
6	Freeways (special cases)
7	<reserved for future use>
8	Reduced capacity collectors and locals
9	Centroid connectors

TABLE 9: LINK MEDIAN TYPE CODES

Code	Median Type
0	No center lane or parkway
1	Continuous Left Turn Lane
2	Parkway or other median controls

2.5.2 TRANSIT NETWORK

The transit network consists of a route table that lists the headways of all transit routes, by direction, and their fare and a stop layer that represents boarding and alighting locations for each route. The base-year transit network is shown in Figure 9, and the route data is shown in Table 10. All base-year transit routes are buses with one-hour or 30-minute headways. IB stands for inbound, OB stands for outbound, with respect to direction to/from downtown Anchorage. A missing value for headway in a specific period indicates that the route does not operate in the listed direction in that period.

FIGURE 9: BASE-YEAR TRANSIT ROUTE SYSTEM

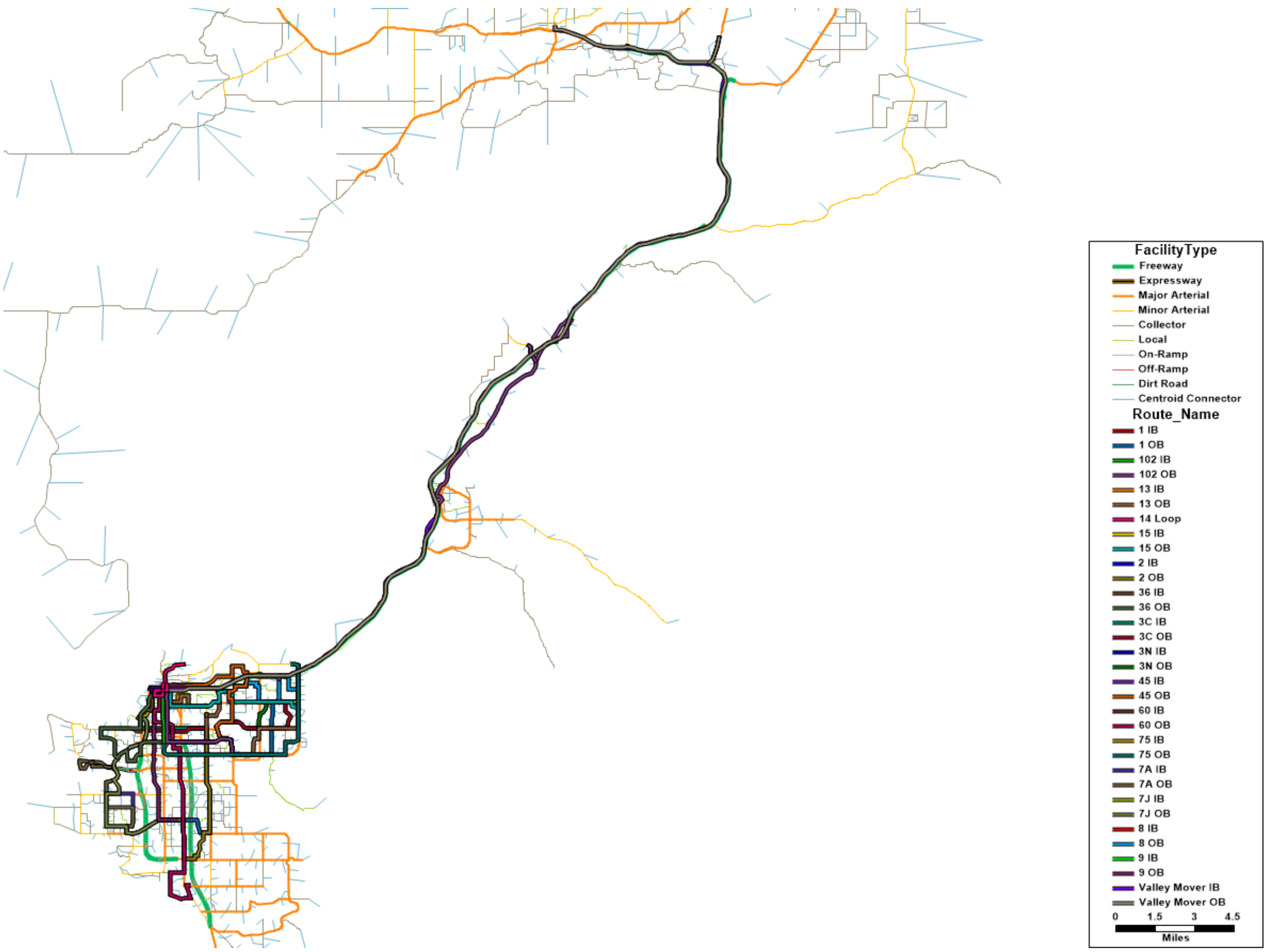


TABLE 10: TRANSIT ROUTE TABLE FIELDS

Field Name	Description
Route_ID	Route ID Number
Route_Name	Route Name
AM_HDWY	AM Period Headway
PM_HDWY	PM Period Headway
OP_HDWY	Off-peak Period Headway
FARE	Fare ($2013)
CAPACITY	Route capacity (not used)
Stops_Mi	Stops per mile (not used)
Mode	Mode Number

TABLE 11: BASE-YEAR TRANSIT ROUTE TABLE

Route_ID	Route_ Name	AM_HDWY	PM_HDWY	OP_HDWY	FARE
1	1 IB	60	60	60	2.00
2	1 OB	60	60	60	2.00
3	2 IB	30	60	60	2.00
4	2 OB	60	30	30	2.00
5	3N IB	60	60	60	2.00
6	3N OB	60	60	60	2.00
7	3C IB	60	60	60	2.00
8	3C OB	60	60	60	2.00
9	7A IB	60	60	60	2.00
10	7A OB	60	60	60	2.00
11	7J IB	60	60	60	2.00
12	7J OB	60	60	60	2.00
13	8 IB	30	60	60	2.00
14	8 OB	60	30	60	2.00
15	9 IB	30	30	30	2.00
16	9 OB	30	30	30	2.00
17	13 IB	30	60	60	2.00
18	13 OB	60	60	60	2.00
19	15 IB	30	30	30	2.00
20	15 OB	30	30	30	2.00
21	36 IB	30	60	60	2.00
22	36 OB	60	30	60	2.00
23	45 IB	30	30	20	2.00
24	45 OB	30	30	20	2.00
25	60 IB	30	60	60	2.00

26	60 OB	60	30	60	2.00
27	75 IB	30	30	60	2.00
28	75 OB	30	30	60	2.00
29	102 IB	60	30		2.00
30	102 OB		30	60	2.00
31	Valley Mover IB	30	60	60	7.00
32	Valley Mover OB	60	30	60	7.00
33	14 Loop	60	60	60	2.00

2.6 TRAFFIC COUNTS

Traffic count data can aid in the validation of travel demand models and are used to compare modeled and observed vehicle flows along links and across screenlines[3]. State and local agencies provided hourly traffic counts to support the AMATS model update to 2013 average weekday conditions. The provided counts were processed and merged into a single database. The merged counts were then grouped by direction of travel, time period (a.m., p.m., off-peak), and vehicle class (all vehicles, single-unit truck, multi-unit truck), and loaded onto the model network.

Traffic Count Sources

The Alaska Department of Transportation and Public Facilities (ADOT&PF) and the Municipality of Anchorage (MOA) provided traffic counts.

ADOT&PF Counts

The Alaska Department of Transportation and Public Facilities provided hourly directional traffic counts in three formats:

- An Excel workbook format containing general vehicle counts for permanent traffic recorders (PTRs) in the model region for 2013 to 2014;
- A text format containing general vehicle counts for permanent and temporary traffic recorders in the model region for 2010 to 2013;
- A text format containing vehicles classification counts in the model region for 2010 to 2013.

[3] Screenlines are imaginary lines that intersect multiple facilities across a region. They are used to measure flow from one side of the line to the other, compensating for route choice error for each individual facility.

ADOT&PF also provided a geographic file containing spatial coordinates for many of the count stations in the region. An automated process was applied to spatially join the count stations to directional model links.

The traffic counts were then geocoded to model links in one of two ways. Where possible, each traffic count was joined to the geographic file based on its count station ID and then assigned whichever model link had been spatially joined to that count station. Otherwise, the traffic count was manually assigned a model link ID based on the text description of its location. Twenty-four count locations had to be determined manually.

After correcting for redundant counts across the three file formats, the ADOT&PF counts yielded weekday observations for 270 directional links.

In addition to an overall vehicle count, the ADOT&PF classification counts also yielded counts for:

- Passenger vehicles
- Single-unit trucks (light commercial)
- Multi-unit trucks (heavy commercial)

ADOT&PF classification counts were available for 55 directional links.

Municipality of Anchorage (MOA) Counts

The Municipality of Anchorage provided hourly directional traffic in two formats:

- A text format containing intersection counts, including turning movements, for general vehicles for 2009 to 2014
- A text format containing link counts for general vehicles for 2014

The MOA intersection traffic counts were converted to link counts, yielding one count for each intersection approach but no counts for links departing the intersection (even though it may have been possible to infer counts for departing links). No departing links were used to avoid potentially double-counting information.

The MOA intersection counts were joined to the network by first manually assigning a network node ID to the intersection based on the text description of its location. The intersection counts were then automatically assigned to link approaches by relating directional information from the count text files to the topological and directional information of the model links. The MOA intersection counts yielded weekday observations for 398 directional links.

The MOA links counts were collected in 2014 to support the estimation of bluetooth trips matrices. These counts were manually assigned to links based on the text descriptions of their locations. The MOA Link counts yielded weekday observations for 17 directional links.

Together, the MOA intersection and link counts yielded observations for 412 unique directional links.

Seasonal Factoring

ADOT&PF provided monthly seasonal factors for 2013 and 2014 for some count locations. Seasonal factors can be applied to make the counts consistent with average yearly conditions.

Unique seasonal factors were provided for 24 permanent traffic recorders in the region. ADOT&PF also provided a methodology for estimating seasonal factors, based on proximity to permanent traffic recorders, for 356 potential count locations in the region. An average of the 2013 and 2014 seasonal factors was applied to those ADOT&PF that were not for either 2013 or 2014, but could be matched to permanent traffic recorders.

Seasonal factors were then developed for the MOA counts and those ADOT&PF counts that had not been assigned a factor. First, counts were segmented based on being located south or north of the Knik Arm or River. Second, the ADOT&PF seasonal factors were likewise segmented by location and then averaged, yielding one set of monthly factors for each segment.

Aggregating Counts

The seasonally adjusted counts were then averaged, yielding one set of hourly counts for each link. The counts were then grouped by model period (a.m., p.m., off-peak) and loaded onto the model network. Daily counts, and where possible, two-way daily counts were also computed.

Count Totals

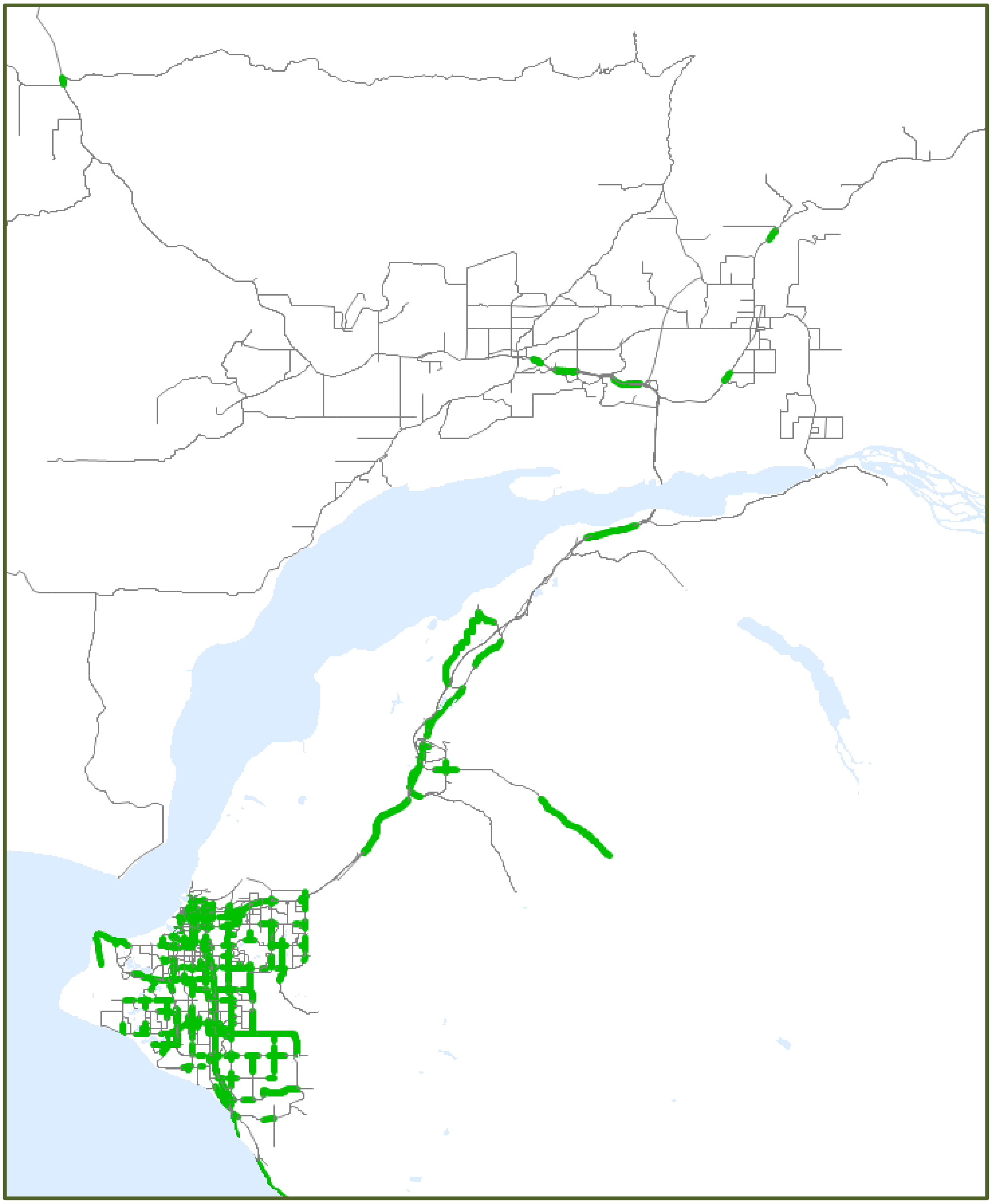
After merging the ADOT&PF and MOA counts, a total of 620 directional links could be assigned count observations. Table 12 shows how the counts were distributed by facility type.

TABLE 12: COUNTS BY FACILITY TYPE

Facility Type	Counts
Highway	42
Major Arterial	343
Minor Arterial	125
Collector	73
Frontage Road	9
Ramp	10
Local	18

Figure 10 presents a map of the count locations.

FIGURE 10: COUNT LOCATIONS



3.0MODEL SYSTEM OVERVIEW

The overall AMATS travel demand modeling system is presented in Figure 11. The model follows the general four steps of travel forecasting:

- Trip generation: determines the number of trip ends by TAZ and purpose
- Trip distribution: links trip ends into flows or trip tables
- Mode choice: determines the mode of each trip
- Trip assignment: determines the route of each trip

However, the system is a bit more complicated than the four general steps. The model system starts with a network processing step which codes relevant network characteristics necessary for assignment and other model steps. Then a set of auto assignments is performed where trip tables are assigned to the highway network. Note that the AMATS model is run several times, or “iterations.” Trip tables are assigned to the auto network at the start of the model system, in order to develop travel level-of-service matrices or “skims” for subsequent model components. Auto and transit assignments are also run at the end of all iterations, for final set of assignment results. This process is used to ensure that the demand output from the model system is consistent with the demand used to estimate travel times. In the interests of keeping the model documentation consistent with the four steps shown above, we discuss trip assignment last.

After initial auto assignment, the auto and transit networks are “skimmed”. This means that shortest paths are traced through the network to create a set of level-of-service matrices (also known as “skims”) containing travel times and costs for each pair of TAZs. The rest of the model system reads these skims when a model needs to know the cost of travel between two zones.

Next, a set of general accessibility variables are created in the TAZ processing step. These variables are used to reflect the level-of-service from a given origin zone to all possible activities in destination zones.

The trip generation step is run next. This step estimates daily person-based trip productions for each TAZ and purpose. The next step splits these daily productions into peak (a.m. plus p.m.) and off-peak productions. Trip distribution and mode choice models are applied separately for peak and off-peak trips. The trip distribution models use a measure of accessibility from mode choice called a “logsum.” The logsum represents the accessibility of travel by all modes of transportation, where each mode is weighted by its probability or share of use. The mode choice models then split the trips by purpose into trips by purpose and mode.

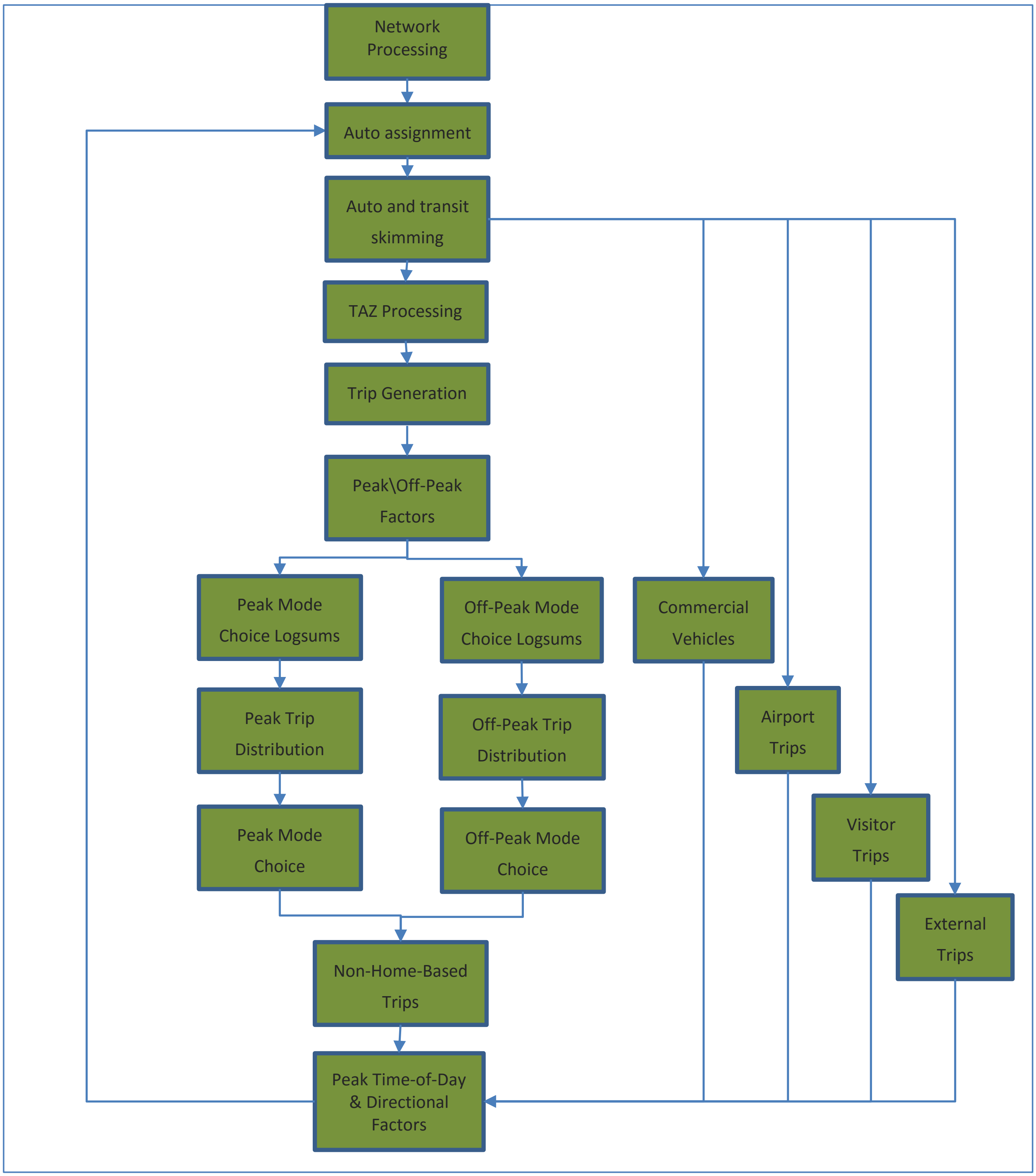
The AMATS model system includes a commercial vehicle model that represents both light trucks and non-goods movement commercial vehicles, as well as heavy trucks. A simple airport ground access model was developed to represent auto travel to and from Ted Stevens Anchorage International Airport. And a visitor model was developed to represent auto travel to and from hotels made by overnight visitors to Anchorage.

After mode choice is run, trips are transformed from production-attraction format to origin-destination format so that they can be assigned to networks. Peak trips are further split out into a.m. and p.m. truck, airport and visitor trips are also included.

After the model system completes iterating three times, a final auto assignment is performed, transit trips are assigned, and model reports are run.

The AMATS Model User's Guide describes outputs from each step in detail, including summary reports. This document describes the mathematical formulation of each model component, the parameters estimated for the model if applicable, the calibration of the model to observed data if applicable and the validation of the overall model system to traffic counts and transit boarding.

FIGURE 11: AMATS MODEL SYSTEM FLOWCHART



3.1 NETWORK PROCESSING

The network processing step codes capacity, free flow time and other values necessary for assigning trips to auto and transit networks. The AMATS auto assignment step takes into account both mid-link and intersection delay, based on the number of through lanes on the link, the intersection control type, the link facility type, opposing link facility type and other factors. The network processing step takes into account all of these factors and creates additional link fields required for auto assignment.

The calculation of mid-link and intersection capacity is based upon the method developed for the San Diego Association of Governments (SANDAG) travel demand model system. Mid-link capacity is calculated by direction and time-period according to Equation 1.

EQUATION 1: MID-LINK CAPACITY

$MLCapacity_{per,dir}$ = [$lanes_{dir}$ * CPL_{ft} + CAF_{ft} + ($AuxLanes_{dir}$ * CPA) + CAM] * $PeriodFactor_{per}$

Where:

$MLCapacity_{per,dir}$ = Mid-link capacity by period (*per*) and direction (*dir*)

$lanes_{dir}$ = Number of through lanes in the direction

CPL_{ft} = capacity per lane by facility type (*ft*) as shown in

Table 13.

CAF_{ft} = capacity adjustment factor by facility type (independent of number of lanes) as shown in

Table 13.

$AuxLanes_{dir}$ = Number of auxiliary lanes in the direction, currently assumed to be 0 for all facilities

CPA = Capacity per auxiliary lane, coded to 1200 vehicles

CAM = Capacity adjustment for medians, set to -200 for no median, -100 for continuous left-turn lanes, and 0 for full median control

$PeriodFactor_{per}$ = The factor to convert hourly capacity to period capacity, set to 2, 3, and 8 for a.m.,p.m. and off-peak periods respectively

Intersection capacity is calculated according to the intersection control type, the facility type of the link and the facility type of the intersecting link, the number of lanes, and turn lanes. The intersection capacity formula is shown in Equation 2 for controlled intersections (node intersection control 1, 2 or 3 according to Table 5). If the downstream node is uncontrolled, the intersection capacity defaults to a maximum value of 99999.

EQUATION 2: INTERSECTION CAPACITY

$$INCapacity_{per,dir} = [\ lanes_{dir} * CPL_{ft} * GCRatio_{c,l,ft,ift} + (RTLanes_{dir} + LTLanes_{dir}) * CPTL_{ft}] * PeriodFactor_{per}$$

Where:

$INCapacity_{per,dir}$ = Intersection capacity by period (*per*) and direction (*dir*)

$lanes_{dir}$ = Number of through lanes in the direction

CPL_{ft} = capacity per lane by facility type (*ft*) as shown in

Table 13

$GCRatio_{c,l,ft,ift}$ = The green time to cycle length ratio for the control type (*c*), number of legs (*l*), approach facility type (*ft*), and intersecting facility type (*ift*). Green time ratios are shown in Table 14 through Table 16 for 4-leg signalized intersections, 3-leg signalized intersections, and synthetic ratios for stop-controlled intersections respectively.

$RTLanes_{dir}$ = Number of right turn lanes in the approach. Since number of right turn lanes are not an explicit network attribute, the AMATS model currently assumes that 1 right turn lane is available at each signalized intersection where the approach link is major arterial, expressway, or freeway.

$LTLanes_{dir}$ = Number of left turn lanes in the approach. Since number of left turn lanes are not an explicit network attribute, the AMATS model currently assumes that 1 right turn lane is available at each signalized intersection where the approach link is major arterial, expressway, or freeway.

$CPTL_{ft}$ = capacity per turn lane by facility type (*ft*) as shown in

Table 13.

$PeriodFactor_{per}$ = The factor to convert hourly capacity to period capacity, set to 2, 3, and 8 for a.m., p.m., and off-peak periods respectively

In addition to mid-link and intersection capacity, the cycle length is required by the volume-delay function for each controlled intersection. Cycle lengths are shown in Table 17 by approach facility type and intersecting facility type.

Since the auto path generalized cost calculation takes into account both toll cost and auto operating cost, an auto operating cost attribute is also calculated for each link. The auto operating cost is 19 cents per-mile, which includes an average fuel cost of 15 cents per-mile and average costs of maintenance and tires of five cents per-mile, as per the AAA publication "Your Driving Costs 2013"[4]. Note that costs of ownership are not included as auto ownership is a separate model.

[4] https://newsroom.aaa.com/wp-content/uploads/2013/04/YourDrivingCosts2013.pdf

TABLE 13: MID-LINK CAPACITIES AND ADJUSTMENT FACTORS BY FACILITY TYPE

Class	Description	Capacity Per Lane (CPL_{ft})	Capacity Adjustment Factor (CAF_{ft})	Turning Lane Capacity (TLC_{ft})
1	Freeway	1900	0	250
2	Expressway	1800	0	250
3	Major Arterial	1800	-200	250
4	Minor Arterial	1800	-300	150
5	Collector	1400	-100	100
6	Local	1400	-100	100
7	On Ramp	1400	0	100
8	Off-Ramp	1400	0	100
9	Reserved	0	0	0
10	Frontage Road	1400	0	100
11	Dirt Road (only used in the MSB)	950	0	100
99	Centroid Connector	99999	0	0

TABLE 14: GREEN TIME TO CYCLE LENGTH RATIO FOR 4-LEG SIGNALIZED INTERSECTIONS

	Intersecting Facility Type										
Approach FT	Free-way	Exp-way	Major Arterial	Minor Arterial	Coll-ector	Local	On-Ramp	Off-Ramp	Re-served	Frontage Road	Dirt Road
Freeway	0.35	0.35	0.39	0.50	0.56	0.63	0.47	0.47	0.00	0.63	0.63
Expressway	0.35	0.35	0.39	0.50	0.56	0.63	0.47	0.47	0.00	0.63	0.63
Major Arterial	0.33	0.33	0.37	0.48	0.60	0.63	0.45	0.45	0.00	0.63	0.63
Minor Arterial	0.22	0.22	0.26	0.38	0.47	0.58	0.35	0.35	0.00	0.58	0.58
Collector	0.22	0.22	0.26	0.38	0.48	0.59	0.35	0.35	0.00	0.59	0.59
Local	0.09	0.09	0.11	0.18	0.27	0.40	0.16	0.16	0.00	0.40	0.40
On-Ramp	0.26	0.26	0.30	0.41	0.51	0.61	0.39	0.39	0.00	0.61	0.61
Off-Ramp	0.26	0.26	0.30	0.41	0.51	0.61	0.39	0.39	0.00	0.61	0.61
Reserved	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frontage Road	0.09	0.09	0.11	0.18	0.27	0.40	0.16	0.16	0.00	0.40	0.40
Dirt Road	0.09	0.09	0.11	0.18	0.27	0.40	0.16	0.16	0.00	0.40	0.40

TABLE 15: GREEN TIME TO CYCLE LENGTH RATIO FOR 3-LEG SIGNALIZED INTERSECTIONS

	Intersecting Facility Type										
Approach FT	Free-way	Exp-way	Major Arterial	Minor Arterial	Coll-ector	Local	On-Ramp	Off-Ramp	Re-served	Frontage Road	Dirt Road
Freeway	0.46	0.46	0.52	0.65	0.74	0.82	0.62	0.62	0.00	0.82	0.82
Expressway	0.46	0.46	0.52	0.65	0.74	0.82	0.62	0.62	0.00	0.82	0.82
Major Arterial	0.41	0.41	0.46	0.60	0.70	0.80	0.57	0.57	0.00	0.80	0.80
Minor Arterial	0.28	0.28	0.32	0.46	0.58	0.71	0.43	0.43	0.00	0.71	0.71
Collector	0.26	0.26	0.30	0.44	0.56	0.69	0.40	0.40	0.00	0.69	0.69
Local	0.11	0.11	0.13	0.21	0.31	0.46	0.19	0.19	0.00	0.46	0.46
On-Ramp	0.31	0.31	0.36	0.50	0.61	0.74	0.46	0.46	0.00	0.74	0.74
Off-Ramp	0.31	0.31	0.36	0.50	0.61	0.74	0.46	0.46	0.00	0.74	0.74
Reserved	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frontage Road	0.11	0.11	0.13	0.21	0.31	0.46	0.19	0.19	0.00	0.46	0.46
Dirt Road	0.11	0.11	0.13	0.21	0.31	0.46	0.19	0.19	0.00	0.46	0.46

TABLE 16: SYNTHETIC GREEN TIME TO CYCLE LENGTH RATIO FOR STOP CONTROLLED INTERSECTIONS AND ROUNDABOUTS

	Intersecting Facility Type										
Approach FT	Free-way	Exp-way	Major Arterial	Minor Arterial	Coll-ector	Local	On-Ramp	Off-Ramp	Re-served	Frontage Road	Dirt Road
Freeway	0.34	0.34	0.37	0.44	0.55	0.62	0.53	0.53	0.00	0.62	0.62
Expressway	0.34	0.34	0.37	0.44	0.55	0.62	0.53	0.53	0.00	0.62	0.62
Major Arterial	0.33	0.33	0.37	0.44	0.58	0.67	0.36	0.36	0.00	0.67	0.67
Minor Arterial	0.31	0.31	0.35	0.44	0.63	0.79	0.48	0.48	0.00	0.79	0.79
Collector	0.26	0.26	0.29	0.37	0.51	0.64	0.29	0.29	0.00	0.64	0.64
Local	0.08	0.08	0.11	0.16	0.32	0.48	0.16	0.16	0.00	0.48	0.48
On-Ramp	0.29	0.29	0.33	0.42	0.63	0.79	0.63	0.63	0.00	0.79	0.79
Off-Ramp	0.29	0.29	0.33	0.42	0.63	0.79	0.63	0.63	0.00	0.79	0.79
Reserved	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frontage Road	0.08	0.08	0.11	0.16	0.32	0.48	0.16	0.16	0.00	0.48	0.48
Dirt Road	0.08	0.08	0.11	0.16	0.32	0.48	0.16	0.16	0.00	0.48	0.48

TABLE 17: CYCLE LENGTH FOR CONTROLLED INTERSECTIONS (MIN)

	Intersecting Facility Type										
Approach FT	Free -way	Exp-way	Major Arterial	Minor Arterial	Coll-ector	Local	On-Ramp	Off-Ramp	Re-served	Frontage Road	Dirt Road
Freeway	2.5	2.5	2.0	1.5	1.5	1.5	1.5	1.5	0.0	1.5	1.5
Expressway	2.5	2.5	1.5	1.5	1.5	1.5	1.5	1.5	0.0	1.5	1.5
Major Arterial	2.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0
Minor Arterial	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0
Collector	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0
Local	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0
On-Ramp	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0
Off-Ramp	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0
Reserved	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Frontage Road	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0
Dirt Road	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0

TransCAD software requires transit travel times to be coded explicitly as a line layer attribute. Since all base-year transit services are bus lines that travel along the street network, the transit time is based upon the auto time for each time period, plus a factor that takes into account dwell time and relatively slower bus speeds due to acceleration, deceleration and generally less maneuverability than autos. These time calculations were largely adopted from the previous AMATS travel demand model. The transit travel time function is given in Equation 3.

EQUATION 3: TRANSIT TRAVEL TIME FUNCTION

$$Time_{dir,mode,per} = Max(\ AutoTime_{dir,per} + (length * (AverageDwellPerStop / 60) * StopSpace\ ),\ 60/MaxTrSpd_{mode} * length)$$

Where:

$Time_{dir,transit}$ = Transit travel time in minutes by direction, mode, and period

$AutoTime_{dir,auto}$= Auto travel time in minutes by direction and period

Length = Link length

AverageDwellPerStop = average dwell time per stop, currently set to 20 seconds

StopSpace = average stops per mile

$MaxTrSpd_{mode}$= Maximum transit speed per mode

3.2 AUTO ASSIGNMENT

Auto assignment is performed using a static equilibrium assignment algorithm in TransCAD. The assignment algorithm used for the AMATS model is an Origin-Based assignment algorithm based on Algorithm B developed by Dial[5]. According to the TransCAD User's Guide,"…this is a bush-based method (Nie, 2009[6]) that provides a path-based solution without explicit enumeration of paths, and it can compute solutions to much tighter convergence than can be reached with the traditional algorithms. This makes it possible to compare traffic assignments with more highly converged ones, and research has indicated that use of smaller gaps increases the accuracy and validity of project impact assessments. The OUE traffic assignment in TransCAD is a Caliper implementation that has some proprietary modifications to Dial's bush-based published algorithm…"

The AMATS model assigns trip tables to networks for the three-time periods shown in Table 19. In the first pass through the model system, base-year calibrated trip tables are assigned to the network. In subsequent passes, the output trip tables from Peak Time of Day and Directional Factoring are assigned. The algorithm chooses a least cost path for each vehicle class and zone pair according to a generalized cost calculation that includes both the time that it takes to travel along each link in the network and the cost (auto operating cost plus the toll) of the link. The time is converted to cost using a value of time so that each component is comparable. Certain links are excluded for vehicle classes that cannot utilize those facilities due to occupancy or weight restrictions. The vehicle classes that are assigned to the network, along with their values of time, and the types of links that are excluded for each class, are shown in Table 18. Value-of-time for person-based trip tables are based on a wage rate which is calculated as one-half of the mid-point of each income range. For trucks, the values are based on a literature review performed for Ohio State Department of Transportation for the Ohio Statewide travel demand model. Auto operating and toll costs are further scaled for shared-ride vehicles based on occupancy factors, consistent with mode choice. The factors are 1/1.8 for shared-ride 2 vehicles and 1/2.3 for shared-ride 3+ vehicles. Guidance regarding values-of-time and cost factoring by occupancy can be found in recent a Strategic Highway Research Project report on model enhancements for pricing and reliability[7].

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[5] See Dial, Robert B. Algorithm B: Accurate Traffic Equilibrium (and How to Bobtail Frank-Wolfe), Volpe National Transportation Systems Center, Cambridge, MA, July 25, 1999; and Dial, Robert B., *"A Path-Based User-Equilibrium Traffic Assignment Algorithm that Obviates Path Storage and Enumeration"* Transportation Research Part B, March 13, 2006

[6] Y Nie, "*A class of bush-based algorithms for the traffic assignment problem*", Transportation Research Part B, (2009)

[7] 3. Parsons Brinckerhoff, Northwestern University, Mark Bradley Research, University of California at Irvine, Resource Systems Group, University of Texas at Austin, Frank Koppelman, and GeoStats. 2013. SHRP 2 Report S2-C04-RW-1: Improving Our Understanding of How Highway Congestion and Pricing Affect Travel Demand. Washington, D.C.: Transportation Research Board of the National Academies, Washington D.C.

TABLE 18: VEHICLE TRIP TABLES

Number	Mode	VOT Bin	Link Exclusions	Value-of-time ($/hour)
1	Drive-alone	Low VOT (income < $25k)	HOV2 and HOV3+ lanes	$3.11
2	Drive-alone	Medium-low VOT ($25k< income <$50k)	HOV2 and HOV3+ lanes	$7.88
3	Drive-alone	Medium-high VOT ($50k< income <$100k)	HOV2 and HOV3+ lanes	$15.38
4	Drive-alone	High VOT ($100k+)	HOV2 and HOV3+ lanes	$35.34
5	Shared 2	Low VOT (income < $25k)	HOV 3+ lanes	$3.11
6	Shared 2	Medium-low VOT ($25k< income <$50k)	HOV 3+ lanes	$7.88
7	Shared 2	Medium-high VOT ($50k< income <$100k)	HOV 3+ lanes	$15.38
8	Shared 2	High VOT ($100k+)	HOV 3+ lanes	$35.34
9	Shared 3+	Low VOT (income < $25k)	None	$3.11
10	Shared 3+	Medium-low VOT ($25k< income <$50k)	None	$7.88
11	Shared 3+	Medium-high VOT ($50k< income <$100k)	None	$15.38
12	Shared 3+	High VOT ($100k+)	None	$35.34
13	Light trucks	All	None	$25.00
14	Heavy trucks	All	None	$36.00

TABLE 19: ASSIGNMENT TIME PERIODS

Period	Hours	Abbreviation	Skim Period
AM Peak	Between 7 AM and 9 AM (2 hours)	AM	PK
PM Peak	Between 3 PM and 6 PM (3 hours)	PM	NA
Off-Peak	Between 6 PM and 7 AM, and between 9 AM and 3 PM (19 hours)	OP	OP

An auto volume-delay function (VDF) is used to calculate link travel time based upon link characteristics such as free-flow time and capacity, and assigned auto volume. The volume-delay function for the AMATS auto assignment is based on a function developed by Pima Association of Governments and also used in the San Diego Association of Governments travel model. It is shown in Equation 4.

EQUATION 4: AUTO TIME VOLUME-DELAY FUNCTION

$$T_f = T_0 * \left[1 + \alpha_l * \left(\frac{V}{C_s}\right)^{\beta_l}\right] + P * \frac{c}{2} * \left(1 - \frac{g}{c}\right)^2 * \left[1 + \alpha_i * \left(\frac{V}{C_i}\right)^{\beta_i}\right]$$

Where:

T_f = the congested travel time on the link

T_0 = free-flow travel time on the link

V = assigned volume

P = signal progression factor for link

c = signal cycle length

$\frac{g}{c}$ = green time to cycle length ratio for controlled intersection

C_i = intersection capacity (taking into account number of lanes and g\c ratio)

α_l, β_l, α_i, β_i = calibrated parameters for link delay and intersection delay respectively

The calculation of all of the above fields with the exception of the VDF parameters is given in the above section on network coding. Starting values for parameters were based on validated results from SANDAG, and adjusted to better match observed traffic volumes for AMATS. The final calibrated assignment parameters are shown in Table 20.

TABLE 20: CALIBRATED AUTO ASSIGNMENT PARAMETERS

Parameter	Value
α_l	0.15
β_l	4 (6 for facilities with speed 55 MPH +)
α_i'	0.15
β_i	2.0

3.3 AUTO AND TRANSIT SKIMMING

In the skimming step, level-of-service matrices (skims) are created for A.M. Peak and Off-peak time periods for use in travel demand models. Auto skims are created in TransCAD by finding the least-cost path for each time period (a.m. versus off-peak), income group (LOW, MLO, MHI, and HIGH), mode (DA, S2, S3+, LT, HT) and zone-pair and accumulating time, length and cost fields into separate matrices. Transit skims are similarly created, however the algorithm is different than the auto least-cost path because of the complexity of transit. The TransCAD Pathfinder algorithm is used for transit network skimming, just as is used in transit assignment. Transit skims include in-vehicle time, first wait time, transfer wait time, number of boardings, walk or drive access time, auxiliary walk time, egress walk time and fare. Income segmentation is not used in truck or transit skimming or assignment.

3.4 TAZ PROCESSING

The TAZ processing step prepares inputs for trip generation, including running household socio-economic sub-models, which determine the number households by various classifications of socio-economic categories for each TAZ.

3.4.1 ZONE ACCESSIBILITY VARIABLES

The first step in this model component is the creation of zonal accessibility variables required for input to household socio-economic sub-models and other model components. These variables are all calculated as zonal vectors, and they are listed in Table 21. The first set of fields counts total intersections, households, employment, and acres within ½ mile of the zonal centroid. Additionally, total population within ¼ mile of transit service is calculated for each zone, for use in model output reporting (see Model User’s Guide).

The second set of zonal accessibility variables are a bit more complicated. They represent accessibility to certain categories of trip attractions (also known as “zone size”) by different modes of transportation (drive-alone, walk and walk-transit) according to peak level of service. The measures are calculated by taking the natural log of the denominator of a simple destination choice logit model, where the zone size and the accessibility term are varied accordingly. Essentially the variable represents the utility of travel to all possible destinations for a given activity and mode, where the destination is weighted by the modal accessibility to the destination from the origin TAZ. For more information on the formulation of these terms, see the sections on mode choice and destination choice, below.

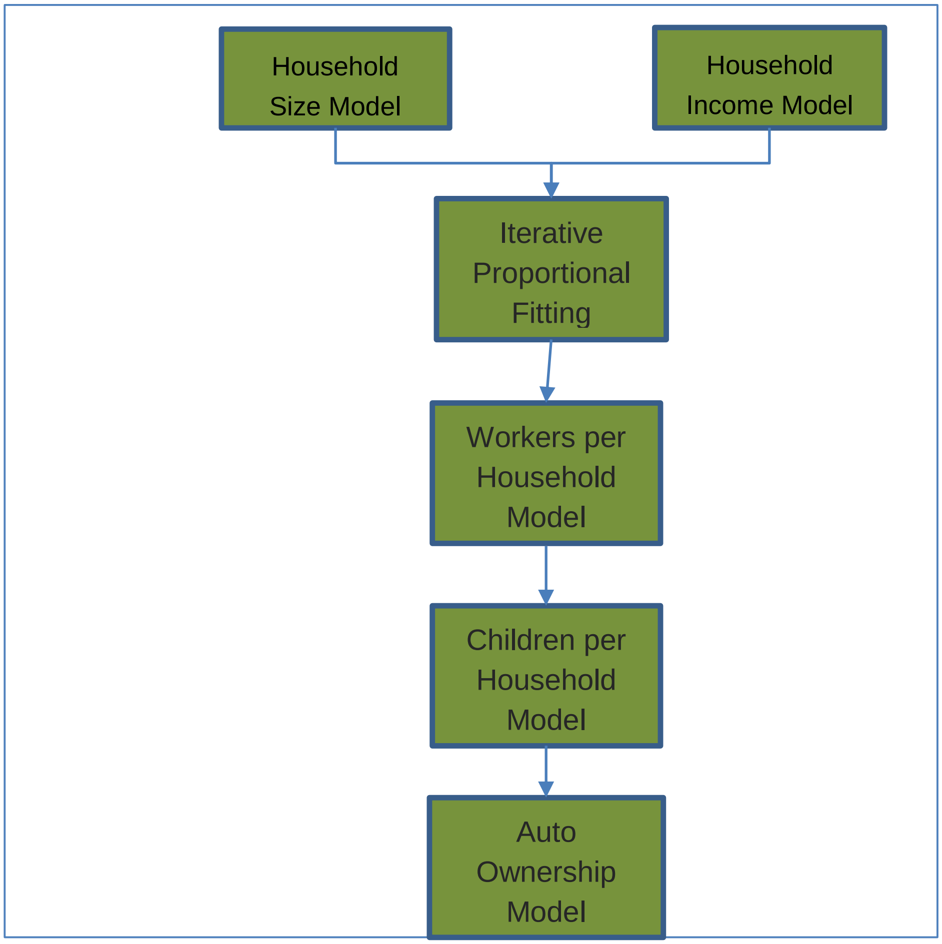
TABLE 21: TAZ ACCESSIBILITY VARIABLES

Field Name	Description
TOTINTERHM	Total intersections within ½ mile
TOTHHHM	Total households within ½ mile
TOTEMPHM	Total employment within ½ mile
TOTACRESHM	Total acres within ½ mile
POPQMTRAN	Total population within ¼ mile of transit service (buffer calculation)
EMP30MINAUTO	Total employment within 30 minutes of auto travel time
EMP30MINTRAN	Total employment within 30 minutes of transit travel time
EmpAccByDA	Destination choice logsum of total employment by drive-alone utility
EmpAccByWK	Destination choice logsum of total employment by walk utility
RetAccByWK	Destination choice logsum of retail employment by walk utility
EmpAccByWT	Destination choice logsum of total employment by walk-transit utility

3.4.1.1 Household Sub-models

Household sub-models were developed to create cross-classifications of households by various socio-economic segmentations for use in subsequent travel demand models. The household sub-model flow is shown in Figure 12. The process starts with models of household size and household income. These models predict the number of households by household size bin (1,2,3,4+) and household income bin (low: $0-$25k, medium-low: $25-$50k, medium-high ($50k-$100k) and high ($100k+) for each TAZ. These marginal distributions are input to an iterative proportional fitting (IPF) procedure which creates a cross-classification of households by household size and household income for each TAZ. Then a series of multinomial logit models is run to further break out households by workers per household, children per household, and auto ownership. Each sub-model component is described more fully below.

FIGURE 12: HOUSEHOLD SUB-MODEL FLOW



3.4.1.2 Household size model

For each TAZ, this model predicts proportion of households by size, given the average household size of the TAZ. The household size models are a set of curves developed considering the following household sizes:

- 1-person household (HH1),
- 2-person household (HH2),
- 3-person household (HH3), and
- 4 or more-person household (HH4p).

The dataset used for this model was developed by AMATS using the following sources:

- Average household size: 2010 Census, and
- Households by size: 2009-2013 ACS 5-Year Estimates

To develop the curves for household size, first, proportion of total households by size was plotted against average household size to identify potential relationships between these two variables. Next, outliers were excluded from the dataset. The resulting dataset was then used to estimate a series of polynomial regression models by household size. The model that fitted the data best was chosen as the final specification for each household size. Next, the estimated models were applied to predict proportion of total households by size. Finally, the predicted values were adjusted to satisfy the following conditions:

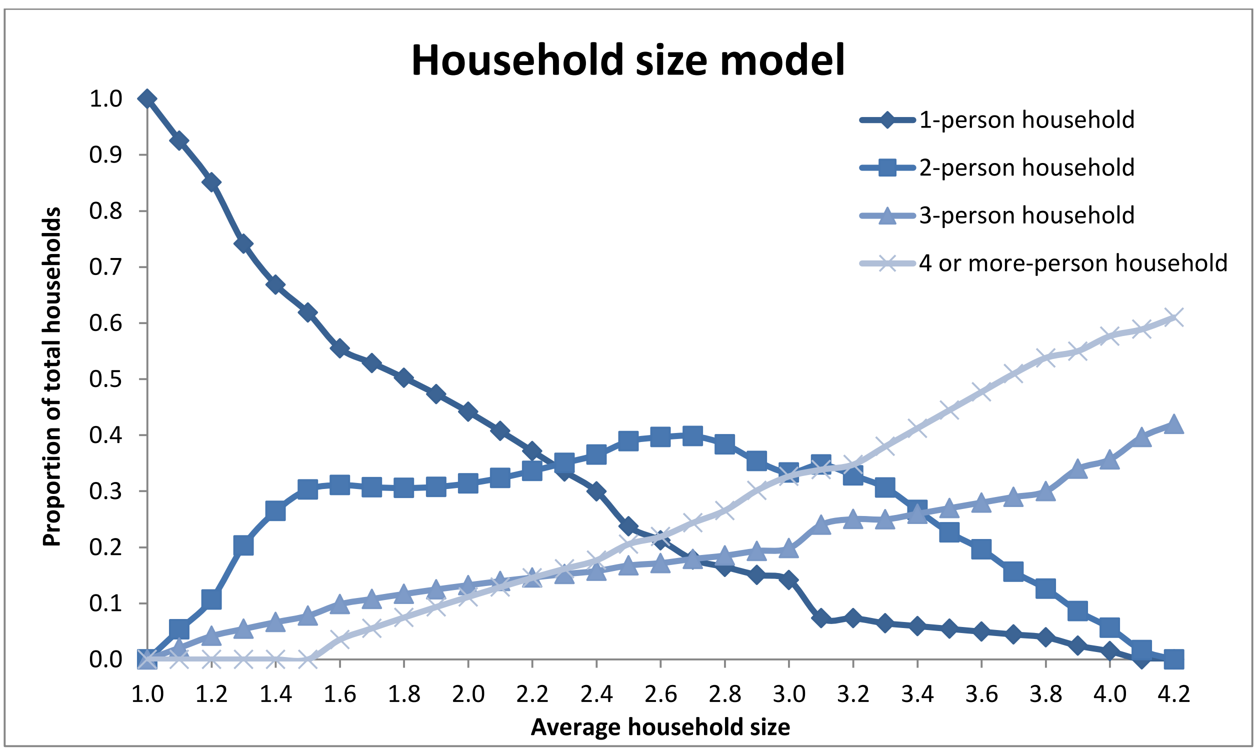
- For each average household size, summation of proportion of total households by size is equal to one.
- Average household size obtained from the proportion of total households by size is equal to the corresponding average household size used in the model estimation. For this, an average household size of 4.8, calculated using 2011-2013 ACS 3-Year PUMS data, was used for four or more-person household size category.

For example, for average household size two, the curves predict the following proportion of total households for HH1, HH2, HH3, and HH4p categories: 0.4417, 0.3140, 0.1327, and 0.1116. Summation of these four proportions is one. Also, average household size calculated from these proportions is:

$$\textit{Average household size} = (0.4417 \times 1) + (0.3140 \times 2) + (0.1327 \times 3) + (0.1116 \times 4.8) = 2.0$$

Figure 13 presents fitted household curves by size. In model application, proportion of total households by size (provided by these curves) will be multiplied by the number of households in each TAZ to obtain number of households by size. Outputs from these curves, that is distribution of households by size, is used to estimate downstream models such as workers per household, children per household, and household auto ownership model.

FIGURE 13 AVERAGE HOUSEHOLD SIZE VS. PROPORTION OF TOTAL HOUSEHOLDS BY SIZE



3.4.1.3 Household income

This model is used to predict proportion of households by income group for each TAZ, given the income index[8] for that TAZ. Dataset used for this model was also developed by AMATS using 2009-2013 ACS 5-Year Estimates. In addition to average household income, the dataset included number of households by the following income categories: income <10k, 10k ≤income < 25k, 25k ≤income < 35k, 35k ≤income < 40k, 40k ≤income < 50k, 50k ≤income < 60k, 60k ≤income < 75k, 75k ≤income < 100k, and income≥100k. For the current model, the 9 income categories were aggregated to the following 4 groups:

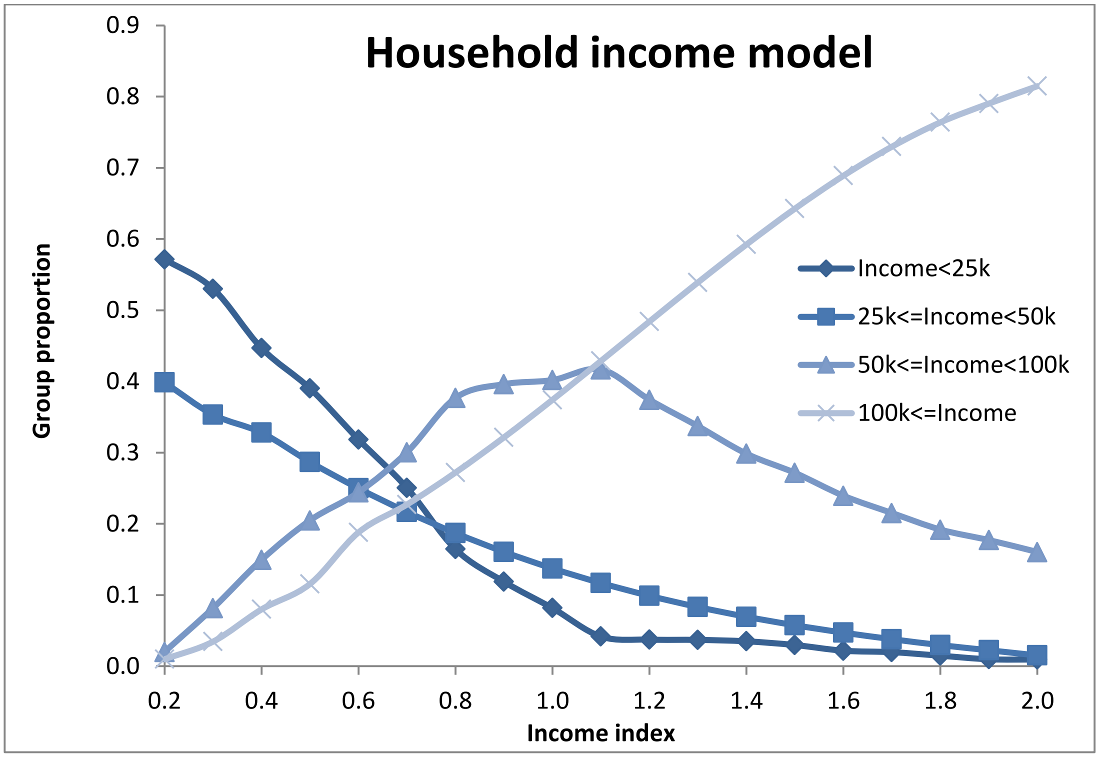
- Low income (income < 25k)
- Medium-low income (25k ≤income < 50k)
- Medium-high income (50k ≤income < 100k)
- High income (income ≥ 100k)

Similar to household size model, income model is also developed as a set of curves. For this, first average income for high income category was calculated using 2011-2013 ACS 3-Year PUMS data. Next, average regional income for the study area was calculated using mid-point income for all categories, except the last category (for income≥100k category, average income calculated from PUMS data was used). Then, average zonal income and average regional income was used to calculate income index for each TAZ. Next, proportion of total households by income group was plotted against income index to understand the correlation between these two quantities. Then, a series of polynomial regression models by income group was estimated after excluding outliers from the dataset. The model that provided the best fit was chosen as the final model for each income group and was used to predict proportion of total households by income group. Finally, the predicted values were adjusted so that for each income index, summation of proportion of total households by income group is equal to one.

Figure 14 shows fitted curves by income group. Similar to household curves, values from income curves will be multiplied by the number of households in each TAZ to get number of households by income group. Outputs from these curves will also feed into workers per household, children per household, and household auto ownship model.

[8] Income index is the ratio of the average zonal income to average regional income.

FIGURE 14 INCOME INDEX VS. PROPORTION OF HOUSEHOLDS BY INCOME GROUP



3.4.1.4 Iterative Proportional Fitting

Iterative Proportional Fitting (IPF) estimates the joint distribution of households by household size and household income for each zone. This is done by fitting the regional distribution of households by size and income from the 2008-2011 Public Use Microdata Sample (PUMS) for Anchorage to the marginal distributions of households by size and income from each model. A 2-D distribution table for household size and income was generated using 2013 3-Year ACS PUMS data (see

Table 22). Public Use Microdata Areas (PUMA) that correspond to the study area are PUMA 101, 102, and 200. For this analysis, only PUMA 101 and PUMA 102 (Anchorage Municipality area) were considered since PUMA 200 covers an area much larger than Mat-Su.

TABLE 22 2-D HOUSEHOLD SIZE & HOUSEHOLD INCOME

Household size	Income <25k	25k≤Income <50k	50k≤Income <100k	100k≤Income	Total
1	7,931	7,841	7,511	3,410	26,693
2	2,398	5,516	12,370	14,951	35,235
3	914	2,272	6,641	7,296	17,123

4+	1,599	2,571	8,370	13,389	25,929
Total	12,842	18,200	34,892	39,046	104,980

The algorithm uses row and column balancing to adjust the above regional matrix of households to the estimated household size and income marginal for each TAZ.

3.4.1.5 Number of workers in the household

This model is applied to predict the number of workers in a household. The model is formulated as a multinomial logit (MNL) model[9] after specification testing. A MNL specification models an individual's choice making behavior from among a finite set of alternatives. In this case, each of the workers per household groups are treated as an alternative to the model. MNL models make use of utility based choice theory wherein a utility is computed for each of the available alternatives as a function of alternative and decision-maker attributes. Utility theory assumes that an individual would try to maximize his/her overall utility, therefore, an alternative is chosen if its utility is greater than all other available alternatives. For each alternative, a utility equation can be specified as follows:

$$U_i = \sum_{\forall J} \beta_j * X_{ij}$$

Where X_{ij} is the j^{th} input variable that adds to the utility of a given alternative "i", while β_j is the utility coefficient corresponding to that input variable. Utility coefficients define the direction and quantifies the impact of an input variable. Once the utilities for each of the alternatives or segments have been computed, the segment shares are computed as follows:

$$Share_i = \frac{\exp(U_i)}{\sum_N \exp(U_i)}$$

Where, $\exp(U_i)$ is the natural exponent of segment *i*'s utility and $\sum_N \exp(U_i)$ is the sum of the utilities of all *N* segments or alternatives.

The final model estimation results are summarized below in Table 23. A weighted sample of 3,101 observations were used to estimate the model. The base alternative in the model is 1 worker (i.e., coefficient =0), and the coefficients for other alternatives are estimated with respect to this base alternative. The final model has an adjusted rho-square value of 0.273, indicating that the model fits observed data relatively well. The main inferences of the estimated coefficients are the following:

- Households are more likely to have no worker and less likely to have multiple workers, relative to 1 worker.
- Relative to 4 or more persons households, 1 to 3 persons households are more likely to have 3 or fewer workers.

[9] As MNL model is a widely used tool in transportation, the model specification is not presented here to conserve space. Please see the following for more information: Ben-Akiva, M., Lerman, S.R., 1985. Discrete Choice Analysis: Theory and Application to Travel Demand. The MIT Press, Cambridge.

- High income households are less likely to have no workers and more likely to have multiple workers, relative to low income households (income <$25,000).
- Households with no workers are likely to decrease with an increase in access to employment by auto. Similarly, access to employment by walk and walk-transit modes are likely to have positive impact on households with multiple workers.

3.4.1.6 Number of children in the household

This model is applied after number of workers in household model to predict number of children in household (0 children, 1 child, 2 children, or 3+ children). The final MNL model estimation results, obtained after specification testing, are in Table 24.

A weighted sample of 2,346 observations were used to estimate the model. Overall, the model fits household travel survey data quite well, with an adjusted rho-square value of 0.483. The main implications of the estimated coefficients are summarized below:

- Households are more likely to have 1 child than no children or 2+ children.
- 2 or 3 persons households are more likely to have no children, relative to 4+ persons households. Also, 3 persons households are less likely to have 2 children than 4+ persons households.
- High income households are more likely to have no children, relative to low income households. These households also show a preference towards having 2 children over 1 or 3+ children.
- Households with no workers or 2+ workers are more likely to have no children, relative to households with 1 worker. Also, these households are less likely to have 3+ children, compare to households with 1 worker.

TABLE 23: NUMBER OF WORKERS IN HOUSEHOLD ESTIMATION RESULTS

Variable	Alternatives (base: 1 worker)					
	0 worker		2 workers		3+ workers	
	Co-efficient	t-statistic	Co-efficient	t-statistic	Co-efficient	t-statistic
Alternative-specific constant (base: 1 worker)	3.270	3.18	-2.230	-8.42	-5.350	-4.79
Household size (base: 4 or more persons household)						
1 person household	2.450	10.23				
2 persons household	2.450	10.23	1.440	15.37		
3 persons household	0.736	2.11	1.270	9.50	1.100	6.08
Income (base: income < $25,000)						
$25,000 ≤ Income < $50,000	-1.560	-8.78	0.322	1.14	1.280	1.13
$50,000 ≤ Income < $100,000	-1.780	-10.65	0.983	3.75	2.560	2.34
$100,000 ≤ Income	-2.100	-11.04	1.690	6.45	3.610	3.31
Accessibility to total employment by drive alone mode	-0.405	-4.62				
Accessibility to total employment by walk					0.054	1.48
Accessibility to total employment by walk-transit mode			0.017	2.09	0.017	2.09
Observations	3,101					
Final log likelihood	-3,103.2					
Adjusted rho-square	0.273					

TABLE 24: NUMBER OF CHILDREN IN HOUSEHOLD ESTIMATION RESULTS

Variable	Alternatives (base: 1 child)					
	0 children		2 children		3+ children	
	Co-efficient	t-statistic	Co-efficient	t-statistic	Co-efficient	t-statistic
Alternative-specific constant (base: 1 child)	-5.790	-11.06	-1.920	-4.80	-0.206	-1.81
Household size (base: 4 or more persons household)						
2 persons household	7.320	17.68				
3 persons household	2.620	6.77	-1.800	-8.30		
Income (base: income < $25,000)						
$25,000 ≤ Income < $50,000	0.947	2.46	0.567	1.62		
$50,000 ≤ Income < $100,000	1.590	4.58	0.567	1.62		
$100,000 ≤ Income	1.920	5.48	0.953	2.70		
Number of workers (base: 1 worker)						
No worker	0.994	3.65			-0.883	-2.32
2 workers	0.525	2.43			-0.916	-5.30
3 or more workers	3.910	9.32			-1.060	-2.79
(Household size – workers) (C) when C ≥ 2			1.820	7.71		
Observations	2,346					
Final log likelihood	-1,664.8					
Adjusted rho-square	0.483					

- A variable (C) derived by subtracting number of workers from household size was used as a proxy for number of children in a household. As expected, when C≥2, coefficient for this variable has a positive sign when interacted with households with two children.

3.4.1.7 Number of vehicles in the household

This socio-economic model is applied after children per household model to predict vehicle ownership level of a household (i.e., no vehicle, 1 vehicle, 2 vehicles, and 3+ vehicles households). The base alternative for the MNL model is 2 vehicles. A weighted sample of 3,101 observations were used to estimate the model. The final model has an adjusted rho-square of 0.36, indicating that the model fits the data reasonably well. The estimation results, summarized in Table 25, indicate the following:

- Households in the study area are more likely to own no vehicle or 1 vehicle than two or more vehicles.
- Households with multiple adults are more likely to own multiple vehicles.
- An increase in workers to adults ratio is likely to decrease number of households with 0 vehicle.
- An increase in children to adults ratio is likely to have a negative effect on 0 and 1 vehicle ownership level, relative to 2+ vehicle ownership level.
- Household income has a positive correlation with number of vehicles in the household. Vehicle ownership level is likely to increase with increase in income.
- An increase in intersection density within ½ mile radius of residential TAZ centroid is likely to promote 0 and 1 vehicle ownership levels. Household density within ½ mile radius of residential TAZ centroid is also likely to have a similar effect on 0 vehicle ownership level.
- As access to any type of employment by auto increases, 0 vehicle ownership level is likely to decrease. On the other hand, an increase in access to employment by walk-transit mode is likely to increase 0 and 1 vehicle ownership levels. And, in a similar vein, an increase in access to retail employment by walk is likely to increase 0 and 1 vehicle ownership levels and decrease 3+ vehicle *ownership levels.*

TABLE 25: NUMBER OF VEHICLES IN HOUSEHOLD ESTIMATION RESULTS

Variable	Alternatives (base: 2 vehicles)					
	0 vehicle		1 vehicle		3+ vehicles	
	Co-efficient	t-statistic	Co-efficient	t-statistic	Co-efficient	t-statistic
Alternative-specific constant (base: 2 vehicles)	4.440	1.26	2.180	8.81	-1.950	-3.96
Number of adults in the household (base: 1 adult)						
2 adults	-2.300	-9.35	-2.440	-20.83		
3 adults	-2.300	-9.35	-2.440	-20.83	1.680	10.45
4+ adults	-2.300	-9.35	-2.140	-2.83	2.900	6.41
Number of workers/number of adults	-0.561	-2.33				
Number of children/number of adults	-1.010	-4.03	-0.753	-10.74		

Income (base: income < $25,000)						
$25,000 ≤ Income < $50,000	-2.500	-7.54	-0.888	-3.72	0.765	1.47
$50,000 ≤ Income < $100,000	-3.630	-10.36	-1.490	-6.73	1.400	2.84
$100,000 ≤ Income	-5.000	-8.20	-2.320	-9.94	1.920	3.90
ln(1 + intersection density within ½ mile radius of residential TAZ centroid)	0.309	1.78	0.154	2.12		
ln(1 + household density within ½ mile radius of residential TAZ centroid)	0.316	1.61				
Accessibility to total employment by drive alone mode	-0.647	-1.65				
Accessibility to total employment by walk-transit mode	0.031	1.12	0.014	1.09		
Accessibility to retail employment by walk mode	0.428	3.36	0.082	2.11	-0.106	-5.38
Observations	3,101					
Final log likelihood	-2,720.7					
Adjusted rho-square	0.360					

3.5 TRIP GENERATION

The trip generation model predicts the number of total daily home-based trip productions for each TAZ in the region. In the AMATS travel demand model, non-home-based trip productions are predicted by an innovative non-home-based travel model, described later. Home-based productions are predicted by multiplying the number of households classified by socio-economic variables by the trip rate for each category and trip purpose. This is referred to as cross-classification trip generation. Trip purpose definitions are shown in Table 26. The trip rates shown in were computed from the 2014 regional household survey.

TABLE 26: TRIP PURPOSES

Number	Abbreviation	Purpose	Description
1	HBW	Home-Based Work	Trips between home and work
2	HBU	Home-Based College\University	Trips between home and school (pre-school through grade 12)
3	HBC	Home-Based School	Trips between home and college\university\trade school
4	HBS	Home-Based Shop	Trips between home and shopping
5	HBO	Home-Based Other	Trips between home and any other type of destination
6	NHW	Non-Home-Based Work	Trips between work and other places besides home
7	NHO	Non-Home-Based Other	Trips between two non-home/non-work locations

TABLE 27: HOME-BASED WORK TRIP RATES

Workers	Rate
0	0
1	1.230353
2	2.160468
3	3.64494

TABLE 28: HOME-BASED COLLEGE TRIP RATES

Adults	Work0	Work1	Work2	Work3
1	0.266532	0.061038	0	0
2	0.399936	0.381761	0.203317	0
3	0.06455	0.739341	1.182897	0.827615
4	1.672865	2.685084	2.513693	3.649297

TABLE 29: HOME-BASED SCHOOL TRIP RATES

Children	Triprate
0	0
1	0.969299
2	2.098906
3	3.660022

TABLE 30: HOME-BASED SHOP TRIP RATES

HHSize	HHINC1	HHINC2	HHINC3	HHINC4
1	0.972157	0.532591	0.440164	0.316807
2	1.206032	0.710456	0.704716	0.654584
3	1.33052	1.397726	1.109562	0.804216
4	1.551121	1.383368	1.511152	1.205

TABLE 31: HOME-BASED OTHER TRIP RATES

HHSize	HHINC1	HHINC2	HHINC3	HHINC4
1	1.707247	1.300095	1.480562	1.496748
2	2.640602	2.554051	2.242913	2.236062
3	3.486886	2.410078	3.380875	3.451547
4	4.02667	4.208053	5.48791	6.267194

3.5.1 TRIP GENERATION APPLICATION RESULTS

Results from applying trip rates to household survey data are shown in Table 32. These results are based on application of cross-classification trip production models to estimated households by socio-economic stratification and TAZ. The total estimated trips compare well to observe for most trip purposes. It should be noted that Home-Based College trip production rates were scaled up to more closely match total college enrollment. This is necessary because household travel surveys are typically biased against the inclusion of persons in group quarters and shared non-family housing. Also Non-Home-Based trip totals were scaled up slightly to better match traffic counts.

TABLE 32: ESTIMATED VERSUS OBSERVED TOTAL TRIPS BY PURPOSE

	Est	Obs	Obs/Est Ratio
HBW	205,246	195,481.00	0.95
HBC	95,804	97,755.00	1.02
HBU	15,573	14,070.00	0.90
HBS	128,529	116,416.00	0.91
HBO	437,901	394,934.00	0.90
NHW	159,482	155,252.00	0.97
NHO	325,379	302,176.00	0.93
Total	1,367,913	1,276,085.00	0.93

3.6 TRIP DISTRIBUTION

Trip distribution models are used to predict the destination choice of the trip makers. Trip distribution models are based on the assumption that the trips between zone *i* and zone *j* are a function of the number of trips originating in zone *i* and the relative attractiveness of zone *j* with respect to all other zones. The output of a trip distribution model is an origin-destination flow matrix. Two popular methods for developing trip distribution models are gravity models and destination choice models. Both models can be shown to be mathematically equivalent under certain constraints; however, gravity models are typically calibrated using an aggregate application framework whereas destination choice models can be statistically estimated using disaggregate data.

Destination choice models are estimated using a multinomial logit specification using the household travel survey data for estimation of utility coefficients. Details of MNL specification were discussed in the household sub-model section. In MNL destination choice models, the choice alternatives are the destination zones. Independent variables in the utility equation may include attributes of the zone, decision maker characteristics and the attributes of the origin or destination zone. A general form of the utility equation (deterministic part) for the destination choice model is as follows:

$$U_{ijp} = S_j + \alpha L_{ij} + \sum_k \beta^k D_{ij}^k + \sum_k \beta^k D_{ij}^k N_n^k + \sum_k \beta^k Z_j^k$$

Where:

S_j : *Size term*

αL_{ij}: *Mode Choice Logsum* (natural log of the denominator of the mode choice model)

$\sum_k \beta^k D_{ij}^k$: *Distance delay terms*

$\sum_k \beta^k D_{ij}^k N_n^k$: *Distance terms interacted with decision maker attributes*

$\sum_k \beta^k Z_j^k$: *Zonal attributes*

A separate model was estimated for each of the seven purposes defined in the trip generation section. Logsums, or composite utilities, from the mode choice model serve as accessibility measures. Mode choice logsums are segmented by trip purpose, income group and auto sufficiency (autos compared to adults) for home-based trip purposes. The mode choice logsum coefficient was constrained between zero and one to mimic a nested logit model structure where mode is nested under destination. Distance-based terms supplement the mode choice logsums as accessibility measures and help to match the observed trip length frequency distribution.

Non-home based trips require special treatment, as their mode has already been determined prior to trip distribution, and therefore no mode choice model is applied to NHB trips (and no NHB trip logsums are generated). Instead, the measure of accessibility for NHB trip destination choice is a mode choice utility for the mode of the NHB trip.

Finally, total households and employment data by different categories were used as attraction variables to capture the “size” of each destination zone for HB trip purposes.

For NHB destination choice models, total number of NHB trip ends generated by HB trips were used as a proxy for size term. Specifically, for each NHB trip purpose, expanded trip ends were aggregated by TAZ and chosen mode to obtain size term. In addition to size term, mode and time-of-day-specific NHB utilities from mode choice models were used as accessibility term.

3.6.1 DESTINATION CHOICE ESTIMATION RESULTS

Table 33 to Table 36 present HB model estimation results. The main inferences of the estimated coefficients are the following:

- Mode choice logsum coefficients for HBW and HBS destination choice models are significantly greater than zero and less than one, suggesting that the nesting structure adopted here (mode choice nested under destination choice) is appropriate for these models. For HBC, HBU, and HBO trip purposes, the estimated coefficients were just over one, therefore they were constrained to one.
- Coefficients associated with travel distance-related impedance are negative for all HB models, indicating that individuals are likely to choose destinations closer to origin/production zone than farther away, all things being equal. That is, utility decreases as distance between origin/production and destination/attraction increases, as shown in Figure 15.
- For HBW, individuals living in Matanuska-Susitna Borough (Mat-Su) are more likely to work in Anchorage, while individuals living in Anchorage are less likely to work in Mat-Su.

- Size terms used for HBW, HBC, HBU, and HBS are total employment, total school enrollment, total college/university enrollment, and total retail employment, respectively. For identification purpose, coefficients for these size terms were set to 0 (i.e., $e^0 = 1$).
- For HBO, the base size term is accommodation, food services, and entertainment (i.e., exponentiated coefficient value for this size term is 1), and all other size coefficients were estimated with respect to this base size term. For example, the model specification indicates that the average effect of retail employment on utility is about 45 percent of that of total employment in accommodation, food services, and entertainment. Other size terms that were found to be significant include total households, government, health care and social assistance, fire, professional services and other.

Table 38 and Table 39 summarize NHBW and NHBO model estimation results, respectively. The results indicate that probability of a destination being chosen increases as a destination becomes more accessible (indicated by positive coefficients on utility variable in the tables).

TABLE 33 HBW DESTINATION CHOICE MODEL

Variable	Coefficient	t-statistic
Impedance term(s)		
Mode choice logsum coefficient	0.295	70.50*
Distance	-0.035	-22.60
Logarithm(1 + Distance)	-0.656	-65.60
District/location-specific constant(s)		
Production TAZ is in Mat-Su while attraction TAZ is in Anchorage	0.536	17.87
Production TAZ is in Anchorage while attraction TAZ is in Mat-Su	-0.0722	-2.41
Size term(s)**		
Total employment	1.000	-
Observations	4,187	
Final log likelihood	-1,115,850.8	
Rho-square at zero	0.153	
*** t-statistic with respect to 1.**		
**** Exponentiated value is reported**		

TABLE 34 HBC DESTINATION CHOICE MODEL

Variable	Coefficient	t-statistic
Impedance term(s)		
Mode choice logsum coefficient	1.000	-
Distance	-0.068	-29.20
Logarithm(1 + Distance)	-1.880	-188.00
Size term(s)**		
Total enrollment	1.000	-
Observations	1,516	
Final log likelihood	-263,448.4	
Rho-square at zero	0.550	
**** Exponentiated value is reported**		

TABLE 35 HBU DESTINATION CHOICE MODEL

Variable	Coefficient	t-statistic
Impedance term(s)		
Mode choice logsum coefficient	1.000	-
Logarithm(1 + Distance)	-0.415	-20.75
Size term(s)**		
Total college/university enrollment	1.000	-
Observations	211	
Final log likelihood	-17,377.5	
Rho-square at zero	0.772	
**** Exponentiated value is reported**		

TABLE 36: HBS DESTINATION CHOICE MODEL

Variable	Coefficient	t-statistic
Impedance term(s)		
Mode choice logsum coefficient	0.135	28.83*
Distance	-0.045	-26.00
Logarithm(Distance) where Distance ≥2 miles	-1.540	-154.00
Size term(s)**		
Retail employment	1.000	-
Observations	2,314	
Final log likelihood	-355,215.3	
Rho-square at zero	0.498	
*** t-statistic with respect to 1.**		
**** Exponentiated value is reported**		

TABLE 37 HBO DESTINATION CHOICE MODEL

Variable	Coefficient	t-statistic
Impedance term(s)		
Mode choice logsum coefficient	1.000	-
Logarithm(1 + Distance)	-2.110	-801.80
Size term(s)**		
Accommodation, food services, and entertainment	1.000	-
Retail trade	0.449	-65.50
Health care and social assistance	0.278	-114.70
Fire, professional services and other	0.212	-138.00
Government	0.800	-27.90
Total households	0.310	-160.70
Observations	7,929	
Final log likelihood	-1,995,062.9	
Rho-square at zero	0.192	

**** Exponentiated values are reported**

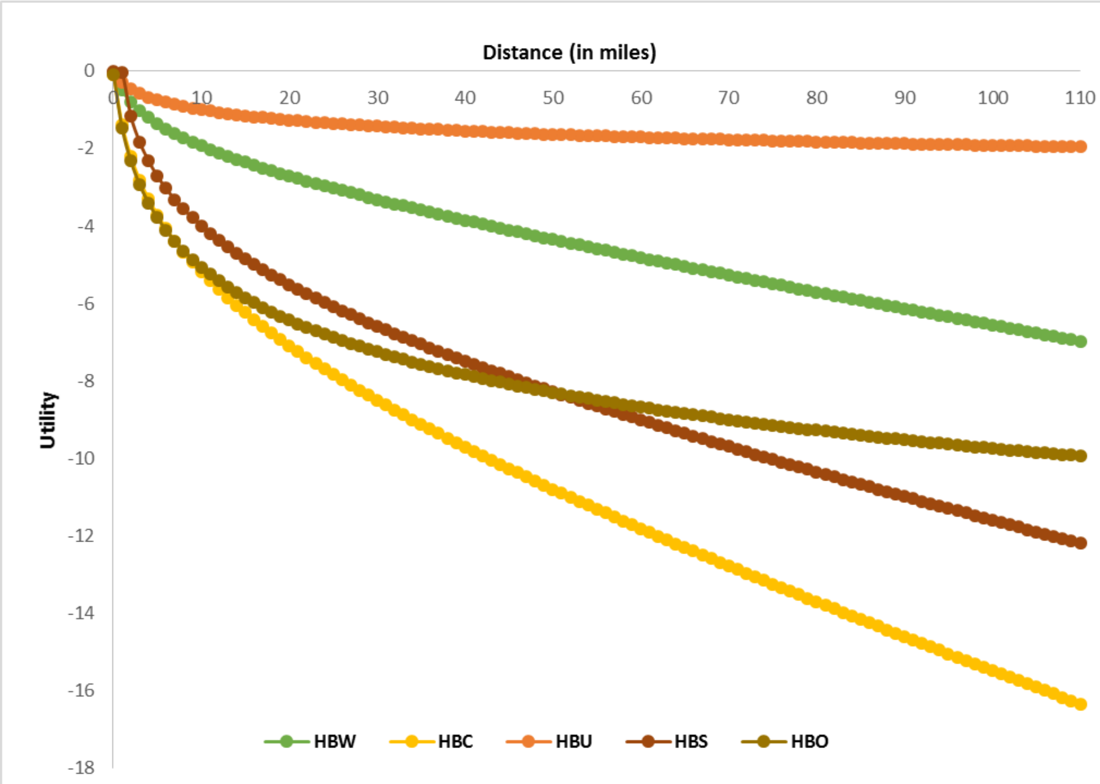


FIGURE 15 UTILITY VERSUS DISTANCE PLOTS

TABLE 38 NHBW DESTINATION CHOICE MODEL

Variable	Coefficient	t-statistic
Utility	2.770	277.00
Weighted sum of NHB trip ends (purpose and mode-specific)	1.000	-
Observations	3,344	
Final log likelihood	-770,827.4	
Rho-square at zero	0.244	

TABLE 39 NHBW DESTINATION CHOICE MODEL

Variable	Coefficient	t-statistic
Utility	0.552	55.20
Logarithm(1 + Distance)	-1.47	-300.50
Weighted sum of NHB trip ends (purpose and mode-specific)	1.000	-
Observations	6,346	
Final log likelihood	-1,284,236.0	
Rho-square at zero	0.337	

3.6.2 DESTINATION CHOICE CALIBRATION RESULTS

We use the term ‘model calibration’ to refer to the adjustment of model parameters when running the model in aggregate in order to better match observed data. In the case of trip distribution, this means evaluating estimated versus observed trip length frequency distributions, average trip lengths and district flows to ensure that the model is reasonably replicating base year data. In some cases we adjust the distance coefficient term in the relevant trip purpose, and/or introduce district-interchange specific constants in the utility equation to improve model fit. Typically we calibrate the trip distribution models until we are within either 5 percent or within ½ mile of average trip length, for each trip purpose. In some cases we add district-level interchange constants to better match flows between Mat-Su, Palmer, Knik Arm, Eagle River and Anchorage districts. This is a trial-and-error process that involves a good deal of judgement. The basic philosophy guiding the introduction of or adjustment of model parameters is to do as little as possible to the estimated models in order to match observed data. This is based on the fact that introduction of large constants in the model can reduce the sensitivity of the model to its inputs. Our observed data is based on summaries of the household travel survey and the Bluetooth Origin Destination survey that is described above.

The final estimated versus observed average trip length by purpose is shown in Table 40. Final estimated versus observed trip length frequency distributions (by miles) are shown in

Figure 16 through.

Figure 22. Overall the plots demonstrate a very close match to observed trip length frequency. Some of the distance terms were adjusted in application to better match observed average trip lengths. Final calibrated parameters are shown in

Table 41.

TABLE 40: ESTIMATED VERSUS OBSERVED AVERAGE TRIP LENGTH BY PURPOSE

	Average Length (mi)			
	Est	Obs	Diff	Perc Diff
HBW	9.22	9.50	(0.28)	-3%
HBC	4.03	4.01	0.02	1%
HBU	9.40	8.90	0.50	6%
HBS	4.53	4.63	(0.11)	-2%
HBO	5.58	5.63	(0.05)	-1%
NHW	5.39	5.17	0.21	4%
NHO	4.31	4.58	(0.27)	-6%

FIGURE 16: ESTIMATED VERSUS OBSERVED HOME-BASED WORK TRIP LENGTH FREQUENCY DISTRIBUTION

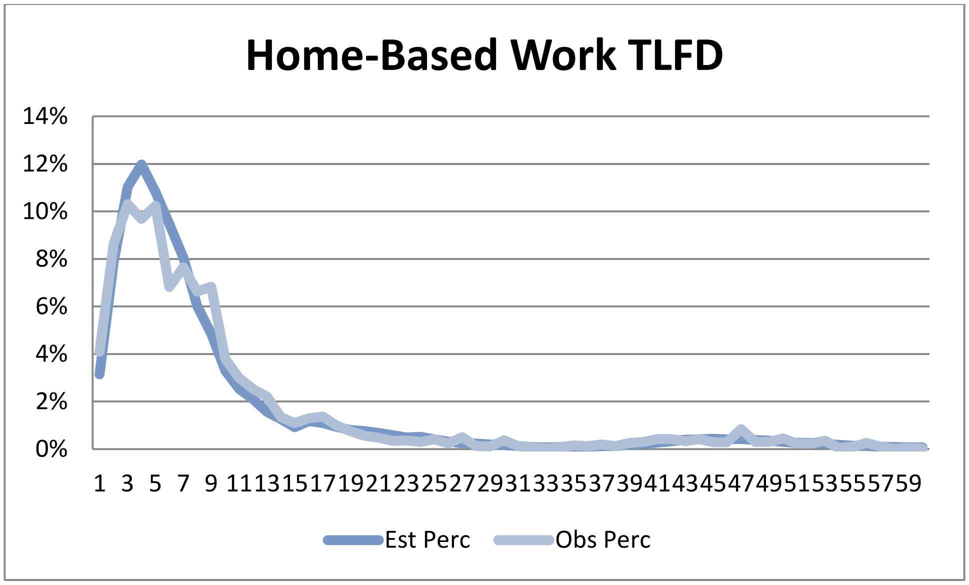


FIGURE 17: ESTIMATED VERSUS OBSERVED HOME-BASED SCHOOL TRIP LENGTH FREQUENCY DISTRIBUTION

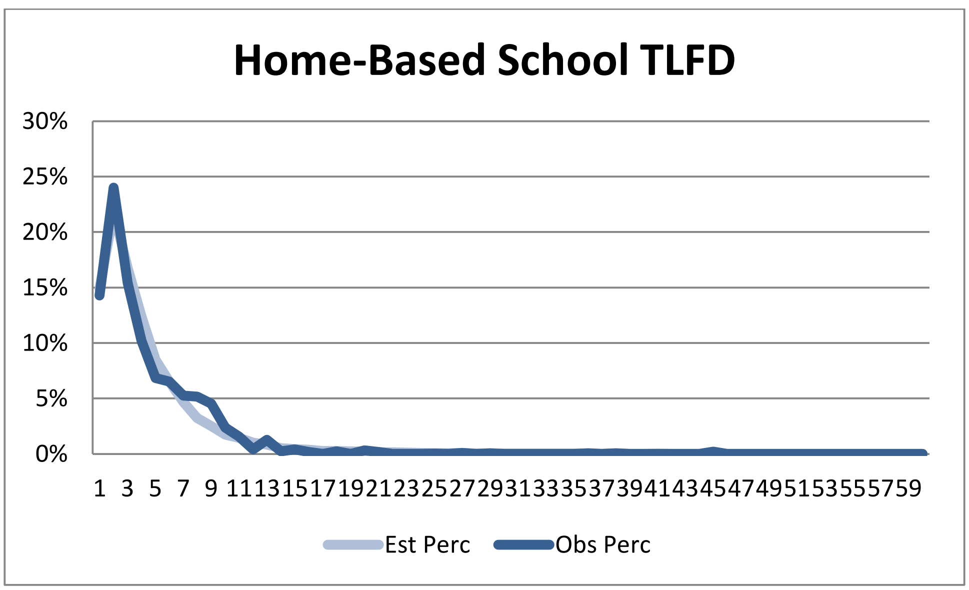


FIGURE 18: ESTIMATED VERSUS OBSERVED HOME-BASED UNIVERSITY TRIP LENGTH FREQUENCY DISTRIBUTION

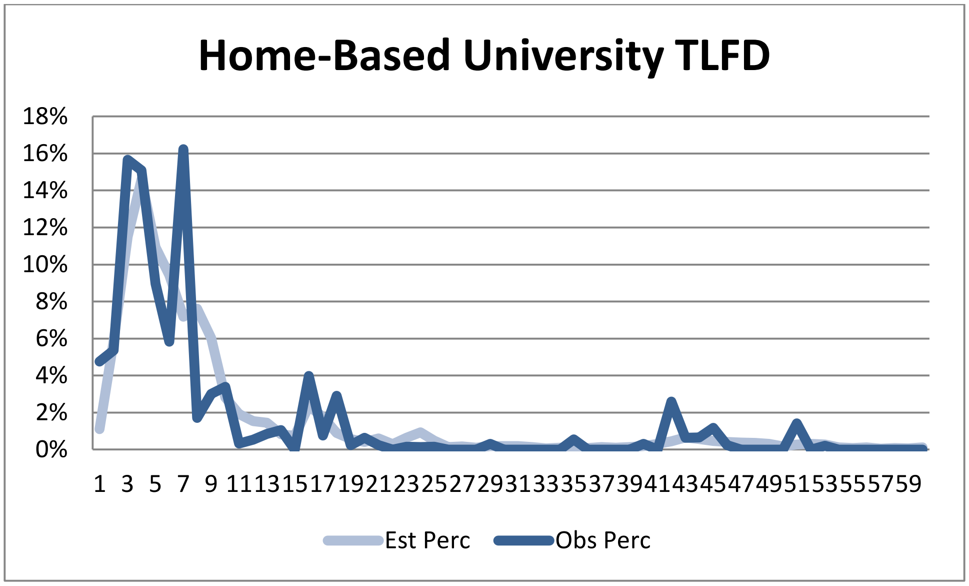


FIGURE 19: ESTIMATED VERSUS OBSERVED HOME-BASED SHOP TRIP LENGTH FREQUENCY DISTRIBUTION

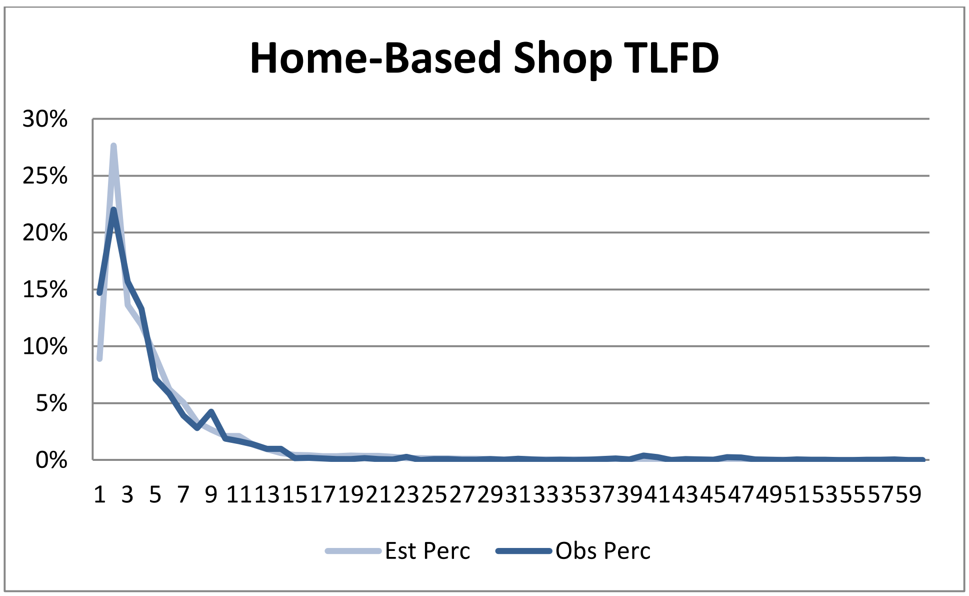


FIGURE 20: ESTIMATED VERSUS OBSERVED HOME-BASED OTHER TRIP LENGTH FREQUENCY DISTRIBUTION

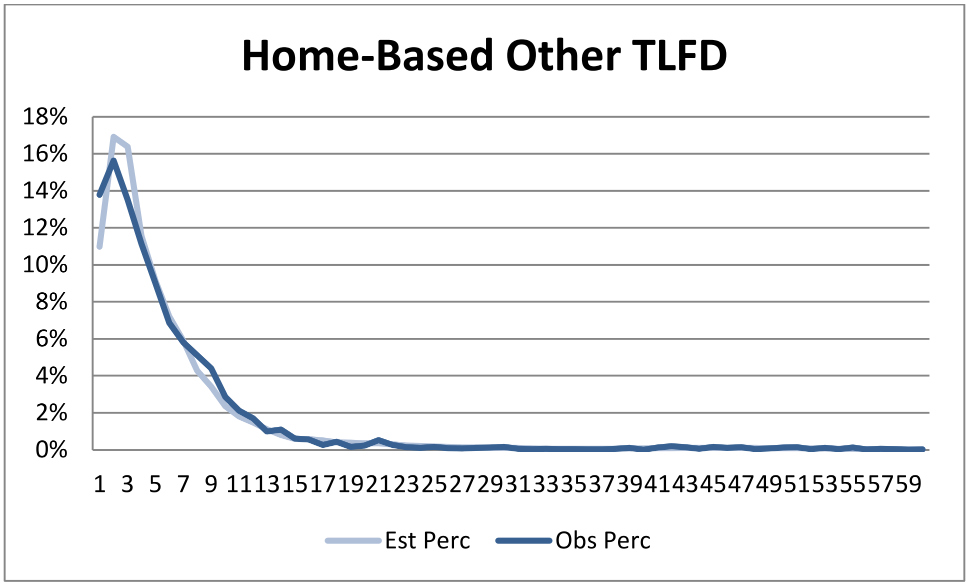


FIGURE 21: ESTIMATED VERSUS OBSERVED NON-HOME-BASED WORK TRIP LENGTH FREQUENCY DISTRIBUTION

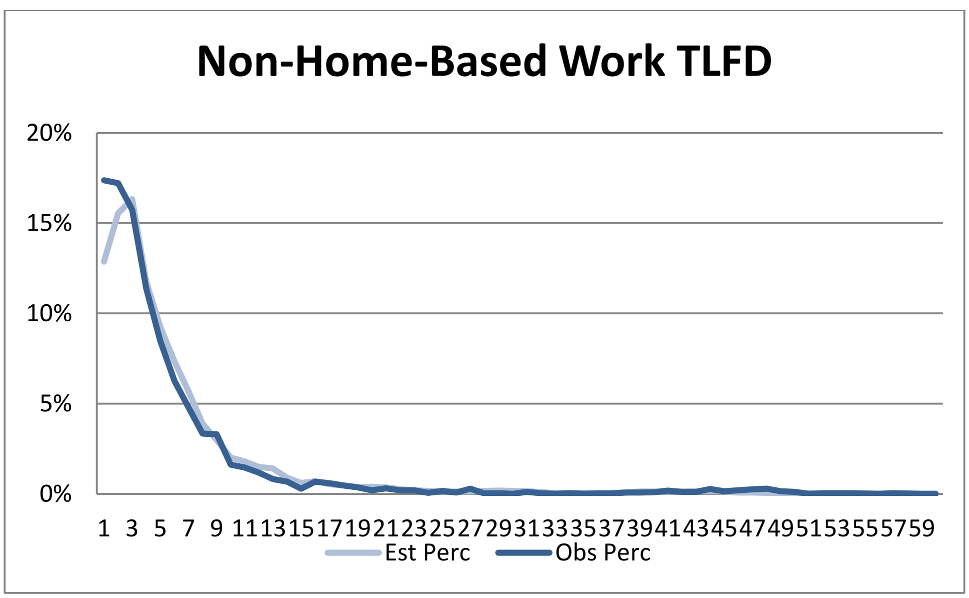
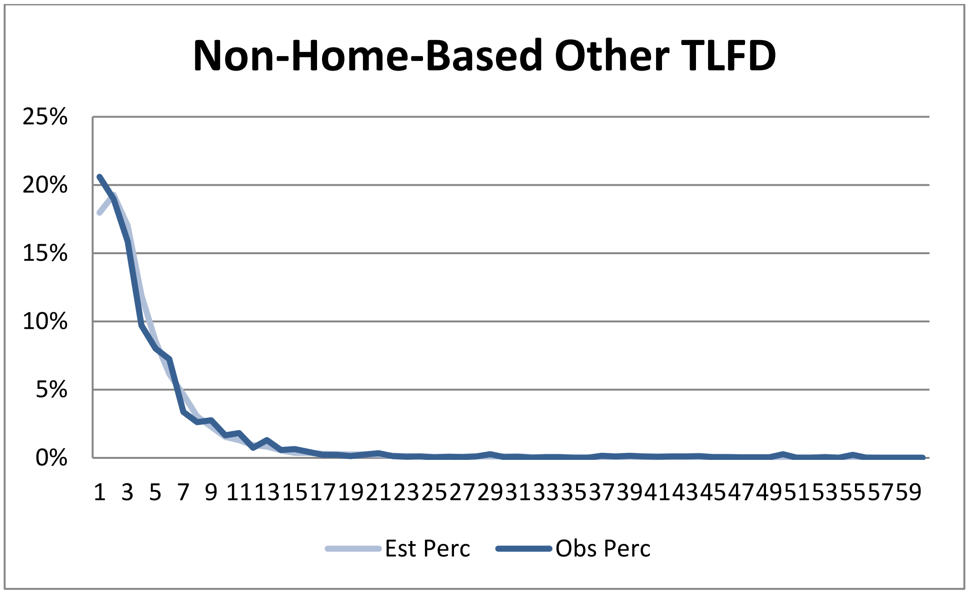


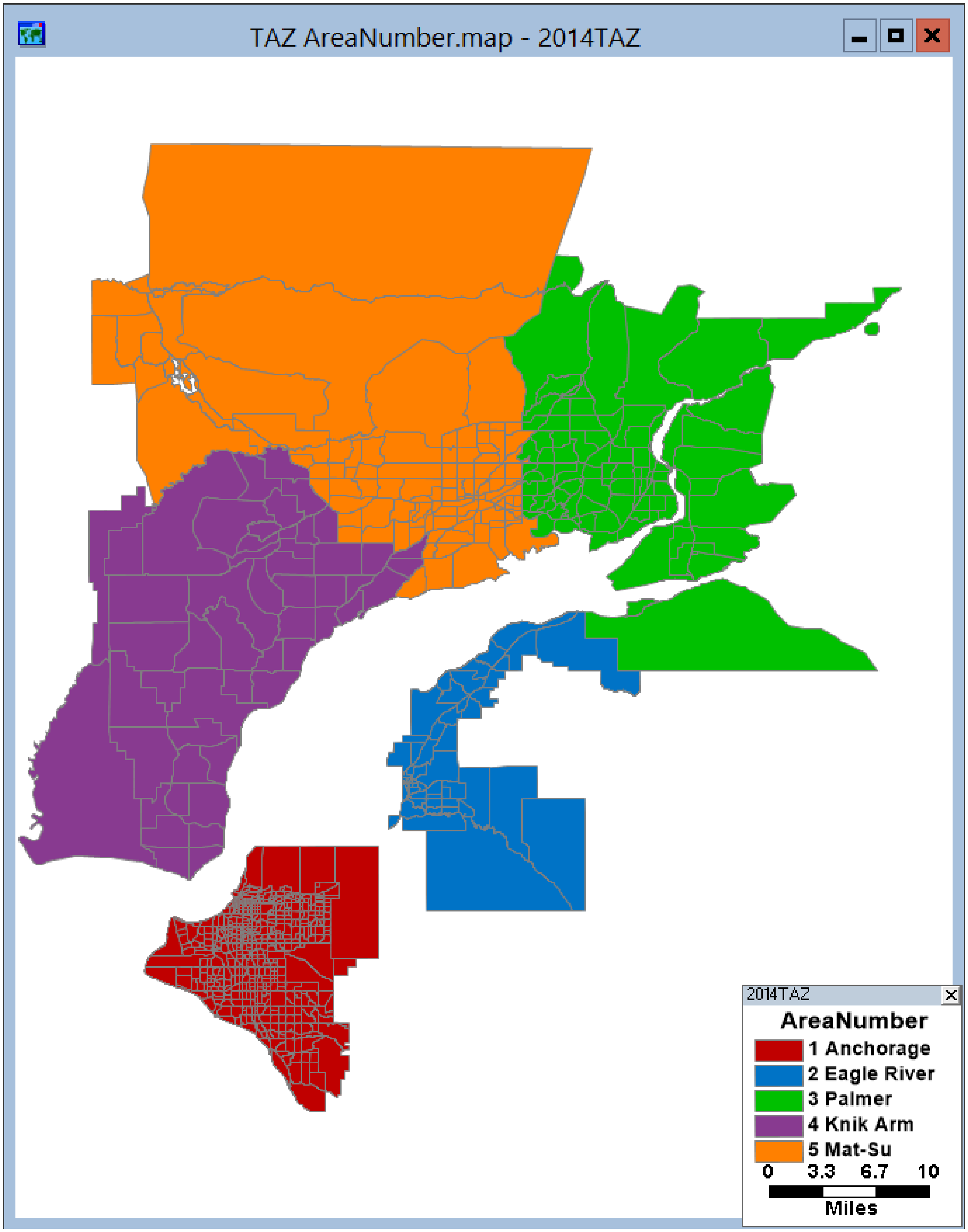
FIGURE 22: ESTIMATED VERSUS OBSERVED NON-HOME-BASED OTHER TRIP LENGTH FREQUENCY DISTRIBUTION



As part of the model calibration process, the output trip tables were also compared to district level flows from Census, Bluetooth data and the expanded household travel survey. We perform this analysis along the five key areas shown in Figure 23 where possible.

Census journey-to-work flow data is available from the five-year American Community Survey 2009-2013. According to this dataset there were 11,280 workers who lived in the Mat-Su Borough and worked in the Municipality of Anchorage (MOA), and 1077 workers who lived in MOA and work in Mat-Su Borough. According to the household travel survey, there are approximately 12,500 Home-Based Work trips produced in Mat-Su and attracted to MOA from 11,700 workers, and approximately 2,000 HBW trips produced in MOA and attracted to Mat-Su. So the number of expanded workers and HBW trips from Mat-Su to MOA in the household survey appears to be in reasonable agreement with the number of workers making that commute in Census. The number of work trips from MOA to Mat-Su in the survey appears to be a bit high compared to Census. Initial estimates of work trips from Mat-Su to MOA were a bit higher than the household survey (15k estimated versus 12.5k observed) so we introduce a small negative constant adjustment to the estimated Mat-Su to MOA interaction term in the HBW trip purpose to reduce the number of work trips produced in Mat-Su and attracted to MOA to match the number in the household survey (12k). The new term reduces from 0.53 to 0.4. The model estimates approximately 700 workers residing in MOA and working in Mat-Su, so no adjustments were made to this value.

FIGURE 23: TAZS BY AREA NUMBER



Another useful check on trip distribution is traffic counts at key locations (screenlines). The geography of the model region provides a useful screenline on the Glenn Highway at the Knik River bridge, since this count measures traffic between MOA\Eagle River (areas 1 and 2 in Figure 23) and Mat-Su\Palmer\Knik Arm (areas 3, 4, and 5). Initial assignment results indicated too much interaction between these regions. However, the modeled trip tables demonstrated close match to the expanded household survey for these districts. Based on the over-assignment, the non-work trips from the household survey were scaled down to match the traffic counts and these scaled trips were used as a point of comparison for the trip distribution outputs. The result of this comparison was the introduction of a set of factors to better match the observed flows from Mat-Su to MOA for the HBO and NHBO trip purposes. Finally, flows between Eagle River and Anchorage were calibrated to better match household survey data; initial results demonstrated an over-estimate of trips between these two areas.

Final destination choice parameters (excluding size term parameters which have not been modified from the originally-estimated values) are shown in

Table 41. Note that the interaction terms between Mat-Su and Anchorage are mostly negative, reflecting additional perceived disutility of travel between these parts of the region beyond travel time and cost. Sensitivity of the model to these parameters should be analyzed in the context of any investment-grade forecast of a new bridge between MOA and the Mat-Su Borough, as the availability of a more convenient crossing could influence the perception of travel and reduce the disutility, leading to more interaction than the model would currently forecast.

TABLE 41: FINAL CALIBRATED DESTINATION CHOICE PARAMETERS

Variable	HBW	HBC	HBU	HBS	HBO	NHW	NHO
Logsum (mode utility)	0.295	1	1	0.135	1	2.77	0.552
Distance	-0.065	-0.068	0	-0.099	0	0.18	0
Distance^3	0	0	0	0	0		
Log(Distance + 1)	-0.656	-1.88	-0.7	0	-1.65	-1.2	-1.4
Log(Distance + 1) if > 2	0	0	0	-1.45	0	0	
Mat-Su->Anchorage	0.4	0	0	0	-2	0	-1.35
Anchorage->Mat-Su	-0.0722	0	0	0	-2.6	0	-0.74
EagleRiver -> Anchorage	0	0	0	0	-1.2	-1	-0.7

3.7 MODE CHOICE

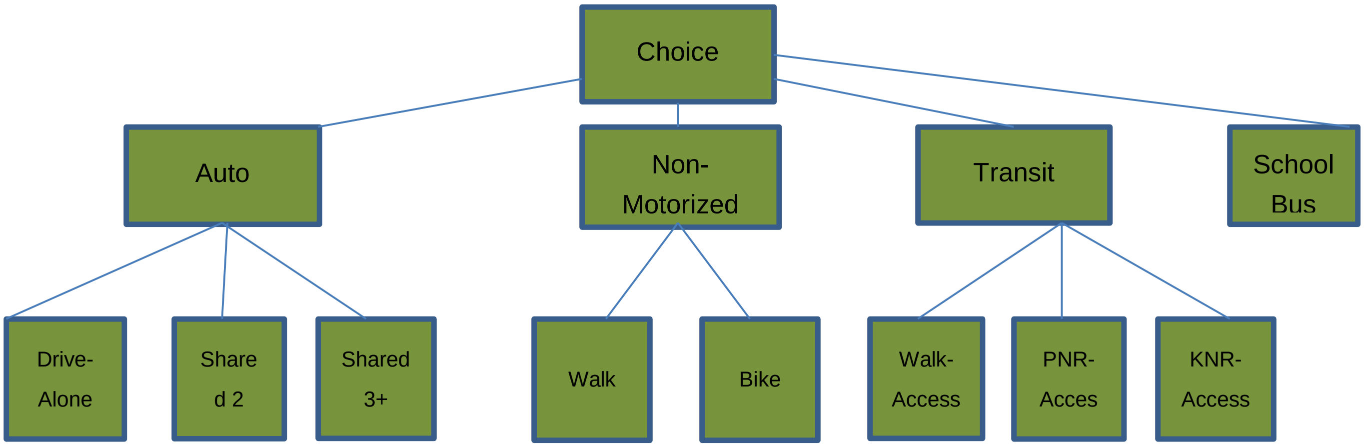
Mode choice models are used to predict the mode for each trip, based upon trip purpose, traveler characteristics, travel times and costs by mode, land-use and other variables. Based upon an investigation of the household travel survey data trips by mode, and anticipated modeling needs for the AMATS region, the mode choice model considers the following modes:

- Drive-alone
- Shared-2
- Shared 3+
- Walk
- Bike
- Walk-Transit
- PNR-Transit
- KNR-Transit
- School bus (Home-Based School only)

A nested logit model formulation is used, which reflects unequal competition among modes. That is, similar alternatives are grouped together to reflect higher cross-elasticities between them. The nested logit model utilizes an extension of the multinomial logit model described above in order to accomplish this. The nested logit model groups similar alternatives together under the assumption that the error terms for those alternatives are more similar than non-nested alternatives. That is, alternatives in the same nest have more unidentified characteristics than alternatives not in the same nest. This is done by segmenting the error terms into components; one component for the attributes in common, and one component for the attributes that are not in common. The ratio (lambda_2/lambda_1) of the dispersion parameter for the attributes in common for the nest (lambda_1) to the dispersion parameter for the total error term for the alternatives (lambda_2) is the nesting coefficient or logsum parameter.

A survey of nested models used throughout the United States indicates that most models group auto modes together, non-motorized modes, and transit modes. The nested structure used for AMATS is shown in Figure 11.

FIGURE 24: NESTED MODE CHOICE MODEL STRUCTURE



In order to apply the model, the utility of each alternative *m* is calculated at the lowest level of the nesting structure by scaling the multinomial utility by the nesting coefficient β_{nest}:

$NestedUtility_m = MNLUtility_m / \beta_{nest}$

Dividing by the nesting coefficient effectively scales the utilities, increasing the impact of differences in utility across nested alternatives. Note that the nesting coefficient must be constrained to be greater than zero and less than one, where one is equivalent to a multinomial choice and becomes equivalent to an all-or-nothing choice as the nesting coefficient approaches zero.

The utility of each nest is calculated by taking the natural log of the sum of the exponentiated lower-level utilities and multiplying by the nesting coefficient. For example, the utility of auto is:

$Utility_{auto} = \beta_{nest} * (e^{NestedUtility}{}_{Drive\text{-}Alone} + {}^{NestedUtility}{}_{Shared\ 2} + {}^{NestedUtility}{}_{Shared\ 3+})$

The probability of each alternative is calculated by moving down the nesting structure:

$Probability_{auto} = e^{Utility}{}_{Auto} / (e^{Utility}{}_{Auto} + e^{Utility}{}_{Non\text{-}motorized} + e^{Utility}{}_{Transit})$

and:

$Probability_{Drive\text{-}Alone} = e^{NestedUtility}{}_{Drive\text{-}Alone} / (e^{NestedUtility}{}_{Drive\text{-}Alone} + {}^{NestedUtility}{}_{Shared\ 2} + {}^{NestedUtility}{}_{Shared\ 3+})$

Mode choice models are segmented based upon the markets shown in Table 42, in addition to trip purpose and peak\off-peak segmentation. This requires that destination choice models also include the same segmentation, since they utilize logsums by trip purpose as a measure of accessibility and because the mode choice models require trip tables by purpose and market segment as an input. The income segmentation identified above is useful in order to represent the correlation of value-of-time with household income. Auto sufficiency, which is the relationship of number of autos to number of licensed drivers (adults is used as a proxy for licensed drivers) is helpful to represent "transit captive" households versus "choice" riders, and is also useful to model the need for ride-sharing within the household.

TABLE 42: MODE AND DESTINATION MARKET SEGMENTS

Number	Auto Sufficiency	Income
1	0 autos	<$25k income
2	0 autos	$25k - $50k income
3	0 autos	$50k-$100k income
4	0 autos	$100k+ income
5	0<autos<adults	<$25k income
6	0<autos<adults	$25k - $50k income
7	0<autos<adults	$50k-$100k income
8	0<autos<adults	$100k+ income
9	Autos>=adults	<$25k income
10	Autos>=adults	$25k - $50k income
11	Autos>=adults	$50k-$100k income
12	Autos>=adults	$100k+ income

Mode choice coefficients will be asserted based upon best practices and guidance from Federal Transit Administration, due the lack of variability in cost data for the Anchorage region and relatively few “choice” transit riders compared to other metropolitan areas. However, alternative-specific constants are calibrated by auto sufficiency to match observed trips by purpose from the household survey and transit on-board survey. Furthermore, special non-motorized model coefficients are borrowed from the San Diego Association of Governments trip-based models. These coefficients take into account land-use density, mixed use and intersection density variables in the propensity to choose non-motorized travel modes including walking and biking. They serve as a proxy for more sophisticated variables such as bicycle network connectivity. The mode choice model coefficients are given in Table 43. Note the following:

- A nesting coefficient, which is set equal across all three-mode groupings, and is set to 0.5.
- In-vehicle time coefficient applies to time spent in an auto for the auto modes or in the transit vehicle for transit modes, inclusive of dwell time.
- Two coefficients are specified for wait time; short initial wait time, equal to twice the in-vehicle time coefficient, which applies to the first 10 minutes of waiting time, and long initial wait time, equal to the in-vehicle time coefficient, which applies to any time over 10 minutes. The step-wise wait time parameters are applied to reflect the convenience of frequent transit service with increased sensitivity to short headways.
- Transfer wait time refers to any wait time associated with transfers. It is asserted at twice the in-vehicle time coefficient.

- Two coefficients are specified for number of transfers; one for walk-access and one for drive-access. The coefficients are segmented by mode of access to reflect the increased likelihood of a driver to find a boarding location that does not require a transfer.
- Walk access time refers to all time spent walking to/from transit including walking time required for transfers (e.g. walking between stops). It is asserted to be twice the in-vehicle time coefficient.
- Drive access time refers to all time spent driving to transit at the production end of the trip. It is asserted to be twice the in-vehicle time coefficient.
- Walk mode time refers to the time spent walking specifically for the walk mode, at an assumed speed of three miles per-hour. It is asserted to be equal to three times the in-vehicle time coefficient, based on a review of other model systems. The maximum trip walk distance is set to three miles, or one hour.
- Bike mode time refers to the time spent biking specifically for the bicycle mode, at an assumed speed of 10 miles per-hour. It is asserted to be equal to four times the in-vehicle time coefficient, based on a review of other model systems. The maximum trip bicycle distance is set to 10 miles, or one hour.
- Cost coefficients are segmented by income to better reflect the distribution of cost sensitivity, and were asserted based upon the average hourly wage rate within each income group. Half of the average hourly wage rate was assumed for Home-Based Work and Home-Based University purposes, while one-third of the average hourly wage rate was assumed for other purposes. The cost coefficient was calculated as follows:
    - The average hourly wage rate was calculated for each income bin using the average income within each bin, divided by 2080 (working hours per year) and further divided by the average number of workers in each household in each bin (average wage rate = average income/2080/average workers). For NHB trips, the average wage rate across all bins was used.
    - The value-of-time for the bin was set equal to the average wage rate multiplied by 0.5 for HBW\HBC and 0.333 for all other purposes (VOT = Average wage rate * Purpose factor).
    - The cost coefficient was calculated by dividing the in-vehicle time coefficient by the value-of-time for the bin and multiplying the result by 60 minutes per-hour /100 cents per-dollar (cost coefficient = IVT/VOT * 0.6).

  All costs are in cents for Year 2013. Cost coefficients are further scaled by occupancy for shared-ride modes, reflecting the tendency of household members to rideshare. Scaling is not exactly proportional to occupancy, however. The scaling coefficients are 1.8 for shared-ride 2 and 2.8 for shared-ride 3+ modes.

  Cost variables include the following components for relevant modes:

    - Auto operating cost at an assumed 19 cents per-mile, which includes an average fuel cost of 15 cents per-mile and average costs of maintenance and tires of five cents per-mile, as per the AAA publication “Your Driving Costs 2013”. Note that costs of ownership are not included as auto ownership is a separate model.
    - Parking cost, calculated as the average hourly parking cost for the attraction zone, multiplied by the average duration of each activity by purpose in hours, multiplied by one-half to reflect two trips on average per activity.

- Toll cost per trip, in cents.
- Transit fare, calculated as a weighted average of cash fare and monthly pass fare converted to a per-trip fare assuming 44 transit trips per month (22 work days per-month * two trips per-day) on average, from the transit on-board survey.

- Transit CBD coefficients, reflecting the tendency of CBD to attract transit trips, by access mode. These parameters can be calibrated to match summaries of transit trips by access mode and purpose attracted to the CBD.
- A coefficient applied to non-motorized modes if the production or attraction zone has a high intersection count, reflecting a highly connected network conducive to walking and bicycling. The count is based on a floating calculation of total intersections based on a ½ mile buffer around each TAZ centroid. A zone is rated as a high intersection count zone if the number of intersections is 130 or more. This coefficient was borrowed from the SANDAG trip-based model, which was estimated based upon extensive analysis of household survey data. The coefficient on high intersection density was capped at 45 minutes of equivalent in-vehicle time, similar to the way it was applied in San Diego.

TABLE 43: MODE CHOICE COEFFICIENTS

Coefficient	Purpose					
	HBW	HBU	HBC	HBS	HBO	NHB**
Nesting coefficient	0.5	0.5	0.5	0.5	0.5	N.A.
In-Vehicle Time (min)	-0.025	-0.025	-0.015	-0.02	-0.02	-0.02
Short Initial Wait Time, <10 minutes (min)	-0.05	-0.05	-0.03	-0.04	-0.04	-0.04
Long Initial Wait Time, >=10 minutes (min)	-0.025	-0.025	-0.015	-0.02	-0.02	-0.02
Transfer Wait Time (min)	-0.05	-0.05	-0.03	-0.04	-0.04	-0.04
Number of Transfers, Walk Access*	0	0	0	0	0	0
Number of Transfers, Drive Access*	-0.5	-0.5	-0.3	-0.4	-0.4	-0.4
Walk Access Time (min)	-0.05	-0.05	-0.03	-0.04	-0.04	-0.04
Drive Access Time (min)	-0.05	-0.05	-0.03	-0.04	-0.04	-0.04
Walk Mode Time 3 mph (60/3 * miles)	-0.075	-0.075	-0.045	-0.06	-0.06	-0.06
Bike Mode Time 10 mph (60/10 * miles)	-0.1	-0.1	-0.06	-0.08	-0.08	-0.08
Max walk distance	3 mi	3 mi	3 mi	3 mi	3 mi	3 mi

(intrazonal always allowed)						
Max bike distance (intrazonal always allowed)	10 mi	10 mi	10 mi	10 mi	10 mi	10 mi
School Bus Time **20 mph (60/20 * distance)**	NA	NA	-0.015	NA	NA	NA
Cost, <$25k (cents)	-0.00482	-0.00482	-0.00435	-0.0058	-0.0058	-0.00091
Cost, $25k-$50k (cents)	-0.0019	-0.0019	-0.00171	-0.00229	-0.00229	-0.00091
Cost, $50k-$100k (cents)	-0.00098	-0.00098	-0.00088	-0.00117	-0.00117	-0.00091
Cost, $100k+ (cents)	-0.00042	-0.00042	-0.00038	-0.00051	-0.00051	-0.00091
CBD Transit Walk-Access Coefficient*	0	0	0	0	0	0
CBD Transit Drive-Access Coefficient*	0	0	0	0	0	0
High Density Intersection - Non-motorized	0.675	0.675	0.675	0.675	0.675	0.675

* Indicates a parameter that will be calibrated to match survey data. Starting value for parameter is shown in table.
** Coefficients are specified for the NHB purpose as mode choice logsums must be calculated for NHB trips for trip distribution.

The application of mode choice requires two “run modes”. In the first “logsum generation” mode, mode choice logsums are calculated for each purpose and market segment and saved in matrices. These matrices are used in trip distribution and therefore must be calculated prior to running the trip distribution step. An additional set of mode-specific utilities are calculated for distributing NHB trips. It is not necessary to create mode-specific utilities for drive-transit modes or school bus modes, however, since there are no NHB trips for these modes.

In the second “trip calculation” run mode, trip tables are also read into mode choice and the program writes out trips by mode. In order to save time, this run mode reads in matrices of exponentiated utilities and calculates probabilities by purpose, market segment and mode in the logsum generation mode, so that utilities do not need to be re-calculated.

3.7.1 MODE CHOICE CALIBRATION

The mode choice models were calibrated against observed trip-by-trip purpose, auto sufficiency, and mode. The observed trips were tabulated from the household travel survey, with the exception of transit trips which were sourced from the transit on-board survey. Auto and non-motorized trips were scaled to match estimated trips by purpose and auto sufficiency in order to account for calibration factors introduced in various upstream model components, and compensate for any errors or biases in the survey data and expansion factor process.

TABLE 44: ESTIMATED VERSUS OBSERVED HOME-BASED WORK TRIPS BY AUTO SUFFICIENCY AND MODE

	Observed				Estimated				Diff-erence	Percent Difference
Mode	0 Autos	Autos<Adults	Autos>=Adults	Total	0 Autos	Autos<Adults	Autos>=Adults	Total	Total	Total
DA	-	22,070	150,836	172,907	-	22,008	151,036	173,044	137	0%
S2	360	6,748	7,297	14,405	375	6,759	7,246	14,380	(25)	0%
S3	80	3,680	4,860	8,620	81	3,650	4,770	8,501	(119)	-1%
WLK	1,490	1,396	2,754	5,640	1,446	1,372	2,745	5,563	(77)	-1%
BIK	424	3,260	4,755	8,439	453	3,355	4,716	8,524	85	1%
WLK-TRN	1,641	1,094	271	3,007	1,639	1,076	265	2,980	(27)	-1%
PNR-TRN	-	20	33	53	-	-	38	38	(15)	-29%
KNR-TRN	141	152	15	308	143	200	7	350	42	14%
SCHBUS	-	-	-	-	-	-	-	-	-	0%
Total	4,137	38,420	170,823	213,380	4,137	38,420	170,823	213,380	-	0%

TABLE 45: ESTIMATED VERSUS OBSERVED HOME-BASED UNIVERSITY TRIPS BY AUTO SUFFICIENCY AND MODE

	Observed				Estimated				Diff-erence	Percent Difference
Mode	0 Autos	Autos<Adults	Autos>=Adults	Total	0 Autos	Autos<Adults	Autos>=Adults	Total	Total	Total
DA	-	3,663	23,722	27,385	-	3,659	23,705	27,364	(21)	0%
S2	827	2,243	3,732	6,802	766	2,231	3,737	6,734	(68)	-1%
S3	413	1,755	1,623	3,791	369	1,741	1,623	3,733	(58)	-2%
WLK	413	74	1,393	1,881	378	78	1,401	1,857	(24)	-1%
BIK	83	496	592	1,170	87	495	591	1,173	3	0%
WLK-TRN	356	442	236	1,034	492	470	240	1,202	168	16%
PNR-TRN	-	-	-	-	-	-	-	-	-	0%
KNR-TRN	-	-	-	-	-	-	-	-	-	0%
SCHBUS	-	-	-	-	-	-	-	-	-	0%
Total	2,092	8,674	31,297	42,063	2,092	8,674	31,297	42,063	-	0%

TABLE 46: ESTIMATED VERSUS OBSERVED HOME-BASED SCHOOL TRIPS BY AUTO SUFFICIENCY AND MODE

	Observed				Estimated				Diff-erence	Percent Difference
Mode	0 Autos	Autos<Adults	Autos>=Adults	Total	0 Autos	Autos<Adults	Autos>=Adults	Total	Total	Total
DA	-	44	4,090	4,133	-	-	4,090	4,090	(43)	-1%
S2	73	1,540	21,081	22,694	71	1,549	21,086	22,706	12	0%
S3	36	3,707	33,188	36,931	39	3,720	33,202	36,961	30	0%
WLK	525	1,228	6,108	7,860	526	1,238	6,128	7,892	32	0%
BIK	36	153	1,025	1,215	36	153	1,019	1,208	(7)	-1%
WLK-TRN	41	123	85	249	41	124	84	249	0	0%
PNR-TRN	-	-	-	-	-	-	-	-	-	0%
KNR-TRN	-	-	-	-	-	-	-	-	-	0%
SCHBUS	1,746	4,087	18,761	24,594	1,744	4,097	18,729	24,570	(24)	0%
Total	2,457	10,881	84,338	7,676	2,457	10,881	84,338	97,676	-	0%

TABLE 47: ESTIMATED VERSUS OBSERVED HOME-BASED SHOP TRIPS BY AUTO SUFFICIENCY AND MODE

	Observed				Estimated				Diff-erence	Percent Difference
Mode	0 Autos	Autos< Adults	Autos>=Adults	Total	0 Autos	Autos< Adults	Autos>=Adults	Total	Total	Total
DA	-	6,420	52,276	58,696	-	6,417	52,263	58,680	(16)	0%
S2	651	6,742	24,817	32,210	648	6,739	24,815	32,202	(8)	0%
S3	839	4,182	21,195	26,216	837	4,185	21,207	26,229	13	0%
WLK	4,339	1,633	2,745	8,717	4,367	1,654	2,768	8,789	72	1%
BIK	840	637	1,127	2,604	812	617	1,107	2,536	(68)	-3%
WLK-TRN	1,186	468	133	1,787	1,192	470	132	1,794	7	0%
PNR-TRN	-	-	-	-	-	-	-	-	-	0%
KNR-TRN	-	-	-	-	-	-	-	-	-	0%
SCHBUS	-	-	-	-	-	-	-	-	-	0%
Total	7,856	20,082	102,292	130,230	7,856	20,082	102,292	130,230	-	0%

TABLE 48: ESTIMATED VERSUS OBSERVED HOME-BASED OTHER TRIPS BY AUTO SUFFICIENCY AND MODE

	Observed				Estimated				Diff-erence	Percent Difference
Mode	0 Autos	Autos< Adults	Autos>= Adults	Total	0 Autos	Autos< Adults	Autos>= Adults	Total	Total	Total
DA	-	17,345	135,764	153,109	-	17,329	135,744	153,073	(36)	0%
S2	2,147	23,298	101,640	127,086	2,169	23,376	101,795	127,340	254	0%
S3	2,428	18,371	87,958	108,757	2,458	18,456	88,200	109,114	357	0%
WLK	10,307	10,676	30,303	51,285	10,250	10,522	30,006	50,778	(507)	-1%
BIK	865	1,334	5,995	8,193	876	1,343	5,922	8,141	(52)	-1%
WLK-TRN	1,840	565	272	2,677	1,834	563	265	2,662	(15)	-1%
PNR-TRN	-	-	-	-	-	-	-	-	-	0%
KNR-TRN	-	-	-	-	-	-	-	-	-	0%
SCHBUS	-	-	-	-	-	-	-	-	-	0%
Total	17,587	71,589	361,932	451,108	17,587	71,589	361,932	451,108	-	0%

TABLE 49: ESTIMATED VERSUS OBSERVED NON-HOME-BASED WORK TRIPS BY MODE

Mode	Total Obs	Total Est	Difference	Percent Diff
DA	118,680	118,511	(169)	0%
S2	18,220	18,439	219	1%
S3	7,697	7,669	(28)	0%
WLK	14,340	14,100	(240)	-2%
BIK	2,265	2,488	223	10%
WLK-TRN	513	508	(5)	-1%
PNR-TRN	-	-	-	0%
KNR-TRN	-	-	-	0%
SCHBUS	-	-	-	0%
Total	161,715	161,715	-	0%

TABLE 50: ESTIMATED VERSUS OBSERVED NON-HOME-BASED OTHER TRIPS BY MODE

Mode	Total Obs	Total Est	Difference	Percent Diff
DA	109,560	109,507	(53)	0%
S2	95,829	96,341	512	1%
S3	88,881	88,894	13	0%
WLK	29,921	29,321	(600)	-2%
BIK	3,535	3,651	116	3%
WLK-TRN	1,425	1,437	12	1%
PNR-TRN	-	-	-	0%
KNR-TRN	-	-	-	0%
SCHBUS	-	-	-	0%
Total	329,151	329,151	-	0%

TABLE 51: ESTIMATED VERSUS OBSERVED TOTAL TRIPS BY MODE

Mode	Total Obs	Total Est	Difference	Percent Diff
DA	644,471	644,269	(202)	0%
S2	317,246	318,142	896	0%
S3	280,894	281,101	207	0%
WLK	119,645	118,300	(1,345)	-1%
BIK	27,422	27,721	299	1%
WLK-TRN	10,691	10,832	141	1%
PNR-TRN	53	38	(15)	-29%
KNR-TRN	308	350	42	14%
SCHBUS	24,594	24,570	(24)	0%
Total	1,425,323	1,425,323	(0)	

TABLE 52: CALIBRATED MODE CHOICE ALTERNATIVE-SPECIFIC CONSTANTS

Purpose	Auto Sufficiency	Drive-Alone	HOV-2	HOV-3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit	School Bus
HBW	0 Autos	-999	0	-0.89953	3.182355	0.113976	4.375205	-999	2.497084	-999
HBW	Autos< Adults	0	-0.69847	-1.06483	-1.59411	-2.20099	-1.09096	-6.65847	-2.94744	-999
HBW	Autos> =Adults	0	-1.61278	-1.89101	-2.50644	-3.39332	-3.88588	-5.69894	-4.6931	-999
HBU	0 Autos	-999	0	-0.46411	0.220064	-2.73947	3.817953	-999	-999	-999
HBU	Autos< Adults	0	-0.37144	-0.57527	-2.60658	-2.54507	0.616014	-999	-999	-999
HBU	Autos> =Adults	0	-1.05981	-1.57289	-1.12654	-3.73008	-1.3896	-999	-999	-999
HBC	0 Autos	-999	0	-0.49967	2.023301	-0.22575	1.195395	-999	-999	3.044755
HBC	Autos< Adults	0	3.947068	4.363731	3.604278	1.600924	2.174235	-999	-999	4.475799
HBC	Autos> =Adults	0	0.786877	0.996694	-0.30463	-2.20365	-3.33355	-999	-999	0.370765
HBS	0 Autos	-999	0	0.047206	1.909662	0.137662	2.45614	-999	-999	-999
HBS	Autos< Adults	0	-0.05254	-0.33921	-1.41957	-2.54356	-1.41407	-999	-999	-999
HBS	Autos> =Adults	0	-0.43873	-0.55885	-2.60821	-3.86948	-4.20534	-999	-999	-999
HBO	0 Autos	-999	0	-0.00671	1.558382	-0.94199	2.074757	-999	-999	-999
HBO	Autos< Adults	0	0.070844	-0.09162	-0.46622	-2.89357	-2.11326	-999	-999	-999
HBO	Autos> =Adults	0	-0.20667	-0.31534	-1.08664	-3.22164	-4.4386	-999	-999	-999

3.8 NON-HOME-BASED TRIPS

Non-Home-Based (NHB) trips are trips where neither end of the trip is the home of the traveler. For AMATS, we have implemented a novel approach to NHB trip generation, distribution and mode choice that takes into account actual home-based trip attraction locations and modes in the generation of NHB trip ends. NHB trips are generated based upon Home-based trip attractions by zone, purpose and mode. That requires NHB trip distribution models to be run after home-based trips have been run through mode choice, as shown in

Figure 25 below. The methodology begins to approach a tour-based model, where trips are tracked all the way from home through a series of non-home locations, back to home. However, the method cannot ensure full consistency in mode, scheduling and other important dimensions that tour and activity-based model address. Furthermore, the socio-economic attributes of the traveler are unknown in the AMATS formulation.

Also note that some NHB trip ends are not generated from home-based trip attractions, but rather from other NHB trip ends. For example, a tour which begins at home, makes three out-of-home stops, and returns home, has two home-based trips and two NHB trips. The origin of the first NHB trip and the destination of the second NHB trip can be determined from the attraction location of the home-based trips.

However, the destination of the first NHB trip (which is the origin of the second NHB trip) is not predicated on the attraction end of a home-based trip. In the current methodology, NHB trip ends not associated with home-based trip ends are addressed by applying a factor to home-based trip ends to account for these stops. A more sophisticated approach would be to generate a set of NHB stops, and model their mode separately. However, we do not feel that the additional effort for developing these supplemental models is justified, given that one could adopt a tour-based paradigm with much greater return on investment.

Figure 25 shows the flow of the Non-Home-Based trip model. The model is based on the number of home-based trip attractions by purpose, mode, and TAZ. These data are fed into a model that predicts, for each Home-Based trip end, whether a Non-Home-Based trip is generated and if so, by what mode. Then a trip distribution model is run to link the Non-Home-Based trip ends into flows. The model that determines whether a NHB trip end is generated, and if so, by what mode can be conceptualized as a combination trip generation and mode choice model, as shown in

Figure 26. This model could be formulated as a discrete choice model but in the case of the AMATS model it is implemented as a set of transition probabilities or combined trip generation and mode rates for Non-Home-Based trips that are segmented by home-based trip purpose and mode. The trip generation\mode rates are given in Table 53 through Table 62.

For example, Table 53 shows that each Home-Based Work trip attraction generates 0.3436 Non-Home-Based Work drive-alone trip ends, 0.0226 Non-Home-Based Work shared 2 trip ends, 0.0121 Non-Home-Based Work shared 3+ trip ends, and so on.

FIGURE 25: NHB TRIP MODEL

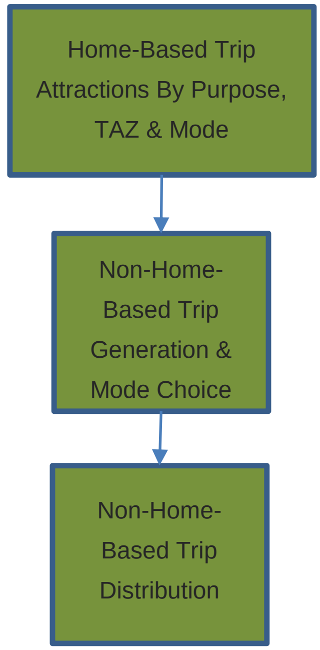


FIGURE 26: NON-HOME-BASED MODEL GENERATION\MODE CHOICE

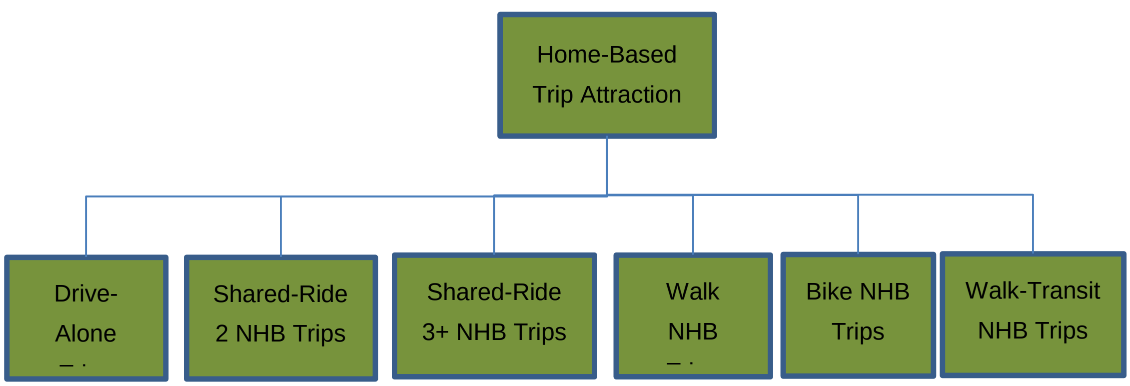


TABLE 53: NON-HOME-BASED WORK TRIP GENERATION\MODE RATES FOR HOME-BASED WORK TRIPS

Non-Home-Based Mode	Home-Based Mode								
	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit	School Bus
Drive-Alone	0.3436	0.0616	0.0359	0.0265	0.0042	0	0.157	0	0
Shared 2	0.0226	0.2518	0.0235	0.0258	0.0231	0.055	0	0	0

Shared 3+	0.0121	0.0157	0.2757	0	0.0264	0	0.0574	0	0
Walk	0.0232	0.0702	0.023	0.1979	0.1202	0.1524	0.0371	0.1225	0
Bike	0.0012	0	0	0	0.1897	0.0224	0	0	0
Walk-Transit	0	0.0065	0	0.0216	0	0.2117	0.1004	0	0

TABLE 54: NON-HOME-BASED WORK TRIP GENERATION\MODE RATES FOR HOME-BASED SCHOOL TRIPS

Non-Home-Based Mode	Home-Based Mode								
	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit	School Bus
Drive-Alone	0.054	0	0	0	0	0	0	0	0
Shared 2	0	0.0077	0.0044	0	0	0	0	0	0.0022
Shared 3+	0	0.0021	0.0053	0	0	0	0	0	0
Walk	0	0.002	0.0013	0	0	0	0	0	0
Bike	0	0	0	0	0	0	0	0	0
Walk-Transit	0	0	0	0	0	0	0	0	0

TABLE 55: NON-HOME-BASED WORK TRIP GENERATION\MODE RATES FOR HOME-BASED UNIVERSITY TRIPS

Non-Home-Based Mode	Home-Based Mode								
	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit	School Bus
Drive-Alone	0.0902	0.3509	0.1465	0	0	0	0	0	0
Shared 2	0.0034	0.0127	0.0485	0	0	0	0	0	0
Shared 3+	0	0.0081	0.013	0	0	0	0	0	0
Walk	0	0.0094	0	0	0	0	0	0	0
Bike	0	0	0.0064	0	0.0898	0	0	0	0
Walk-Transit	0	0.0017	0	0	0	0.1768	0	0	0

TABLE 56: NON-HOME-BASED WORK TRIP GENERATION\MODE RATES FOR HOME-BASED SHOP TRIPS

Non-Home-Based Mode	Home-Based Mode								
	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit	School Bus
Drive-Alone	0.1925	0	0.0022	0	0	0	0	0	0
Shared 2	0	0.0255	0.0034	0	0	0	0	0	0
Shared 3+	0.0009	0	0.0083	0	0	0	0	0	0
Walk	0	0	0	0.0319	0	0.0368	0	0	0
Bike	0	0	0	0	0.1274	0	0	0	0
Walk-Transit	0	0	0	0.0143	0	0	0	0	0

TABLE 57: NON-HOME-BASED WORK TRIP GENERATION\MODE RATES FOR HOME-BASED OTHER TRIPS

Non-Home-Based Mode	Home-Based Mode								
	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit	School Bus
Drive-Alone	0.1212	0.0559	0.012	0.0055	0.0098	0	0.3242	0	0
Shared 2	0.0031	0.0139	0.0086	0	0	0	0	0	0
Shared 3+	0.0028	0.0002	0.0063	0	0	0	0	0	0
Walk	0.0022	0.0015	0.001	0.0027	0	0.0078	0	0	0
Bike	0.0005	0.0003	0.0003	0	0.0781	0	0	0	0
Walk-Transit	0.0002	0	0	0	0	0.0065	0	0	0

TABLE 58: NON-HOME-BASED OTHER TRIP GENERATION\MODE RATES FOR HOME-BASED WORK TRIPS

Non-Home-Based Mode	Home-Based Mode								
	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit	School Bus
Drive-Alone	0.0028	0	0	0	0	0.1965	0.003	0	0
Shared 2	0.0008	0.002	0.0081	0.0034	0.016	0.0637	0.1844	0.0633	0
Shared 3+	0.0003	0	0.0419	0	0	0.0816	0.1038	0.2588	0
Walk	0	0	0	0	0	0	0.0276	0.0185	0
Bike	0	0	0	0	0	0	0	0	0
Walk-Transit	0	0	0	0	0	0	0	0	0

TABLE 59: NON-HOME-BASED OTHER TRIP GENERATION\MODE RATES FOR HOME-BASED SCHOOL TRIPS

Non-Home-Based Mode	Home-Based Mode								
	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit	School Bus
Drive-Alone	0.1965	0.003	0	0	0	0	0	0	0
Shared 2	0.0637	0.1844	0.0633	0	0.038	0	0	0	0.016
Shared 3+	0.0816	0.1038	0.2588	0.064	0.0233	0.106	0	0	0.0845
Walk	0	0.0276	0.0185	0.0736	0.1868	0.1143	0	0	0
Bike	0	0	0	0	0.1704	0	0	0	0
Walk-Transit	0	0	0	0	0	0.0621	0	0	0

TABLE 60: NON-HOME-BASED OTHER TRIP GENERATION\MODE RATES FOR HOME-BASED UNIVERSITY TRIPS

Non-Home-Based Mode	Home-Based Mode								
	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit	School Bus
Drive-Alone	0.1561	0.143	0.1058	0	0	0	0	0	0
Shared 2	0.0555	0.0511	0.1682	0	0	0	0	0	0
Shared 3+	0.0139	0.0489	0.1626	0.02	0	0.3638	0	0	0
Walk	0	0.0027	0	0.051	0	0.2356	0	0	0
Bike	0	0	0	0	0.0895	0	0	0	0
Walk-Transit	0	0.0037	0	0.0225	0	0	0	0	0

TABLE 61: NON-HOME-BASED OTHER TRIP GENERATION\MODE RATES FOR HOME-BASED SHOP TRIPS

Non-Home-Based Mode	Home-Based Mode								
	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit	School Bus
Drive-Alone	0.4615	0.0008	0	0.0109	0	0	0	0	0
Shared 2	0.003	0.5934	0.0016	0.0118	0	0	0	0	0
Shared 3+	0.0009	0	0.6305	0	0	0	0	0	0
Walk	0.0062	0	0	0.2293	0.0226	0.0474	0	0	0
Bike	0	0	0	0	0.1779	0	0	0	0
Walk-Transit	0	0	0	0.0077	0	0.2713	0	0	0

TABLE 62: NON-HOME-BASED OTHER TRIP GENERATION\MODE RATES FOR HOME-BASED OTHER TRIPS

Non-Home-Based Mode	Home-Based Mode								
	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit	School Bus
Drive-Alone	0.3004	0.0601	0.0208	0.0134	0.0076	0	0	0	0
Shared 2	0.07	0.3007	0.063	0.0021	0.0048	0.0049	0	0	0
Shared 3+	0.0174	0.043	0.3974	0.0025	0	0.0709	0	0	0
Walk	0.0152	0.0078	0.0092	0.1566	0.0104	0.1675	0	0	0
Bike	0.0013	0.001	0	0	0.213	0	0	0	0
Walk-Transit	0	0	0	0.0011	0	0.17	0	0	0

NHB trip distribution is performed for each mode separately, where the utility for the relevant mode from the NHB mode choice model is used as the accessibility variable. The destination choice coefficients and results are shown in the Trip Distribution section, above. Mode choice is not necessary for NHB trips, since their mode is determined at the trip generation stage.

3.9 COMMERCIAL VEHICLE TRIPS

The commercial vehicle model for AMATS consists of two models designated by commercial vehicle trip type: the long-haul model component derived from the American Transportation Research Institute (ATRI) trip matrix and the short haul model component derived from the commercial vehicle research done by FHWA. Both components are presented in detail below.

3.9.1 LONG HAUL COMMERCIAL VEHICLE MODEL

The base year long haul commercial vehicle traffic is derived primarily from factoring an origin-destination matrix prepared using the ATRI truck GPS data. For the AMATS study region, ATRI provided GPS locations of trucks operated by its member companies in the Anchorage and Mat-Su region for the months of March, June, August and November in 2014. An OD matrix was created from the data based upon trip origin and destination zones. Since these trips spanned several days within the four months, the matrix needed to be factored cell-by-cell in order to make it comparable to daily commercial vehicle counts on various links in the model. Links with available counts are show in Figure 27.

FIGURE 27: TRUCK COUNTS IN AMATS REGION

Based on a study done in Iowa using similar ATRI GPS data, it was observed that trucks making shorter trips are generally underrepresented and those making longer trips are overrepresented in the ATRI database. Thus, the following weighting scheme was applied to the ATRI matrix based on the free flow travel time bins (Table 63). For example, all trips that were between zero to 10 minutes long were weighted by a factor of 2.528316 and trips that were between 60 and 100 minutes long were weighted by a factor of 0.90447. The ATRI matrix was also unbalance, thus it was transposed and averaged to impose symmetry so that it can be used as an OD matrix for traffic assignment.

TABLE 63: WEIGHTING SHORTER TRIPS

Travel Time Bin	Weight
10	2.528316
20	1.778393
30	1.522611
40	1.291605
60	1.063353
100	0.90447
140	0.876008
180	0.817808
220	0.784623
260	0.786243
300	0.775964
340	0.759638
420	0.731398
500	0.739662
600	0.718316
1000	0.796263

The weighted and balanced ATRI matrix was then assigned to the AMTS network and an area-based modified ODME process was applied to factor various cells in the matrix. The study area was divided into four "regions" – Internal Anchorage, Internal Mat-Su, Anchorage to Mat-Su and Mat-Su to Anchorage. For each of these areas, a ratio of counts and assigned traffic volume from the ATRI matrix was calculated and applied to the particular cells of the matrix. These steps were iterated until the ratios from one iteration to the next changed by less than 0.0001.

In order to accurately predict traffic at the Port of Anchorage in the base year, the count near the port was weighted higher than all other truck counts in the area. Table 64 and Table 65 presents the summary statistics of adjusting the ATRI OD matrix to heavy along and medium and heavy commercial vehicles combined, respectively. Clearly, the adjusted ATRI OD matrix represents the heavy truck traffic more accurately than the medium and heavy truck combined, thus it was assumed that the ATRI OD matrix be used to represent the heavy truck traffic in the AMATS region.

TABLE 64: COUNT VS MODEL VOLUME - HEAVY TRUCKS

ITEM	NUMOBS	TOTCNT	TOTMOD	AVGERR	PCTERR
Freeway	6	1203.90	1058.06	-24.31	-12.11
Major Arterial	23	1423.50	444.44	-21.28	-68.78
Minor Arterial	18	1913.99	545.59	-38.01	-71.49
Collector	18	1110.98	1253.66	4.20	12.84
0 to 1000 AADT	3	10.47	28.14	3.53	168.83
1001 to 5000 AADT	32	1793.02	1487.15	-5.01	-17.06
5001 to 9,999 AADT	14	2034.90	429.15	-57.35	-78.91
10,000 to 19,999 AADT	16	1662.46	1094.30	-21.04	-34.18
20,000 to 29,999 AADT	2	181.00	284.14	34.38	56.99

TABLE 65: COUNT VS MODEL VOLUME – MEDIUM + HEAVY TRUCKS

ITEM	NUMOBS	TOTCNT	TOTMOD	AVGERR	PCTERR
Freeway	6	7087.13	3709.15	-563.00	-47.66
Major Arterial	23	10292.04	1729.95	-186.13	-83.19
Minor Arterial	18	7547.66	2890.69	-129.36	-61.70
Collector	18	4173.69	5003.76	24.41	19.89
0 to 1000 AADT	3	177.09	163.06	-2.81	-7.92
1001 to 5000 AADT	32	7610.67	6323.95	-21.09	-16.91
5001 to 9,999 AADT	14	7621.81	2244.45	-192.05	-70.55
10,000 to 19,999 AADT	16	11744.83	3814.34	-293.72	-67.52
20,000 to 29,999 AADT	2	2122.00	850.64	-423.79	-59.91

3.9.2 SHORT HAUL COMMERCIAL VEHICLE MODEL

The short-haul commercial vehicle model for AMATS was developed keeping in mind the recommendations from the Quick Response Freight Manual (QRFM) II. As noted in the manual, long-haul commodity flow data (such as ATRI) misses many commercial vehicle trips and some short-haul goods movement trips. The freight model includes a short-haul commercial vehicle model to better account for these missing light and medium truck trips.

The primary source for definition, model structure and parameters of the short-haul commercial vehicle model comes from FHWA report, “Accounting for Commercial Vehicles in Urban Transportation Models” (Federal Highway Administration n.d.). This section defines commercial vehicles as a range of vehicle types that are used for commercial, rental, educational or government services.

Commercial vehicles are grouped into three main categories based on what is being carried and the economic, demographic and land use factors influencing the magnitude and distribution of the commercial vehicle trips. These categories are:

- **Commercial Passenger (Moving People) Vehicles**– includes school buses, shuttle services, rental cars, taxis and paratransit vehicles.
- **Freight (Goods) Vehicles**– includes mail delivery, trash collection, warehouse delivery, parcel pickup and delivery, and construction vehicles.
- **Services Vehicles** – includes household/building services such as plumbers and cleaning services as well as public safety, utility maintenance and retail support functions.

The short-haul commercial vehicle model assumes that the commercial vehicles described here do not include trips from outside the model region based on the understanding that the long-haul freight model captures the inter-regional movements.

3.9.3 TRIP GENERATION

The data in

Table 66 were used to obtain the total commercial vehicle trips by commercial vehicle category and truck type. These commercial vehicle trip rates were adapted from QRFM II and were adjusted in model calibration to produce the final trip rates.

Table 66 shows the estimated commercial vehicle short haul trip rates by vehicle type and the attractor variables used to distribute these trips in the model.

TABLE 66: SHORT HAUL COMMERCIAL VEHICLE TRIPS RATES

Type	Trip Rates			Attraction variables
	Light	Medium	Heavy	
School Bus	0.00029	0.00116	0	Households
Shuttle Service	0.00174	0.00019	0	Households + Employment
Private Transport	0.00126	0.00014	0	Employment
Package/Product/Mail	0.00044	0.00001	0	Households + Employment
Urban Freight	0.04077	0.00506	0	Agriculture, Mining & Construction
	0.34450	0.00423	0	Industrial
	0.03261	0.00443	0	Retail
	0.01605	0.00119	0	Other
	0.00922	0.00173	0	Households
Construction	0.00810	0.00248	0	Households + Emp. + 2* Const. Emp.
Safety	0.00418	0.00250	0	Households + Employment
Utility Vehicles	0.00779	0.00288	0	Households
Business/Personal Services	0.08249	0.01689	0	Households + Employment

3.9.4 TRIP DISTRIBUTION

Similar to the long-haul data, the short haul commercial trips are distributed using a gravity model. Friction factors were adapted using QRFM and other states' coefficients for light, medium and heavy vehicle types. The friction factor function used is as follows:

$$\boldsymbol{FF = A \times e^{-BX}}$$

Where
FF = Friction Factor

A = Coefficient (which is assumed to be 1 in all cases)

B = Coefficient

X = Travel impedance (time in minutes)

The A and B coefficients varied by vehicle type as shown in Table 67 and Figure 28.

TABLE 67 SHORT-HAUL COMMERCIAL VEHICLE FRICTION FACTOR COEFFICIENTS

	A	B
Light	1	0.0700
Medium	1	0.0430

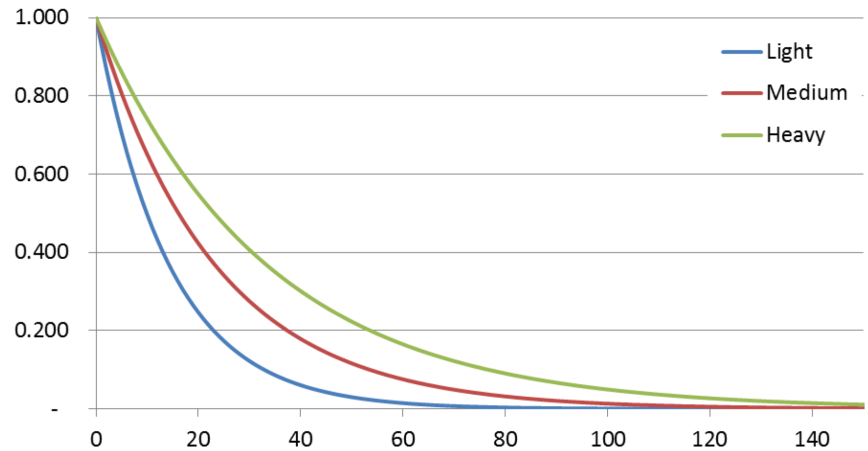


FIGURE 28 SHORT-HAUL COMMERCIAL VEHICLE FRICTION FACTOR GRAPH

3.9.5 MODEL VALIDATION

Table 68 shows average FHWA commercial vehicle rates and type percentages and Figure 29: Percent Light TrucksFigure 29 and Figure 30 show the comparison of percent trucks by type to the AMATS model outputs. Overall, the model appears to match the suggested values reasonably, though there is a lack of data for regions of comparable size to Anchorage upon which to validate trip rates or lengths.

TABLE 68 AVERAGE FHWA COMMERCIAL VEHICLE RATES & VEHICLE TYPE PERCENTAGES

	Vehicle Type	Trips/1000 persons	VMT/trip	Type		
				Light	Medium	Heavy
Moving People	School Bus	0.47	15.83	20%	80%	0%
	Shuttle Service	1.65	21.70	90%	10%	0%
	Private Transport	0.74	27.19	90%	10%	0%
Goods	Package/Product/Mail	0.40	39.00	95%	3%	2%
	Urban Freight	24.86	61.21	67%	8%	25%
	Construction	14.15	44.24	50%	15%	35%
Services	Safety	7.31	36.44	49%	24%	27%
	Utility Vehicles	3.47	22.33	73%	27%	0%
	Business/Personal Services	84.96	51.61	83%	17%	0%

FIGURE 29: PERCENT LIGHT TRUCKS

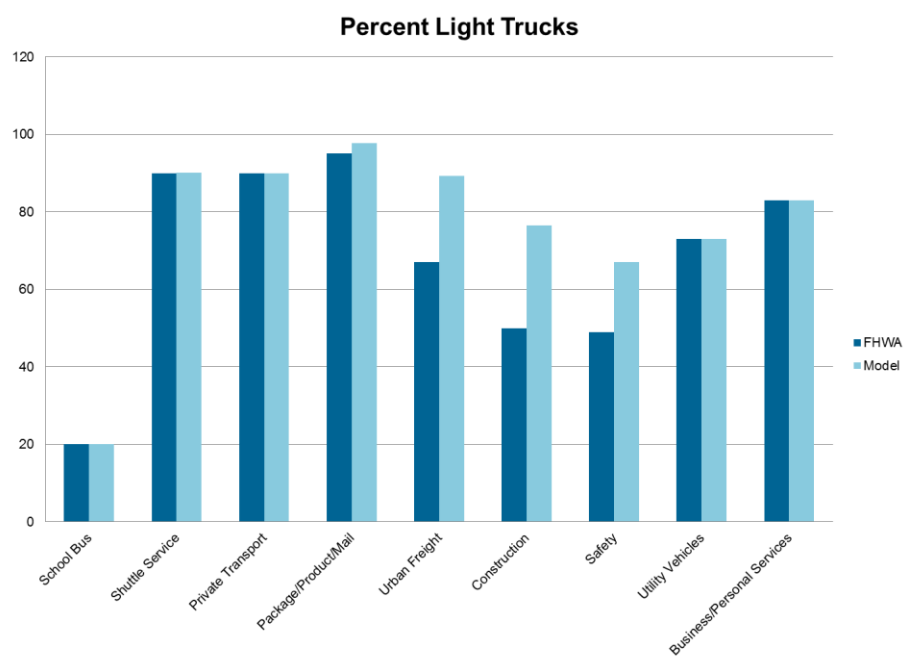
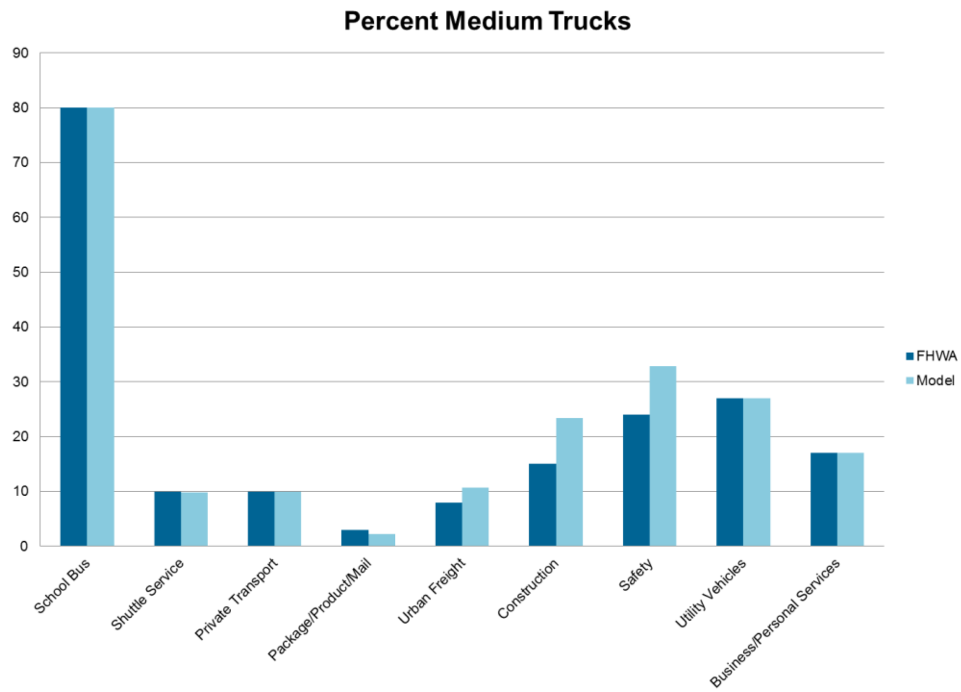


FIGURE 30: PERCENT MEDIUM TRUCKS



3.9.6 FUTURE YEAR COMMERCIAL VEHICLE MODEL

The long and short haul commercial vehicle models are applied in the future years differently and the methodology for the same is presented below.

3.9.7 FUTURE YEAR LONG HAUL COMMERCIAL VEHICLES

Future year commercial long haul vehicle traffic for the AMATS mode will be pivoted off of the base year estimates using the "eight-case method" that was take from Daly, Fox and Tuinenga (2005) "Pivot-Point Procedures in Practical Travel Demand Forecasting." In this approach factor pivoting is applied for what is termed 'normal growth'. However, the eight-case method also uses additive pivoting, where the difference between future and base demand model predictions is applied to the base matrix for 'extreme growth' cases. Table 69 below presents how the predicted matrix P is obtained from the cell factor pivoting process as a function of the:

- base matrix B
- 'synthetic' base Sb – base year output from the demand models before pivoting
- 'synthetic' future Sf – future year output from the demand models before pivoting

Eight specific cases are defined, allowing for situations where one or more of the items are zero.

TABLE 69: EIGHT PIVOTING CASES

Case	Base (B)	*Synthetic base (Sb)*	*Synthetic future (Sf)*	Predicted (P)	
1	0	0	0	0	
2	0	0	>0	Sf	
3	0	>0	0	0	
4	0	>0	>0	Normal growth (Sf < X1)	0
				Extreme growth (Sf > X1)	Sf – X1
5	> 0	0	0	B	
6	> 0	0	>0	B + Sf	
7	> 0	> 0	0	0	
8	> 0	> 0	>0	Normal growth (Sf < X2)	B * Sf / Sb
				Extreme growth (Sf > X2)	B * SX2/ Sb + (Sf – X2)

Where:

K1 = 0.5;

K2 = 5;

X1 = K2 *Sb; and,

X2 = K1 * Sb + K2 * Sb * max(Sb/B , K1/ K2)

3.9.8 FUTURE YEAR SHORT HAUL COMMERCIAL VEHICLES

Future year short haul commercial traffic for the AMATS mode will be estimated using the same trip generation and distribution equations presented in

Table 66 and Table 67.

3.10 AIRPORT TRIPS

Vehicle trips to and from Ted Stevens International Airport are explicitly represented by a relatively simple airport model. The model utilizes daily enplanements (not counting transferring passengers) multiplied by a trip factor per enplaned passenger to calculate total number of trips. The model then distributes these trips from the airport TAZ (TAZ 28) to all TAZs in the region using a destination choice model framework (see above description under Trip Distribution) where the size term is based on the total households and hotel rooms in the destination and the accessibility term is the distance between the airport and the destination.

According to the 2014 Master Plan Update for Ted Stevens International Airport (http://www.ancmasterplan.com/library/) there were almost 2.4 million total annual enplaned passengers in 2013 for a total of approximately 6,500 enplaned passengers per day using an annualization factor of 365. Approximately 190k annual passengers transferred, or approximately 500 passengers per-day, leaving 6,000 total enplaned passengers per-day, not including transfers. Projections call for approximately 8,500 total daily enplaned passengers in 2030, not including transfers.

A vehicle occupancy factor of 1.1 was based on airport models developed for San Diego California and Portland Oregon. A trip rate per passenger of 2.0 was calibrated to traffic counts on West International Airport Boulevard.

The destination choice model utility equation for airport trips is given in Equation 5 below.

EQUATION 5: AIRPORT DESTINATION CHOICE MODEL UTILITY EQUATION

$$U_j = \delta * \left(\beta_{time} * Time_{ij} + \beta_{cost} * Distance_{ij} * AOC\right) + \log(Size_j)$$

Where:

U_j is the utility of travel from airport zone i to non-airport zone j

δ is a parameter on the accessibility of non-airport zone j to airport zone I, currently asserted at 1.0

β_{time} is a parameter on travel time, currently asserted at -0.03, consistent with the Portland Airport Model

β_{cost} is a parameter on travel cost, currently asserted at -0.001, yielding a value of time for air passengers of $18/hour, consistent with the Portland Airport Model

$Time_{ij}$ is the auto off-peak travel time between airport zone i and non-airport zone j

$Distance_{ij}$ is the auto off-peak travel distance between airport zone i and non-airport zone j

AOC is the auto operating cost per mile, 20 cents.

$Size_j$ is the size term for zone j, as shown in Equation 6 below.

EQUATION 6: AIRPORT DESTINATION CHOICE MODEL SIZE TERM

$$Size_j = hotel_j + \emptyset_{resident} * households_j$$

Where

$Size_j$ is the size of non-airport zone *j*

$hotel_j$ is the sum of all hotel rooms weighted by the occupancy rate for each hotel in non-airport zone *j*

$households_j$ is the number of households in non-airport zone *j*

$\emptyset_{resident}$ is a coefficient for residents equal to the ratio of the mean of $hotel_j$ across all zones to the mean of $households_j$ across all zones multiplied by the share of air passenger trips by residents (0.3).

The airport destination choice size term uses a weighted distribution of households and hotel rooms, where the weights reflect the split between resident and visitor air passengers. According to the same report, approximately 70 percent of persons exiting Alaska by air were visitors and 30 percent were residents. Typically the entire destination choice model would be estimated using observed travel survey data for air passengers, collected via specific passenger surveys conducted at departure gates. Since in this case such data was not available, the coefficients had to be asserted. The coefficient on households ($\emptyset_{resident}$) is based on the share of resident air passenger trips (0.3), but is factored by the ratio of the mean number of hotel rooms compared to the mean number of households across all zones in the region to take into account the difference in scale between hotel rooms in the region (approximately 8k) compared to households (approximately 143,000).

Calibration and validation summaries are not given for the airport model since observed travel data for air passengers is not available. We recommend that AMATS conduct an airport passenger ground access travel survey in the future so that the model coefficients can be estimated from observed data and the model application results can be verified. Such a survey would also be useful for further airport master planning, for example examining parking policies (price, quantity and location) and/or transit service. However, the estimated trip length frequency distribution for airport trips is shown in Figure 31. The average trip length is miles.

FIGURE 31: AIRPORT GROUND ACCESS MODEL TRIP LENGTH FREQUENCY DISTRIBUTION

$$Size_j = hotel_j + \emptyset_{resident} * households_j$$

Where

$Size_j$ is the size of non-airport zone *j*

$hotel_j$ is the sum of all hotel rooms weighted by the occupancy rate for each hotel in non-airport zone *j*

$households_j$ is the number of households in non-airport zone *j*

$\emptyset_{resident}$ is a coefficient for residents equal to the ratio of the mean of $hotel_j$ across all zones to the mean of $households_j$ across all zones multiplied by the share of air passenger trips by residents (0.3).

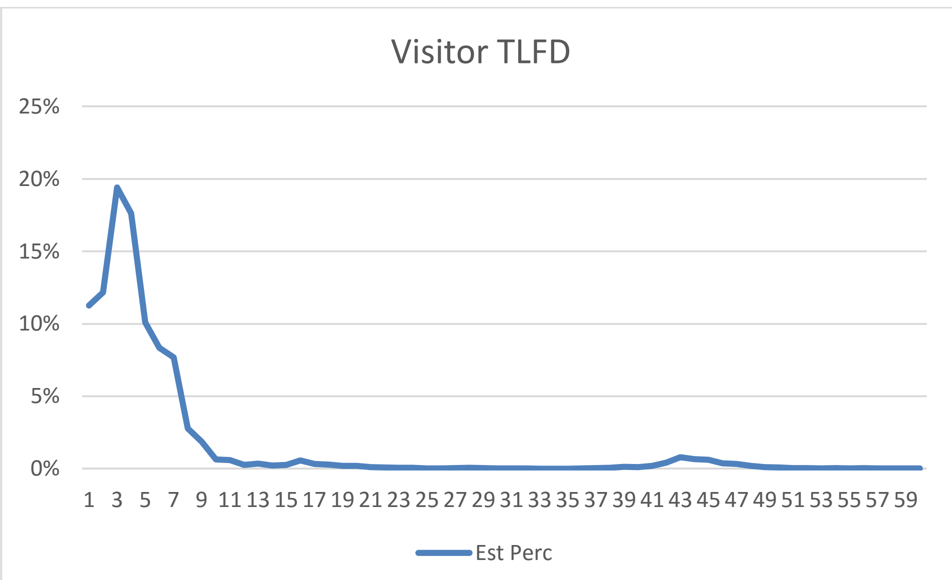
3.11 VISITOR TRIPS

Trips made by overnight visitors to and from hotel rooms are explicitly modeled by a relatively simple visitor travel model. This model replicates the functionality of the visitor special market model used in earlier versions of the AMATS model system, but tracks these trips in a separate purpose so that they can be calibrated to observed data when such data becomes available. The form of the model is similar to that used by the Airport Model described above. Visitor trips are generated based on an inventory of hotel rooms and the occupancy rate for each room. The trip rate per room (8.3) was borrowed from the previous version of the AMATS model. The trips are distributed to non-hotel zones based on a simple destination choice model as shown in Equation 5. However, the size term for overnight visitors is different than that used for airport trips. The size term for the Visitor Model is the same as the size term for the Home-Based Other trip purpose as shown in

Table 37, but without household or government employment variables.

Calibration and validation summaries are not given for the visitor model since observed travel data for overnight visitors is not available. If AMATS were to perform an airport survey, an additional survey component could be added to gather travel data on visitors. However, there were 40,890 total visitor trips to/from hotels estimated by application of the trip rate to total hotel rooms in the AMATS region in 2013. The estimated trip length frequency distribution for visitor trips is shown in Figure 32. The average trip length is 5.7 miles.

FIGURE 32: VISITOR TRIP LENGTH FREQUENCY DISTRIBUTION



3.12 INTERNAL\EXTERNAL AND EXTERNAL\EXTERNAL TRIPS

Internal\External trips refer to all trips with one trip end in the AMATS modeling area and one end at an external station. External\External trips refer to trips where both ends are external stations. Both travel markets are represented via a special trip table developed based upon traffic counts and Bluetooth survey data.

The development of these trip tables began with a summary of Bluetooth data between each external station and between external stations and internal districts. Since Bluetooth data cannot be summarized by actual origin\destination, the internal districts were aggregated to Municipality of Anchorage versus Mat-Su Borough. For external stations, the closest Bluetooth station to each external station was used. This results in a set of trip tables (one for each period of a.m., p.m. and off-peak) with five rows and columns (MOA, Mat-Su, and three external stations). Heavy truck volumes from expanded ATRI data were added to these trip tables and the results were scaled to traffic counts at each external station. The results of this process are shown in Table 70 through Table 71.

Next, full zone-to-zone trip tables were constructed from these data. Trips between external station pairs were taken right from the tables. For internal\external and external-internal trips, a destination choice method was applied. For external station, the total external-internal trips (count minus external-external trips) were distributed to internal zones within each district using the utility equation shown below.

EQUATION 7: EXTERNAL-INTERNAL DESTINATION CHOICE UTILITY EQUATION

$$U_i = \beta_{time} * Time_{ij} + \beta_{cost} * Distance_{ij} * CPM + \ln(households_i + 2 * employment_i)$$

Where:

U_i	is the utility for internal zone i
$\beta_{time}, \beta_{cost}$	are parameters on time and cost, set to -0.03 and -0.0042 respectively
CPM	is the cost per mile, set to 20 cents
$Time_{ij}, Distance_{ij}$	is the time and distance between internal zone i and external station j
$households_i, employment_i$	are the total households and employment in zone i

TABLE 70: A.M. INTERNAL\EXTERNAL AND EXTERNAL\EXTERNAL TRIPS

Origin District	Destination District					Total
	Anchorage	Mat-Su	970	971	972	
Anchorage			270	24	19	313
Mat-Su			49	41	34	124
970	205	22		2	3	232
971	24	34	2		6	66
972	13	27	2	3		45
Total	242	84	323	69	62	780

TABLE 71: P.M. INTERNAL\EXTERNAL AND EXTERNAL\EXTERNAL TRIPS

Origin District	Destination District					Total
	Anchorage	Mat-Su	970	971	972	
Anchorage			765	99	51	916
Mat-Su			84	103	133	320
970	698	139		9	6	852
971	99	134	8		11	252
972	71	124	9	18		221
Total	867	397	867	229	201	2,562

TABLE 72: OFF-PEAK INTERNAL\EXTERNAL AND EXTERNAL\EXTERNAL TRIPS

Origin District	Destination District					Total
	Anchorage	Mat-Su	970	971	972	
Anchorage			2,355	273	227	2,854
Mat-Su			323	287	380	990
970	2,522	395		30	31	2,978
971	279	354	24		38	695
972	250	414	27	48		739
Total	3,051	1,163	2,728	638	676	8,256

3.13 TIME-OF-DAY AND DIRECTIONAL FACTORING

This step is the hidden step in the four-step modeling process, but it is very important. The inputs to the step include the trip tables by purpose and mode, in production to attraction format, that are output from mode choice, as well as other models (trucks, airport trips and visitor trips). The time-of-day and directional factoring step applies time of day factors and auto occupancy factors derived from survey data to these trip tables. In the time-of-day factoring step, the production attraction format trip tables are converted to origin-destination format. The conversion of production attraction (PA) format trip tables to origin destination (OD) format trip tables occurs in three general steps as described below:

Step 1: In this step, the PA format HBW trip table is transposed. The transpose trip table is basically where the rows and columns are switched ($Transpose_{ij} = Trips_{ji}$).

Step 2: The trip table and its transpose are multiplied by time-of-day factors. If a daily PA trip table is being converted to a daily OD trip table, then the factors are 0.5 for each (trip table and transpose). That assumes that over a 24-hour period, half of the trips will be in the production to attraction direction and half the trips would be in the attraction to production direction. If a daily PA trip table is being converted to OD trip tables for each period, then the factors would be need to be calculated by time-of-day. This is the form of the AMATS model, since we have peak and off-peak trips, and the peak trips are converted to AM and PM Peak.

Step 3: The resulting factored trip tables are added together for each period. The result is a period-specific trip table in OD format that is ready for trip assignment.

The actual formula is given in Equation 8.

EQUATION 8: FORMULA FOR FACTORING PA TRIP TABLE INTO OD TRIP TABLES BY PERIOD

$$Trips_{od,k,m} = Factor_{k,m} * [(\left(1 - APFactor_{k,m}\right) * Trips_{pa,m}) + (APFactor_{k,m} * Trips_{ap,m})] * Occ_m$$

Where:

$Trips_{od,k,m}$ is the vehicle (or person) trips from origin TAZ *o* to destination TAZ *d* in period *k* for mode *m*

$Factor_{k,m}$ is the period *k* factor for mode *m*

$APFactor_{k,m}$ is the percent of trips occurring in the attraction to production direction in period *k* for mode *m*

$Trips_{pa,m}$ is the person trips from production TAZ *p* to attraction TAZ *a* for mode *m*

$Trips_{ap,m}$ is the person trips from attraction TAZ *a* to production TAZ *p* for mode *m*

Occ_m is the vehicle occupancy factor for mode *m*

Period specific factors for daily trip tables are given in Table 73. Period and mode specific factors ($Factor_{k,m}$) for peak person trip purposes are given in Table 74. For example, of 44 percent of all peak period drive-alone trips in the Home-Based Work trip purpose occur in the a.m. peak period, and 56 percent occur in the p.m. peak period. Note that since the trip tables are already segmented by peak and off-peak after trip generation, only peak period trips need to be further segmented into a.m. peak and p.m. peak. Off-peak period trips use an implicit factor of 1.0.

The percent of trips occurring in the attraction to production direction in each period for each mode ($APFactor_{k,m}$) is given in Table 75 and Table 76. For example, only 3 percent of all drive-alone Home-Based Work trips occurring in the a.m. peak period are made from work (attraction end) to home (production end). That means that 97percent occur in the home to work direction, which is logical given that this is the work trip purpose in the morning commute period.

Finally, a set of occupancy factors (Occ_m) are applied to convert person trips into vehicle trips for auto assignment. They are 1.0 for drive-alone trips (1 vehicle per person), 0.5 for shared-ride two trips, and 1/3.5 for shared-ride 3+ trips. Factors of 1.0 are used for all other modes (note that transit vehicles are preloaded onto the network without respect to occupancy, based on the transit route file).

TABLE 73: AM, PM, AND OFF-PEAK PERIOD FACTORS FOR DAILY TRIP TABLE TIME-OF-DAY FACTORING

Period	Travel Market			
	Airport	Visitor	Light Trucks	Heavy Trucks
AM Peak	0.08	0.05	0.05	0.09
PM Peak	0.17	0.10	0.15	0.16
Off-Peak	0.75	0.85	0.80	0.75

TABLE 74: AM AND PM PEAK PERIOD FACTORS FOR PEAK TRIP TABLE TIME-OF-DAY FACTORING

Mode	Period	Purpose						
		HBW	HBC	HBU	HBS	HBO	NHW	NHO
Drive Alone	AM	0.44	0.76	0.44	0.08	0.31	0.31	0.16
	PM	0.56	0.24	0.56	0.92	0.69	0.69	0.84
Shared-2	AM	0.5	0.6	0.59	0.04	0.34	0.35	0.21
	PM	0.5	0.4	0.41	0.96	0.66	0.65	0.79
Shared 3+	AM	0.32	0.56	0.49	0	0.32	0.24	0.27
	PM	0.68	0.44	0.51	1	0.68	0.76	0.73
Walk	AM	0.48	0.47	0.57	0.13	0.24	0.41	0.2
	PM	0.52	0.53	0.43	0.87	0.76	0.59	0.8
Bike	AM	0.4	0.5	0.22	0.07	0.14	0.4	0.15
	PM	0.6	0.5	0.78	0.93	0.86	0.6	0.85
Walk-Transit	AM	0.48	0.59	0.7	0.1	0.4	0.54	0.31
	PM	0.52	0.41	0.3	0.9	0.6	0.46	0.69
PNR-Transit	AM	0.34	0	0	0	0	0	0
	PM	0.66	0	0	0	0	0	0
KNR-Transit	AM	0.46	0	0	0	0	0	0
	PM	0.54	0	0	0	0	0	0

TABLE 75: AM AND PM ATTRACTION TO PRODUCTION FACTORS FOR PEAK TRIP TABLE TIME-OF-DAY FACTORING

Mode	Period	Purpose						
		HBW	HBC	HBU	HBS	HBO	NHW	NHO
Drive Alone	AM	0.03	0.04	0.16	0.19	0.43	0.5	0.5
	PM	0.94	1	0.64	0.8	0.57	0.5	0.5
Shared-2	AM	0	0.03	0.12	0.47	0.14	0.5	0.5
	PM	0.77	0.92	0.97	0.71	0.59	0.5	0.5
Shared 3+	AM	0	0.01	0	0	0.06	0.5	0.5
	PM	0.94	0.92	0.77	0.68	0.56	0.5	0.5
Walk	AM	0.02	0	0.24	0.11	0.34	0.5	0.5
	PM	0.83	0.98	0.5	0.56	0.4	0.5	0.5
Bike	AM	0.06	0.11	0	0	0.06	0.5	0.5
	PM	0.95	1	1	0.53	0.5	0.5	0.5
Walk-Transit	AM	0	0	0	1	0.06	0.5	0.5
	PM	0.91	0	1	0.68	0.94	0.5	0.5
PNR-Transit	AM	0	0	0	0	0	0	0
	PM	1	0	0	0	0	0	0
KNR-Transit	AM	0	0	0	0	0	0	0
	PM	1	0	0	0	0	0	0

TABLE 76: ATTRACTION TO PRODUCTION FACTORS FOR OFF-PEAK TRIP TABLE TIME-OF-DAY FACTORING

Mode	Purpose						
	HBW	HBC	HBU	HBS	HBO	NHW	NHO
Drive Alone	0.38	0.68	0.45	0.62	0.54	0.5	0.5
Shared-2	0.38	0.48	0.64	0.59	0.52	0.5	0.5
Shared 3+	0.43	0.52	0.11	0.64	0.57	0.5	0.5
Walk	0.6	0.69	0.61	0.55	0.42	0.5	0.5
Bike	0.36	0.45	0.3	0.6	0.51	0.5	0.5
Walk-Transit	0.41	0.84	0.48	0.48	0.65	0.5	0.5
PNR-Transit	0	0	0	0	0	0	0
KNR-Transit	0	0	0	0	0	0	0

3.14 FINAL AUTO ASSIGNMENT & VALIDATION

After three full iterations of feedback, final auto assignments are performed and the outputs are compared to traffic counts. The validation process was fairly thorough and involved adjustments to trip generation rates, trip distribution parameters, auto assignment parameters, signal timing and progression factors, and reviewing and fixing network characteristics (adding traffic signals and correcting network connectivity). A scatterplot of estimated versus observed daily traffic counts is shown in Figure 33. The overall R^2 for the plot is 0.87. This is considerably high given that the previous AMATS model resorted to Origin-Destination Matrix Estimation (ODME) procedures in order to achieve a comparable or better goodness-of-fit. ODME can be a useful procedure to adjust base-year trip tables to traffic counts for short-range forecasts, particularly for input to traffic micro-simulation models, but such methods can hide problems with route choice and significantly distort the underlying trip table. Therefore they are not recommended for long-range forecasting[10]. Also note that the slope of the line is sufficiently close to 1, indicating neither a consistent under-estimate or over-estimate of traffic compared to counts.

[10] NCHRP Report 765: Analytical Travel Forecasting Approaches for Project-Level Planning and Design, Transportation Research Board, Washington, D.C., 2014, p138.

FIGURE 33: SCATTERPLOT OF ESTIMATED VERSUS OBSERVED DAILY TRAFFIC

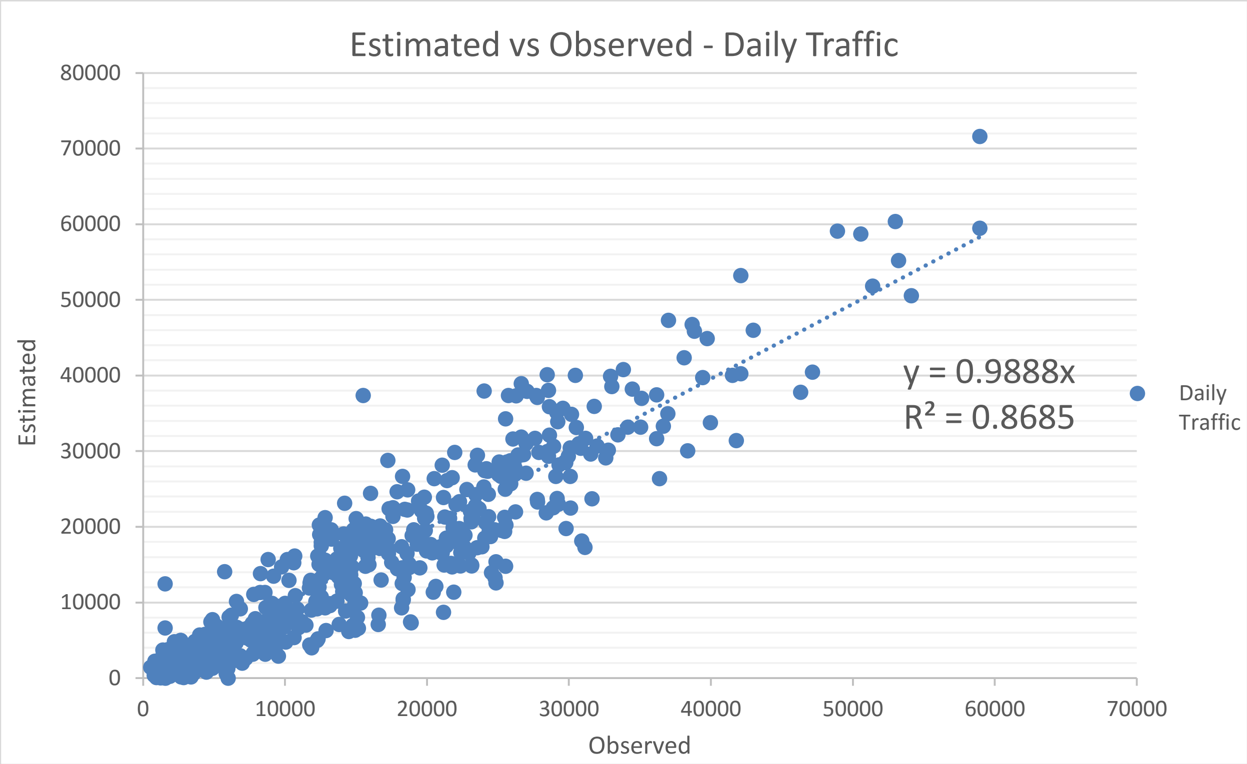


Table 77 shows estimated versus observed daily traffic by observed volume range. Percent root mean square error (RMSE) is a useful statistic that measures the average deviation from counts across all links. The equation for RMSE is given below.

EQUATION 9: ROOT MEAN SQUARE ERROR

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(V_i - C_i)^2}$$

Where

n is the number of links

V is the estimated volume on the link

C is the counted volume on the link

From the table it is clear that error decreases as one moves from lower to higher observed volume. This is common in network models where smaller facilities suffer from aggregation bias due to large zone sizes, incorrect turning movements due to centroid loadings, and errors in applying aggregate models to disaggregate groups of households. Overall the percent root mean square error is fairly low (32%) – especially given the large number of counts on low volume facilities. Also shown on the table is the maximum desirable PRMSE according to the Ohio Department of Transportation. All AMATS count ranges are within or less than the maximum desired PRMSE.

TABLE 77: ESTIMATED VERSUS OBSERVED TRAFFIC BY VOLUME GROUP

VolumeRange	NumberLinks	TotalEst	TotalObs	Difference	PercDiff	PercRMSE	Max Desriable PRMSE
0-5,000	325	711866	830259	-118393	-14.3%	57.14%	50% - 200%
5,000-10,000	164	1087339	1203754	-116415	-9.7%	39.22%	36% - 45%
10,000-15,000	151	1869637	1882595	-12957	-0.7%	26.6%	31%-34%
15,000-20,000	84	1474433	1434536	39898	2.8%	22.41%	28% – 30%
20,000-25,000	29	624943	642656	-17713	-2.8%	20.5%	26%
25,000-50,000	34	1023823	932818	91005	9.8%	17.96%	22%-26%
Total	787	6792043	6926617	-134575	-1.9%	32.3%	

Table 78 shows estimated versus observed volumes by facility type. The PRMSE is very low for freeways and major arterials, and significantly higher for minor arterials and below, for the same reasons cited above. Some facility types (expressway, ramps, and frontage roads) have too few observed volumes to draw any conclusions about accuracy of the model at a facility type level.

TABLE 78: ESTIMATED VERSUS OBSERVED TRAFFIC BY FACILITY TYPE

FacilityType	NumberLinks	TotalEst	TotalObs	Difference	PercDiff	PercRMSE
Freeway	48	1064227	933295	130932	14%	23.8%
Expressway	8	110644	111162	-518	-0.5%	32.5%
Major Arterial	408	4648270	4752210	-103940	-2.2%	26.8%
Minor Arterial	170	734013	821548	-87535	-10.7%	47.2%
Collector	115	177619	228421	-50801	-22.2%	76%
Local	18	11275	18812	-7537	-40.1%	67%
On-Ramp	1	2721	3004	-283	-9.4%	9.4%
Off-Ramp	6	21786	25466	-3680	-14.5%	44.1%
Frontage Road	13	21489	32701	-11213	-34.3%	52.2%
Total	787	6792043	6926617	-134575	-1.9%	32.3%

Table 79 summarizes estimated versus observed volume by area type. It shows that there is no clear bias with respect to percent root mean square error by area type, and the overall percent difference by area type appears to be reasonable.

TABLE 79: ESTIMATED VERSUS OBSERVED TRAFFIC BY AREA TYPE

AreaType	NumberLinks	TotalEst	TotalObs	Difference	PercDiff	PercRMSE
Urban-CBD	50	343600	343316	284	0.1%	29.4%
Central City	101	1267216	1353473	-86256	-6.4%	25.7%
Suburban	419	3645011	3796814	-151803	-4%	32.4%
Rural	97	254307	259137	-4829	-1.9%	38.2%
Expressways	8	110644	111162	-518	-0.5%	32.5%
Freeways	55	1088733	961765	126968	13.2%	25%
Reduced capacity	57	82531	100951	-18421	-18.2%	52.5%
Total	787	6792043	6926617	-134575	-1.9%	32.3%

Screenlines are imaginary lines that are drawn across a series of parallel facilities and are used to check model flows (trips) across the line. This way, bias introduced in the route choice model is minimized, and the comparison highlights the accuracy of the underlying trip tables. Figure 34 shows screenlines for the AMATS model. Estimated versus observed traffic for each screenline is shown in Table 80. Most screenlines are less than 10 percent difference in total counted versus observed volume. Screenlines with a higher percentage difference tend to have a lower overall count.

Overall, the model matches traffic counts well. Corridor level adjustments may be required at the project level. One must take care to ensure that the traffic counts used for such adjustments are appropriate – this is particularly important given the high seasonality of counts in the Anchorage region.

3.15 FINAL TRANSIT ASSIGNMENT & VALIDATION

After three full iterations of feedback, final transit assignments are performed and the outputs are compared to transit boardings. Transit assignments are performed for three time periods (A.M., P.M., and off-peak) and three access modes (Walk, Park-and-Ride, and Kiss-and-Ride). In the P.M. period, drive transit trips are assigned using transit networks built with walk access at the trip origin and drive egress at the trip destination end to replicate the way most transit users access and egress the transit system in the evening. The assignment results are shown in Table 81. Transit boardings are a bit low (-8.5%) compared to observed data, which indicates a lower transfer rate in the model than indicated by the on-board survey. This could be adjusted by lower transfer wait time penalties in the mode choice or assignment process. However, the overall match to observed data is reasonable given the low number of boardings in the Anchorage region. The overall R^2 at a route level is approximately 0.62.

TABLE 80: ESTIMATED VERSUS OBSERVED TRAFFIC BY SCREENLINE

Screenline	NumberLinks	TotalEst	TotalObs	Difference	PercDiff
101_Tudor	23	217154	226884	-9729	-4.3%
201_Dimond_Abbott_N	19	150947	171613	-20666	-12%
301_OMalley	12	57747	59663	-1915	-3.2%
401_5thAve_GlennHwy	20	163566	161786	1781	1.1%
501_Muldoon	13	119101	103549	15553	15%
601_Boniface	8	143017	132346	10671	8.1%
602_Parallel_Seward	10	23677	26664	-2987	-11.2%
701_LakeOtis	14	204095	182809	21286	11.6%
702_LakeOtis	17	67704	70914	-3210	-4.5%
801_Seward	30	322399	295687	26712	9%
901_AirportRd	15	180229	178055	2174	1.2%
1001_Dimond_Abbott_S	20	118478	130868	-12390	-9.5%
2001_Glenn_Knik	1	16873	15968	905	5.7%
2002_Glenn_Birchwood	4	46075	40030	6045	15.1%
2003_Glenn_Eagle	2	68303	59686	8617	14.4%
2005_3rdAve	6	27477	26113	1364	5.2%
2006_Gambell	10	74714	67689	7025	10.4%
2007_9thAve	14	127017	113367	13650	12%
2010_15th_Fireweed	18	229954	220934	9020	4.1%
2013_Hickel_Airport	8	79094	71951	7143	9.9%
2016_Hickel	9	73784	82030	-8246	-10.1%
2020_NewSewardHwy	2	7953	8893	-940	-10.6%

TABLE 81: ESTIMATED VERSUS OBSERVED TRANSIT BOARDINGS BY ROUTE

Route	Avg Daily Riders	Model	Diff	% Diff
Route 1	647	855	208	32.1%
Route 2	953	1,029	76	8.0%
Route 3	1,437	989	(448)	-31.2%
Route 7	1,389	1,041	(348)	-25.1%
Route 8	615	410	(205)	-33.3%
Route 9	855	1,001	146	17.1%
Route 13	732	395	(337)	-46.0%
Route 14	202	104	(98)	-48.5%
Route 15	925	964	39	4.2%
Route 36	574	773	199	34.7%
Route 45	2,359	1,418	(941)	-39.9%
Route 60	713	920	207	29.0%
Route 75	1,015	1,098	83	8.2%
Route 102	235	578	343	146.0%
Total	**12,651**	**11,575**	**-1076**	**-8.5%**

FIGURE 34: AMATS MODEL SCREENLINES (ANCHORAGE BOWL)