SANDAG ABM2+ ENHANCEMENTS FINAL REPORT

Report Title:

SANDAG ABM2+ enhancements Final Report

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Report Prepared for:

San Diego Association of Governments

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LIST OF ABBREVIATIONS

EDD   Employment Development Department

GUI   Graphical User Interface

IPEDS   Integrated Postsecondary Education Data System

ITE   Institute of Transportation Engineers

KSF   Thousand Square Feet

LU   Land Use

MGRA   Master Geographic Reference Areas

MSA   Metropolitan Statistical Area

NAICS   North American Industry Classification System

NCES   National Center for Education Statistics

PUMA   Public Use Microdata Area

RBA   Rentable Building Area

RP   Regional Plan

SAN   San Diego Airport

SANDAG   San Diego Association of Governments

SANGIS   SANDAG Geographic Information System

SCAG   Southern California Association of Governments

TAZ   Transportation Analysis Zones

VMT   Vehicle Miles Traveled

1.0 INTRODUCTION

The San Diego Association of Governments (SANDAG)'s Activity-Based Model Version 2+ (ABM2+) enhancements were designed to adapt existing procedures from ABM Version 1 that integrates land use and socioeconomic data with the travel model to better link these demand and supply components. The enhancements will allow member agencies to provide growth forecasts from general plans or data provided by developers and convert these forecasts to the socioeconomic data required by ABM2+.

1.1 OVERVIEW

RSG developed the land use converter tool to apply employment densities for each land use type based on available data sources. SANDAG provided land use definitions for each land use type; these are provided in Appendix A. The methodology and data sources are provided in Chapter 2, along with the employment densities by land use type provided in Appendices B and C for employment-based and acreage-based densities, respectively.

The Service Bureau at SANDAG runs several model scenarios for alternatives analysis in support of Traffic Impact Studies and General/Community Plan Updates. In the trip-based model, Service Bureau staff split Transportation Analysis Zones (TAZs) to isolate the traffic impacts associated with new land use developments for alternatives analysis and would like the same functionality in ABM2+. This workflow was established and refined over the years for the trip-based model and needs additional updates to best work with ABM2+. The regional model land use inputs can be updated or overridden by the project-specific land use data provided in the request to run model scenarios for a new project. Custom geographies created by these TAZ splits have implications for data management and reporting that were also considered.

This report describes the methodology and assumptions for the SANDAG ABM2+ Application Tool developed as part of the SANDAG ABM2+ Enhancements study. The key improvements included in this ABM2+ Application Tool are listed below:

- **Option to split TAZs** – Land use developments exist in some areas that will benefit from splitting TAZs to isolate the new development. This is currently standard practice at the Service Bureau. In some cases, it may be beneficial to keep the existing TAZ system, so this option has been added to allow bypassing the TAZ splits which reduces runtimes. Cases where splitting TAZs (or not) are described to help with this decision for each development.

- **Land use converter** – The land use converter automates the steps to convert the land use data to the format of the ABM2+. This also produces consistent and efficient outputs

(a html file with tabular summaries and spatial maps) for the client to ensure the quality of the model setup.

- **PopulationSim Repop –** This is a new feature to generate population for the new development without having to regenerate the no-build population for the build scenario.

- **Household sampling in synthetic population files –** This is a new process that updates synthetic population files to over-sample households in the subarea and under-sample households outside the study area to produce a more stable and accurate travel demand in the subarea.

- **Resident model run with household sampling -** This runs the resident CT-RAMP model with the household sampling rate set in synthetic population files to produce a more stable and accurate travel demand in the subarea.

- **Automated steps for updating shadow pricing –** This automates the steps to update shadow pricing for the no-build and build scenarios. Shadow pricing is run for both no-build and build to provide the most consistent comparisons for work and school locations that are balanced to meet expectations for work and school employment.

- **Increase number of select link\zone queries –** This updates the model system to increase the available number of select link\zone queries to five.

This final report describes the SANDAG ABM2+ Application Tool as implemented as part of the ABM2+ enhancements plan and how the tool was developed. A companion document called the SANDAG *ABM2+ Application Tool User Guide* provides user instructions and information on how to use the ABM2+ Application Tool*.*

1.2 CONTENTS OF THIS REPORT

This report documents the development and testing of the ABM2+ Application Tool. This was a collaborative project, with RSG and SANDAG staff working together to develop technical content for employment densities and trip rates. This chapter introduces the ABM2+ application study and provides an overview of the ABM2+ Application Tool enhancements and the contents of this report.

Chapter 2 presents the development of the employment densities, including the data used and the recommended densities for each land use type. In addition, a comparison to Southern California Association of Government's (SCAG) land use densities was provided as a quality check on the SANDAG densities.

The development of the ABM2+ Application Tool is provided in Chapter 3. This chapter includes the client land use form, how to introduce TAZ splits if desired, and how to update the model

inputs. The ABM2+ Application Tool documentation also includes discussions about how to include shadow pricing and select links as optional features.

Chapter 4 presents an analysis of trip rates by land use type estimated from available data sources and an analysis of the minimum thresholds desired for statistical reliability. These thresholds define the minimum population and employment required to ensure that ABM2+ applications can produce reliable impacts for residential and commercial developments.

Chapter 5 presents a brief overview of the application tests with selected results from the application tests to evaluate the ABM2+ Application Tool efficacy that RSG was responsible for. SANDAG staff performed the majority of the application tests which are included in this overview; this documentation does not include the results from these application tests.

This document concludes with a brief summary of the study and four technical appendices. Appendix A provides the land use definitions used throughout the model application process. Appendices B and C present the employment densities by square feet and by acre, respectively. Appendix D provides the Java code changes required for household sampling procedures.

2.0 EMPLOYMENT DENSITIES

The employment density refers to the number of employees associated with area or feature of a land use development. Service Bureau staff estimate the number of new employees generated by a land use change using the employment densities calculated in this study. This chapter describes the methodology for determining the employment densities and how these employment densities are used in the land use converter tool.

2.1 METHODOLOGY

The employment density refers to the number of square feet of building space (or other special unit such as acres, enrollment, or hospital beds) per employee for a given land use type. When only the building size and land use specification are available, the Service Bureau uses the employment density to calculate the number of new employees generated by a development. The current work was to update the current densities used by the SANDAG Service Bureau, which were derived in 2012.

Datasets

The employment density datasets used in this analysis are shown in Table 1. These are further described below:

- The employment data is a point layer showing the location of each business from the California Employment Development Department (EDD). The analysis only includes businesses with reported employment for quarter three (Q3) of 2019.

- The land use file is a polygon layer of each subparcel in San Diego County with its associated land use code. Subparcel is the smallest unit of land in which the land use codes are unique.

- The CoStar dataset is a point layer which provides locations of buildings (or floors) and the rentable building area (RBA) of each unit. RBA refers to the usable building area and its associated share of the common areas in square feet. It is the space the tenant will occupy in addition to the associated common areas of the building such as the lobby, hallways, bathrooms, equipment rooms, etc.

- The building outlines file is a polygon layer file showing the outline of the building shapes. The corresponding area derived from this dataset is the ground area in square feet of the building footprint and does not reflect the floor area of a multistory building.

- The school's geographic dataset is a point layer with the location of K-12 public and private schools. The analysis merges school enrollment data obtained from the National

Center for Education Statistics (NCES) for the 2019 school year to the geographic location using the County-District-School administration code.

- The college's geographic dataset is a point layer with the location of colleges, universities, and vocational schools with the Integrated Postsecondary Education Data System (IPEDS) ID of each institution. The analysis merges the IPEDS enrollment statistics for the fall of 2019 to the school location using the IPEDS ID.

TABLE 1: EMPLOYMENT DENSITY DATASETS

DATASET	SOURCE	TYPE	USE
CA EDD	SANDAG	Spatial Point	2019 Quarter 3 Employment
Land use Parcel	SANDAG	Spatial Polygon	Parcel Level Land Use and Shape
CoStar	CoStar	Spatial Point	Building Area
Building Outline	SANGIS	Spatial Polygon	Building Footprint Area
Colleges	SANGIS	Spatial Point	College Location
Schools	SANGIS	Spatial Point	School Location
K-12 Enrollment	NCES	CSV	K-12 Enrollment by school
College Enrollment	IPEDS	CSV	College/University Enrollment by School

Square Footage-based Calculations

For land use types using the general 'Square Feet per Employee' density[1], square footage refers to the building area for the associated employment (ideally RBA). These land uses include primarily nonresidential land uses (e.g., industrial, transportation, retail, office, government, education, etc.) and some nonstandard residential uses (e.g. dormitories, military barracks, hotels and resorts).

The procedure to calculate the densities is as follows:

1. Merge CoStar data to land use polygons.

2. Group by subparcel (unique ID) to determine total 'RBA' sum in each subparcel.

3. Intersect building outline data to subparcel and sum building floor area by subparcel.

4. Merge these two datasets so each subparcel contains both 'RBA' area and building outline area.

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[1] Densities are presented in SF/employee for readability. Note the client land use input form accepts project KSF for readability and the conversion is done internally when calculating project employment.

5. Merge employment EDD data to subparcel and sum 2019 Q3 employment by subparcel. The EDD data were provided by SANDAG to ensure that any prior cleaning and data processing of these data were included.

6. Filter only records for subparcels with nonzero Q3 employment.

7. Calculate the density using the CoStar RBA/employment in each parcel where the CoStar RBA is available, otherwise use the building outline area as the numerator.

$$density = \frac{Building\ Square\ Footage}{Total\ Employees}$$

8. For each land use type perform an outlier analysis:

    a. First, an outlier analysis based on total number of employees in each parcel drops records below the 10th and above the 90th percentile for total employees.

    b. Then, an outlier analysis based on the adjusted box-plot methodology as described by Hubert and Vandervieren[2] is applied on the employment densities.

The above steps resulted in a density dataset called "CoStar + Building." A second calculation of densities repeated the above steps but using only parcels with existing CoStar data. This resulted in a second density dataset called "CoStar Only." For each land use type, the final analysis chose a density either from the "CoStar + Building" dataset or the "CoStar Only" dataset depending on the number of parcels captured in either dataset and the comparison to the 2012 SANDAG density calculation. The final employment densities for land use data using the square feet metric is provided in Appendix A.

Acreage-based Calculations

Several land use types are acreage-based, since these involve larger land uses with fewer employees. For example, these land uses include tourist attractions, parks, golf courses, marinas, beaches, and vineyards. For these land use types using acres instead of building area as the numerator for the density calculation is calculated as follows:

$$density = \frac{Parcel\ Acres}{Total\ Employees}$$

The acre per employee calculations applied the same outlier analyses used for the square feet/employee calculations.

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[2] M. Hubert, E. Vandervieren, *An adjusted boxplot for skewed distributions, Computational Statistics & Data Analysis,* Volume 52, Issue 12, 2008, Pages 5186-5201, ISSN 0167-9473, https://doi.org/10.1016/j.csda.2007.11.008.

City of San Diego Densities

The City of San Diego also has existing densities specific within the city jurisdiction. To update these densities, the original values were adjusted according to the same factor of adjustment between the 2012 and 2019 densities for the county of the parent land use type.

Nonstandard Use Calculations

Several land use codes use a nonstandard measurement for density. These land use types are shown in Table 2. In these cases, there may be more than one appropriate density. The recommended value 1-3 lists the priority of these densities.

TABLE 2: NONSTANDARD EMPLOYMENT DENSITY

LAND USE TYPE	DESCRIPTION	RECOMMENDED VALUE NO. 1	RECOMMENDED VALUE NO. 2	RECOMMENDED VALUE NO. 3
1401	Jail/Prison	4.69 beds/employee	108 s.f./employee	
1403	Military Barracks	7.92 beds/employee		
1409	Other Group Quarters Facility	1.08 beds/employee		
4101	Commercial Airport	25,500 enplanements/ employee		
4120	Marine Terminal	.14 berths/employee		
5008	Service Station	1.29 pumps/ employee	188.68 s.f./employee	
6501	UCSD/VA Hospital/ Balboa Hospital	(rooms)	393 s.f./employee	0.17 beds/employee
6502	Hospital - General	(rooms)	393 s.f./employee	0.17 beds/employee
7207	Marina	8.87 berths/employee		
7210	Other Recreation	46.64 seats/ employee	0.09 screens/ employee	680 s.f./employee

VRPA reviewed and recommended that service stations, hospitals, and other recreation land use types (land use codes 5008, 6501, 6502, and 7210) use density values from the Institute of Transportation Engineers trip generation reports.

Group quarters (land use codes 1401, 1403, and 1409) densities used existing group quarter population data (assumed to be equal to the number of beds) and total adjusted employment by Master Geographic Reference Area (MGRA) file (as provided by SANDAG). The Application Tool also assumes a 100% occupancy rate for group quarters beds.

For commercial airports (land use code 4101), enplanements per employee density used 2016 land use data for the San Diego International Airport (total employment in the MGRA and number of enplanements). For marine terminals (land use code 4120), the berths/employee calculation used the EDD data for parcels of this land use type and number of berths reported at the Tenth Avenue and National City marine terminals. For marinas (land use code 7207), the berths per employee calculation used adjusted employment for MGRAs of this land use type and reported berths as provided by SANDAG. RSG conducted an outlier analysis on this dataset by first removing all zero employment and zero berth records, then applying the same outlier analysis as described in section 2.1.

For schools, the employment density uses reported enrollment.

$$density = \frac{Total\ Enrollment}{Total\ Employees}$$

The density calculation uses enrollment statistics obtained for schools and colleges through the NCES datasets for both public and private K-12 schools, college enrollment data obtained through NCES's IPEDS, and the geographic layer for schools and colleges obtained through the SANGIS warehouse. First, the calculation appends enrollment data to the geographic location of each institution. Then, the calculation uses only education employment from the CA EDD data (filtered by North American Industry Classification System [NAICS] code) and the enrollment in education related parcels (by land use code) for the final density. Table 3 shows these densities.

TABLE 3: SCHOOL EMPLOYMENT DENSITY

LAND USE TYPE	DESCRIPTION	DENSITY (ENROLLMENT/EMPLOYEE)
6801	SDSU/CSU San Marcos/UCSD	50
6802	Other University or College	250
6803	Junior College	150
6804	Senior High School	650
6805	Junior High School or Middle School	700
6806	Elementary School	700
6809	Other School	650
6891	City of San Diego SDSU/CSU San Marcos/UCSD	5
6892	City of San Diego Other University or College	45
6893	City of San Diego Junior College	13
6894	City of San Diego Senior High School	10
6895	City of San Diego Junior High School or Middle School	10
6896	City of San Diego Elementary School	8
6899	City of San Diego Other School	4

2.2 UPDATED DENSITIES

RSG compared the newly generated values of employment density from square footage to the 2012 values provided by SANDAG. This comparison yielded a recommendation for each land use type between the 2012 value for density, the new "CoStar + Buildings" density or the "CoStar Only" density. Each recommendation accounted for land use type, number of observations in each category, and change in value from the SANDAG 2012 value. Appendix A shows these results. Appendix B shows the updated densities for land use types whose employment is associated with total land acres.

2.3 COMPARISON TO SCAG DENSITY

As an added check for reasonableness, RSG also compared the new densities with SCAG employment densities from the 2001 employment density study summary report (Table 4).[3] This

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[3] Southern California Association of Governments, Employment Density Study Summary Report, 2001.,tables II-A and II-B.

comparison required a re-calculation of the employment densities to better follow the methodology used by the SCAG calculation. The re-calculation preserves the employment and square footage data from the original analysis including the outlier analyses. RSG recalculated the land use codes to be re-grouped into the nine land use categories used in the SCAG analysis, and then computed the weighted average and total average of density in each of the nine categories. Note that the SANDAG regional weighted average falls more in line with the regional average used in the SCAG density methodology.

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https://docplayer.net/30300085-Employment-density-study-summary-report-october-31-prepared-for-southern-california-association-of-governments.html

TABLE 4: COMPARISON OF SANDAG DENSITY TO SCAG DENSITY

REGION		RETAIL	OTHER RETAIL/ SERVICES	LOW-RISE OFFICE	HIGH-RISE OFFICE	HOTEL/ MOTEL	LIGHT MFG.	HEAVY MFG.	WARE-HOUSE	GOVT. OFFICES
SANDAG (2019)	Regional (Weighted Avg.)	561	388	334	351	1,128	483	153	898	380
SCAG Density (Avg.)	Regional	857	344	288	311	1,152	344	439	814	261
	Los Angeles		424	319	440		1,796	829	1,518	1,442
	Orange	704	325	287	218		466	558	979	206
	San Bernardino	1,009	124	697		2,544	834	705	1,195	188
	Riverside	268	629	481		3,476	867	1,548	581	208
	Ventura	1,165	271	389			269	189	131	94
SCAG Density (Median)	Regional	1,023	585	466	300	1,804	527	924	1,225	672
	Los Angeles		730	471	377	1,179	1,717	1,214	1,518	2,182
	Orange	2,322	450	352	235		511	786	1,350	408
	San Bernardino	1,392	432	1,014		1,747	1,833	1,538	2,111	851
	Riverside	165	1,148	598		5,273	1,121	2,221	819	1,475
	Ventura	990	412	659			277	202	149	120

3.0 ABM2+ APPLICATION TOOL

The ABM2+ Application Tool automates the steps to convert the land use data to the format of the ABM2+ model. This also produces consistent and efficient outputs for the client to ensure the quality of the model setup. This process uses the employment densities defined in Chapter 2.0 to calculate new employment associated with the project. Other land use data is also updated including group quarters, enrollment, hotel rooms, and open space acres/beaches. Figure 1, Figure 2 and Figure 3 shows the workflow for this tool for Tasks 1-5, 6, and 7-10, respectively. All scripts within the ABM2+ Application Tool were converted to python for consistency.

FIGURE 1: ABM2+ APPLICATION TOOL WORKFLOW – TASKS 1-5
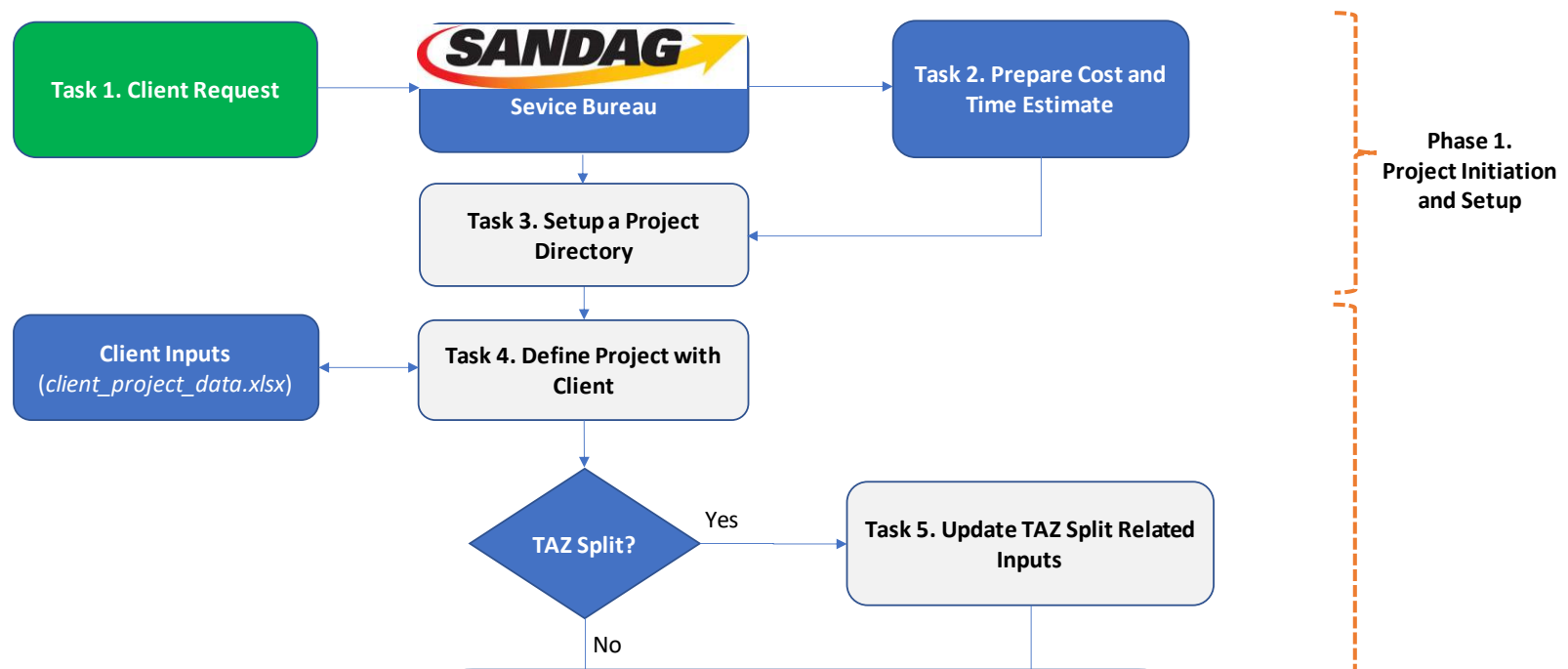
FIGURE 2: ABM2+ APPLICATION TOOL WORKFLOW – TASK 6
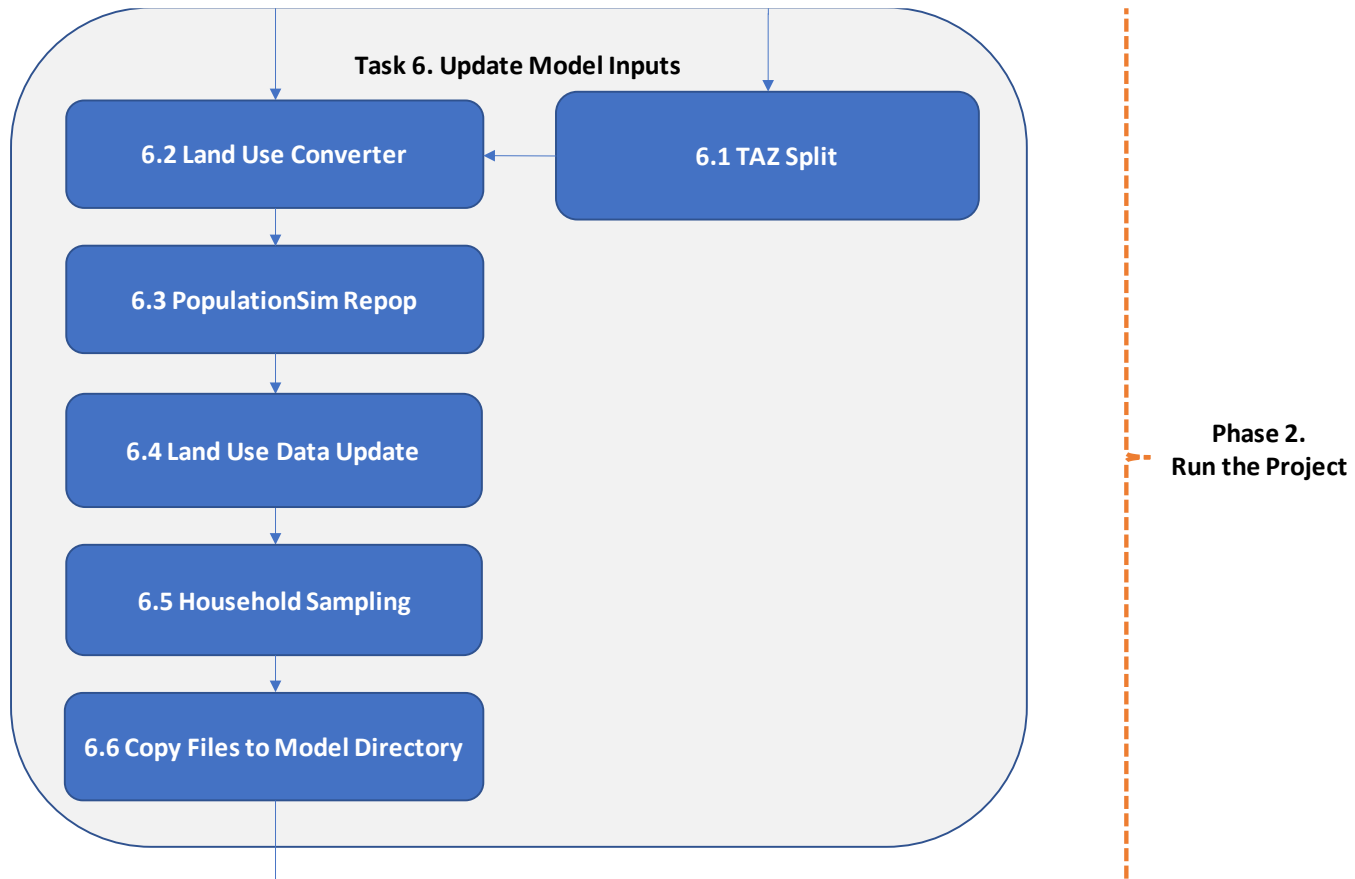
FIGURE 3: ABM2+ APPLICATION TOOL WORKFLOW – TASKS 7-10
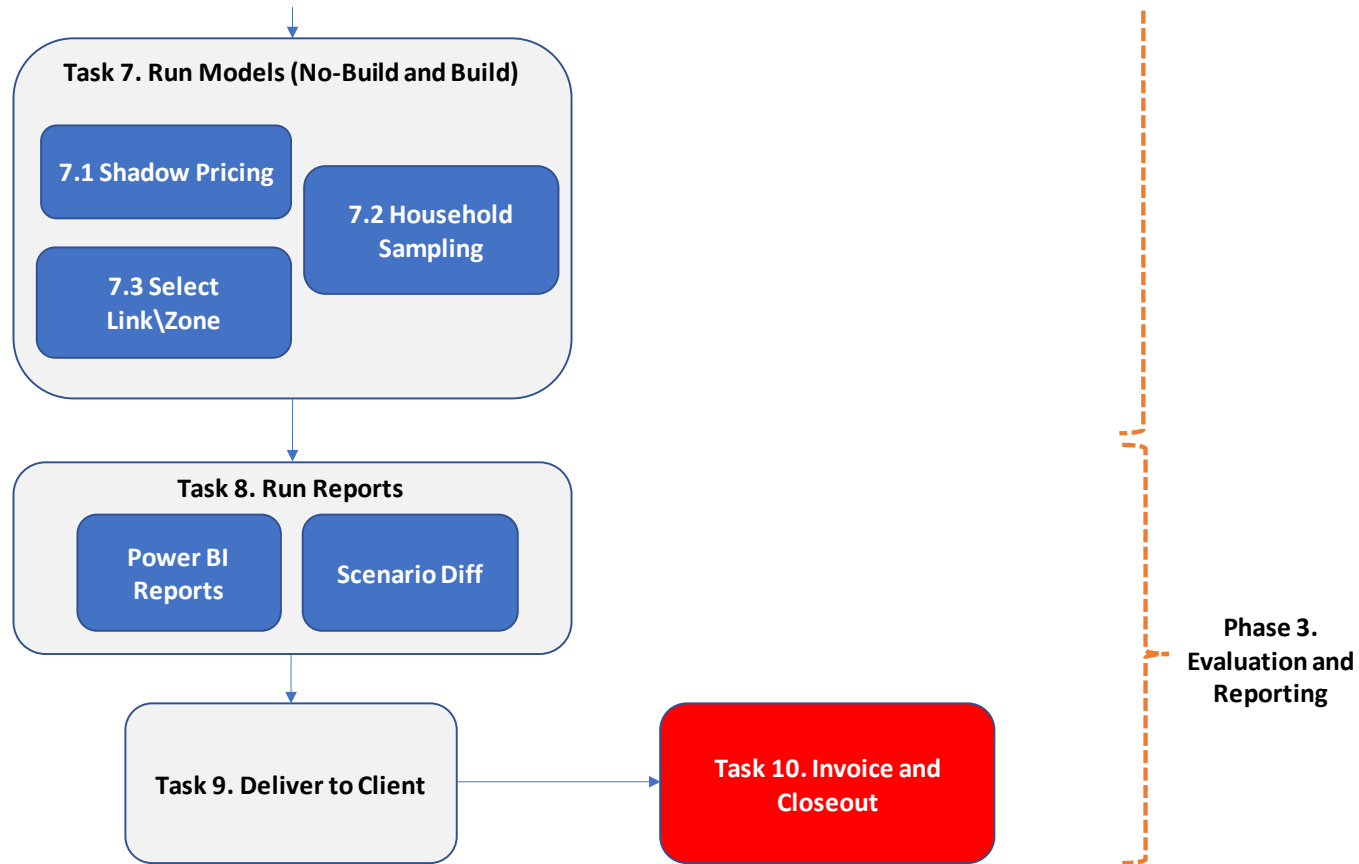
3.1 CLIENT LAND--USE FORM

Figure 4 shows a template of the client land--use form (sheet 'Project_Data'). The client fills this form with as much information about the project as possible.

FIGURE 4: CLIENT LAND--USE FORM FOR ABM2+ APPLICATION TOOL

The first column "lu_code" lists all available land use codes with a brief description under column "LU Description." The spreadsheet contains a sheet 'Land Use Descriptions' that includes a more detailed description of each land use code. The sheet 'README' provides information on the rest of the columns in the form. The "MGRA" column is for the ID of the MGRA where the project will be. "Dwelling Unit" represents the total number of housing structures for the project and is only applicable for housing related land uses. If the project includes affordable housing, column "Share Affordable" indicates the decimal share of multi-family housing that will be affordable (e.g., fill the column with '0.2' for a 20% share of affordable housing). The column "Acre" indicates the land acres in the MGRA which applies to that land use. If the client is unsure of the acreage and wants to use the entire MGRA, simply fill the column with "MGRA," which prompts the tool to use the total geographic acreage of the MGRA polygon. The column "Employees" should be used if the client knows the number of employees expected for a given project. Leave this column blank if the number is unknown and the tool uses the employment densities instead. The column "Thousand Square Feet (KSF)" indicates the kilo-square footage of the project building(s) in the indicated MGRA.

The column "Hotel Rooms" indicates the number of new hotel rooms to be added in the project. Hotel rooms can be separated into five types: budget, economy, luxury, midprice, and upscale. To allocate the total hotel rooms to each hotel room type, the tool uses a precalculated share based on the 2016 land use totals in each hotel land use type. The client land use form keeps these shares on the tab "HotelRoomShare" and uses these values by default. Figure 5 shows the default hotel room shares. If the client wishes to adjust the shares, they may do so directly in this tab.

FIGURE 5: HOTEL ROOM SHARES

	A	B	C	D	E	F	G	H	
1	lu_code	DESC	budgetroom	economyroom	luxuryroom	midpriceroom	upscaleroom	hotelroomtotal	
2	1501	Hotel / Motel (Low Rise)	0.14	0.16	0.09	0.42	0.19	1	
3	1502	Hotel / Motel (High Rise)	-	0.01	0.60	0.03	0.35	1	
4	1503	Resort	-	0.01	0.74	0.07	0.18	1	
5									

HotelRoomShare | Land Use Descriptions (+)

Ready — Accessibility: Investigate — Display Settings

The column "Beds" refers to beds in group quarters facilities or beds in hospitals. For group quarters, the number of beds will directly become the project's noninstitutional group quarter population as the tool assumes a 100% occupancy rate. If specifying hospital beds, the tool uses the number of beds to determine the number of employees. The column "Students" refers to number of enrolled students in school land uses. The remaining columns ("Pumps," "Spaces," "Seats," "Screens," "Enplanement," "Berths") are for nonstandard densities which Table 2 describes.

To complete this form, the client shall, for all applicable land use types for the project, complete the MGRA(s) of the project and enter information in applicable columns. If multiple MGRAs use the same land use code, copy that land use code row, and add a new line so that each applicable MGRA has a line for each land use code. A few notes to keep in mind while completing the form:

- Cells in grey are not applicable; data should not be entered in these cells.

- For readability, rows without data may be deleted but it is not necessary.

- After entering data, check the sheet "Project Summary" to review project level totals by data type (columns in the form) and verify that the project summary is consistent with the project specifications.

3.2 TAZ SPLIT

In the case of a TAZ split for a given project, SANDAG shall update the necessary files in the project directory under the "network_build" folder according to SANDAG procedures. If there is a TAZ split, the tool expects the files listed below:

- MGRA to TAZ crosswalk ("mgra_zone.csv") under the directory "network_build\data." The file shall have two columns: MGRA, TAZ.

- Network files (highway, active transportation, and transit) under a user-specified directory within "network_build".

- Zone centroids ("tazcentroids_cvm.csv") under a user-specified directory within "network_build." The file shall have five columns: TAZ, x_coord_spft, y_coord_sqft, x_coord_albers, y_coord_albers.

- Zone-to-jurisdiction and CPA crosswalk ("zone_jur.csv") under a user-specified directory under "network_build."

3.3 MODEL INPUTS

The model inputs are defined by five steps: changes to zones and networks, land use converter, PopulationSim repop, land use data update, and household sampling. The first step for TAZ splits is optional and can be skipped if no changes to the zone system are required. These five steps are described in more detail below.

Changes to Zones or Networks

First, the tool checks for the existence of the "network_build\data\mgra_zone.csv" file. This file should include the internal MGRA to TAZ correspondences in the new schema. External zones (1-12) should not be included. If it exists, the TAZ split step uses a python script to update relevant inputs and utility expression calculators (UECs) for the new TAZ(s) as shown in Table 5. These files are saved in the "1_taz_split\outputs" directory so they can later be copied to the build directory during the last step. New network files (highway, transit, and active transportation) and the zone centroid file from the network build folder are also copied to the "input_updates\1_taz_split\outputs" directory in place to be copied to the build directory in the last step. If there is no zone split, no files are updated and the MGRA to TAZ crosswalk remains the same.

TABLE 5: TAZ SPLIT SETTINGS DESCRIPTION

FILE	UPDATE
conf\sandag_abm.properties	Update the setting "zone.count" with new zone count.
conf\cvm.properties	Update the setting "EndZone" with new zone count.
uec\CrossBorderDestinationChoiceSoaAlternatives{year}.csv	Update to include new zones. Add alternatives for new zone(s) using the same values that exist for the original zone that is split. Here, year = 2020,2025,2035,2050.
uec\SoaTazDistAlts.csv	Update to add alternatives for new zones.
uec\TourDcSoaDistanceAlts.csv	Update to add alternatives for new zones.
input\zone.term	Update only if the split TAZ has a zone terminal time. New TAZ is added with the same terminal time as the split TAZ.
Input\tazcentroids_cvm.csv	New TAZ centroid is assumed to be the same as the parent TAZ it was split from.

Land use Converter

The land use converter tool uses several static inputs prepared by SANDAG and RSG as well as the client land use form described in the previous section.

Static Inputs

A spreadsheet in the land use converter inputs ("input_updates\2_landuse_converter\inputs") called "LandUseUnitTypes.xlsx" contains static inputs the land use converter uses. Table 6 describes the information contained in this spreadsheet.

TABLE 6: LAND USE CONVERTER STATIC INPUTS

INPUT DATA	SHEET NAME	DESCRIPTION
Employment Densities	Densities	Employment densities as calculated in Chapter 2.0
Density Priorities	Unit Type Correlation	Priority order of densities to be used for each land use type
Employment Shares by Subtype	Allocation	Allocation of employment by subtype
Land use Correspondences	LU Correspondence	Corresponding land uses for land use input columns

Employment Densities

Figure 6 shows the 'Densities' tab in the "LandUseUnitTypes.xlsx" spreadsheet. This sheet contains all available densities for each land use type under the appropriate column.

FIGURE 6: DENSITIES TAB

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	lu_code	description	Dwelling Unit	Beds	SqFt	Acre	Hotel Roo	Students	Pumps	Spaces	Seats	Screens	Enplanem	Berths
2	1401	Jail/Prison		4.69	100									
3	1402	Dormitory			50									
4	1403	Military Barracks		7.91741276	9100									
5	1404	Monastery			1150									
6	1409	Other Group Quarters Facility		1.07695358	600									
7	1410	Retirement/Senior Citizen Housing			700									
8	1411	Congregate Care Facility			250									
9	1499	Group Quarters			350									
10	1501	Hotel (Low-Rise)			1600									
11	1502	Hotel (High-Rise)			1550									
12	1503	Resort			700									
13	1504	Motel			1650									
14	1592	Hotel (High-Rise)			1500									
15	1599	Hotel/Motel			1450									
16	2001	Heavy Industry			300									
17	2091	Heavy Industry			200									
18	2101	Industrial Park			600									
19	2103	Light Industry - General			700									
20	2104	Warehousing			1250									
21	2105	Public Storage			22900									

Unit Type Correlation | **Densities** | Allocation | LU Correspondence | ⊕

Density Priorities

Figure 7 shows the "Unit Type Correlation Tab." This tab lists each land use type and the priority in which the tool uses each density if multiple ones are available. A value of 99 indicates the density is not available, and values one through three indicate the priority of use. For example, the land use code 7293 "Racetrack" has a density based on the acreage of the project and the square footage of the project. The acre density has a priority of one and the square footage has a priority of two. If the client inputs both acreage and square footage in the client land use form for the project, the tool will only use the acre density since it has higher priority. If one or the other is specified, the tool uses the available density.

FIGURE 7: UNIT TYPE CORRELATION TAB

	A	B	C	D	E	F	G	H	I	J	K
1	lu_code	TM Description	Dwelling Unit	Beds	Thousand Square Feet (KSF)	Hotel Rooms	Students	Acre	Pumps	Spaces	Seats
176	7291	Other Recreation - Low	99	99	1	99	99	99	99	99	99
177	7293	Racetrack	99	99	2	99	99	1	99	99	99
178	7294	Golf Course	99	99	2	99	99	1	99	99	99
179	7601	Park - Active	99	99	99	99	99	1	99	99	99
180	7603	Open Space Park or Preserve	99	99	99	99	99	1	99	99	99
181	7604	Beach - Active	99	99	99	99	99	1	99	99	99
182	7606	Landscape Open Space	99	99	99	99	99	1	99	99	99
183	7607	Residential Recreation	99	99	99	99	99	1	99	99	99
184	7609	Undevelopable Natural Area	99	99	99	99	99	1	99	99	99
185	7691	Park - Active	99	99	2	99	99	1	99	99	99
186	7693	Open Space Park or Preserve	99	99	2	99	99	1	99	99	99
187	7696	Landscape Open Space	99	99	2	99	99	1	99	99	99
188	7697	Residential Recreation	99	99	2	99	99	1	99	99	99
189	8001	Orchard or Vineyard	99	99	99	99	99	1	99	99	99
190	8002	Intensive Agriculture	99	99	99	99	99	1	99	99	99

Unit Type Correlation | Densities | Allocation | LU Correspondence | ⊕

Employment Shares by Subtype

Figure 8 shows the "Allocation" tab which stores the share of employment by subtype for each land use category. The employment densities estimate the total employment associated with the project, but the land use input file requires individual employment categories. The allocation saved the share of each employment type associated with each land use. The tool distributes the total employment into these categories according to their shares. For example, land use code 1401 Jail/Prison has three employment categories: emp_fed_non_mil, emp_prof_bus_svcs, and emp_state_local_gov_blue (Figure 8). According to the allocation listed in the sheet under "value_per_unit," the tool categorizes 80% of the employment to be "emp_state_local_gov_blue" and 10% to each of the other employment categories. The tool verifies that the total employment after allocation matches the input totals.

FIGURE 8: ALLOCATION TAB

lu_type_id	lu_code	abm_category	value_per_unit
3	1401	emp_fed_non_mil	0.1
3	1401	emp_prof_bus_svcs	0.1
3	1401	emp_state_local_gov_blue	0.8
3	1402	emp_public_ed	0.5
3	1402	emp_pvt_ed_post_k12_oth	0.5
3	1403	emp_fed_mil	1
3	4102	emp_fed_mil	1
3	6701	emp_fed_mil	1
3	6702	emp_fed_mil	1
3	6703	emp_fed_mil	1
3	6799	emp_fed_mil	1
3	1404	emp_own_occ_dwell_mgmt	0.5
3	1404	emp_pvt_hh	0.5
3	1409	emp_health	1
3	1410	emp_fed_non_mil	0.1
3	1410	emp_prof_bus_svcs	0.1
3	1410	emp_state_local_gov_blue	0.8
3	1411	emp_fed_non_mil	0.1

Unit Type Correlation | Densities | **Allocation** | LU Correspondence

Land use Correspondences

Figure 9 shows the "LU Correspondence" tab which keeps lists of land use codes that are applicable for different land use columns. These lists do not allow certain land use headings to be put in the wrong columns as an extra check on the client land use form. For example, in the land use input file the column "parkactive" represents the acres of active parks[4]. If the project includes acres of active park, the client should specify number of acres under either land use 7601 or 7691 (Park – Active, City of San Diego Park – Active) otherwise the tool will not recognize the acreage as being active park and the land use input file will not be updated with the new active parks.

FIGURE 9: LU CORRESPONDENCES TAB

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	parkactive_lu	openspaceparkpreserve_lu	beachactive_lu	hotel_lu	sf_lu	mf_lu	mh_lu	k8	hsch	coll	oth_coll	adlt_enrl	zeroden_lu	gq_civ_lu	gq_mil_lu
2	7601	7603	7604	1501	101	102	103	6806	6804	6801	6802	6809	4112	1401	1403
3	7691	7693		1502				6805	6894	6891	6803	6899	4117	1402	
4				1503					6896		6893		4118	1409	
5				1504					6895		6892			1404	
6				1592										1499	
7				1599										1410	
8														1411	
9															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															

Unit Type Correlation | Densities | Allocation | **LU Correspondence**

Methodology

Table 7 lists the user settings for the land use converter step. The override Booleans indicate how the land use should be updated. The "OVERRIDE_HH" setting if set to YES will delete existing households (and group quarters) in the project MGRA and add the new ones. If this is set to NO, the project households (and group quarters) will be added to the existing ones in the MGRA. Similarly, "OVERRIDE_EMP" will either erase the existing employment and replace it with the new project employment or add the new employment to the existing employment. "OVERRIDE_LU" applies the same concept to all other land use updates such as hotels, enrollment, and active park/beach/openspace acres. This step also calculates new household and employment accessibilities using the same methodology as the 4D tool which finds nearby MGRAs within a buffer distance and calculates the household and employment accessibility by summing the total amount of households/employment for MGRAs within the buffer and dividing by total acres of MGRAs in the buffer. The "BUFFER" variable in the land use converter step is

---

[4] https://github.com/SANDAG/ABM/wiki/input-files#master-geographic-reference-areas-inputs

the buffer distance used to find nearby MGRAs. This setting should not be updated unless the 4D tool is also updated.

TABLE 7: LAND USE CONVERTER SETTINGS

SETTING	TYPE	DEFAULT VALUE	DESCRIPTION
REQUIRED			
OVERRIDE_HH	YES/NO	YES	Indicates whether new households should override (YES) or append (NO) the existing households in the project MGRA(s).
OVERRIDE_EMP	YES/NO	YES	Indicates whether new employment should override (YES) or append (NO) the existing employment in the project MGRA(s).
OVERRIDE_LU	YES/NO	YES	Indicates whether new land use data should override (YES) or append (NO) the existing land use data in the project MGRA(s). Here, the land use data include hotels, open space acres, and school enrollment.
OPTIONAL			
BUFFER	Float	0.65	Buffer distance in miles for selecting households and employment for density.

The land use converter updates the land use input file with all the categories available in the client land use form. If the client specifies "employees" associated with the project, this value is always taken as the number of new employees. If this value is not specified, the tool then uses the densities to calculate new employment. The list below describes the steps in the methodology:

1. Cross reference the available project data, the available densities, and the density priorities.

2. Choose the highest priority density which is available.

3. Calculate the total new employment for the project using that density.

4. Calculate the share of employment in subcategories using the employment shares by subtype allocation.

5. Update the MGRA land use input file by either adding the employment to the existing values or erasing existing employment and replacing it with the new employment.

Housing

The tool updates the number of dwelling units directly from the client land use form. To determine the occupancy rate and the number of households resulting from the dwelling units, the tool calculates the existing occupancy rate in the no-build land use data for either single family or multi-family housing in the same CPA as the project and applies it to the total number of single family or multi-family dwelling units. The tool applies an occupancy rate of 100% for mobile home units and group quarter beds.

Housing inherently produces some employment for home-based businesses and telecommuters. A total of 605 MGRAs are designated as household only land use types, which means the parcels contained inside the MGRA are only residential land uses (excluding roadways and other infrastructure). RSG tagged these MGRAs in the input MGRA shape file so the tool can determine the number of employees associated with these new households. The tool groups the household only MGRAs and uses the no-build input land use file to determine a dwelling unit per employee density in the pseudomsa of the project. Figure 10 shows the pseudomsa boundaries in San Diego County. If there are not any household only MGRAs in the project pseudomsa, then the tool uses a regional density. The allocation by subemployment type is also calculated from these 605 MGRAs using the no-build land use input file. The logfile prints out a message showing the total number of employees which came directly from the household units.

Enrollment

School employment densities use enrollment or number of students so the client must specify the expected enrollment of a school related project. To update the individual enrollment by grade level, the tool updates the appropriate enrollment specified by the land use codes in the "LU Correspondences" tab shown in Figure 9.

FIGURE 10: PSEUDOMSA BOUNDARIES
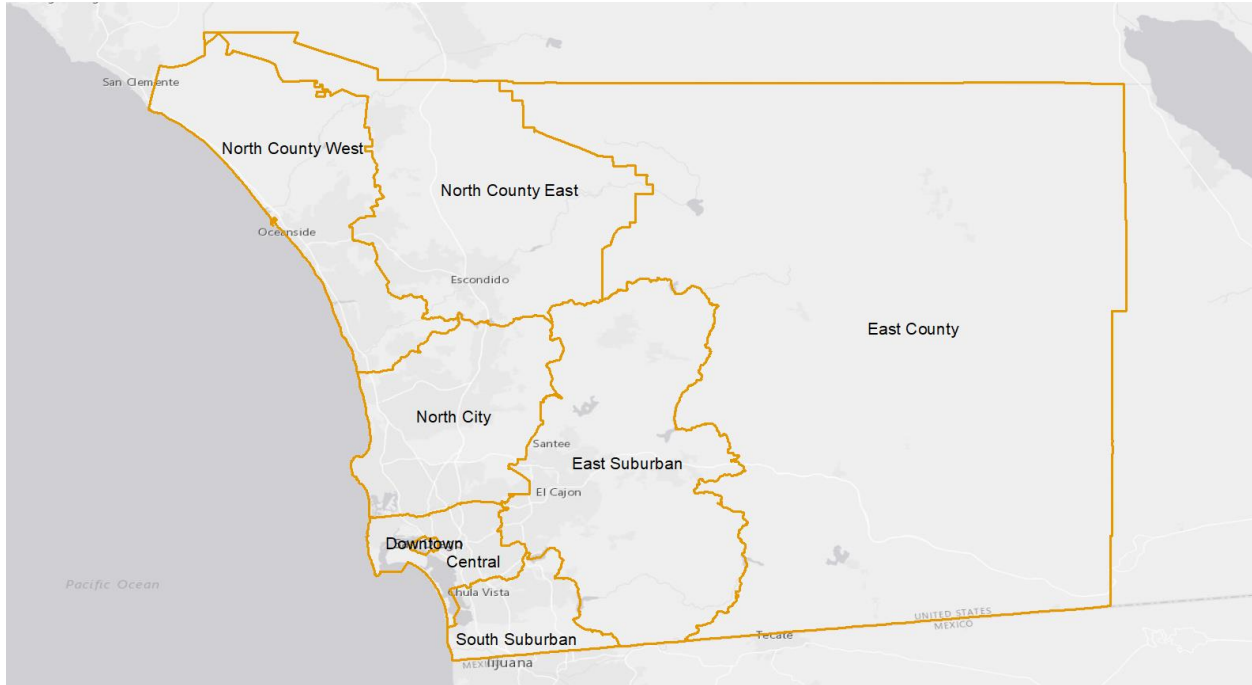
Open Space Acres

To update open space data (active park, active beach, open space/park/preserve), the tool updates the appropriate column specified by the land use codes in the "LU Correspondences" tab shown in Figure 9 with the acreage in the client land use form.

Once the tool runs, a new land use input file is saved under the folder "input_updates\2_landuse_converter\outputs" which includes the project households, employment, enrollment, open space acres, and hotels. For QA/QC purposes, the user should open the HTML file called "input_updates\2_landuse_converter\outputs\landuse_updates.html" that presents a tabular and spatial summary of the changes in the MGRA land use file due to addition of the project.

The HTML file contains two tabs:

- First tab (Land use Data) shows three tables: initial land use, final land use, and change in land use as shown in Figure 11. These tabular summaries are useful to verify project level changes in the land use file.

FIGURE 11: LAND USE CONVERTER – HTML FILE (LAND USE DATA TAB)

- The second tab (Map) shows a spatial map of the project changes at MGRA level, see Figure 12. The user may hover the mouse over the layer icon in the top right corner and select single or multiple layers to draw. Note that only project-specific layers are available. For example, the layers 'households' and 'household density' are available only if the project involves a housing development.

FIGURE 12: LAND USE CONVERTER – HTML FILE (MAP TAB)
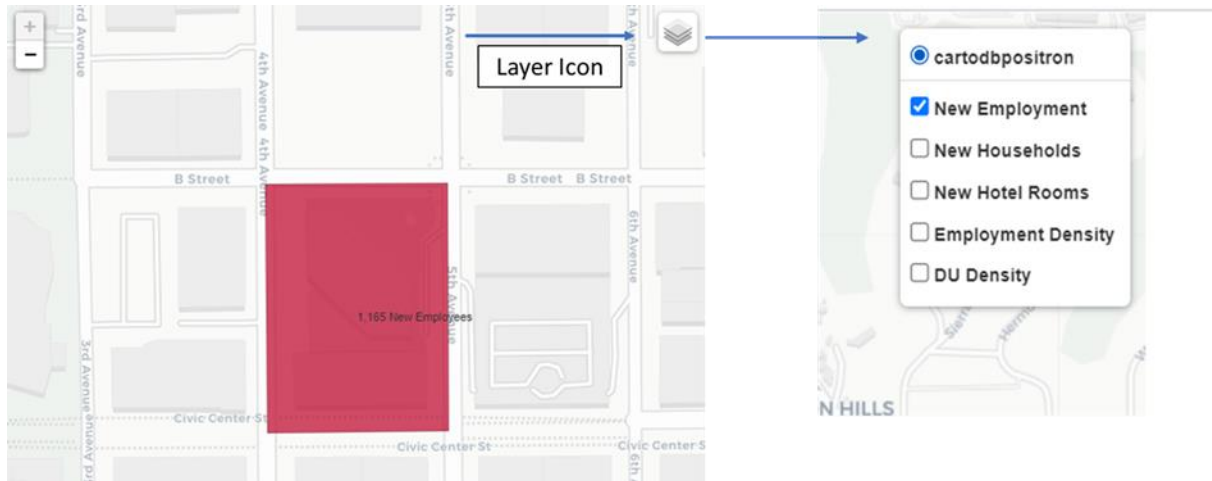
Additionally, the tool creates the files "input_updates\2_landuse_converter\outputs\tmp\has_hh(gq).txt" if the project includes households or group quarters. These files become flags for the tool which indicate if other household or group quarter updates are needed.

Geographic Crosswalk

In the case of a TAZ split, the tool uses the updated MGRA to TAZ correspondence in the input land use file. The user must place this file in the folder where the 'mgra_zone.csv' file from the

TAZ split is stored. If this file does not exist, the tool simply keeps the same correspondence as the no-build scenario.

PopulationSim Repop

The tool uses PopulationSim software to re-estimate the household and group quarter populations based on the added units from the project. Typically, this software requires a set of controls created from Census data and a seed population from the ACS PUMS datasets. However, in this case we use the existing population in the model setup as the seed and control population. The 'repop' feature allows for adjustments only to be made within the project MGRAs such that there are no demographic changes outside the project boundaries. This ensures comparability between the build and no-build scenarios outside of the project. If no households or group quarters are included in the project, the tool skips this step.

Create Geographic Crosswalk

PopulationSim requires a geographic crosswalk file which includes the correspondence between the MGRA and TAZ and Public Use Microdata Area (PUMA) geographies. In case of a TAZ split, the land use input file is updated in the step "2_landuse_converter" to include the new correspondence. If there is no split, the correspondence is the same. Therefore, the crosswalk step always uses the output of the "2_landuse_converter" as the new crosswalk from MGRA to TAZ. Since the PUMA geographies are not affected, the TAZ to PUMA crosswalk is a static input. The TAZ to PUMA crosswalk was generated using the geopandas library. The representative point of each TAZ was intersected with the PUMA layer to create a single crosswalk from each TAZ to one PUMA geography. In the case of a TAZ split, the parent TAZ crosswalk is used for the new TAZs.

Build Pipeline File

The repop feature of PopulationSim usually requires a full run of the PopulationSim software, which creates a pipeline file to store data in various stages of the process so that the repop feature can pick up in the middle of the process. Since the existing population is used as the seed population, the Application Tool creates a dummy pipeline file for the repop feature to use. A skeleton pipeline file was generated by taking an existing pipeline file and emptying the dataframes stored within it. These skeleton files are saved in the Application Tool setup under the "input_updates\3_synthetic_population\Data\pipeline_templates." The skeleton pipelines ensure the formatting remains consistent and if the PopulationSim step is run multiple times, it will start from a fresh pipeline each time.

The pipeline requires a geographic crosswalk, household, and person files. The geographic crosswalk is created in the previous step. The household and person files are taken directly from the no-build model directory and loaded into the pipeline.

Build Controls

For the project, controls must be set for the new population to match the allocation of different household and person attributes. Table 8 shows the user settings for the PopSim step which the tool uses to build controls. The override settings from the "2_landuse_converter" step are preserved in the PopSim step, such that if households are overridden, PopSim removes all population in the project MGRAs and adds the new one, otherwise, existing population is left untouched and the new project households are added on top.

TABLE 8: POPSIM USER SETTINGS

SETTING	TYPE	DEFAULT VALUE	DESCRIPTION
OPTIONAL			
THRESH_HH	Integer	50	Minimum number of households needed to develop controls for a given household type. Applicable only when corresponding MGRA list is empty.
THRESH_TAZ	Integer	5	Minimum number of TAZs needed to develop controls for a given household type. Applicable only when corresponding MGRA list is empty.
MGRA_SF	List	[]	MGRA(s) from which to develop controls for Single Family housing population. If empty ([]), default geographic search is used.
MGRA_MF	List	[]	MGRA(s) from which to develop controls for multi-family housing population. If empty ([]), default geographic search is used.
MGRA_MH	List	[]	MGRA(s) from which to develop controls for Mobile Homes population. If empty ([]), default geographic search is used.
MGRA_GQ	List	[]	MGRA(s) from which to develop controls for Group Quarters population. If empty, default geographic search is used.
MGRA_AF	List	[]	MGRAs from which to develop controls for Affordable Housing population. Presently, all affordable housing is assumed to be Multi-family. If an affordable housing share is specified this list is REQUIRED.

To sample households for attributes the tool provides two options: geographic sampling or sampling from specific MGRAs. The tool executes this sampling for each household type in the project (single family, multi-family, and mobile homes). For geographic sampling, each project MGRA with households searches the existing population within a half mile radius for MGRAs with at least 85% share of matching household types. The user sets a household and TAZ threshold as described in Table 8. If the search does not return a sample that matches these thresholds, the radius of the search is extended by one-quarter mile. This is continued until the thresholds are met. Due to a low incidence of group-quarters and mobile homes, for these household types the sample is always taken at the regional level.

To override the geographic sampling for a household type, the user may use the MGRA list settings shown in Table 8. The tool will then only sample households from the specified MGRAs. This feature is useful if the client has a specific example of what the new households will look like. For affordable housing, a list *must* be provided since the tool is unable to determine which households in the region would qualify as affordable. Only multi-family housing is used for the affordable housing sample.

Once the sample is acquired, the tool creates shares of household attributes within those samples. Table 9 describes the household attributes PopSim controls for at the MGRA level.

TABLE 9: REPOP HOUSEHOLDS CONTROLS

TARGET	DESCRIPTION	SEED TABLE
num_hh	Total number of households	households
hh_size_1	1 person households	households
hh_size_2	2 person households	households
hh_size_3	3 person households	households
hh_size_4	4+ person households	households
hh_wrks_0	0 worker households	households
hh_wrks_1	1 worker households	households
hh_wrks_2	2 worker households	households
hh_wrks_3m	3+ worker households	households
hh_unit_single	Single unit households	households
hh_unit_multi	Multiunit households	households
hh_unit_mobile	Mobile home unit households	households
age_0_5	Persons under 5 years old	persons
age_6_15	Persons between 6 and 15 years old	persons
age_16_17	Persons between 16 and 17 years old	persons
age_18_64	Persons between 18 and 64 years old	persons
age_65p	Persons older than 65 years old	persons

Table 10 describes the group quarter attributes PopSim controls for at the MGRA level.

TABLE 10: REPOP GROUP QUARTER CONTROLS

TARGET	DESCRIPTION	SEED TABLE
num_gq	Total Number of Group Quarter Population	households
age_0_16	GQ population less than 16 years old	persons
age_16_18	GQ population between 16 and 18 years old	persons
age_18_24	GQ population between 18 and 24 years old	persons
age_24p	GQ population greater than 24 years old	persons

Run Repop

The tool kicks off a repop run using the newly created geographic crosswalk, the pipeline file, and the controls. The following steps describe this process:

1. If the project includes households, run repop for households with either append/replace according to the override setting in the land use converter step.

2. If the project includes group quarters, run repop for group quarters with either append/replace according to the override setting in the land use converter step.

3. If the project includes an affordable housing share, run repop for affordable households to replace the multi-family households run in step 1.

4. Recombine all the files to a single household and population file. If any step was not run, the original records are preserved from the no-build scenario.

Final Land use Update

If a new population is generated or population is removed, the tool employs a python script to update the land use file with the new population in each MGRA and the number of households in each of the ten income categories in each MGRA. The tool starts with the land use file which is output from step 2 and updates the relevant columns to reflect the new population. If no changes were made to the population this step automatically moves on.

Household Sampling

The ABM2+ Application Tool is now capable of using geographically-based household sampling. The tool allows the user to specify three different household sampling rates for MGRAs by distance from the project location. This feature allows for oversampling of the project households and households near the project which reduces the simulation variability in the modeling results.

Household Sampling Settings

The user may specify the household sampling setting for the project. Table 11 describes the settings available to the user. The buffer distances represent miles, and the starting point is always the project MGRAs. "SAMPLE1" is the sample rate which will apply to the project and all MGRAs within "BUFFER1" distance of the project. "SAMPLE2" applies to all MGRAs between buffer distance "BUFFER1" and "BUFFER2," and "SAMPLE3" applies to all MGRAs outside buffer distance "BUFFER2."

TABLE 11: HOUSEHOLD SAMPLING SETTINGS

SETTING	TYPE	DEFAULT VALUE	DESCRIPTION
OPTIONAL			
BUFFER1	Float	2	Distance (miles) from project MGRA(s) to assign first household sample rate (SAMPLE1).
BUFFER2	Float	5	Distance (miles) from project MGRA(s) to assign second household sample rate (SAMPLE2). This value must be greater than BUFFER1.
SAMPLE1	Float	4	Household sample rate assigned to MGRAs that are within BUFFER1. A value of 0.5 means 50% and a value of 4 means 400%.
SAMPLE2	Float	2	Household sample rate assigned to MGRAs that are outside BUFFER1 but inside BUFFER2. A value of 0.5 means 50% and a value of 2 means 200%.
SAMPLE3	Float	1	Household sample rate assigned to MGRAs that are outside BUFFER2. A value of 0.5 means 50% and a value of 1 means 100%.

Sampling Methodology

With the target sampling rates set at the MGRA level, the tool then applies the rate to individual households. Within each MGRA, the tool groups households by size bins (1, 2, 3, 4+ person households) and income bins (<$50K, $50-$100K, >$100k). The process then samples these groups with the sample rate set for that MGRA. The sampling is random with a fixed random seed so results are repeatable. This method of sampling ensures that the total number of households remains consistent, but slight variation in the population may occur when sampling households with four or more people since the sample set does not have a uniform household size. In case of oversampling in integers (e.g., 2, 3, and so on), we used a simpler methodology where the household and person records in the oversampled geography are simply replicated to match the oversampling and assigned the corresponding sampling rate. This ensures consistency in the population as well. For the other cases (undersampling and oversampling in

non-integers), the tool applies the sampling by the two groups, household size and income bins, as mentioned earlier.

The household and person files outputted by the tool contains an additional field "SampleRate" which assigns sample rate (e.g., 4,2,1) as specified by the user. The tool also generates a spatial map ("input_updates\05_hh_sampling\outputs\sample_rate_map.html") of household sampling by mgra based on the output population files for QA/QC purposes. Figure 13 shows an example of this map.

FIGURE 13: HOUSEHOLD SAMPLE RATE MAP
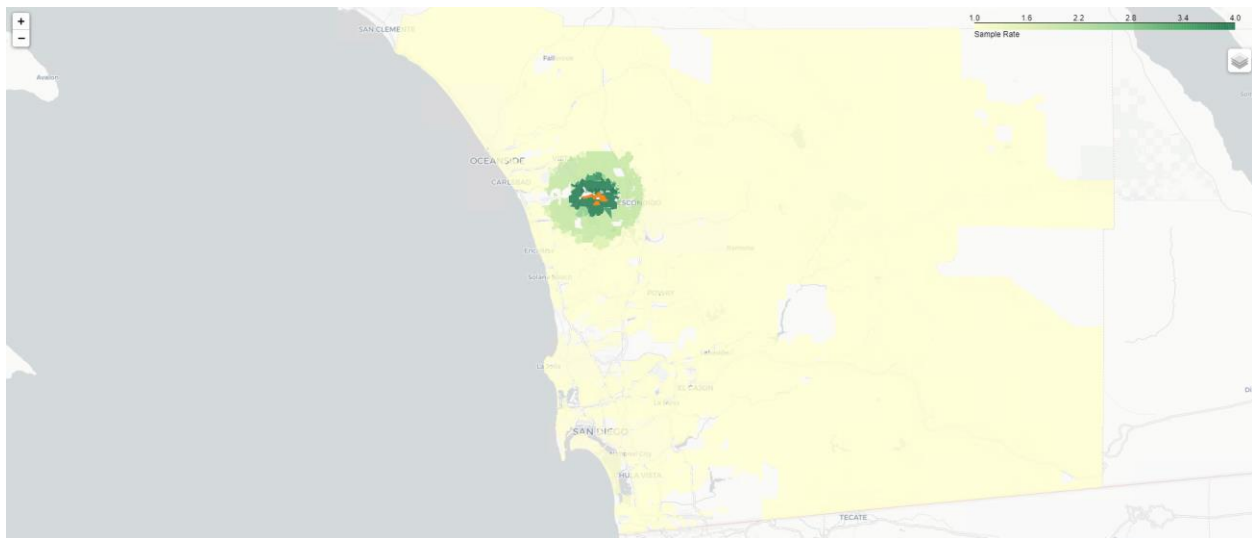
RSG updated the Java code for the SANDAG CT-RAMP model to read the SampleRate field in population files and incorporate that in simulating travel for residents. The changes affect two resident travel segments: internal-internal and internal-external. Appendix D lists the affected Java files. The demand model outputs now contain a new field 'sampleRate' that contains the same value as in the input household and person files. The user should use 1/sampleRate to calculate the true number of households in the input files.

We also updated the data exporter script in the model to incorporate household sampling in the weight fields in reports.

3.4 SHADOW PRICING

As part of the ABM2+ model enhancements plan, the shadow pricing procedure is now integrated with the model setup via the EMME Modeler graphical user interface (GUI). Previously, users needed to separately run shadow pricing and manually move the output files and update the configuration file. Now, the process is seamlessly integrated in the setup. Figure 14 shows the new EMME Modeler GUI with the new option "Skip shadow pricing." If the user

does not select this option on the first iteration the configuration file is updated to the settings shown in Figure 15 which prompts the model to run shadow pricing. On the next iteration, after this step completes, the configurations are updated again with where the tool will find the newly generated shadow pricing files.

FIGURE 14: EMME MODELER GUI

FIGURE 15: RUN SHADOW PRICING INITIAL CONFIGURATION UPDATE

```
UsualWorkLocationChoice.ShadowPrice.Input.File = output/ShadowPricingOutput_work_9.csv
UsualSchoolLocationChoice.ShadowPrice.Input.File = output/ShadowPricingOutput_school_9.csv
uwsl.ShadowPricing.Work.MaximumIterations = 1
uwsl.ShadowPricing.School.MaximumIterations = 1
uwsl.ShadowPricing.OutputFile = output/ShadowPricingOutput.csv
```

If the 'Skip shadow pricing' option is selected, no changes are made to the configuration file and the existing settings will be used. The user should always be aware of this setting. The updates added in the 'master_run.py' script are shown in Figure 16.

FIGURE 16: SHADOW PRICING UPDATES TO 'MASTER_RUN.PY'

```python
if not skipCoreABM[iteration]:
    if not skipShadowPricing:
        if iteration == 0:
            props['UsualWorkLocationChoice.ShadowPrice.Input.File'] = ""
            props['UsualSchoolLocationChoice.ShadowPrice.Input.File'] = ""
            props['uwsl.ShadowPricing.Work.MaximumIterations'] = 10
            props['uwsl.ShadowPricing.School.MaximumIterations'] = 10
            props.save()

        else:
            props['UsualWorkLocationChoice.ShadowPrice.Input.File'] = "output/ShadowPricingOutput_work_9.csv"
            props['UsualSchoolLocationChoice.ShadowPrice.Input.File'] = "output/ShadowPricingOutput_school_9.csv"
            props['uwsl.ShadowPricing.Work.MaximumIterations'] = 1
            props['uwsl.ShadowPricing.School.MaximumIterations'] = 1
            props.save()
```

Previously, the process included an error catch which would crash the model run if it detects that the configuration file was edited after it is loaded. Because this procedure must make changes to the configuration file after it is loaded, this error is now muted to avoid a crash when running these steps. Figure 17 shows the muted warning in the property class in the properties.py file under "python\emme\toolbox\utilities" in the model setup.

FIGURE 17: PROPERTY CLASS MUTED WARNING

```python
    def save(self, path=None):
        if not path:
            path = self._path
            # check for possible interference if user edits the
            # properties files directly while it is already open in Modeller
            timestamp = os.path.getmtime(path)
            # if timestamp != self._timestamp:
                # raise Exception("%s file conflict - edited externally after loading" % path)
```

As part of the 14_3_0 release the iteration global sample rates are set to 1 for each iteration. The land use tool also adjusts the sample rates to 1,1,1 if the no-build scenario is from an earlier release with different sample rates. It is recommended to run shadow pricing for both build and no-build scenarios while using the iteration sample rates of 1,1,1.

3.5 SELECT LINKS

Updates to the EMME databank setup have been included to allow users to query up to five select links for a model run. This update requires the EMME databank to be dimensioned to include enough space for the new attributes.

By default, the 'extra_attribute_values' for the EMME databank is large enough to run up to three select links. If the user specifies four or five select links, then a process is triggered to

calculate the additional space needed and re-dimension the EMME databank. Figure 18 shows the updates to the 'master_run.py' script to incorporate these updates.

FIGURE 18: SELECT LINK UPDATES TO 'MASTER_RUN.PY'

```python
#change emme databank dimensions based on number of select links - SANDAG ABM2+ Enhancements (06-28-2021)
num_select_links = 0
if select_link:
    num_select_links = len(_json.loads(select_link))
change_dimensions = modeller.tool("inro.emme.data.database.change_database_dimensions")
dims = main_emmebank.dimensions
num_nodes = dims["regular_nodes"] + dims['centroids']
num_links = dims["links"]
num_turn_entries = dims["turn_entries"]
num_transit_lines = dims['transit_lines']
num_transit_segments = dims['transit_segments']
num_traffic_classes = 15

additional_node_extra_attributes = 4
additional_link_extra_attributes = 26
additional_line_extra_attributes = 4
additional_segment_extra_attributes = 12

extra_attribute_values = 18000000
extra_attribute_values += (num_nodes + 1) * additional_node_extra_attributes
extra_attribute_values += (num_links + 1) * additional_link_extra_attributes
extra_attribute_values += (num_transit_lines + 1)* additional_line_extra_attributes
extra_attribute_values += (num_transit_segments + 1) * additional_segment_extra_attributes

if num_select_links > 3:
    extra_attribute_values += (num_select_links - 3) * ((num_links + 1) * (num_traffic_classes + 1) + (num_turn_entries + 1) * (num_traffic_classes))

if extra_attribute_values > dims["extra_attribute_values"] or dims["full_matrices"] < 9999:
    dims["extra_attribute_values"] = extra_attribute_values
    dims["full_matrices"] = 9999
    #add logging for when this setp is run, add before and after attribute value
    change_dimensions(emmebank_dimensions=dims, emmebank=main_emmebank, keep_backup=False)
with open(_join(self._path, "logFiles", "select_link_log.txt"),"a+") as f:
    f.write("Num Select links {}\nExtra Attribute Value {}".format(num_select_links,extra_attribute_values))
f.close()
```

Additionally, a new property is added for the ABM2+ Model run called "traffic.sla_limit" shown in Figure 19. This property allows the user to specify the number of select links during the emme initialization step.

FIGURE 19: SELECT LINK LIMIT NEW PROPERTY

```python
# Destination zones for the transponder accessibility calculator
transponder.destinations = 4027,2563,2258
traffic.sla_limit = 3
```

The 'init_emme_project.py' script uses this new property to initialize the EMME databank dimensions as shown in Figure 20.

FIGURE 20: UPDATES TO 'INIT_EMME_PROJECT.PY' FOR DATABANK REDIMENSIONING

```python
def init_emme_project(root, title, emmeversion):
    project_path = _app.create_project(root, "emme_project")
    project_root = os.path.dirname(project_path)
    desktop = _app.start_dedicated(project=project_path, user_initials="WS", visible=False)
    project = desktop.project
    project.name = "SANDAG Emme project"
    prj_file_path = os.path.join(project_root, 'NAD 1983 NSRS2007 StatePlane California VI FIPS 0406 (US Feet).prj')
    with open(prj_file_path, 'w') as f:
        f.write(WKT_PROJECTION)
    project.spatial_reference_file = prj_file_path
    project.initial_view = _ws_types.Box(6.18187e+06, 1.75917e+06, 6.42519e+06, 1.89371e+06)

    property_path = os.path.join(root, "conf", "sandag_abm.properties")
    properties = load_properties(property_path)
    sla_limit = properties.get('traffic.sla_limit', 3)

    num_links = 90000
    num_turn_entries = 13000
    num_traffic_classes = 15
    if sla_limit > 3:
        # extra_attribute_values = 18000000 + 90000 * (sla_limit - 3)
        extra_attribute_values = 18000000 + (sla_limit - 3) * ((num_links + 1) * (num_traffic_classes + 1) + (num_turn_entries + 1) * (num_traffic_classes))
    else:
        extra_attribute_values = 18000000
```

4.0 TRIP RATES AND THRESHOLDS

RSG estimated trip rates from the 2016 ABM2+ model outputs of person and vehicle trips for any MGRAs with a single land use type. This isolates the person and vehicle trips for a single land use type, where any MGRA with multiple land use types cannot be segmented directly for each land use type. This process to isolate MGRAs with uniform land use types produced a reasonable sample size for most land use types, but a few land use types were aggregated to produce a larger sample size. The vehicle trip rates were compared to the Institute of Transportation Engineers (ITE) trip rates where available.

4.1 SAMPLE

The sample of MGRAs with uniform land use types is provided in Table 12. For specialized land use types, RSG aggregated similar land use types to produce an aggregated land use type with five or more MGRAs. These aggregated land use types are included in Table 12 for any land use types that were aggregated.

TABLE 12: SAMPLE OF UNIFORM MGRAS BY LAND USE TYPE

LAND USE CODE	DESCRIPTION	# UNIFORM MGRAS	AGGREGATED LAND USE CODES
1401	Jail/Prison	4	1409
1402	Dormitory	2	1409
1403	Military Barracks	0	1409
1409	Other Group Quarters Facility	7	
1501	Hotel (Low-Rise)	5	1501
1502	Hotel (High-Rise)	8	
1503	Resort	1	1501
2001	Heavy Industry	3	2103
2101	Industrial Park	106	
2103	Light Industry – General	78	
2104	Warehousing	11	
2105	Public Storage	3	2104
2201	Extractive Industry	7	
2301	Scrap Yards/Auto Dismantling/Landfill	6	
4101	Commercial Airport	5	
4102	Military Airport	0	6701
4103	General Aviation Airport	4	4103
4104	Airstrip	1	4103

LAND USE CODE	DESCRIPTION	# UNIFORM MGRAS	AGGREGATED LAND USE CODES
4111	Rail Station/Transit Center	5	
4113	Communications and Utilities	18	
4114	Parking Lot – Surface	28	
4115	Parking Lot – Structure	2	4114
4116	Park and Ride Lot	1	4114
4119	Other Transportation	14	
4120	Marine Terminal	5	
5001	Wholesale Trade	4	2104
5002	Regional Shopping Center (300000 SF or more)	20	
5003	Community Shopping Center (100000 SF or more)	81	
5004	Neighborhood Shopping Center (30000 SF or more)	84	
5005	Specialty Commercial (Seaport Village - Tourist)	9	
5006	Automobile Dealership	35	
5007	Arterial Commercial (Street Commercial)	132	
5008	Service Station	2	5009
5009	Other Retail Trade and Strip Commercial	38	
6001	Office (High-Rise - greater than 100000 SF)	15	
6002	Office (Low-Rise - less or equal to 100000 SF)	46	
6003	Government Office/Civic Center	13	
6101	Cemetery	5	
6102	Religious Facility (without day care)	20	
6103	Library	4	6109
6104	Post Office	2	6109
6105	Fire/Police Station	6	
6108	Mission	0	6102
6109	Other Public Services	8	
6501	UCSD/VA Hospital/Balboa Hospital	1	6502
6502	Hospital – General	10	
6509	Other Health Care	5	
6701	Military Use	10	
6702	Military Training	0	6701
6703	Weapons Facility	0	6701
6801	SDSU/CSU San Marcos/UCSD	8	
6802	Other University or College	4	6802
6803	Junior College	4	6802
6804	Senior High School	28	

LAND USE CODE	DESCRIPTION	# UNIFORM MGRAS	AGGREGATED LAND USE CODES
6805	Junior High School or Middle School	12	
6806	Elementary School	58	
6809	Other School	5	
6807	School District Office	3	6003
7201	Tourist Attraction	2	7201
7202	Stadium/Arena	1	
7203	Racetrack	2	7201
7204	Golf Course	22	
7205	Golf Course Clubhouse	1	7204
7206	Convention Center	0	1502
7207	Marina	18	
7208	Olympic Training Center	0	7204
7209	Casino	0	7201
7210	Other Recreation – High	10	
7211	Other Recreation – Low	4	7210
7601	Park – Active	49	
7603	Open Space Park or Preserve	535	
7604	Beach – Active	11	
7606	Landscape Open Space	14	
7607	Residential Recreation	0	7606
7609	Undevelopable Natural Area	9	
8001	Orchard or Vineyard	44	
8002	Intensive Agriculture	28	
8003	Field Crops	44	
9101	Vacant and Undeveloped Land	478	
9201	Bay or Lagoon	16	
9202	Lake/Reservoir/Large Pond	6	

4.2 TRIP RATES

Land Use Type

RSG calculated average weekday vehicle and person trip rates for residential land uses from the trips output from ABM2+ and the households in each uniform MGRA with that land use. These are presented in Table 13. The single and multi-family land use types with no units are vacant, so not included in this calculation.

TABLE 13: RESIDENTIAL TRIP RATES BY LAND USE TYPE

LAND USE CODE	DESCRIPTION	VEHICLE TRIPS	PERSON TRIPS	HOUSE-HOLDS	VEHICLE TRIP RATE	PERSON TRIP RATE
1000		15,183	21,184	1,991		
1110	Single Family	998,054	1,414,248	122,704	8.10	11.46
1120		81,534	113,838	10,450		
1190	Single Family No Units	N/A	N/A	N/A		
1200	Multi-family	462,729	634,802	55,600	8.32	11.41
1280		2,501	3,169	325		
1290	Multi-family No Units	N/A	N/A	N/A		
1300	Mobile Home	67,353	94,420	8,351	8.07	11.31
1409	Other Group Quarters Facility	16,447	19,736	207	4.28	5.14

RSG calculated average weekday vehicle and person trip rates for nonresidential land uses from the trips output from ABM2+ and the employment in each uniform MGRA with that land use. A trip rate is calculated as the ratio of number of trips and employment. The nonresidential land use types that are based on employment are presented in Table 14. The land use categories that are aggregated from Table 12 are not presented here for brevity.

TABLE 14: NONRESIDENTIAL TRIP RATES BY EMPLOYMENT-BASED LAND USE TYPE

LAND USE CODE	DESCRIPTION	VEHICLE TRIPS	PERSON TRIPS	EMPLOY-MENT	VEHICLE TRIP RATE	PERSON TRIP RATE
1501	Hotel (Low-Rise)	4,939	6,213	1,056	4.68	5.88
1502	Hotel (High-Rise)	6,069	7,186	2,151	2.82	3.34
2101	Industrial Park	145,701	181,982	47,274	3.08	3.85
2103	Light Industry - General	87,705	110,970	27,465	3.19	4.04
2104	Warehousing	2,662	3,095	1,355	1.96	2.28
2201	Extractive Industry	69	78	33	2.09	2.36
2301	Scrap Yards/Auto Dismantling/Landfill	425	538	173	2.46	3.11
4101	Commercial Airport	5,475	6,459	2,320	2.36	2.78
4103	General Aviation Airport	2,076	2,616	637	3.26	4.11
4111	Rail Station/Transit Center	318	350	139	2.29	2.52
4113	Communications and Utilities	1,657	1,874	838	1.98	2.24
4114	Parking Lot - Surface	5,166	6,485	515	10.03	12.59

LAND USE CODE	DESCRIPTION	VEHICLE TRIPS	PERSON TRIPS	EMPLOY-MENT	VEHICLE TRIP RATE	PERSON TRIP RATE
4119	Other Transportation	379	483	155	2.44	3.12
4120	Marine Terminal	44	64	11	4.00	5.82
5002	Regional Shopping Center	98,377	128,266	6,414	15.34	20.00
5003	Community Shopping Center	474,331	618,589	29,661	15.99	20.86
5004	Neighborhood Shopping Center	213,072	279,562	18,264	11.67	15.31
5005	Specialty Commercial	18,287	22,398	2,115	8.65	10.59
5006	Automobile Dealership	51,977	70,947	3,406	15.26	20.83
5007	Arterial Commercial	126,406	163,260	12,150	10.40	13.44
5009	Other Retail Trade & Strip Commercial	47,947	62,880	4,073	11.77	15.44
6001	Office (High-Rise)	59,841	70,414	12,507	4.78	5.63
6002	Office (Low-Rise)	65,578	82,898	17,928	3.66	4.62
6003	Government Office/Civic Center	85,682	104,067	20,911	4.10	4.98
6101	Cemetery	424	622	45	9.42	13.82
6102	Religious Facility	2,812	4,210	251	11.20	16.77
6105	Fire/Police Station	202	262	47	4.29	5.57
6109	Other Public Services	4,084	5,920	441	9.26	13.42
6502	Hospital - General	40,422	49,446	9,487	4.26	5.21
6509	Other Health Care	6,687	8,071	2,137	3.13	3.78
6701	Military Use	31,451	38,829	12,295	2.56	3.16
6801	SDSU/CSU San Marcos/UCSD	27,808	32,481	6,581	4.23	4.94
6802	Other University or College	20,353	25,020	1,852	10.99	13.51
6804	Senior High School	161,812	267,616	3,866	41.86	69.22
6805	Junior High School or Middle School	28,836	49,772	828	34.83	60.11
6806	Elementary School	95,822	163,376	3,522	27.21	46.39
6809	Other School	7,208	10,424	1,026	7.03	10.16

RSG calculated average weekday vehicle and person trip rates for selected nonresidential land uses from the trips output from ABM2+ and the acreage in each uniform MGRA with that land use. The selected nonresidential land use types that are based on acreage are presented in Table 15. The land use categories that are aggregated from Table 12 are not presented here for brevity.

TABLE 15: NONRESIDENTIAL TRIP RATES BY ACREAGE-BASED LAND USE TYPE

LAND USE CODE	DESCRIPTION	VEHICLE TRIPS	PERSON TRIPS	ACRES	VEHICLE TRIP RATE	PERSON TRIP RATE
7201	Tourist Attraction	24,875	32,072	378	65.77	84.80
7202	Stadium	5,584	6,728	62	90.12	108.57
7204	Golf Course	13,747	19,404	583	23.57	33.27
7207	Marina	1,220	1,544	15	79.30	100.38
7210	Other Recreation - High	1,005	1,290	108	9.28	11.91
7601	Park - Active	45,663	62,452	959	47.64	65.15
7603	Open Space Park or Preserve	10,400	15,604	430,369	0.02	0.04
7604	Beach - Active	5,113	7,112	154	33.31	46.33
7606	Landscape Open Space	503	730	21	23.91	34.71
7609	Undevelopable Natural Area	590	926	5,379	0.11	0.17
8001	Orchard or Vineyard	284	420	39	0.21	0.31
8002	Intensive Agriculture	1,290	1,672	289	1.70	2.21
8003	Field Crops	159	242	-	0.17	0.26
9101	Vacant and Undeveloped Land	2,682	3,444	444	0.38	0.48
9201	Bay or Lagoon	773	1,114	-	5.51	7.95
9202	Lake/Reservoir/Large Pond	24	32	-	0.24	0.32

Metropolitan Statistical Area (MSA)

Trip rates were also developed by land use type and MSA. This was intended to allow for regional differences between the trip rates, but two-thirds of MGRAs within each segmented land use type and MSA were below the 5 MGRA minimum for confidence in the results. As a result, we recommend that the trip rates not be segmented by MSA to ensure that the trip rates contain enough MGRAs for statistical reliability. The calculated trip rates by MSA are not included in this report but were delivered to SANDAG with the recommended trip rates for comprehensiveness.

4.3 COMPARISON TO ITE TRIP RATES

Figure 21 presents a comparison of the ABM2+ vehicle trip rates in the three residential land use types against the ITE national trip rates by type for the two most recent generations of this reference (the 10th Edition in 2019 and the 8th Edition in 2017). Single family residences have a slightly lower rate than the national average and multi-family and mobile homes have a higher rate than the national average. These are likely the result of a higher-than average density in the San Diego region compared to the national average, so the trip rates for these residential types are more consistent in San Diego than with the national average, where multi-family and mobile home trip rates are much lower than single family. This comparison confirms that the single family residential trip rates are reasonable for use in the ABM2+ application. It may be prudent to further research the multi-family and mobile home trip rates since these differ from the multi-family trip rate in the ITE manual and may be over-estimated.

FIGURE 21: COMPARISON OF ABM2+ AND ITE TRIP RATES PER HOUSEHOLD FOR RESIDENTIAL LAND USE TYPES
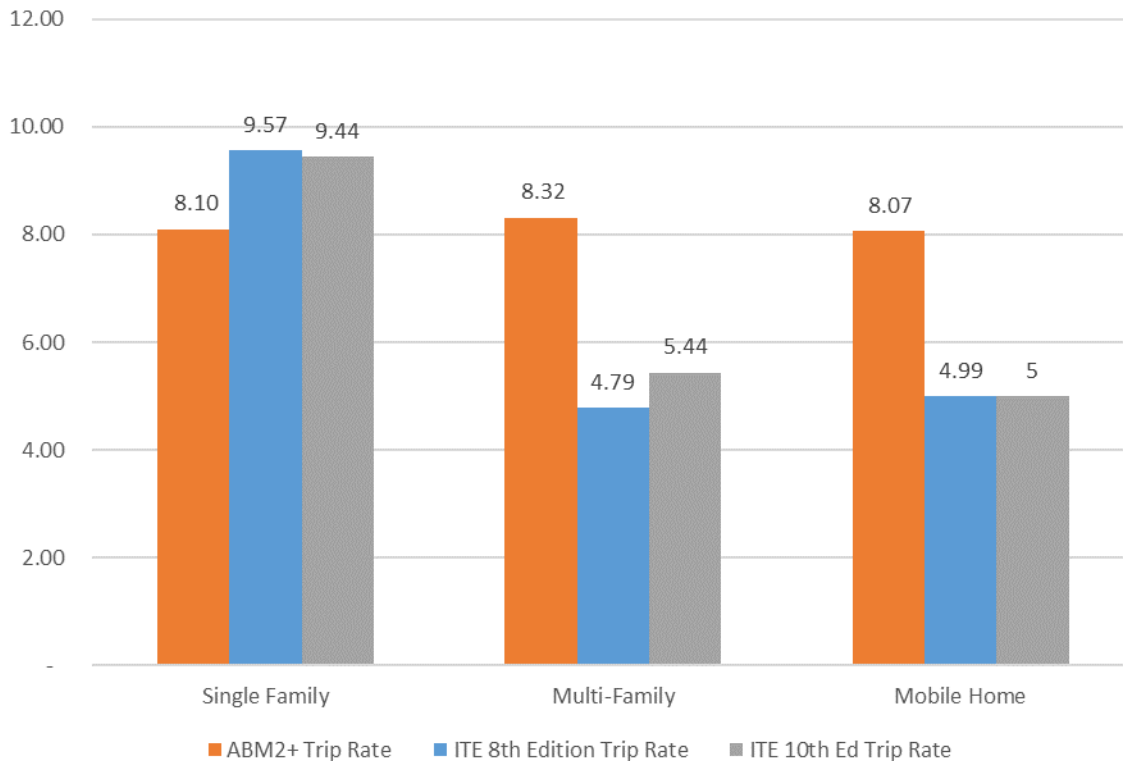
Figure 22 presents a comparison of the ABM2+ vehicle trip rates in selected nonresidential land use types where we had a direct comparison from the ITE national trip rates by type for the two

most recent generations of this reference (the 10th Edition in 2019 and the 8th Edition in 2017). In some cases, the nonresidential trip rates changed significantly between the 8th and the 10th Editions (e.g., golf courses and tourist attractions) so both rates are included for comparison. Most of these nonresidential trip rates compare reasonably well with these ITE trip rates per employee. Some deviations are expected given the differences between the regional (ABM2+) and national (ITE) scales, but there are several categories related to travel (hotels and airports) and cemeteries where ABM2+ has lower trip rates than ITE. This comparison confirms that the majority of the nonresidential trip rates are reasonable for use in the ABM2+ application.

FIGURE 22: COMPARISON OF ABM2+ AND ITE TRIP RATES PER EMPLOYEE FOR NONRESIDENTIAL LAND USE TYPES
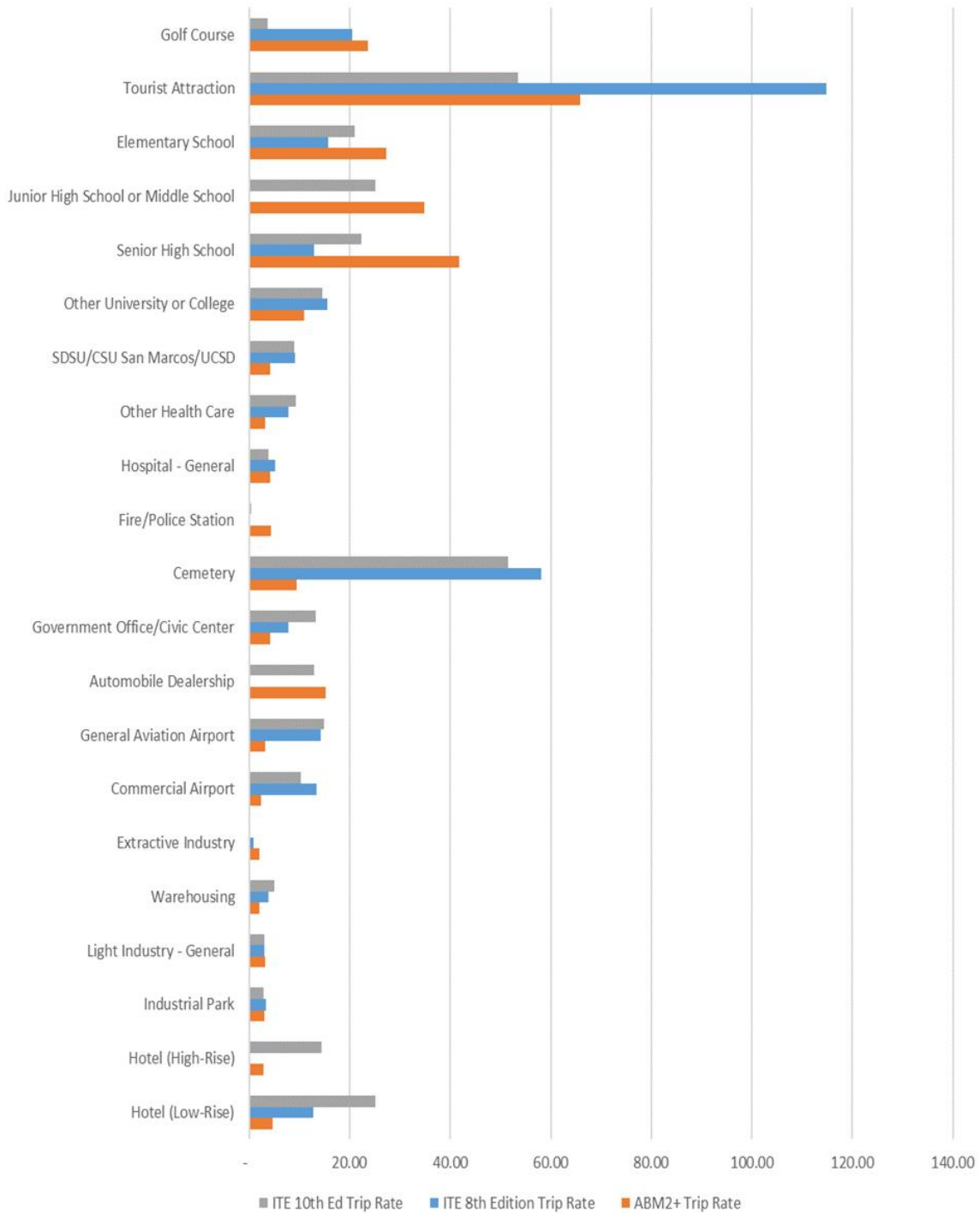
4.4 MARKET AND TRIP SEGMENTS

RSG evaluated nine model runs conducted by SANDAG staff to show variability by market segment; five of which used fixed random seeds and four of which used variable random seeds. These nine model runs were evaluated across four primary market segments, as shown in Table 16.

TABLE 16: RESIDENT AND WORK PURPOSE TOURS BY MARKET SEGMENT

SCOPE	METRIC	SEGMENTS	VEHICLE TRIP RANGE PERCENT	VMT RANGE PERCENT
Residents	Population	50 person increments	Average of the difference between Max and Min trips	Average of the difference between Max and Min VMT
Work Purpose Tours by Employees	Employment	50 employee increments	Average of the difference between Max and Min trips	Average of the difference between Max and Min VMT
Residents	Population	<1%, 1-3%, 3-5%, 5-10%, 10-20%, 20-50%, 50-100%, >100%	Average of the difference between Max and Min trips	Average of the difference between Max and Min VMT
Work Purpose Tours by Employees	Employment	<1%, 1-3%, 3-5%, 5-10%, 10-20%, 20-50%, 50-100%, >100%	Average of the difference between Max and Min trips	Average of the difference between Max and Min VMT

4.5 VARIABILITY AND THRESHOLDS

Variability is explored by comparing the number of vehicle trips and VMT binned in ranges (bins) by the number of residents of an MGRA and by comparing the number of trips and VMT made on work tours by the amount of employment in an MGRA. This variability analysis was summarized for all nine random seed runs and separately for the five fixed and four variable random seed runs. Of these runs, the five fixed random seed runs provided the lowest variability and were used for developing thresholds.

Variability

The regionwide VMT was reported by different trip types as presented in Table 17 and Table 18 for fixed and variable random seeds, respectively. As expected, the range percentage is lower with the fixed random seeds for the majority of trip types and in total than for the variable random seeds. Visitor and San Diego Airport (SAN) trips show lower range percentages with the variable random seeds; these are smaller markets overall and do not affect the overall reduction in variability with the fixed random seeds. The majority of the analysis focused on the fixed random seeds to reduce variability overall.

TABLE 17: REGIONWIDE VMT WITH FIXED RANDOM SEEDS

MODEL	2016A	2016B	2016C	2016D	2016E	RANGE	RANGE PERCENT
Airport - CBX	125,822.80	125,826.70	125,800.60	125,800.00	125,777.60	49.07	0.04
Airport - SAN	555,292.50	555,006.20	554,859.10	556,327.30	555,203.90	1,468.14	0.26
Commercial Vehicle	8,076,274.00	8,077,752.80	8,073,563.00	8,068,921.50	8,078,381.50	9,459.99	0.12
Cross-Border	1,964,924.30	1,963,941.40	1,962,912.00	1,963,152.20	1,962,519.40	2,404.95	0.12
External-External	798,115.50	798,111.10	798,111.10	798,115.50	798,115.50	4.42	0
External-Internal	6,539,894.50	6,539,987.70	6,539,418.20	6,539,982.70	6,539,932.90	569.49	0.01
Individual	57,333,449.90	57,289,674.20	57,316,642.30	57,307,502.50	57,331,917.20	43,775.76	0.08
Internal-External	3,790,531.60	3,792,647.90	3,790,818.20	3,796,335.30	3,793,916.00	5,803.76	0.15
Joint	2,715,938.00	2,704,352.80	2,711,259.30	2,717,712.00	2,709,844.80	13,359.16	0.49
Truck	989,649.70	989,646.20	989,643.00	989,647.70	989,649.80	6.84	0
Visitor	1,094,062.00	1,093,274.20	1,094,587.20	1,100,474.10	1,092,800.90	7,673.28	0.7
Total	84,321,633.30	84,267,485.90	84,293,796.50	84,302,119.10	84,319,169.40	54,147.40	0.06

TABLE 18: REGIONWIDE VMT WITH VARIABLE RANDOM SEEDS

MODEL	2016A	2016F	2016G	2016H	2016I	RANGE	RANGE PERCENT
Airport - CBX	125,822.80	125,847.00	125,850.80	125,812.30	125,808.00	42.82	0.03
Airport - SAN	555,292.50	555,163.70	555,037.80	555,072.80	555,018.50	273.93	0.05
Commercial Vehicle	8,076,274.00	8,044,342.00	8,078,350.80	8,044,322.30	8,034,429.70	43,921.09	0.55
Cross-Border	1,964,924.30	1,964,302.20	1,963,746.10	1,963,358.40	1,962,667.70	2,256.60	0.11
External-External	798,115.50	798,250.50	797,677.80	797,335.60	797,664.70	914.85	0.11
External-Internal	6,539,894.50	6,563,497.90	6,564,087.50	6,563,911.90	6,563,446.10	24,192.96	0.37
Individual	57,333,449.90	57,322,571.10	57,311,672.30	57,257,361.20	57,381,529.70	124,168.54	0.22
Internal-External	3,790,531.60	3,779,337.10	3,775,789.50	3,783,947.50	3,780,816.10	14,742.07	0.39
Joint	2,715,938.00	2,692,983.00	2,706,315.80	2,711,243.50	2,716,608.20	23,625.13	0.87
Truck	989,649.70	990,712.20	990,750.80	990,738.50	990,739.90	1,101.06	0.11
Visitor	1,094,062.00	1,093,927.80	1,094,204.20	1,095,138.70	1,096,852.00	2,924.20	0.27
Total	84,321,633.30	84,266,322.10	84,302,220.60	84,225,879.30	84,339,777.80	113,898.52	0.14

Table 19 presents the VMT maximum across all project sites shown in Figure 23. The commercial vehicle VMT and the cross-border travel have the highest variability, which was expected since SANDAG is planning to update the commercial vehicle model in the near term and the cross-border model update is already underway.

TABLE 19: REGIONWIDE VMT MAXIMUM ACROSS ALL PROJECTS

MODEL	MAXIMUM RANGE	MAXIMUM RANGE PERCENT
Airport - CBX	116.79	31.94
Airport - SAN	137.83	2.36
Commercial Vehicle	12,587.13	178.18
Cross-Border	1,407.04	500
External-External	-	-
External-Internal	5.52	0.04
Individual	12,106.54	3.78
Internal-External	1,957.85	8.75
Joint	3,087.35	10.54
TNC 0-Passenger	587.02	17.99
Truck	1.13	0.03
Visitor	1,290.08	25.99
Total	16,951.86	3.33

FIGURE 23: THRESHOLD VMT TEST PROJECT SITES
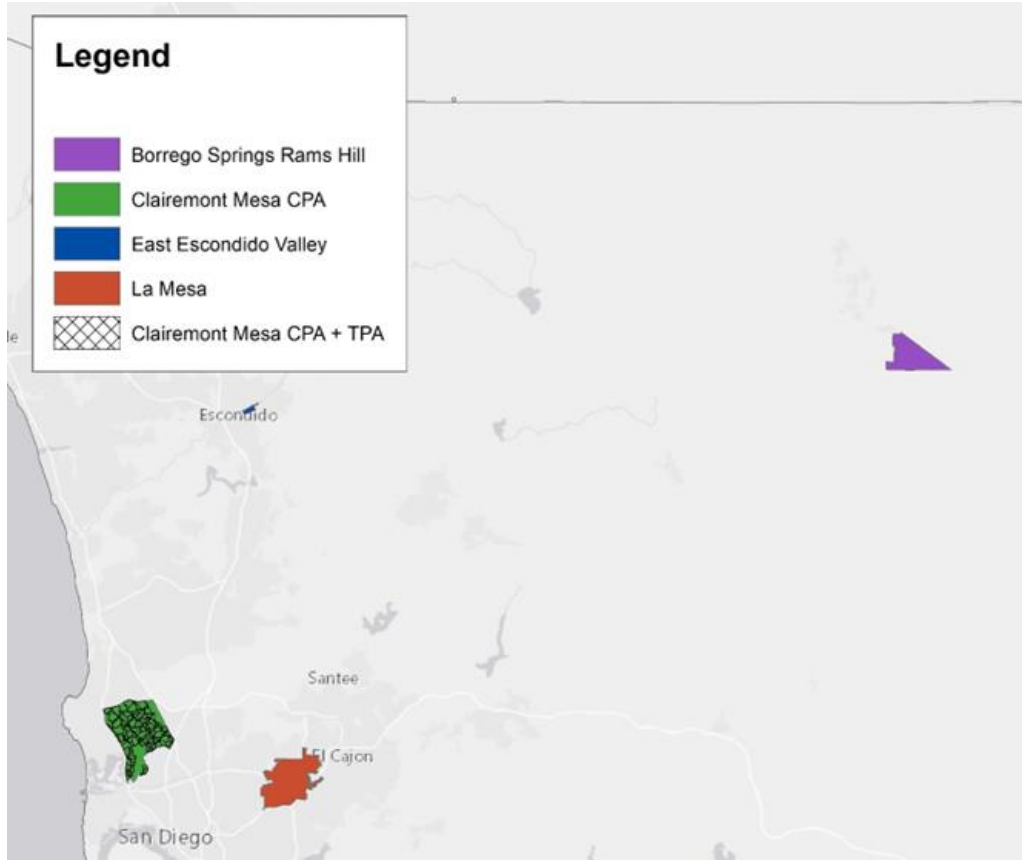
Population Thresholds

Figure 24 presents the trip variability by population bin for the MGRAs with 250 people or more. The mean variability for these MGRAs is 4% or less and the 95-percentile variability is 8% or less. The selection of a threshold is based on judgment to select a threshold that provides a value of less than 10% for the mean, median, first and third quartiles, and the 95-percentile. All of the population bins in Figure 24 meet this threshold.

FIGURE 24: TRIP VARIABILITY BY POPULATION BIN FOR MGRAS WITH >=250 PEOPLE
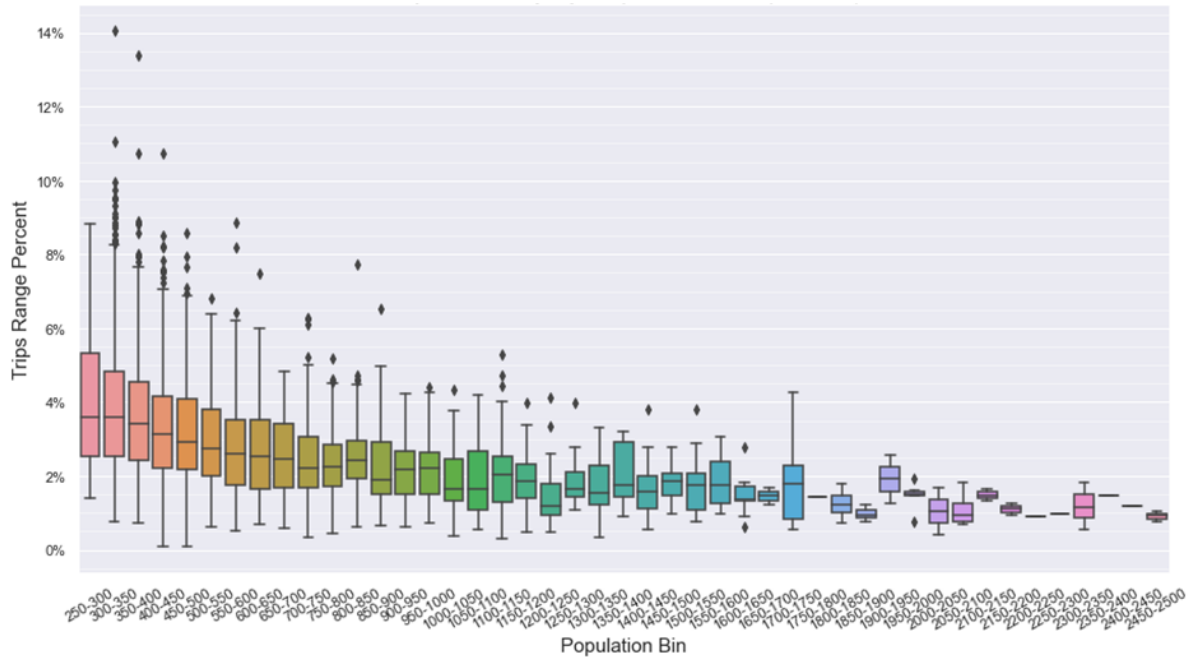
Zoomed View
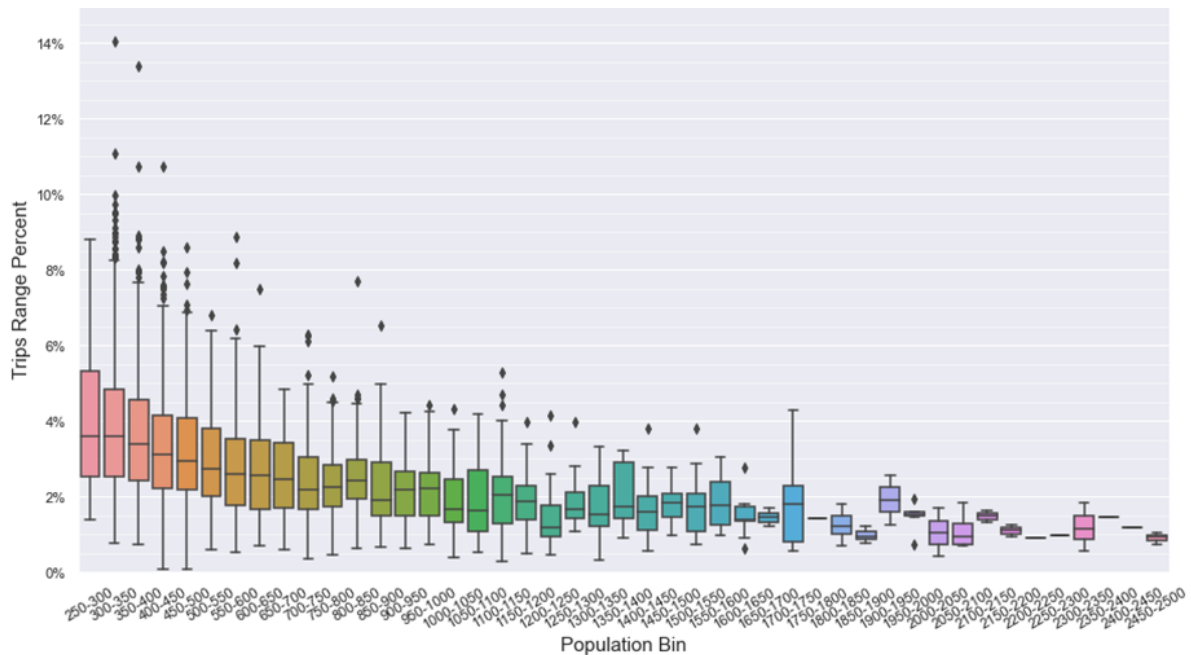
Figure 25 presents the trip variability by population bin for the MGRAs with less than 250 people. As expected, the lower bins have very high variability and would have too much variability for the ABM2+ application process to predict trips. Table 20 presents the numerical trip variability by population bin for these same population bins to select a threshold of 200 people that provides the mean, median, first and third quartiles and the 95-percentile value of less than 10%.

FIGURE 25: TRIP VARIABILITY BY POPULATION BIN FOR MGRAS WITH <250 PEOPLE
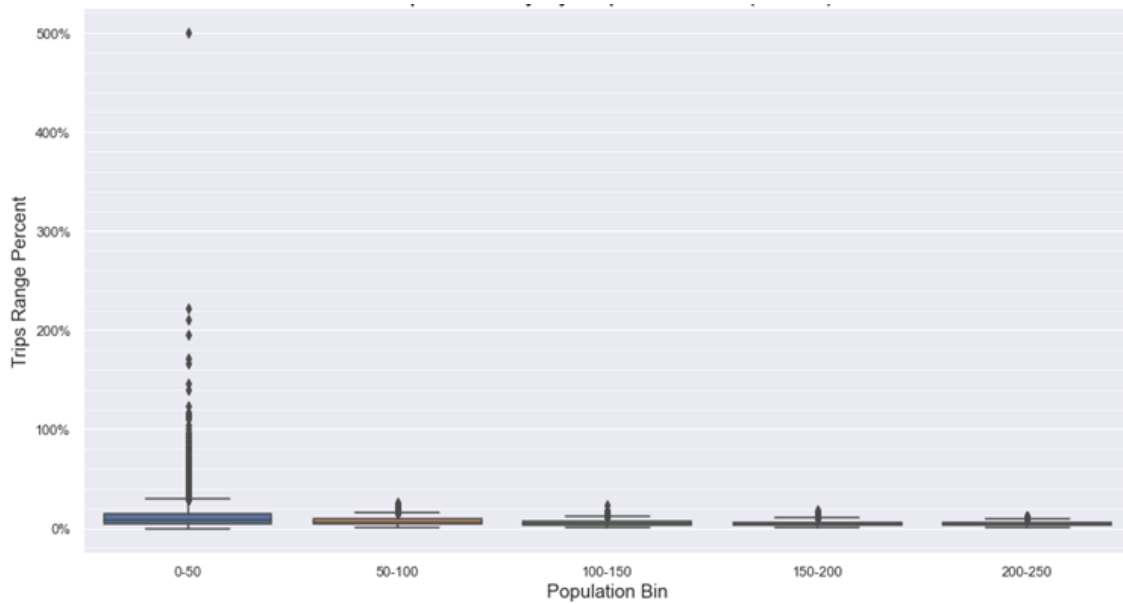
Zoomed View
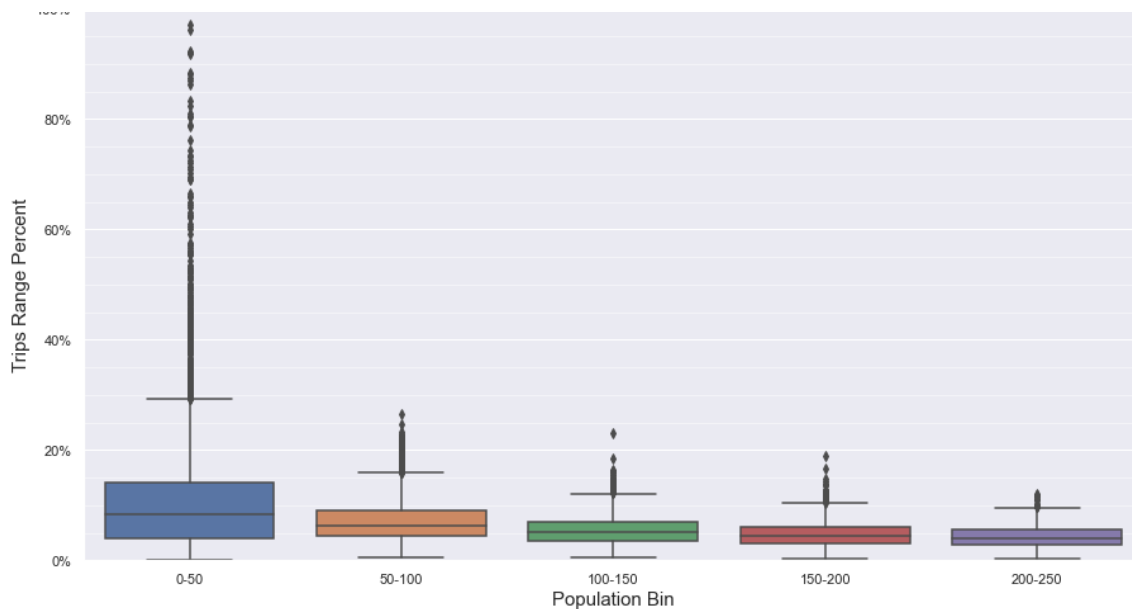
TABLE 20: TRIP RANGE PERCENTAGE BY POPULATION BIN FOR MGRAS WITH <250 PEOPLE

POPULATION BIN	MEAN	MEDIAN	FIRST QUARTILE VALUE	THIRD QUARTILE VALUE	95 PERCENTILE VALUE	COUNT MGRA
0-50	11%	8%	4%	14%	32%	5415
50-100	7%	6%	4%	9%	14%	3356
100-150	6%	5%	4%	7%	11%	2301
150-200	5%	4%	3%	6%	9%	1705
200-250	4%	4%	3%	5%	8%	1204

Figure 26 presents the VMT variability by population bin for the MGRAs with 250 people or more. The mean variability for these populations is 6% or less and the 95-percentile variability is 12% or less. The lowest population bins in Figure 26 do not meet this threshold.

Figure 27 presents the VMT variability by population bin for the MGRAs with less than 250 people. Again, the lowest bins have very high variability and have too much variability for the ABM2+ application process to predict VMT.

Table 21 presents the numerical VMT variability by population bin for the population bins up to 350 people to select a threshold that provides a value of less than 10% for the mean, median, first and third quartiles and the 95-percentile. The lowest population bins in Figure 27 do not meet this threshold for the 95-percentile but do meet this threshold for all other statistics. Higher variability exists to predict VMT when compared to trips, so the population threshold is higher.

FIGURE 26: VMT VARIABILITY BY POPULATION BIN FOR MGRAS WITH >=250 PEOPLE
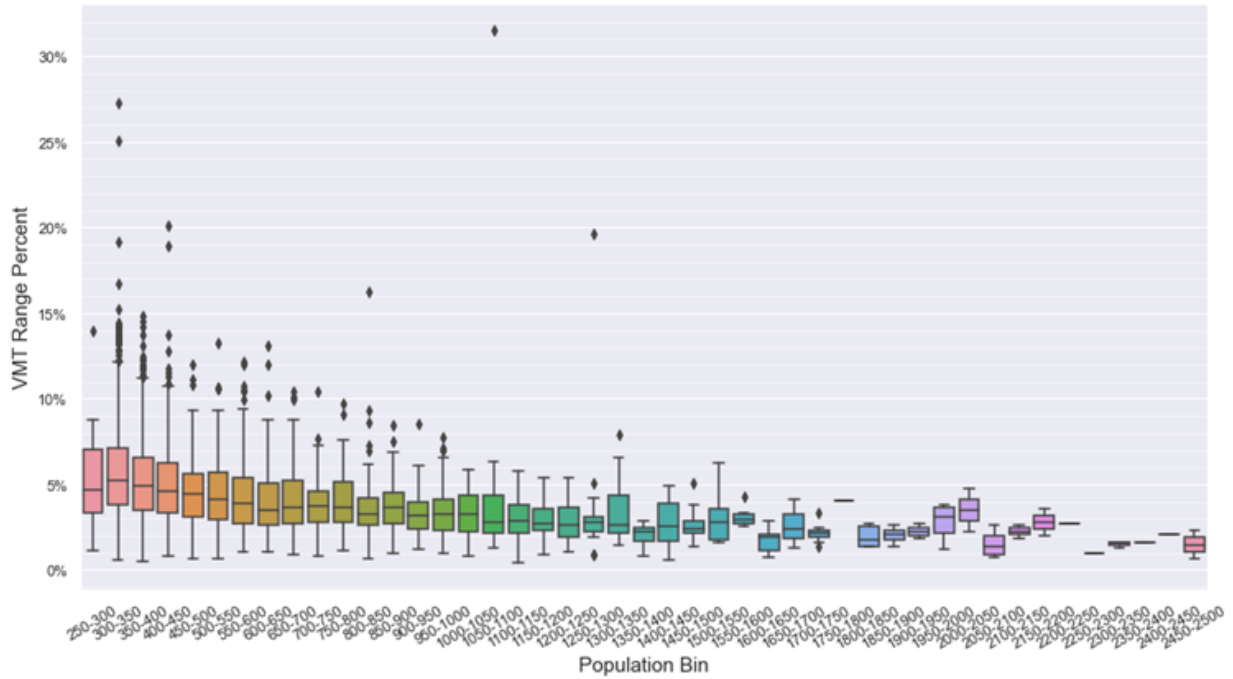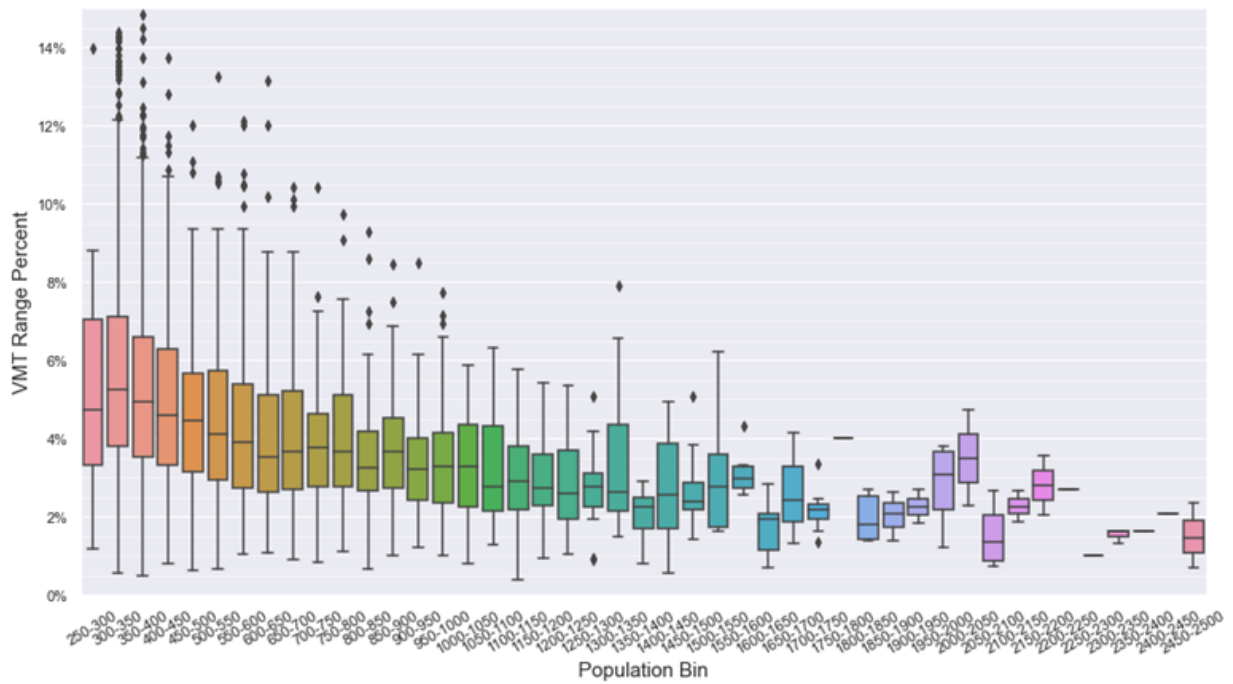
Zoomed View

FIGURE 27: VMT VARIABILITY BY POPULATION BIN FOR MGRAS WITH <250 PEOPLE
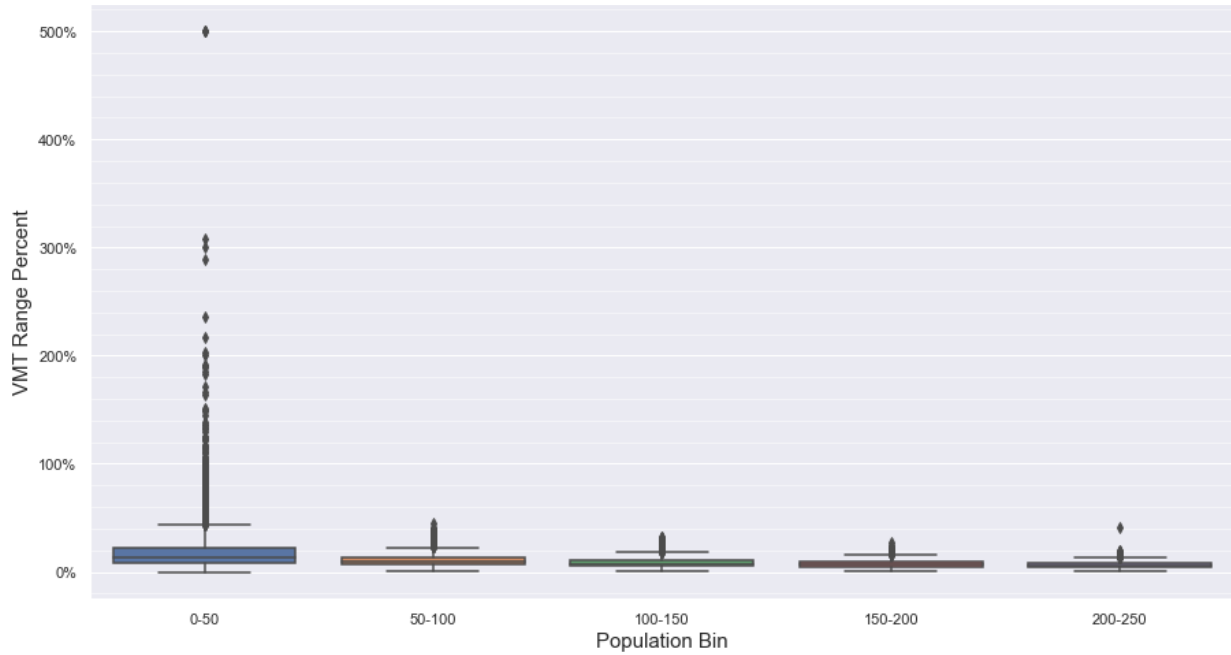
Zoomed View
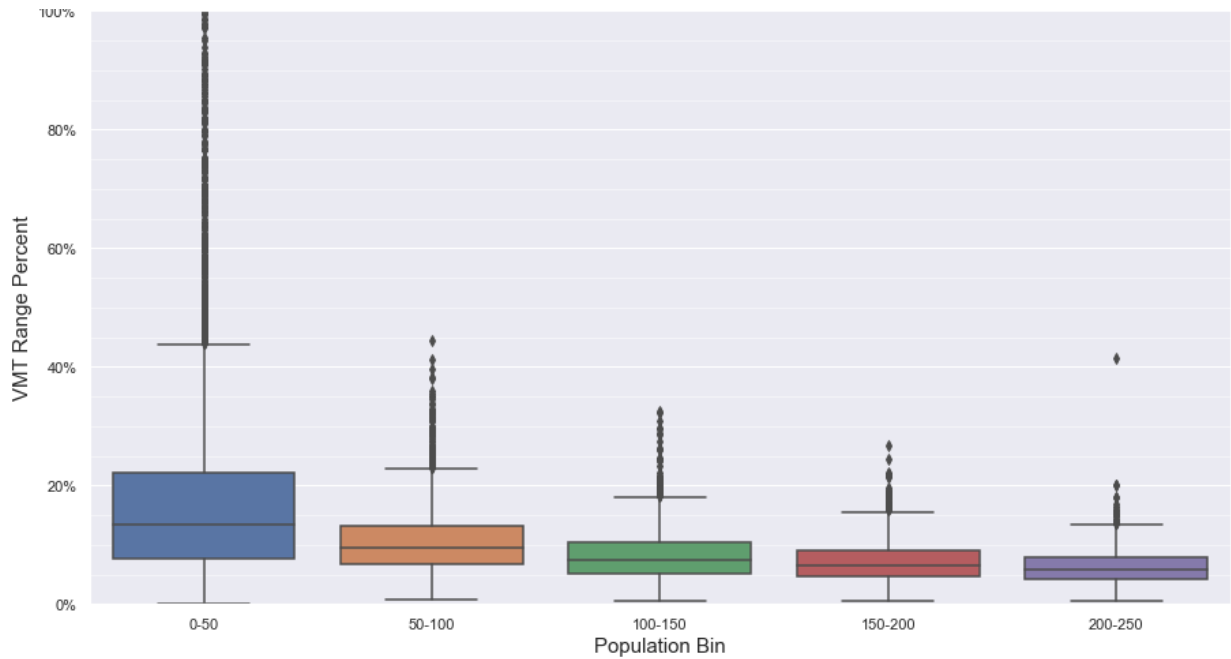
TABLE 21: VMT RANGE PERCENTAGE BY POPULATION BIN FOR MGRAS WITH <350 PEOPLE

POPULATION BIN	MEAN	MEDIAN	FIRST QUARTILE VALUE	THIRD QUARTILE VALUE	95 PERCENTILE VALUE	COUNT MGRA
0-50	19%	13%	8%	22%	51%	5415
50-100	10%	9%	7%	13%	20%	3356
100-150	8%	7%	5%	10%	16%	2301
150-200	7%	7%	5%	9%	13%	1705
200-250	6%	6%	4%	8%	12%	1204
250-300	6%	5%	4%	7%	11%	896
300-350	5%	5%	4%	7%	10%	623

Employment Thresholds

Figure 28 presents the trip variability by employment bin for the MGRAs with employment of 500 or more. The mean variability for these employment bins is 8% or less and the 95-percentile variability is 12% or less. The selection of a threshold is based on judgment to select a threshold that provides a value of less than 10% for the mean, median, first and third quartiles and the 95-percentile. The lowest employment bins in Figure 28 do meet this threshold for the third quartile but do not meet this threshold for the other statistics.

FIGURE 28: TRIP VARIABILITY BY EMPLOYMENT BIN FOR MGRAS WITH >=500 EMPLOYEES
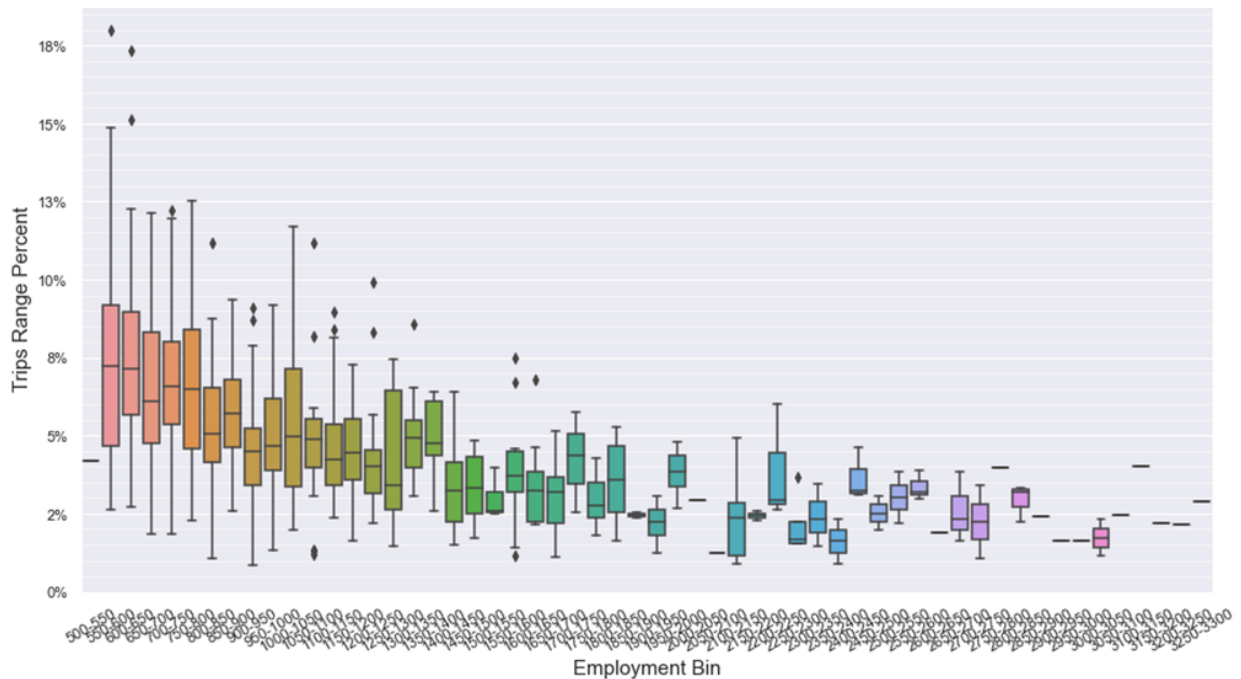
Figure 29 presents the trip variability by employment bin for the MGRAs with employment of less than 250. Again, the lowest bins have very high variability and have too much variability for the ABM2+ application process to predict trips.

FIGURE 29: TRIP VARIABILITY BY EMPLOYMENT BIN FOR MGRAS WITH <500 EMPLOYMENT
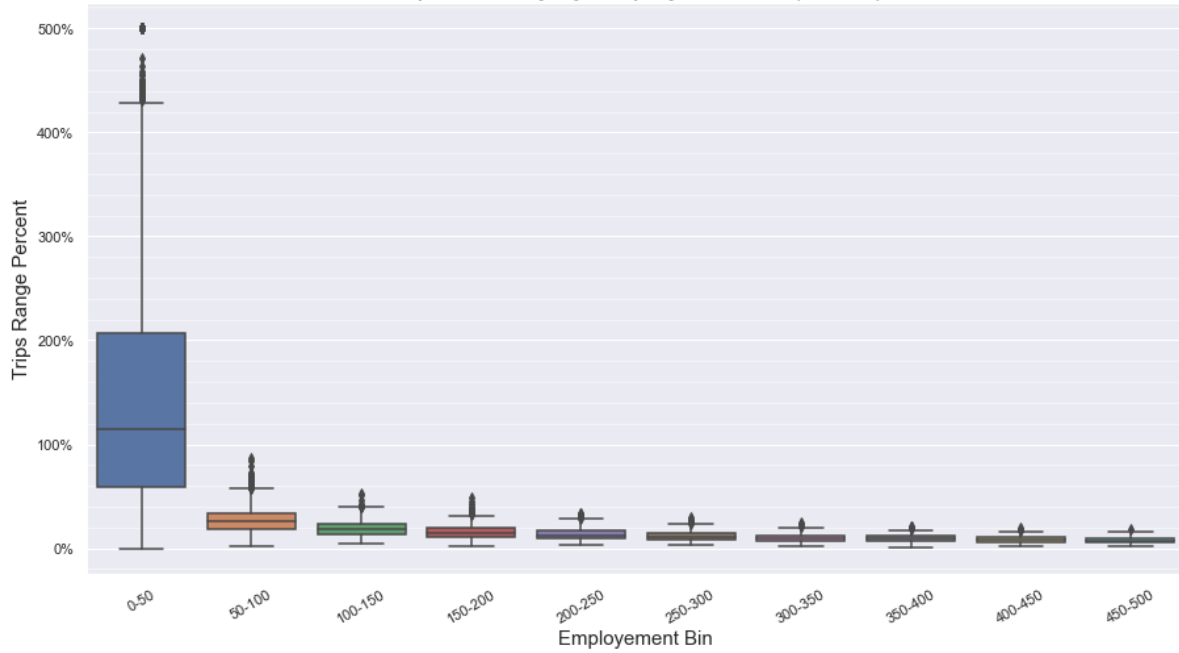
Zoomed View
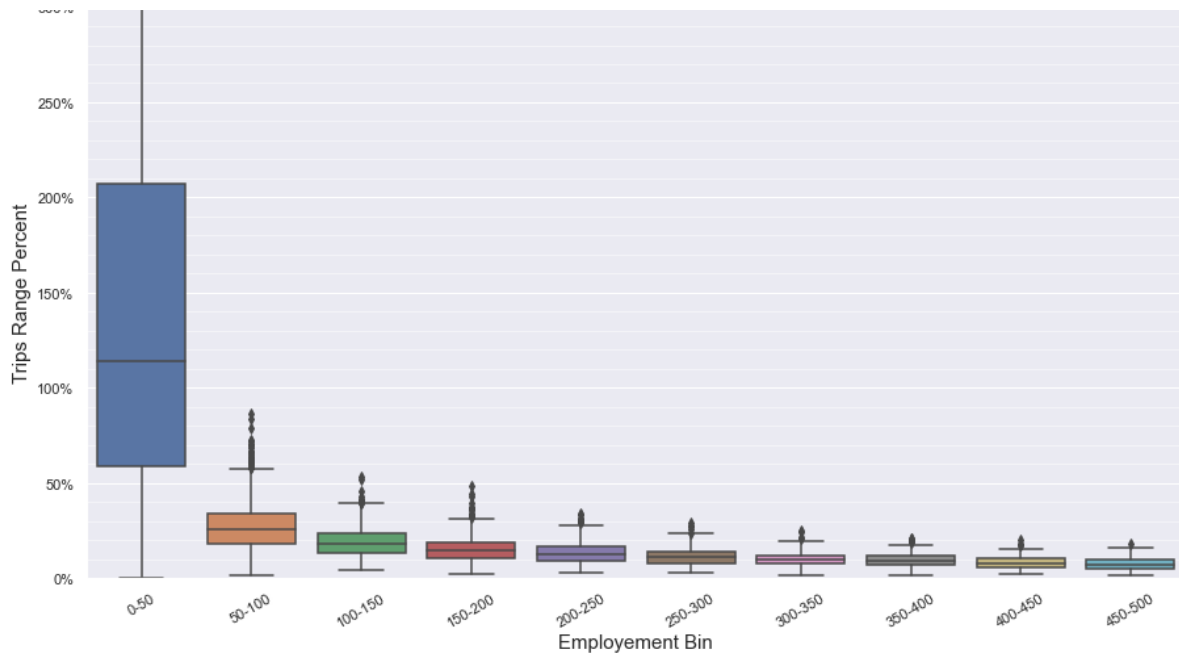
Table 22 presents the numerical trip variability by employment bin for the employment bins up to 750 employment to select a threshold that provides a value of less than 10% for the mean, median, first and third quartiles and the 95-percentile.

TABLE 22: TRIP RANGE PERCENTAGE BY EMPLOYMENT BIN FOR MGRAS WITH <750 EMPLOYMENT

EMPLOYMENT BIN	MEAN	MEDIAN	FIRST QUARTILE VALUE	THIRD QUARTILE VALUE	95 PERCENTILE VALUE	COUNT MGRA
0-50	147%	114%	59%	207%	361%	15410
50-100	27%	26%	18%	34%	51%	1411
100-150	19%	18%	13%	24%	34%	698
150-200	16%	15%	11%	19%	28%	473
200-250	13%	12%	9%	17%	25%	316
250-300	12%	11%	8%	14%	21%	237
300-350	10%	10%	8%	12%	17%	194
350-400	10%	10%	7%	12%	16%	138
400-450	8%	8%	6%	10%	15%	121
450-500	8%	7%	5%	10%	12%	109
500-550	7%	7%	5%	9%	13%	66
550-600	7%	7%	6%	9%	12%	60
600-650	7%	6%	5%	8%	11%	56
650-700	7%	7%	5%	8%	12%	60
700-750	7%	6%	5%	8%	10%	42

Figure 30 presents the VMT variability by employment bin for the MGRAs with employment of 500 or more. The mean variability for these employment bins is 10% or less and the 95-percentile variability is 17% or less. The selection of a threshold is based on judgment to select a threshold that provides a value of less than 10% for the mean, median, first and third quartiles and the 95-percentile. The lowest employment bins in Figure 30 do meet this threshold for the mean, median and first quartile statistics, but do not meet this threshold for the other statistics.

FIGURE 30: VMT VARIABILITY BY EMPLOYMENT BIN FOR MGRAS WITH >=500 EMPLOYEES
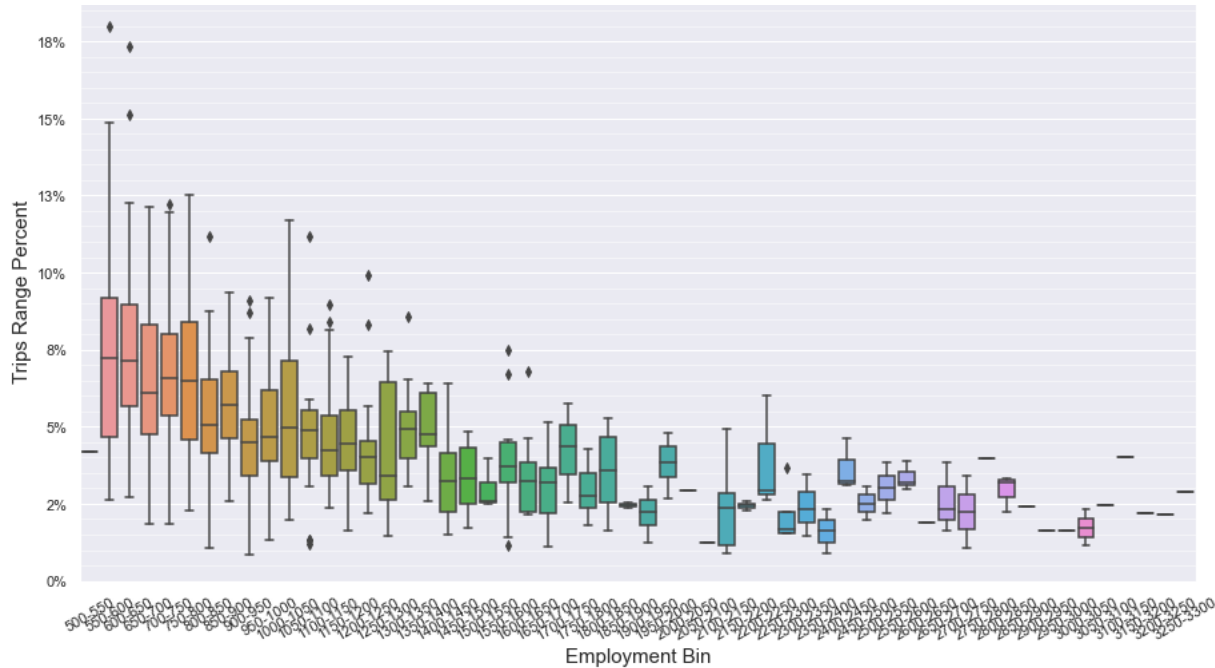
Figure 31 presents the VMT variability by employment bin for the MGRAs with employment of less than 500. Again, the lowest bins have very high variability and have too much variability for the ABM2+ application process to predict VMT. Table 23 presents the numerical trip variability by employment bin for the employment bins up to 800 employment to select a threshold that provides a value of less than 10% for the mean, median, first and third quartiles and the 95-percentile. Only a slightly higher variability exists to predict VMT than trips, so the employment threshold is slightly higher.

FIGURE 31: VMT VARIABILITY BY EMPLOYMENT BIN FOR MGRAS WITH <500 EMPLOYEES
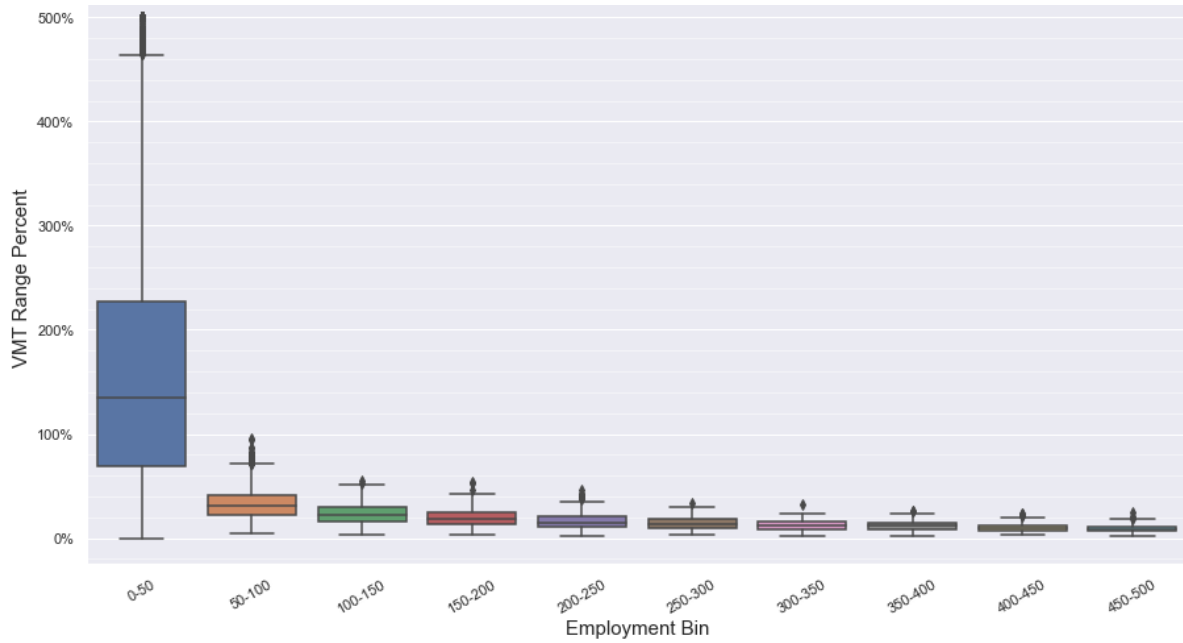
Zoomed View
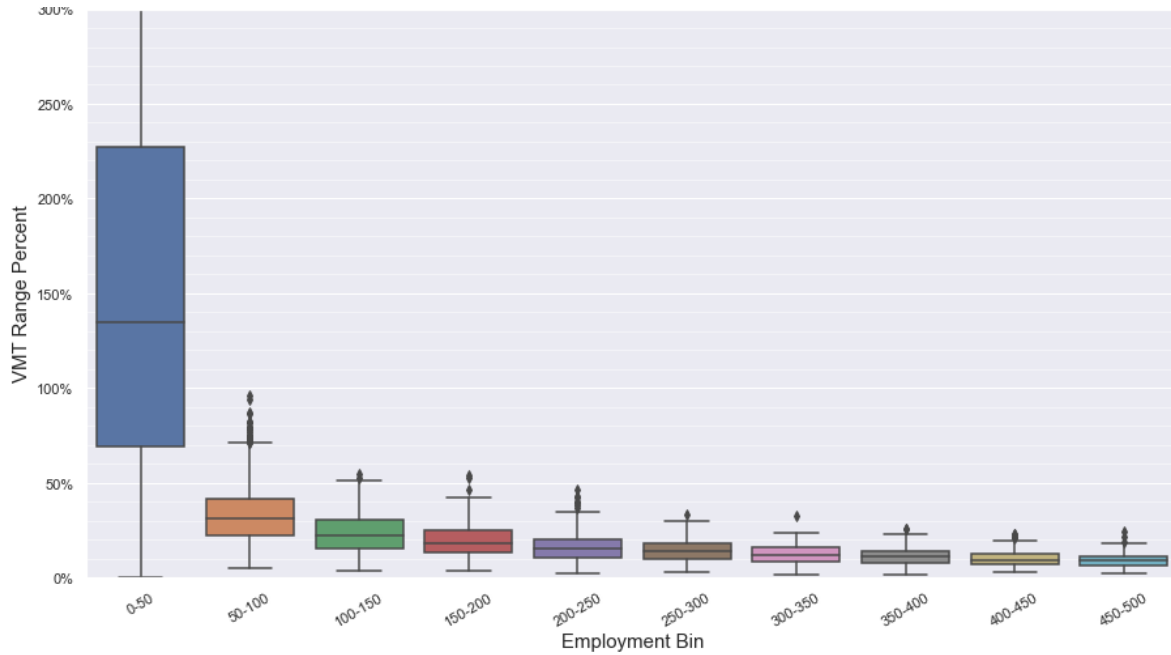
TABLE 23: VMT RANGE PERCENTAGE BY EMPLOYMENT BIN FOR MGRAS WITH <800 EMPLOYMENT

EMPLOYMENT BIN	MEAN	MEDIAN	FIRST QUARTILE VALUE	THIRD QUARTILE VALUE	95 PERCENTILE VALUE	COUNT MGRA
0-50	163%	135%	70%	227%	412%	15410
50-100	33%	31%	22%	42%	61%	1411
100-150	23%	22%	16%	30%	41%	698
150-200	19%	18%	13%	25%	35%	473
200-250	17%	15%	11%	21%	33%	316
250-300	14%	14%	10%	18%	26%	237
300-350	12%	12%	8%	16%	21%	194
350-400	12%	12%	8%	14%	20%	138
400-450	10%	9%	7%	13%	19%	121
450-500	10%	9%	7%	11%	17%	109
500-550	9%	8%	7%	12%	15%	66
550-600	9%	9%	6%	12%	16%	60
600-650	7%	7%	5%	9%	13%	56
650-700	7%	7%	5%	9%	12%	60
700-750	8%	7%	5%	9%	13%	42
750-800	7%	6%	5%	8%	10%	32

5.0 APPLICATION TESTS

The RSG and SANDAG team performed numerous application tests. Table 24 lists the 3 sets of application tests run by RSG. The following sections describe the tests in more detail and discuss results.

TABLE 24: APPLICATION TESTS

#	TEST	DESCRIPTION	TEAM MEMBER
Replicate Service Bureau Projects			
1	San Marcos University District	2016 Vision scenario with land use override inputs for 21 MGRAs	RSG
2	Pardee South Otay	2016 Vision scenario with land use override inputs for 8 MGRAs	RSG
TAZ Split			
3	San Marcos University District	2016 Vision scenario with land use override inputs for 21 MGRAs	RSG
Household Sampling			
4	Seaport Village	2035 No-Build scenario with different sample rates. Total 8 runs.	RSG

5.1 REPLICATE SERVICE BUREAU PROJECTS

RSG performed the following two tests using 2016 version scenarios from the Service Bureau:

1. San Marcos University District (in TAZ 1031 and 1033)
2. Pardee South Otay (in TAZ 4939)

Table 25 and Table 26 present land use summaries for the two projects.

TABLE 25: PROJECT SUMMARY – SAN MARCOS

DATA TYPE	PROJECT TOTAL
Dwelling Unit	6,531
Employee	2,836
Thousand Square Feet (KSF)	2,009
Hotel Rooms	219
Students	20,833

TABLE 26: PROJECT SUMMARY – PARDEE

DATA TYPE	PROJECT TOTAL
Dwelling Unit	5,280
Employee	625
Students	2,750

For each test, RSG first ran the land use converter to setup no-build and build scenarios. We then ran the two model scenarios and compared the results. In addition to comparing build with no-build, we compared the no-build results with the corresponding SANDAG Regional Plan (RP) scenario to see changes just due to model enhancements. For comparisons, we summarized each scenario for population, VMT, and VMT per capita in three geographic segments: project area, rest of the region, and regional. We then calculated the difference in results – no-build is compared with RP 2016 and build is compared with no-build for the same year. Table 27 and Table 28 present San Macros test comparisons and percent differences, respectively, and Table 29 and Table 30 present Pardee test comparisons and percent differences, respectively.

The two tests show expected results. The no-build results are similar to the corresponding RP runs. Compared to the no-build results, the build results show higher VMT in the project area and therefore, regionally as well. The results for the remainder of the region look similar.

TABLE 27: APPLICATION TEST RESULTS - SAN MARCOS

	RP 2016			NO-BUILD			BUILD		
	Persons	VMT	VMT per Capita	Persons	VMT	VMT per Capita	Persons	VMT	VMT per Capita
Project	2,866	38,615	13.47	2,856	41,234	14.44	21,508	283,680	13.19
Remainder	3,262,622	61,666,650	18.90	3,263,483	61,781,722	18.93	3,263,483	61,815,013	18.94
Regional	**3,265,488**	**61,705,265**	**18.90**	**3,266,339**	**61,822,956**	**18.93**	**3,284,991**	**62,098,693**	**18.90**

TABLE 28: APPLICATION TEST RESULTS (PERCENT DIFF) - SAN MARCOS

	NO-BUILD (DIFF WITH RP 2016)			BUILD (DIFF WITH NO-BUILD)		
	Persons	VMT	VMT per Capita	Persons	VMT	VMT per Capita
Project	-0.37%	6.78%	7.17%	653.21%	587.98%	-8.66%
Remainder	0.03%	0.19%	0.16%	0.00%	0.05%	0.05%
Regional	**0.03%**	**0.19%**	**0.16%**	**0.57%**	**0.45%**	**-0.12%**

TABLE 29: APPLICATION TEST RESULTS - PARDEE

	RP 2016			NO-BUILD			BUILD		
	Persons	VMT	VMT per Capita	Persons	VMT	VMT per Capita	Persons	VMT	VMT per Capita
Project	51	933	18.30	50	836	16.72	18,900	285,832	15.12
Remainder	3,265,437	61,704,332	18.90	3,266,145	61,710,193	18.89	3,266,145	61,722,566	18.90
Regional	**3,265,488**	**61,705,265**	**18.90**	**3,266,195**	**61,711,029**	**18.89**	**3,285,045**	**62,008,398**	**18.88**

TABLE 30: APPLICATION TEST RESULTS (PERCENT DIFF) - PARDEE

	NO-BUILD (DIFF WITH RP 2016)			BUILD (DIFF WITH NO-BUILD)		
	Persons	VMT	VMT per Capita	Persons	VMT	VMT per Capita
Project	-1.96%	-10.42%	-8.63%	37700.50%	34094.71%	-9.54%
Remainder	0.02%	0.01%	-0.01%	0.00%	0.02%	0.02%
Regional	**0.02%**	**0.01%**	**-0.01%**	**0.58%**	**0.48%**	**-0.09%**

5.2 TAZ SPLIT

RSG tested the land use converter tool for a TAZ split scenario. For this purpose, we used the San Macros scenario that is described under 5.1 Replicate Service Bureau Projects. We re-created and re-ran the build scenario with three new TAZs resulted from splitting a couple existing TAZs. Table 31 presents the list of new TAZs and their crosswalk with original TAZs and MGRAs.

TABLE 31: TAZ SPLITS

MGRA	ORIGINAL TAZ	NEW TAZ
4677	2236	4999
22544	3576	4997
22545	3576	4998
22547	3576	4998
22548	3576	4998
22550	3576	4998

Table 32 compares the results of the two build scenarios, regular build and build with the TAZ split. The VMT results are very similar regionally and outside the project area (remainder), however, in the project area, the results are different by 10%. The difference is concerning given that the TAZ splits were outside the project area. SANDAG staff have seen similar differences in their other application tests of TAZ split and are investigating into the issue.

TABLE 32: APPLICATION TEST RESULTS - SAN MARCOS TAZ SPLIT

	BUILD			BUILD (WITH TAZ SPLIT)			%DIFF		
	Persons	VMT	VMT per Capita	Persons	VMT	VMT per Capita	Persons	VMT	VMT per Capita
Project	21,508	283,680	13.19	21,508	256,046	11.90	0.00%	-9.74%	-9.74%
Remainder	3,263,483	61,815,013	18.94	3,263,483	61,842,119	18.95	0.00%	0.04%	0.04%
Regional	**3,284,991**	**62,098,693**	**18.90**	**3,284,991**	**62,098,165**	**18.90**	**0.00%**	**0.00%**	**0.00%**

5.3 HOUSEHOLD SAMPLING

RSG performed eight scenario runs with varying household sampling rates in the project area to assess the impact of household level sampling on model results. The tests were designed to have a varying sample rate for three sets of development in the Seaport Village area (TAZ=4123,4070): household and employment, only household, and only employment. Table 33 provides a summary of the Seaport Village development project used in the household sampling tests. All eight tests are developed using the Seaport Village development project. Household and employment tests include the entire project, however, household only tests exclude thousand square feet (KSF) and employment only tests exclude dwelling unit development. Table 34 presents the sample plan for each test.

TABLE 33: PROJECT SUMMARY – SEAPORT VILLAGE HOUSEHOLD SAMPLING

DATA TYPE	PROJECT TOTAL
Dwelling Unit	400
Thousand Square Feet (KSF)	737
Hotel Rooms	550
Students	1,559

TABLE 34: SAMPLING PLAN IN HOUSEHOLD SAMPLING TESTS

TEST	SAMPLING	
	Project Area	Outside
Household and Employment		
No Sampling	100%	100%
Over Sampling 2	200%	100%
Over Sampling 4	400%	100%
Household Only (no KSF)		
No Sampling	100%	100%
Over Sampling 2	200%	100%
Over Sampling 4	400%	100%
Employment Only (no Dwelling Unit)		
No Sampling	100%	100%
Over Sampling 2	200%	100%

Table 35 and Table 36 summarizes the eight tests in terms of number of workers working within the City Community Planning Area (CICPA) of the project and outside the CICPA. Within each set of tests, we compared the number of workers in the over sampling scenario(s) with the no sampling scenario to examine if sampling is producing in big shift in the worker's work location choice. As sampling is applied only to households, only scenarios that have dwelling units as part of the development project will see household sampling changes. In other words, the employment only tests will not see any sampling since there are no dwelling units (households) in the project.

The results look reasonable and do not raise any immediate concerns in sampling methodology. Oversampling either by 200% or 400% do not show a significant change in the number of workers in the CICPA and provides stable results. However, to evaluate the impact of sampling on the stability of model results would require running a particular sampling scenario multiple times with different random seeds and calculating variability across those runs. We recommend SANDAG run the same tests as in 4.5 Variability and Thresholds under Variability but varying household sampling assumptions and process these results to generate summaries of variability across the sampling runs. Then, SANDAG could compare the two sets of variability to assess if household sampling has reduced variability in model results.

TABLE 35: NUMBER OF WORKERS – HOUSEHOLD SAMPLING

	HOUSEHOLD AND EMPLOYEES			HOUSEHOLD ONLY			EMPLOYEES ONLY	
	No Sampling	Over Sampling 2	Over Sampling 4	No Sampling	Over Sampling 2	Over Sampling 4	No Sampling	Over Sampling 2
CICPA	79,752	80,584	80,144	79,501	79,852	79,761	79,863	80,063
Outside	1,597,503	1,596,671	1,597,111	1,597,754	1,597,403	1,597,494	1,597,043	1,596,843
Total	**1,677,255**	**1,677,255**	**1,677,255**	**1,677,255**	**1,677,255**	**1,677,255**	**1,676,906**	**1,676,906**

*CICPA = City Community Planning Area

TABLE 36: APPLICATION TEST RESULTS (PERCENT DIFF) – HOUSEHOLD SAMPLING

	HOUSEHOLD AND EMPLOYEES			HOUSEHOLD ONLY			EMPLOYEES ONLY	
	No Sampling	Over Sampling 2	Over Sampling 4	No Sampling	Over Sampling 2	Over Sampling 4	No Sampling	Over Sampling 2
CICPA		1.04%	0.49%		0.44%	0.33%		0.25%
Outside		0.00%	0.00%		0.00%	0.00%		0.00%
Total		**1.04%**	**0.49%**		**0.44%**	**0.33%**		**0.25%**

CCPA = City Community Planning Area

6.0 SUMMARY

SANDAG transportation modeling staff have tested and approved the ABM2+ Application Tool as part of the PRP141 ABM2+ Release 14.3.0 on July 12, 2022. The ABM2+ subarea enhancements were completed to customize subarea ABM scenarios. This work included converting all scripts to python and providing the following capabilities within the Application Tool:

- A flexible TAZ system that allows the user to split zones within a proposed project development to isolate project impacts from existing development.

- Residential and nonresidential land use assumptions that allow the user to override the land uses in the proposed project development.

- A synthetic population procedure that allows the user to update the regional synthetic population to include the proposed project population.

- A household sampling procedure to over-sample persons and households within the proposed project study area.

In addition, existing procedures for shadow pricing, checking model inputs, and reporting outputs have been automated to allow the user to apply these procedures easily within the Application Tool. Interactive maps help visualize project land use changes, including new household and employment densities.

The ABM2+ model enhancements included research into employment densities and trip rates by land use type. RSG and SANDAG staff ran a series of tests to evaluate the variability for different subareas using fixed and variable random number seeds and ran additional tests to quantify the population and employment variability and set thresholds to ensure statistical reliability. These thresholds provide more confidence in the results for proposed project developments that meet or exceed the thresholds. These model enhancements may also provide value to other metropolitan planning organizations, since these data are not widely available for detailed land use types.

RSG and SANDAG staff worked collaboratively to test the ABM2+ Application Tool. This included a series of 12 application tests. These tests included scenarios to replicate existing Service Bureau projects, evaluate unique land use types (affordable housing, hotels, schools, parks and beaches, and mixed-use developments), and to test sample rates and buffer distances, zone splits, and select link and zone procedures.

APPENDIX A. LAND USE DEFINITIONS[5]

TABLE 37: SANDAG LAND USE TYPE DEFINITIONS

LUCODE	DESCRIPTION	DEFINITION
101	Single Family Residential	
102	Multi-family Residential	Multiple dwelling units contained on a single floor. Examples include rental apartments and single floor condominiums (in general, more than 12 units per acre). Newer developments may include clubhouses, recreation areas, pools, tennis, etc. located within and associated with the residential development, if a separate parcel polygon does not exist.
103	Mobile Home Park	Includes mobile home parks with ten or more spaces that are primarily for residential use. (Recreational vehicle parks which are intended for short term use are included within the commercial recreation category).
1400	Group Quarters	Group living accommodations. Two types of group quarters exist: Institutional (such as correctional facilities, nursing homes, or psychiatric hospitals) and noninstitutional (such as college dormitories, military barracks, group homes, missions, or shelters).
1401	Jail/Prison	
1402	Dormitory	School associated group living accommodations. Must be counted toward the total student housing for the school. Private housing targeted to students is not considered a dormitory.
1403	Military Barracks	Group living accommodations for military personnel. Does not include family or apartment-style housing located on-base.
1404	Monastery	

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[5] Last Revised: February 2018, see
https://www.sandag.org/resources/maps_and_gis/gis_downloads/downloads/codes/Land_Use_Definitions.html for most up to date information.

LUCODE	DESCRIPTION	DEFINITION
1409	Other Group Quarters Facility	Convalescent or retirement homes not associated with or within a health care facility, fraternities/sororities, rooming houses, half-way houses, California Conservation Corps, Honor Camps, and other correctional facilities.
1500	Hotel/Motel/Resort	
1501	Hotel/Motel (Low-Rise)	Hotels, motels, and other transient accommodations with three or less floors. Commonly found along freeways and prime commercial areas.
1502	Hotel/Motel (High-Rise)	Hotels and motels that have four or more floors. Primarily found in downtown areas and near tourist attractions.
1503	Resort	Resorts with hotel accommodations that usually contain recreation areas. Examples of resorts would be La Costa Health Spa, Lawrence Welk, and the Olympic Resort in Carlsbad near the airport.
2000	Heavy Industry	
2001	Heavy Industry	Shipbuilding, airframe, and aircraft manufacturing. Usually located close to transportation facilities and commercial areas. Parcels are typically large, 20-50 acres.
2100	Light Industry	
2101	Industrial Park	Office/industrial uses clustered into a center. The primary uses are industrial but may include high percentages of other uses in service or retail activities.
2103	Light Industry - General	All other industrial uses and manufacturing not included in the categories above. These are not located inside of parks, but are usually along major streets or clustered in certain areas. Includes manufacturing uses such as lumber, furniture, paper, rubber, stone, clay, and glass; as well as light industrial uses as auto repair services and recycling centers. Mixed commercial and office uses (if not large enough to be identified separately) are also included. General industrial areas comprise 75% or more of industrial uses (manufacturing, warehousing, and wholesale trade).

LUCODE	DESCRIPTION	DEFINITION
2104	Warehousing	Usually large buildings located near freeways, industrial, or strip commercial areas.
2105	Public Storage	Public self-storage buildings are typically long, rectangular and closely spaced. Also includes recreational vehicle storage areas.
2200	Extractive Industry	
2201	Extractive Industry	Mining, sand and gravel extraction, salt evaporation.
2300	Junkyards/Dumps/Landfills	
2301	Junkyard/Dump/Landfill	The landscape should show visible signs of the activity. Also include auto wrecking/dismantling and recycling centers.
4100	Airports	
4101	Commercial Airport	Lindbergh Field only.
4102	Military Airport	Airports owned and operated by the military. Found on Military bases.
4103	General Aviation Airport	All general aviation airports.
4104	Airstrip	
4110	Other Transportation	
4111	Rail Station/Transit Center	Major transit centers (e.g. Oceanside Transit Center, El Cajon Transit Center), rail stations (e.g. Santa Fe Depot, Solana Beach Station), Coaster stations (Oceanside, Carlsbad Village, Carlsbad Poinsettia, Encinitas, Solana Beach, Sorrento Valley, Old Town, San Diego), major trolley stations, and seaport terminals (Port of San Diego). Parking areas associated with these uses are included. Transit centers within shopping centers are included within the shopping center category.
4112	Freeway	Divided roadways with four or more lanes, restricted access, grade separations, and rights of way greater than 200 ft. wide. Includes all right of way and interchange areas, but not frontage roads.

LUCODE	DESCRIPTION	DEFINITION
4113	Communications and Utilities	TV and radio broadcasting stations, relay towers, electrical power generating plants, water and sewage treatment facilities, and large public water supply storage tanks.
4114	Parking Lot - Surface	All surface parking lots not associated with another land use.
4115	Parking Lot - Structure	All large parking structures not associated with another land use.
4116	Park and Ride Lot	Stand-alone parking areas that are not associated with any land use. These are usually located near freeways.
4117	Railroad Right of Way	All railroad ROWs.
4118	Road Right of Way	All street ROWs.
4119	Other Transportation	Maintenance yards and their associated activities, transit yards and walking bridges.
4120	Marine Terminal	National City and 10th Street (Center City) marine terminals.
5000	Commercial	
5001	Wholesale Trade	Usually located near transportation facilities. Structures are usually large and cover the majority of the parcel. Examples are clothing and supply. Also includes swap meet areas.
5002	Regional Shopping Center	Contain one to five major department stores, and usually have more than 50 tenants. Typically are larger than 40 acres in size.
5003	Community Shopping Center	Smaller in size than the regional shopping centers. Contain a junior department store or variety store (i.e. a Target Center with other commercial stores) as a major tenant and have 15 to 50 other tenants. Smaller in size, 8 to 20 acres. May also have a variety store (i.e. Target, Home Depot, or Price/Costco) by itself.
5004	Neighborhood Shopping Center	Usually less than 10 acres in size with on-site parking. Includes supermarket and drug store centers not identified as community commercial. May include office uses that are not large enough to code separately. Neighborhood centers with over 100,000 sq. ft. are inventoried by the Chamber of

LUCODE	DESCRIPTION	DEFINITION
		Commerce, and The Union Tribune (Copley) also collects data on neighborhood centers.
5005	Specialty Commercial	Tourist or specialty commercial shopping areas such as Seaport Village, Marina Village, Ferry Landing at Coronado, Bazaar del Mundo, Flower Hill, Glasshouse Square, The Lumberyard, Park Plaza at the Village, Promenade, Belmont Park, Del Mar Plaza.
5006	Automobile Dealership	Includes National City Mile of Cars and Carlsbad Car Country, among others.
5007	Arterial Commercial	Includes commercial activities found along major streets (not in planned centers), with limited on-site parking. May include mixed office uses that are not large enough to be identified as a separate area. Also may include mixed residential uses, i.e. residential on top of commercial or residential units adjacent to commercial establishments.
5008	Service Station	Includes gasoline service stations and associated convenience store on stand-alone parcels where it is the primary use.
5009	Other Retail Trade and Strip Commercial	Other retail land uses not classified above.
6000	Office	
6001	Office (High-Rise)	High-rise buildings with more than four stories containing banking, offices for business and professional services (finance, insurance, real estate), some retail activities and restaurants.
6002	Office (Low-Rise)	Low-rise buildings with less than five stories containing banking, offices for business and professional services (finance, insurance, real estate), some retail activities and restaurants.
6003	Government Office/Civic Center	Large government office buildings or centers (outside of military reservations) and civic centers, or city halls of local

LUCODE	DESCRIPTION	DEFINITION
		governments. Also includes the Chamber of Commerce buildings and Department of Motor Vehicles Offices.
6100	Public Services	
6101	Cemetery	
6102	Religious Facility	
6103	Library	
6104	Post Office	
6105	Fire/Police Station	
6108	Mission	
6109	Other Public Services	Cultural facilities, museums, art galleries, social service agencies, humane societies, historic sites, and observatories.
6500	Hospitals	
6501	UCSD/VA Hospital/Balboa Hospital	
6502	Hospital - General	Hospitals not included above.
6509	Other Health Care	Medical centers and buildings or offices, health care services, and other health care facilities. Smaller medical offices and facilities may be included within office, strip commercial, or other surrounding uses.
6700	Military Use	
6701	Military Use	Defense installations, operational facilities, maintenance facilities (nonweapons), research and development, supply and storage (nonweapons), community support facilities and any other military use that does not fall in other categories.
6702	Military Training	Academic, operational and combat training facilities, training ranges, and special purpose training ranges.
6703	Weapons Facility	Weapons assembly, maintenance and storage facilities.
6800	Schools	

LUCODE	DESCRIPTION	DEFINITION
6801	SDSU/CSU San Marcos/UCSD	
6802	Other University or College	
6803	Junior College	Includes trade or vocational schools.
6804	Senior High School	
6805	Junior High School or Middle School	
6806	Elementary School	
6807	School District Office	
6809	Other School	Includes adult schools, nonresidential day care, and nursery schools.
7200	Commercial Recreation	
7201	Tourist Attraction	Sea World, Zoo, and Wild Animal Park, Legoland.
7202	Stadium/Arena	Sports Arena, San Diego Stadium, and Petco Park.
7203	Racetrack	Del Mar, San Luis Rey Downs.
7204	Golf Course	Public and private golf courses.
7205	Golf Course Clubhouse	Clubhouses, swimming and tennis facilities, and parking lots associated with the golf course.
7206	Convention Center	Center City, Embarcadero.
7207	Marina	Includes marinas such as Oceanside Harbor, Quivira Basin, Shelter Island, Harbor Island, Embarcadero, and Chula Vista marina.
7208	Olympic Training Center	Olympic Training Center in Chula Vista.
7209	Casino	Gambling establishments, typically located on Indian Reservations.
7210	Other Recreation - High	High intensity uses primarily in urban areas. Drive-in theaters, fitness clubs, boys/girls clubs, YMCA's, swim clubs, and

LUCODE	DESCRIPTION	DEFINITION
		stand-alone movie theaters. Also includes tennis clubs without golf, rodeo grounds, and recreation centers for older people.
7211	Other Recreation - Low	Campgrounds and other low intensity recreation. Includes public and private primitive and developed camping areas for tents and recreational vehicles. Also includes camps and retreat centers owned or used by religious organizations, scouting, or YMCA. Other low intensity uses such as rifle ranges are included.
7600	Parks	
7601	Park - Active	Recreation areas and centers containing one or more of the following activities: tennis or basketball courts, baseball diamonds, soccer fields, or swings. Examples are Robb Field, Morley Field, Diamond Street Recreation Center, and Presidio Park. Smaller neighborhood parks with a high level of use are also included as active parks.
7603	Open Space Park or Preserve	Wildlife and nature preserves, lands set aside for open space, and parks with limited development and access. Examples are Torrey Pines State Reserve, Penasquitos Canyon Reserve, San Elijo Ecological Preserve, and Nature Conservancy properties.
7604	Beach - Active	Accessible sandy areas along the coast or major water bodies (San Diego and Mission Bay) allowing swimming, picnicking, and other beach related recreational activities. Usually has parking associated with it.
7605	Beach - Passive	Other sandy areas along the coastline with limited parking and access (beaches along cliffs, or near preserves).
7606	Landscape Open Space	Actively landscaped areas within residential neighborhoods such as greenbelt areas and hillsides with planted vegetation (trees/shrubs), among others.
7607	Residential Recreation	Active neighborhood parks that are for residents only such as fenced in areas that may contain pools, tennis and basketball courts, barbecues, and a community meeting room.

LUCODE	DESCRIPTION	DEFINITION
7609	Undevelopable Natural Area	* Planned land use only - Undevelopable natural areas that are not part of an established open space park or preserve. Examples are Cleveland National Forest and open space easements around developments.
8000	Agriculture	
8001	Orchard or Vineyard	
8002	Intensive Agriculture	Nurseries, greenhouses, flower fields, dairies, livestock, poultry, equine ranches, row crops, and grains.
8003	Field Crops	Also includes pasture and fallow land.
9100	Vacant and Undeveloped Land	* Historical and Existing only.
9101	Vacant and Undeveloped Land	
9200	Water	
9201	Bay or Lagoon	
9202	Lake/Reservoir/Large Pond	
9300	Tribal Land	* Planned land use only.
9400	Public/Semipublic	* Planned land use only.
9500	Under Construction	* Historical and Existing only.
9501	Residential Under Construction	Usually located near existing residential developments.
9502	Commercial Under Construction	Usually located near existing commercial or residential areas.
9503	Industrial Under Construction	Usually located near existing industrial or commercial developments.
9504	Office Under Construction	Usually located near existing industrial or commercial developments.

LUCODE	DESCRIPTION	DEFINITION
9505	School Under Construction	
9506	Road Under Construction	
9507	Freeway Under Construction	
9600	Specific Plan Area	* Planned land use only.
9700	Mixed-Use	Vertical mixed-use development with street-level commercial uses and residential or office uses above.

APPENDIX B. EMPLOYMENT DENSITIES BY SQUARE FEET

TABLE 38: SQUARE FOOTAGE-BASED EMPLOYMENT DENSITIES

LU_TYPE	DESCRIPTION	SANDAG DENSITY (2012)	NEW RECOMMENDED DENSITY	
		(SQ.FT./EMPLOYEE)	SQ.FT./EMPLOYEE	SOURCE
1402	Dormitory	50	50	Costar+Bldg
1403	Military Barracks	50	9,100	Costar+Bldg
1409	Other Group Quarters Facility	900	600	Costar
1501	Hotel (Low-Rise)	1,850	1,600	Costar
1502	Hotel (High-Rise)	1,350	1,600	Costar
1503	Resort	550	700	Costar
2001	Heavy Industry	250	300	Costar
2101	Industrial Park	1,050	600	Costar+Bldg
2103	Light Industry - General	1,200	700	Costar+Bldg
2104	Warehousing	1,550	1,250	Costar
2105	Public Storage	15,000	22,950	Costar
2301	Scrap Yards/Auto Dismanttling/Landfill	800	1,200	Costar+Bldg
4101	Commercial Airport	1,050	1,050	SANDAG 2012
4102	Military Airport	50	1,350	Costar+Bldg
4103	General Aviation Airport	300	900	Costar+Bldg
4104	Airstrip	300	1,250	Costar+Bldg
4111	Rail Station/Transit Center	450	750	Costar+Bldg
4112	Right of Way	400	250	Costar+Bldg

LU_TYPE	DESCRIPTION	SANDAG DENSITY (2012)	NEW RECOMMENDED DENSITY	
		(SQ.FT./EMPLOYEE)	SQ.FT./EMPLOYEE	SOURCE
4113	Communications and Utilities	350	650	Costar+Bldg
4114	Parking Lot - Surface	550	350	Costar+Bldg
4115	Parking Lot - Structure	1,150	2,450	Costar
4116	Park and Ride Lot	18,300	350	Costar+Bldg
4117	Railroad Right of Way	550	550	Costar+Bldg
4118	Road Right of Way	550	450	Costar+Bldg
4119	Other Transportation	450	400	Costar+Bldg
4120	Marine Terminal	400	400	SANDAG 2012
5001	Wholesale Trade	800	950	Costar+Bldg
5002	Regional Shopping Center (300000 SF or more)	750	800	Costar+Bldg
5003	Community Shopping Center (100000 SF or more)	500	450	Costar+Bldg
5004	Neighborhood Shopping Center (30000 SF or more)	550	400	Costar+Bldg
5005	Specialty Commercial (Seaport Village - Tourist)	500	250	Costar+Bldg
5006	Automobile Dealership	500	400	Costar+Bldg
5007	Arterial Commercial (Street Commercial)	700	350	Costar+Bldg
5008	Service Station	300	250	Costar+Bldg
5009	Other Retail Trade and Strip Commercial	900	450	Costar+Bldg
6001	Office (High-Rise - greater than 100000 SF)	300	400	Costar+Bldg

LU_TYPE	DESCRIPTION	SANDAG DENSITY (2012)	NEW RECOMMENDED DENSITY	
		(SQ.FT./EMPLOYEE)	SQ.FT./EMPLOYEE	SOURCE
6002	Office (Low-Rise - less or equal to 100000 SF)	200	450	Costar+Bldg
6003	Government Office/Civic Center	200	650	Costar+Bldg
6102	Religious Facility (without day care)	2,700	1,500	Costar+Bldg
6103	Library	550	550	SANDAG 2012
6104	Post Office	200	300	Costar+Bldg
6105	Fire/Police Station	200	200	Costar
6108	Mission	2,150	2,100	Costar+Bldg
6109	Other Public Services	1,300	750	Costar
6501	UCSD/VA Hospital/Balboa Hospital	100	100	Costar+Bldg
6502	Hospital - General	450	300	Costar+Bldg
6509	Other Health Care	500	450	Costar+Bldg
6701	Military Use	300	2,300	Costar+Bldg
6702	Military Training	50	2,300	Costar+Bldg
6807	School District Office	200	100	Costar+Bldg
7206	Convention Center	2,450	2,600	Costar
7209	Casino	50	250	Costar+Bldg

APPENDIX C. EMPLOYMENT DENSITY BY ACRE

TABLE 39: ACREAGE-BASED EMPLOYMENT DENSITIES

LU_TYPE	DESCRIPTION	ACRE/EMPLOYEE
2201	Extractive Industry	0.53
6101	Cemetery	0.86
7201	Tourist Attraction	0.07
7202	Stadium/Arena	0.07
7203	Racetrack	0.26
7204	Golf Course	1.79
7205	Golf Course Clubhouse	0.09
7207	Marina	0.15
7208	Olympic Training Center	0.17
7210	Other Recreation – High	0.34
7211	Other Recreation – Low	2.18
7601	Park – Active	0.48
7603	Open Space Park or Preserve	20.57
7604	Beach – Active	2.89
7606	Landscape Open Space	0.14
7607	Residential Recreation	0.42
7609	Undevelopable Natural Area	57.79
8001	Orchard or Vineyard	3.86
8002	Intensive Agriculture	0.88
8003	Field Crops	4.37
9101	Vacant and Undeveloped Land	1.82
9201	Bay or Lagoon	0.14
9202	Lake/Reservoir/Large Pond	0.25

APPENDIX D. JAVA CHANGES FOR HOUSEHOLD SAMPLING

Table 40 lists the Java files that were changed to implement household sampling in ABM2+. The changes are committed (JIRA ticket: ABM-1396) to the GitHub repository.

TABLE 40: JAVA FILES UPDATED FOR HOUSEHOLD SAMPLING IMPLEMENTATION

#	FILE PATH (GITHUB)
1	src/main/java/org/sandag/abm/active/sandag/SandagBikePathChoiceLogsumMatrixApplication.java
2	src/main/java/org/sandag/abm/application/SandagHouseholdDataManager2.java
3	src/main/java/org/sandag/abm/application/SandagTripTables.java
4	src/main/java/org/sandag/abm/ctramp/DestChoiceDMU.java
5	src/main/java/org/sandag/abm/ctramp/DestChoiceTwoStageModelDMU.java
6	src/main/java/org/sandag/abm/ctramp/Household.java
7	src/main/java/org/sandag/abm/ctramp/HouseholdDataManager.java
8	src/main/java/org/sandag/abm/ctramp/HouseholdDataWriter.java
9	src/main/java/org/sandag/abm/ctramp/Person.java
10	src/main/java/org/sandag/abm/ctramp/Stop.java
11	src/main/java/org/sandag/abm/ctramp/Tour.java
12	src/main/java/org/sandag/abm/internalexternal/InternalExternalModel.java
13	src/main/java/org/sandag/abm/internalexternal/InternalExternalTour.java
14	src/main/java/org/sandag/abm/internalexternal/InternalExternalTourManager.java
15	src/main/java/org/sandag/abm/internalexternal/InternalExternalTrip.java
16	src/main/java/org/sandag/abm/internalexternal/InternalExternalTripTables.java