2055
REGIONAL MOBILITY AND ACCESSIBILITY

DRAFT

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2055 Regional Mobility and Accessibility Plan (RMAP) Technical Addendum

A Report on Population Forecasts and Modeling of Land Use, Travel Demand, and Air Quality for the 2055 RMAP

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POPULATION ESTIMATES AND PROJECTIONS

Population, both current and future, is one of many input variables for various PAG models such as the Travel Demand Model (TDM) and Land Use Model. In the state of Arizona, such population data is generated by the Arizona Office of Economic Opportunity (AOEO). AOEO works with local government agencies and Councils of Governments (COG) to produce July 1st annual population estimates. Several times a decade, AOEO also develops long range population forecasts, typically in the 2nd, 5th and 8th years.

As the COG for the Tucson region, PAG is designated to work with AOEO for the development of the county and sub-county population estimates and projections for Pima County. Being a committee member of the Council of Technical Solutions (CTS), PAG has been involved in the review and comment process to supply AOEO with the locally collected data and ensure the quality of population data products.

2024 POPULATION ESTIMATES

The July 1st, 2024 population of Pima County and sub-county areas with five incorporated jurisdictions and the remaining balance of the county were estimated using the weighted average of the modified composite method and the housing unit method (HUM) developed by the AOEO. A weighted average of household population from the composite method (60%) and from the HUM (40%) was applied to obtain the county total household population.

First, the composite method relies on administration data to estimate the household population of four age groups separately:

- Birth and death data collected from the Arizona Dept. of Health for ages 0-4
- School enrollment data collected from the Arizona Dept. of Education for ages 5-17
- Driver's license and ID card data from the Arizona Dept. of Transportation for ages 18-64
- Medicare and Social Security enrollment data for ages 65+

To estimate the 2024 age group populations listed above through the composite method, each group growth rate from 2023 to 2024 was applied to the base 2023 age group household population. The 2024 household population of the four age group components were aggregated to give the county household population through the composite method. The estimation and the growth rate for each group is presented in **Table 1**.

Table 1. Modified Composite Method Estimation with 2023-2024 Growth Rates

Pima County Total Pop	0-4	5-17	18-64	65+	All ages
2020	55,280	160,852	618,551	210,906	1,045,589
2021	53,844	162,718	623,582	218,174	1,058,318
2022	53,048	164,189	629,415	225,646	1,072,298
2023	52,077	163,464	632,809	231,892	1,080,242
% change of indicator data between 2023 & 2024	-1.523%	0.040%	0.110%	2.298%	0.491%
2024	**51,284**	**163,530**	**633,507**	**237,222**	**1,085,543**

To estimate household population, the group quarters (GQ) population was estimated separately (27,500) with 2020 Decennial Census GQ data and locally collected GQ data since the 2020 Decennial Census and was then removed from the total county population (1,085,543). Household population was estimated as 1,057,841 through the modified composite method.

Second, to estimate county and sub-county level population, the HUM was used with jurisdictional building permit data collected from July 2023 to June 2024 along with the parameters of persons per housing unit from 2020 Decennial Census. The estimated county household population by the HUM is 1,060,569 and its subcounty breakdown and its method is shown in **Table 2**.

Table 2. County and Subcounty Household Population Estimation by Housing Unit Method

	A.	B.	C.	D.	E.	F.	G.	H.
Jurisdiction	Adjusted Census 2020 HU	Adjusted Census 2020 HHPop	Adjusted Census 2020 Persons per HU (=B/A)	Adjusted Census 2020 GQ Pop	Net HU Change from April 2020 to June 2024	FY2024 Cumulative annexed units	FY2024 Cumulative annexed units	FY2024 Uncontrolled HH Pop (=C*G)
Marana	21,521	51,367	2.387	541	4,785	3	26,309	62,795
Oro Valley	23,303	46,607	2	463	1,082	0	24,385	48,771
Sahuarita	13,426	34,078	2.538	56	1,433	0	14,859	37,715
South Tucson	2,116	4,613	2.18	0	-19	0	2,097	4,572
Tucson	242,798	519,495	2.14	23,134	6,939	0	249,737	534,342
Pima County Balance	166,968	359,773	2.155	3,306	5,851	-3	172,816	372,374
Pima County Total	470,132	1,015,933		27,500	20,071	0	490,203	1,060,569

Finally, applying the weights of 40% on the modified composite method and 60% on the HUM, total county household population was estimated as 1,058,932 as shown in **Table 3**.

Table 3. Weighted Average Pima County Household Population

	Adjustment Factor
Derived Composite HH Pop	1,057,841
Uncontrolled HUM HH Pop	1,060,569
Weighted Average of Derived Composite HH Pop (60%) and Uncontrolled HUM HH Pop (40%) as Controlled HH Pop	1,058,932
County Adjustment Factor	**0.998457**

The population living in group quarter facilities was subsequently added to the household population to develop the final total population estimate for each sub-county area. Applying the adjustment factor (0.998457) to match the uncontrolled HUM household population (1,060,569) to the county control number (1,058,932), the final county and sub-county populations were estimated as shown in **Table 4.** Total 2024 July 1st population is estimated as 1,086,634. The official population estimates are available at the AOEO Population Estimates website (https://oeo.az.gov/population/estimates)

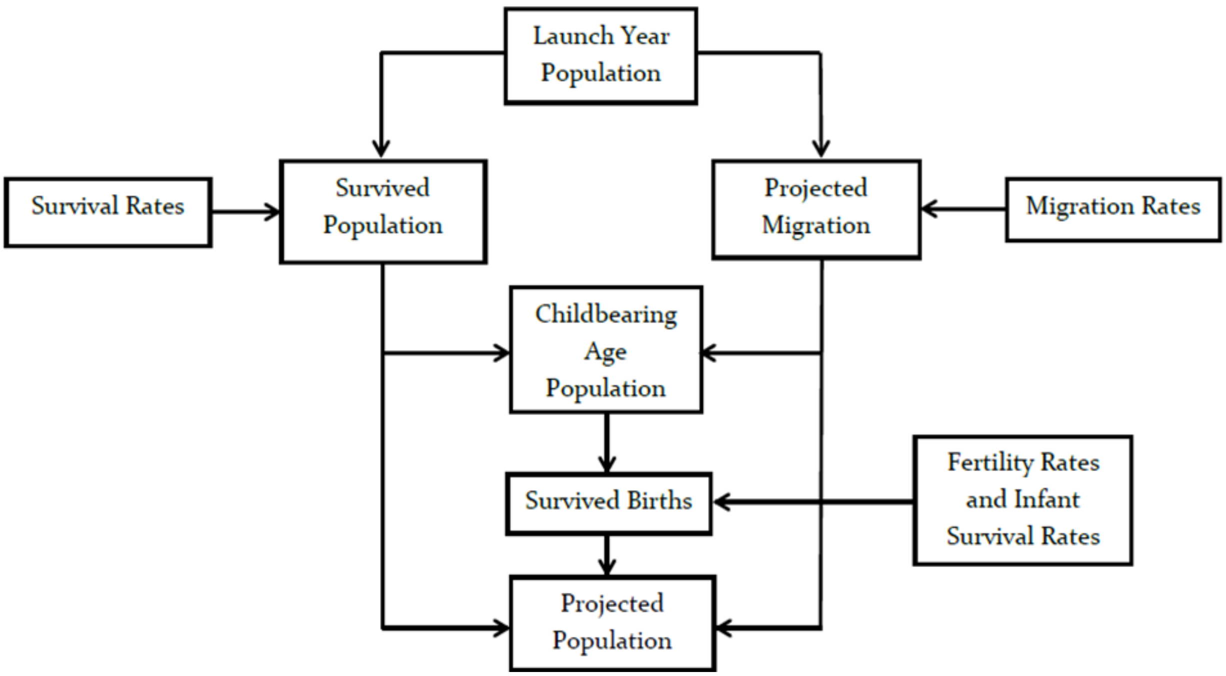
Table 4. 2024 July 1 County and Subcounty Population Estimates

Jurisdiction	H. FY2024 Uncontrolled HH Pop (=C*G)	I. FY2024 HHPop Adj Factor	J. FY2024 Controlled HHPop (=H*I)	K. GQ Pop Change (Census 2020 to GQ 2024)	L. FY2024 GQ Pop (=D+K)	M. FY2024 Total Pop (=J+L)
Marana	62,795	0.998457	**62,698**	-459	**82**	**62,780**
Oro Valley	48,771	0.998457	**48,696**	0	**463**	**49,159**
Sahuarita	37,715	0.998457	**37,657**	0	**56**	**37,713**
South Tucson	4,572	0.998457	**4,565**	0	**0**	**4,565**
Tucson	534,342	0.998457	**533,517**	568	**23,702**	**557,219**
Pima County Balance	372,374	0.998457	**371,799**	93	**3,399**	**375,198**
Pima County Total	1,060,569		**1,058,932**	202	**27,702**	**1,086,634**

2023 SUBCOUNTY POPULATION PROJECTIONS

The 2055 Pima County population forecast was generated by the AOEO in 2022. A cohort-component model (shown in **Figure 1**) was used to account for all components of demographic change, which are fertility, mortality and migration. These components, each projected separately, are combined to produce population projections by age, sex, race and Hispanic origin.

Figure 1. Overview of the Cohort-Component Method for County-level Projection



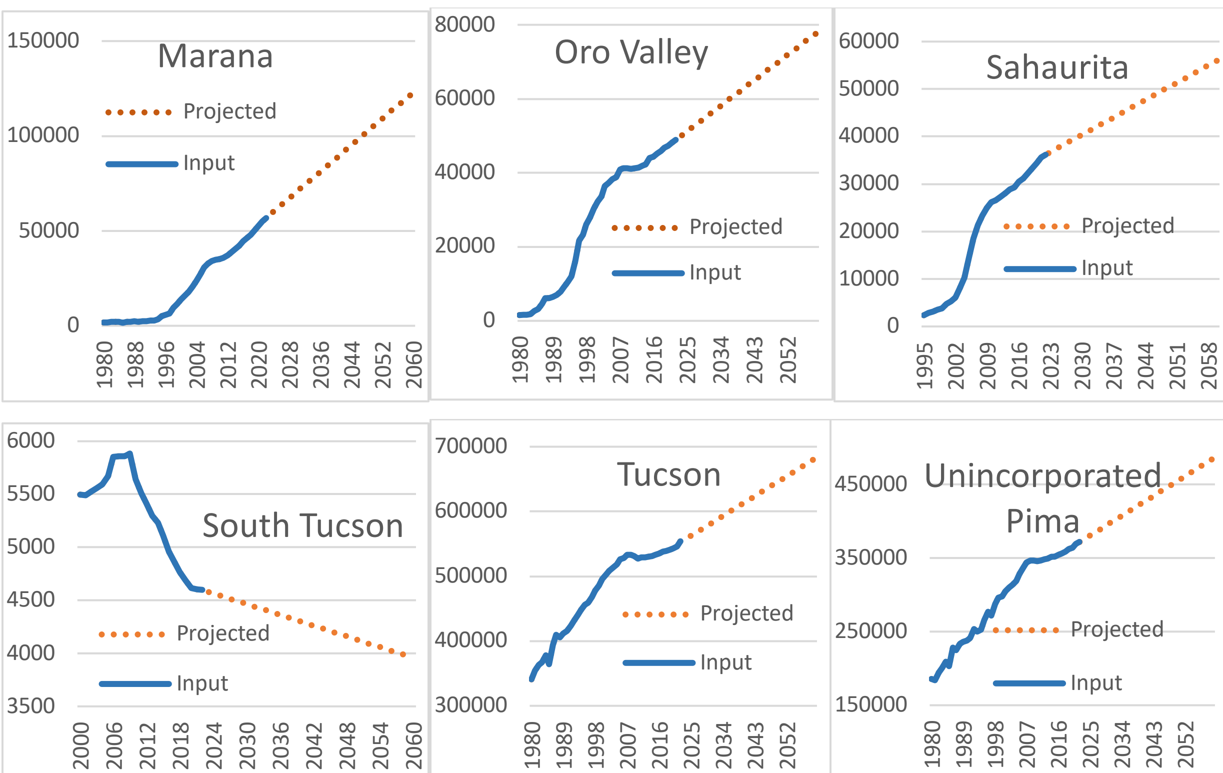
The AOEO projections estimate the population by age, sex, race (White, Black, Asian, Native American, Other) and ethnicity (Hispanic and non-Hispanic). Detailed statistics for population are tabulated by sex, age, and race/Hispanic origin. The age groups, categorized by sex, range from under 1 year to 84 years, in increments of 5 years, with a final group for ages 85 and above.

PAG adopted the AOEO Pima County population projection series. Subsequently, PAG's in-house time-series model (see **Table 5** and **Figure 2**) and adopted 2019 population-share model were implemented to allocate AOEO's projected population growth at the sub-county level.

Table 5. **Time Series Models and Statistics for Subcounty Population Projections**

Jurisdiction	Model Type	R-Squared	MAPE	RMSE
Marana	Brown	0.9989	5.60%	624.81
Oro Valley	Brown	0.9969	4.43%	951.97
Sahuarita	Brown	0.9975	4.41%	600.62
South Tucson	ARIMA (0,2,1)	0.9714	0.85%	73.33
Tucson	Brown	0.9899	0.99%	6,508.92
Unincorporated Pima	Brown	0.9908	1.64%	5,647.24

Figure 2. **Time Series Model for Subcounty Population Projections (No capacity applied)**



In developing sub-county population projections, PAG took into consideration the remaining residential land available for development in each jurisdiction at current densities. Population sub-county forecasts were capped at the point where land for additional residential growth was exhausted. Oro Valley residential population has been capped to 55,850. South Tucson population has been corrected to have zero increase instead of the current decreasing trend through the Population Technical Subcommittee on April 4, 2025. The alternative models were discussed in **Table 6**. The subcommittee unanimously agreed to select the method averaging Time Series with South Tucson Constant and 2019 Population Growth Share Model, "Average Method".

Table 6. Summary of Subcounty Population Projection Model Alternatives

	Time Series Model						Time Series with South Tucson Constant					
	MAR	OV	SAH	STUC	TUC	PC	MAR	OV	SAH	STUC	TUC	PC
2022 Pop	56,758	48,906	36,179	4,599	554,021	371,835	56,758	48,906	36,179	4,599	554,021	371,835
2060 Pop	113,827	55,850	51,846	3,664	631,139	448,886	113,741	55,850	51,807	4,599	630,666	448,549
Growth (22-60)	57,069	6,944	15,667	(935)	77,118	77,051	56,983	6,944	15,628	-	76,645	76,714
Annual Growth	1,502	183	412	(25)	2,029	2,028	1,500	183	411	-	2,017	2,019
Annual Growth Rate	2.65%	0.37%	1.14%	-0.54%	0.37%	0.55%	2.64%	0.37%	1.14%	0.00%	0.36%	0.54%
Annual Growth Rate (10-22)	5.15%	1.60%	3.21%	-1.54%	0.42%	0.63%	5.15%	1.60%	3.21%	-1.54%	0.42%	0.63%
% of Total Growth	24.50%	2.98%	6.73%	-0.40%	33.11%	33.08%	24.47%	2.98%	6.71%	0.00%	32.91%	32.94%
% of Total Growth (10-22)	23.76%	8.63%	11.02%	-1.14%	29.03%	28.70%	23.76%	8.63%	11.02%	-1.14%	29.03%	28.70%

	2019 Pop Share Growth Method						Average Method					
	MAR	OV	SAH	STUC	TUC	PC	MAR	OV	SAH	STUC	TUC	PC
2022 Pop	56,758	48,906	36,179	4,599	554,021	371,835	56,758	48,906	36,179	4,599	554,021	371,835
2060 Pop	118,737	55,850	62,504	4,599	631,558	431,964	116,239	55,850	57,156	4,599	631,112	440,256
Growth (22-60)	61,979	6,944	26,325	-	77,537	60,129	59,481	6,944	20,977	-	77,091	68,421
Annual Growth	1,631	183	693	-	2,040	1,582	1,565	183	552	-	2,029	1,801
Annual Growth Rate	2.87%	0.37%	1.91%	0.00%	0.37%	0.43%	2.76%	0.37%	1.53%	0.00%	0.37%	0.48%
Annual Growth Rate (10-22)	5.15%	1.60%	3.21%	-1.54%	0.42%	0.63%	5.15%	1.60%	3.21%	-1.54%	0.42%	0.63%
% of Total Growth	26.61%	2.98%	11.30%	0.00%	33.29%	25.82%	25.54%	2.98%	9.01%	0.00%	33.10%	29.38%
% of Total Growth (10-22)	23.76%	8.63%	11.02%	-1.14%	29.03%	28.70%	23.76%	8.63%	11.02%	-1.14%	29.03%	28.70%

With the subcounty projections and considering PAG's geographical modeling boundary (Eastern Pima County), the population has been updated and the land-use model (LUM) allocated sub-county population estimates and projections to individual land parcels. Later, the model summarizes the parcel-level population within microanalysis zones (MAZs) nested in transportation analysis zones (TAZs). This allocated growth becomes an input to the next run of the travel demand model (TDM). The combined results of the land-use and travel demand models provide forecasts of future travel demand on regional roadways. These forecasts are essential to facilitate evaluation of transportation plans, project selection, and the development of performance measures. Projected population was also utilized to support other analyses related to the 2055 Regional Mobility and Accessibility Plan (RMAP). Further details will be discussed in Land Use Modeling and Travel Demand Modeling Sections.

LAND USE MODELING

PURPOSE

Efforts over the past years at PAG to develop and implement a long-range land use planning scenario model, or land-use model (LUM), are yielding results. SAM, short for sub-area allocation model, is the land use model used to spatially allocate population and employment growth forecasts to the Tucson metropolitan region. The SAM program enables planners to simulate the development of our region in ways that are consistent with population and employment projections, existing land use and future land use plans. Although the results of the latest SAM modeling scenarios aim to support the planning process of the 2055 RMAP, the model is already contributing to inter-regional planning studies, such as the impact of long-term development on water resources. Going forward, we expect the model and its scenario-testing capabilities to be beneficial for many types of planning. This report describes the model components, methodology, and planning process realized in the 2024-2055 series of spatially allocated population and employment forecasts.

BACKGROUND

The earliest version of what would become the SAM land use model was developed in the mid-1990s for the Maricopa Association of Governments (MAG) in Phoenix. The Mid-Region Council of Governments (MRCOG) in Albuquerque was another early user of the land use model. Around 2003, PAG signed a cooperative agreement with MAG to share the costs of developing an updated version of SAM and supporting databases. Development of the SAM model at PAG continued with assistance from the software consultant through the 2000s but remained incomplete.

In 2011, PAG staff revisited SAM and undertook a sustained effort to understand, develop and calibrate the model. The model calibration process reviewed historical trends of land use change in the Tucson region from 2005-2010. It related these trends in land use change to changes in employment, construction and other factors that can impact land use over time. The calibration, which is the basis for the suitability factors used by the current model, determined that the factors with most impact on land use are derived from transportation facilities and networks, existing land use, and regional accessibility for population and jobs. The previous update in 2018-19 includes a model conversion in R-script together with the utilization of TransCAD for updating SAM model variable inputs.

INPUTS

SAM is a rule-based urban growth model, which means that it simulates a regional process of urbanization by responding to any number of factors or conditions programmed into the model. Input data include the principal factors the model uses to build a representation of the spatial, socio-economic and political forces driving and shaping development over time. The following are major inputs of the SAM land use model:

EXISTING LAND USE

To allocate land for development, the SAM model first needs to identify and evaluate vacant land. This vacant land comes from existing land use derived from property parcels. Each parcel has a use code which must be recoded to one of five SAM classes:

- Existing residential (100)
- Non-occupied, but "in use" (700)
- Existing non-residential (800)
- Vacant and developable (900)
- Tribal land (1000)

Lands "in use" include municipal utilities, parks and other types of open space unavailable for development. Tribal land is outside the scope of the current model so it must be assigned a distinct existing land use code. The SAM model tabulates the urban growth it allocates in terms of seven fundamental growth sectors – six types of employment and residential housing units. Existing land use data, therefore, records the built housing units and count of jobs at each parcel location. Housing units come from 2024 Pima County Assessors' housing unit data plus added residential construction through June 2024. Jobs come from compiled point location employment data using multiple sources or data and a developed in-house QA/QC methodology. To lessen the data processing load for the land use model, contiguous parcels with the same land use are merged into larger geographic units.

GENERAL PLANS

Each jurisdiction in the PAG model region has provided a dataset with future land use designations for land under its jurisdiction. The combined records in the planned land use dataset are essential to the model because they contain information the model needs to allocate growth where capacity still exists. Every polygon in this dataset has a density value for its growth sectors that indicates the build-out capacity, in jobs or housing units per acre, of that land use. Once a piece of land reaches the target growth density across all sectors it is excluded from any further growth allocation. This build-out density analysis looks at well-developed areas with less than 25 percent vacant land. With existing employment and residential density in these sample areas the analysis calculates an average density (representing a hypothetical "build-out" state) for all growth sectors in each land use designation. The build-out density figures were reviewed by PAG staff and jurisdictional members. Manual adjustments were applied in cases where capacity was unrealistic according to local knowledge, development plans, and expectations.

KNOWN PROJECTS

SAM assigns employment or residential growth in the region using a development score, or suitability score, in accordance with population and employment accessibility. Any land-use model has the potential to produce imperfect or biased results in a forecast year, however. Modeling near-term development, within 5-10 years of the base forecast, can sometimes produce unusual estimates in specific areas that lack information about existing projects in the development pipeline. For this reason, PAG, in consultation with jurisdictions, developed a list of known projects as a model input with estimates of future housing and employment by type and size. Known projects encompass developments with varied levels of definition and commitment, from permitted developments in the near term, master planned communities and subdivisions on the near-to-medium term horizon, to longer term aspirational and speculative plans that have entered the public conversation. The initial list of known projects was presented to PAG's jurisdictional partners and revised with feedback gathered from individual and regional Population Technical Subcommittee (PopTech) meetings. For each 10-year growth period, residential units and employment from known projects are subtracted from the sub-county jurisdictional forecast that the SAM land use model allocates. The allocation process directs that known project growth, along with the ordinary allocated forecast growth, to the output which serves as the base for the next round of urban development.

Redevelopment Model & Outputs

As urban areas develop, they also age. The SAM land use model simulates growth of undeveloped parcels but lacks a mechanism for redevelopment, or the reutilization of land and the built environment. In the PAG region, the City of Tucson is actively planning for and expecting increased density with redevelopment along specific corridors and areas within the city. For the 2055 RMAP, PAG conducted research on and created a redevelopment model, with both residential and employment components, to supplement the SAM model allocation process. PAG examined a 10-year period of urban growth from 2010-2020 and developed a methodology to identify property parcels as candidates for redevelopment – identified in part by a change in building square footage -- using information from tax assessor data. For non-residential parcels, floor area ratio (FAR), improvement-to-land value ratio (ILV) and building age are key measures used to predict potential redevelopment during the study period. On this basis, roughly 3.4 percent of non-residential parcels (or 1.2 percent of total non-residential building square footage) redeveloped in the 10-year period. For residential parcels, a land redevelopment choice model was created to estimate, validate, and calibrate the submodel, developing coefficients and selecting for the most important factors driving this type of redevelopment: base year building square footage, age of structure, floor area ratio, and parcel acreage.

The redevelopment model operates by first selecting a set of base year (2024) parcels that intersect with a predefined area and land use within the City of Tucson. The 2013 update of the City's comprehensive plan, Plan Tucson, created land use designations designed to allow greater development density in specific areas of the city, most notably along major north-south and east-west commercial corridors. In addition to redevelopment areas, the City of Tucson approved the Infill Incentive District (IID), a policy overlay to encourage infill redevelopment. The geographic contours of the IID and Plan Tucson redevelopment land use are the basis for the initial selection of developed parcels. These candidates for redevelopment are filtered by development type (residential vs non-residential) and data characteristics (acreage > 0.125, FAR < 0.3, ILV < 0.8, and building age).

The allocation procedure as a whole assigns a probability of redevelopment to each parcel in the respective subsets, residential and non-residential. The residential equation used to calculate probability derives from the redevelopment choice model. Coefficients[1] for non-residential parcels are applied in an equation based on suitability measures like those utilized by the SAM land use model (see below). The final step is to assign housing units and sector employment to parcels with the highest probabilities as long as forecast units or parcels remain in supply. Ultimately, redevelopment in the model is constrained by the availability of the unit forecast. For the City of Tucson, some growth sectors in certain model periods did not have redevelopment because the unit forecast was exhausted by known projects.

Relevant discussions are found at the slides presented at the PopTech meetings below.

- https://pagregion.com/wp-content/docs/pag/2022/08/PAG-PopTech-2022-08-18-Presentation-Redev_Method_Update.pdf
- https://pagregion.com/wp-content/docs/pag/2023/04/PAG-PopTech-2023-04-03-Item-4-Redev-Model-Development.pdf

Undevelopable Lands

There are many reasons – environmental, topographical and utilitarian – that certain lands cannot be developed. The undevelopable lands dataset is a compendium of land in the Tucson region that the land use model removes from consideration during the allocation process. To prepare this dataset PAG consulted with member jurisdictions and experts in environmental planning. Regional undevelopable lands in eastern Pima County include:

- Cemeteries, landfills and parks/preserves
- Lands with greater than 15 percent slopes
- Retention/detention basins
- Davis Monthan AFB open space acquisition properties
- Tucson Water storage and recharge facilities
- Federal lands from the Bureau of Reclamation and Bureau of Land Management
- Regional flood control property and Lee Moore wash flow corridors
- Pima County Conservation Land System (CLS) 95 percent undevelopable riparian areas

[1] Non-residential redevelopment coefficients were developed out of a pseudo calibration/validation process that correlated higher current employment sector location density with higher potential for redevelopment.

Some classes of land under the CLS have flexible constraints that allow development within specific limits. In discussions with Pima County the PAG Data Science team presented a quantitative analysis of planned land use capacity on CLS lands. It was determined that the existing build-out densities in these areas met or exceeded the requirements of the CLS.

ROAD NETWORKS AND ACCESSIBILITY

To allocate growth, the land use model must first determine the relative attractiveness of land available for development. Data inputs for this analysis are road networks and TAZ-level summaries of accessibility to urban residential clusters and employment. For any eligible parcel, measured distances from different road types, classified by traffic volume, serve as inputs that figure into calculating the attractiveness of development for specific growth sectors such as residential, retail, or industrial. Accessibility inputs measure the degree to which jobs and population centers in the region are readily available in terms of travel time or distance. Residents in a dense urban center, as opposed to an isolated low-density subdivision, would have greater population accessibility. Likewise, neighborhoods close to the University and downtown would likely have greater employment accessibility than those in Vail because of the sheer number of job opportunities within a short travel time. The base road network and accessibility datasets are from 2019. Subsequent model runs must use updated road networks and accessibility measures to calculate the next round of suitability. An external process by the TDM after each land use model run uses the new population and employment forecasts by TAZ to update the transportation and accessibility datasets.

Population and Employment Forecasts

The SAM land use model is an allocation model. External forecasts, at the jurisdiction and regional levels, supply the number of housing units and jobs. The task of the model is to spatially distribute this growth according to a set of programmatic rules.

The population forecast is adapted from the official 2024-2055 long-term population forecast prepared by the AOEO and PAG, as shown in **Figure 3**. The AOEO forecast covers the entire Pima County population whereas the PAG modeling area includes only eastern Pima County. The population control totals were adjusted to account for the model study area difference. Population totals from the 2020 Decennial Census were used to estimate the projected population of eastern Pima County. Since the land use model works by allocating housing, not population, control totals needed to be cast for residential housing units. The conversion to housing units initially used an average household size and occupancy rate for the region and its jurisdictions.

Figure 3. 2055 Population Forecast (Eastern Pima County)

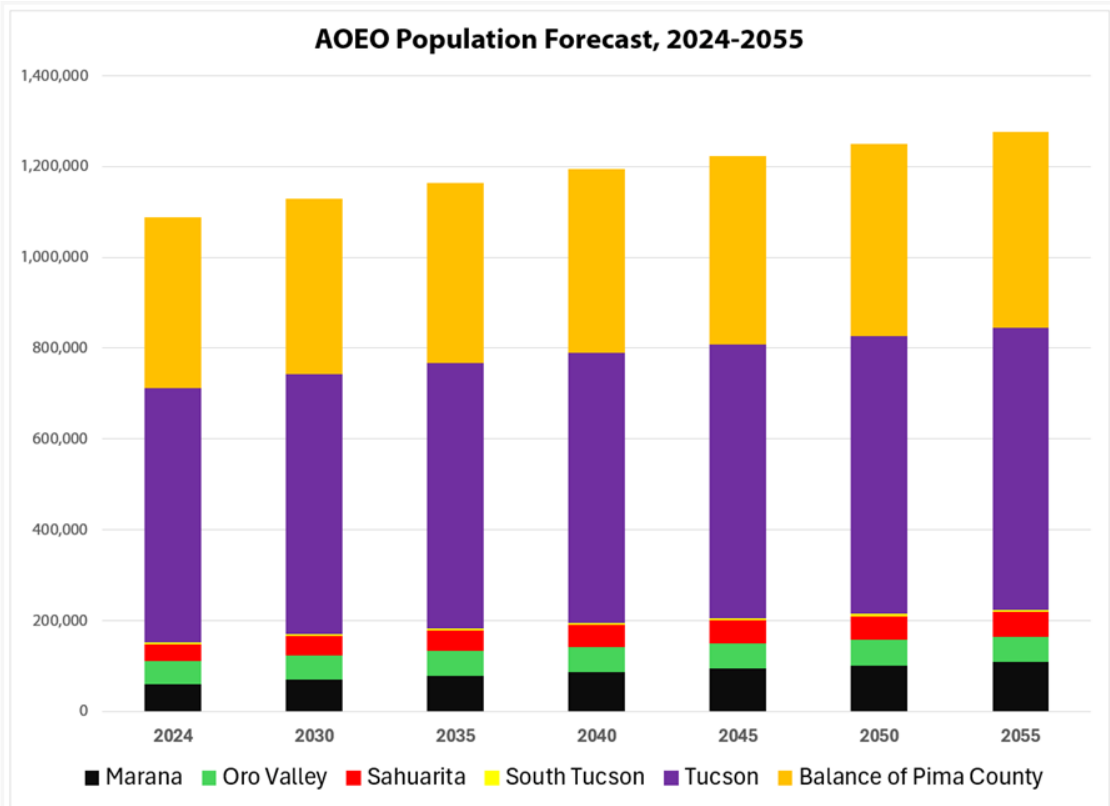


Table 7. Population Forecast (Subcounty)

YEAR	MAR	OV	SAH	STUC	TUC	PC (Uninc.)	Total East PC
2024	60,204	50,193	37,690	4,599	558,906	366,320	1,077,912
2030	70,024	53,573	41,837	4,599	571,827	377,136	1,118,996
2035	78,319	55,431	45,057	4,599	583,352	386,419	1,153,177
2040	86,235	55,751	47,833	4,599	594,332	395,296	1,184,046
2045	94,061	55,850	50,268	4,599	603,724	403,499	1,212,001
2050	101,359	55,850	52,531	4,599	612,203	411,757	1,238,299
2055	108,709	55,850	54,803	4,599	621,385	419,863	1,265,209

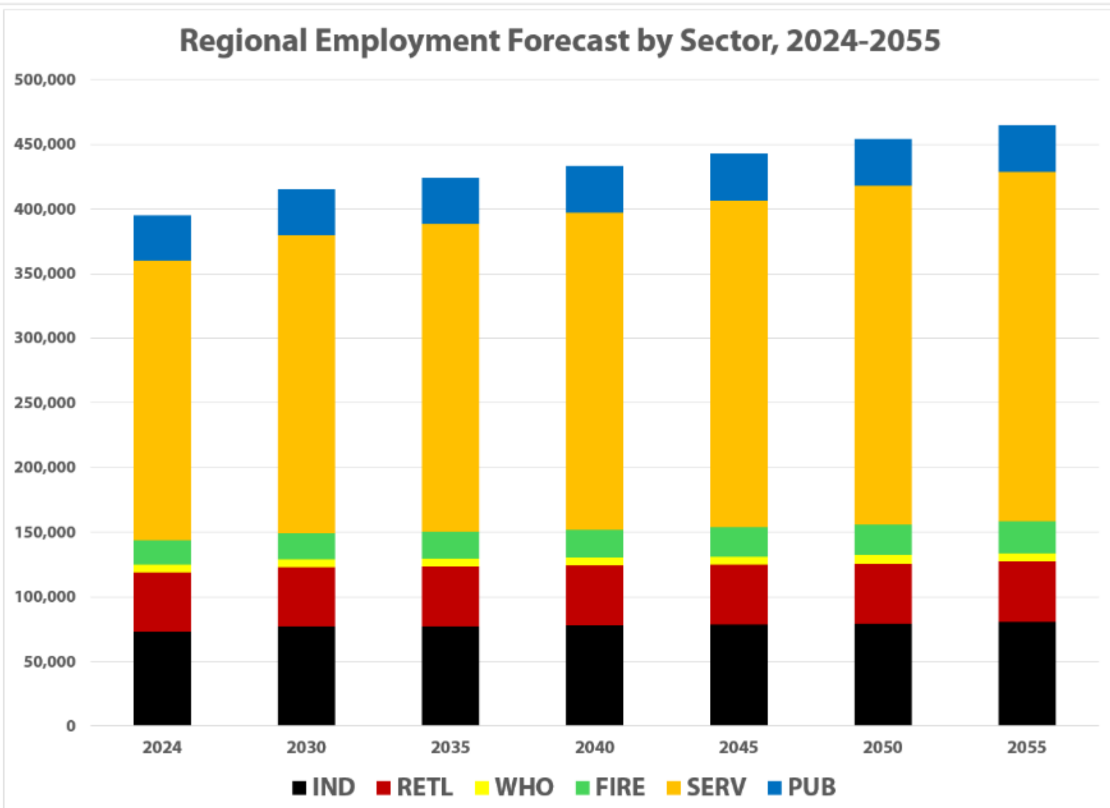
The employment forecast comprises six major industry categories: industrial (IND); retail (RETL); wholesale (WHO); finance, insurance, and real estate (FIRE); service-including public education (SERV); and public, or government (PUB). The forecast combines 2023 employment by sector with a long-range 40-year forecast prepared by the University of Arizona's Economic and Business Research Center (EBRC) at the Eller College of Management. The 2024 3rd Quarter EBRC long range forecast provides the growth rate by sector used to project the 2023 employment figures.

The employment forecast by sector is shown in **Figure 4.** PAG's land-use model (LUM) does not permit the assignment of negative growth, which can occur in the EBRC growth projections. For this reason, the EBRC growth rate for certain sectors was adjusted to have non-negative growth. The adjustment did not affect total forecasted job growth; instead, forecasted job losses in these sectors were offset with jobs taken from growth in the service sector, the widest ranging employment category. Many businesses could be classified as having a service sector component in addition to the primary classification.

Table 8. Employment Forecast by Sector

Year	IND	RETL	WHO	FIRE	SERV	PUB	TOTAL
2024	72,962	46,249	5,848	18,764	216,565	34,865	395,253
2055	80,303	47,053	6,317	24,712	270,370	36,139	464,894
Annual Growth	237	26	15	192	1736	41	2246
Annual Growth Rate (LUM)	0.3%	0.1%	0.3%	1.0%	0.8%	0.1%	0.6%
Annual Growth Rate (EBRC)	0.3%	0.1%	0.3%	1.0%	0.8%	0.2%	0.6%
Sector Share of Total Growth (LUM)	10.5%	1.2%	0.7%	8.5%	77.3%	1.8%	100.0%
Sector Share of Total Growth (EBRC)	10.5%	1.2%	0.7%	8.5%	76.8%	2.5%	100.0%

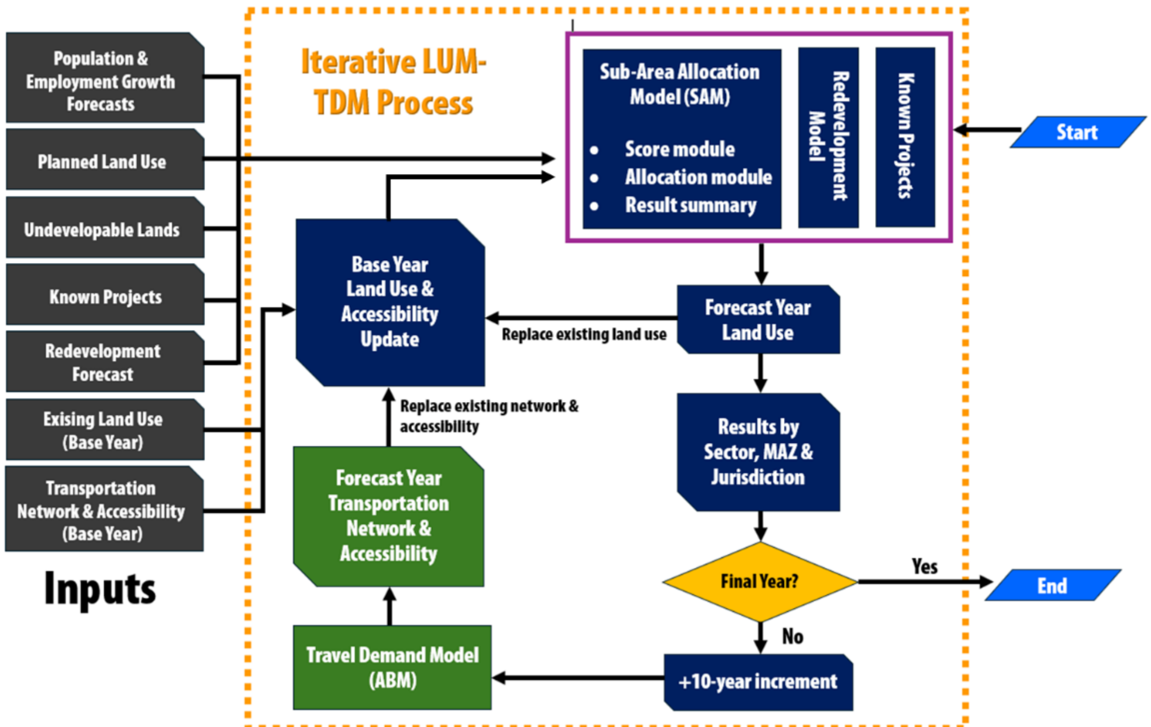
Figure 4. Employment Forecast by Sector



LUM METHODOLOGY

The SAM land use model allocates growth separately for each of the seven sectors: Residential, Retail, Wholesale, FIRE, Industrial, Service, and Public Service (see **Figure 5**). With inputs addressed above, the precise order of allocation by sector is inconsequential because the model keeps track of the build-out density of each. Modeling urban growth in a sequential allocation process is iterative, which, for this model, means that forecasted growth gets allocated for all sectors in five- to ten-year increments.

Figure 5. Iterative Land-use Modeling (LUM) and Travel Demand Modeling (TDM) Process



Iteration also means that the results of one model run set the base conditions for the next one to build on. From the standpoint of allocation suitability, comparative growth in population or employment in one location relative to others may favor more development there in the future. The choice of a five- to ten-year temporal resolution for model runs is somewhat arbitrary but represents a good compromise between the time cost of running the model and the effective resolution that the model can produce. Ultimately, the model allocates regional or sub-regional forecasts into developable parcels. Results may be summarized to multiple geographies – such as school zones, census defined places, jurisdictions, transportation analysis zones (TAZs), and micro-analysis zones (MAZs) – but from the perspective of converting model output data from housing units into population, the best geographies are sub-area jurisdictions, TAZs, and MAZs. The model has been designed with sub-area forecasts in mind and special attention has been paid to minimize inconsistencies between population control totals and model results for sub-area and MAZ geographies.

Suitability

Before each iteration of the model, a suitability dataset must be prepared for all growth sectors. The score module creates utility score datasets for those factors that model calibration has determined have statistically significant impacts on land use change. A utility score dataset indicates where land has higher or lower utility in terms of a single factor for suitability, such as distance from roadways with average weekday traffic volumes above 25,000 vehicles. With measures of proximity, land receives a utility score from 0 (low) to 10 (high) based on its distance to the roadway. Scores decrease in a regular interval as distance from the roadway increases. Beyond a certain distance, the score drops to zero. Other datasets, such as accessibility and the urban index, already contain quantitative or binary ("urbanized" vs. "non- urban") data. This geospatial data is a sufficient measure of utility and needs only to be converted to the data format the SAM model uses for computation.

A suitability dataset is the quantitative combination of all factors (utility scores) into a single suitability score for every parcel-level location in the Tucson metropolitan area. For each sector, a computational formula indicates what factors to include and has a coefficient (from calibration) that determines the impact of that factor on overall suitability. Each growth sector uses the same formula for each model iteration but with updated factors that come from the model results. With each iteration the location and number of road segments at a given traffic volume will reflect modeled population and employment growth. Accessibility and the location of urbanized lands will likewise change after every model iteration.

<u>Suitability Formulation</u>

The general formula that applies to all growth sectors is specified as:

$$S_{i,j} = \beta_1 * GG + \beta_2 * GI + \beta_3 * GA_{25} + \beta_4 * GA_5 + \beta_5 * GA_0 + \beta_6 * GM + \beta_7 * GF$$

$$+\beta_8 * GPA + \beta_9 * GEA$$

Wherein,

i : index of growth sector

j: index of land

$S_{i,j}$: the suitability score of sector i for land parcel j

GG: the score as determined in **Table 4**.

GI : distance (ft) to the nearest major intersection, capped at 11,440 ft

GA_{25}: distance (ft) to the nearest arterial with greater than 25,000 AADT, capped at 11,440 ft

GA_5: distance (ft) to the nearest arterial between 5,000 and 25,000 AADT, capped at 11,440 ft

GA_0: distance (ft) to the nearest arterial with less than 5,000 AADT, capped at 11,440 ft

GM: distance (ft) to the nearest major arterial, capped at 11,440 ft

GF: distance (ft) to the nearest freeway, capped at 11,440 ft

GPA: population accessibility measure

GEA: employment accessibility measure

$\beta_1 \cdots \beta_9$: coefficients as specified in **Table 10**

Table 9. Urban Score

Distance to General Urban Area (feet)	0	1,200	2,400	3,600	4,800	6,000	7,200	8,400	9,600	10,800	12,000+
Score	10	9	8	7	6	5	4	3	2	1	0

Table 10. Coefficients of Suitability Score

Sectors Coeff.	GG β1	GI β2	GA25 β3	GA5 β4	GA0 β5	GM β6	GF β7	GPA β8	GEA β9
RETL	0.939		-0.000019	-0.000128				0.011160	
FIRE	0.268	-0.000236	-0.000559	-0.000144				0.005720	
PUB	0.824			-0.001840				0.033520	0.005960
SERV	0.145				-0.000169	-0.000726		0.014960	
IND	0.750			-0.000152			-0.000010	0.001670	
WHO	0.750			-0.000152			-0.000010	0.001670	
RES	0.810					-0.000099	-0.000070		0.013400

For employment sectors the coefficients for GG, GPA, GEA have a positive effect on suitability scores. Negative coefficients for GI, GA25, GA5, GA0, GM, and GF have the opposite effect.

The residential suitability formula contains the following factors: urban index, distance from major arterials and freeways, and employment accessibility. Model calibration found residential growth strongly correlated with areas of existing "urbanized" development, giving the formula a positive coefficient for the urban index variable. This finding was corroborated in a PAG-hosted "Think Tank" session where residential and commercial land developers expressed clear preference for areas in close-proximity to existing urban infrastructure and amenities. The results of that meeting indicated that greater accessibility to employment opportunities also contributes positively to suitability. Homeowners want to live close to employment centers. Conversely, greater distance from freeways and major arterials has a negative but limited impact on where residential development occurs, hence small but negative coefficients.

Probability Calculation and Implementation

The suitability score for any developable land parcel, the result of suitability calculations discussed above, is equivalent to the utility measure used in the most-commonly deployed discrete choice, or logit model, which estimates the probability of available discrete choices. PAG's land use model calculates suitability by sector for all eligible lands, but the discrete choice to develop a land parcel or not for a particular land use is determined by a logit model whose equation is written as follows:

$$p_{i,j} = \frac{e^{s_{i,k}}}{\sum_{k=1}^{n} e^{s_{i,k}}}$$

Wherein,

$p_{i,j}$ equals the probability of land parcel j to be allocated with growth from sector i

Subsequently, growth will be allocated to eligible lands based on the above calculated probability.

$$g_{i,j} = G_i * p_{i,j}$$

Wherein,

G_i represents the total remaining growth forecast of sector i

$g_{i,j}$ represents sector i growth allocated to land parcel j

Note that some MAZs do not nest perfectly within jurisdictional boundaries. Therefore, MAZs may combine growth from areas within multiple jurisdictions.

It is important to remember that growth allocation of the land use model, as a rule, gives first priority to the development of known residential and employment projects as well as redevelopment in each 5- to 10-year growth cycle. Assignment of the remaining forecasted units in each cycle, after the priority projects and areas have been exhausted, is implemented by the discrete choice probability calculation.

Allocation

There are five major procedural steps in the allocation module: input assembly, growth allocation, compilation, update of the land use dataset, and summary. Before allocating the growth forecast for each 5- to 10-year cycle the model must complete preliminary work to prepare inputs. The process begins with selection of vacant lands from the existing land use dataset. Vacant lands will still be considered vacant as long as there is remaining development capacity in at least one sector. Each iteration by forecast year updates the existing land use dataset with a new version that records base housing units and employment plus cumulative growth.

After selection of the vacant land growth allocation, these steps are repeated for each sector. The first step continues the input assembly to create a sector-specific allocation dataset. Vacant lands minus undevelopable lands are considered eligible for allocation. The model selects eligible lands and, from input data, retrieves the suitability scores, existing and build-out density. Information now stored in the allocation dataset is used to calculate the growth of a sector at any eligible location. The estimated probability from the discrete choice calculation determines where the model distributes regional housing and employment forecasts. For residential development, the allocation process repeats six times, one for each jurisdiction in the region. This option respects the preference for allocated population growth to follow AOEO sub-area forecasts. If any jurisdiction exceeds capacity, the model will allocate the remainder of the forecast to the most suitable locations elsewhere in the PAG region.

The next steps, once the model has recorded added growth to the allocation datasets by sector, are to consolidate all growth into a single growth dataset and then update the existing land use dataset with the growth. Finally, the model summarizes the updated existing land use dataset into selected geographic units, such as MAZs and jurisdictions.

Additional Refinements to Allocation

Model testing and stakeholder review presented opportunities to improve the model's performance in simulating regional urban growth. The urban index was created as a suitability factor to replace the urbanized area variable used in prior RMAP forecasts. The method defines urban locations as those that meet a calculated density threshold. Urbanized areas must have a combined residential and double-weighted employment density per acre greater than 2, exceeding a combined total of 5,000 housing units and double-weighted jobs.

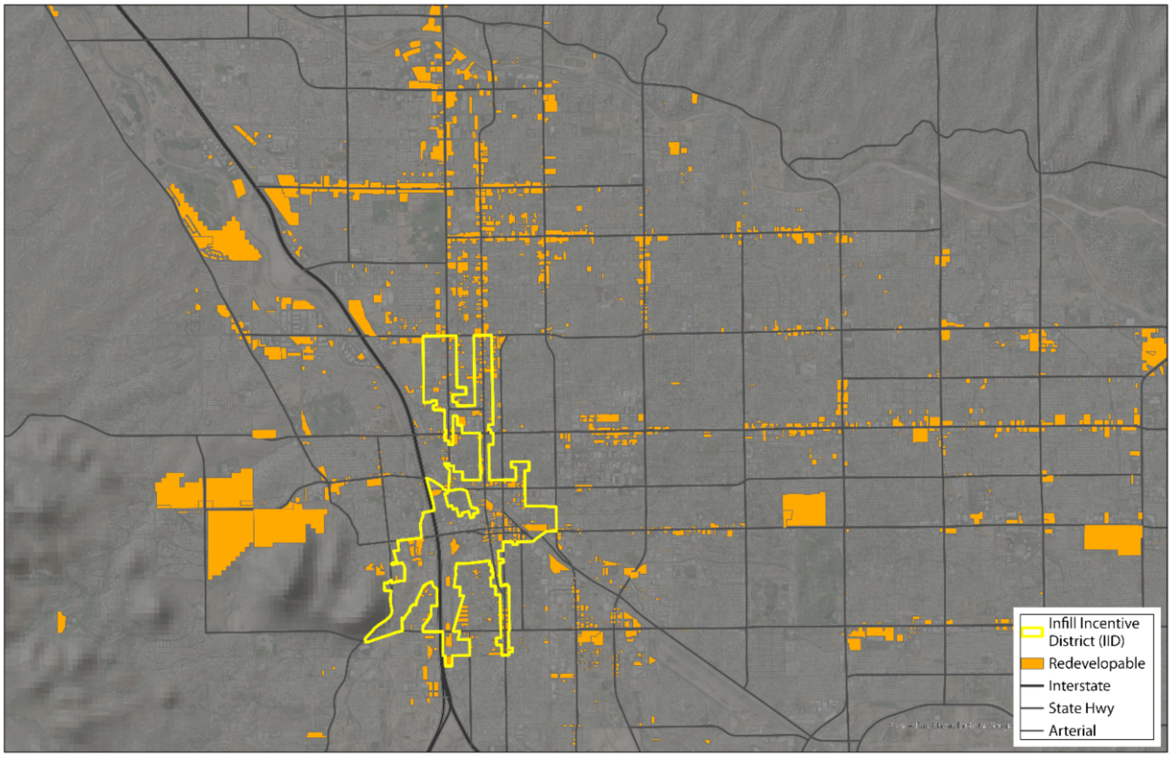
As addressed earlier, known projects are those business or residential projects that are currently under development, have announced plans, or are otherwise expected in the longer term with some uncertainty, but are generally in the public conversation. Known projects with expected employment or residential units are given priority before regular allocation. Their unit allocations are removed from the total units forecast for a given development cycle.

As discussed above, a separate model handles redevelopment within the City of Tucson. The geographic areas under consideration are policy-based: an overlay for infill development and land use designations from Plan Tucson). These added future land use categories have generally higher developmental densities than the underlying zoning and reflect the City's planned vision. Realistically, many of these developed areas are unlikely to see redevelopment immediately or in the near future, yet they are located on highly suitable urban lands that the model would immediately allocate with growth were they vacant. The redevelopment model, assuming the overall growth forecast has not been exhausted by known projects, uses a research-based method to select and rank eligible parcels, then allocates job and housing redevelopment in order of probability.

Relevant discussions and development are found at the slides presented at the PopTech meetings below.

- https://pagregion.com/wp-content/docs/pag/2022/08/PAG-PopTech-2022-08-18-Presentation-Redev_Method_Update.pdf
- https://pagregion.com/wp-content/docs/pag/2023/04/PAG-PopTech-2023-04-03-Item-4-Redev-Model-Development.pdf

Figure 6. **Redevelopment Areas**



Post-Processing

Each iteration of the model requires an update of transportation, accessibility and urban index datasets. The MAZ-level summarized results, housing units and employment by sector of the LUM are inputs to the TDM. In addition, in-house sub-models are applied to create the inputs of TDM such as population, occupancy rate, persons per household, and so on. The TDM generates new traffic volumes and accessibility measures that respond to urban growth. Updates to the urban index calculate a combined housing and employment density variable to determine new boundaries of urbanized areas in the metropolitan region.

Contributions and Feedback

The current version of the SAM land use model benefited from consultation with and feedback from regional stakeholders. The PAG data science team first worked closely with member agencies to obtain the most complete and up-to-date input data. Development of these jurisdictional datasets required coordination and extensive editing to correct topology and data attributes. Regional datasets would not have been possible without the cooperation and efforts of PAG's jurisdictional partners.

Another important contribution to the modeling effort was the feedback PAG received from PAG's jurisdictional partners though meetings of PAG's subcommittee, PopTech, and one-on-one consultations. Responses from the jurisdictions proved invaluable to model development and resulted in improved data and decision-making. Below are some key tasks for which PAG solicited feedback from regional stakeholders.

- Review of county-level population projections as well as development of sub-county population and employment projections
- Review and discussion of PAG's land-use model through jurisdictional one-on-one consultations
- Review of PAG's model inputs, especially for known projects and outputs, such as assigned housing units and employment by sector
- Development of jurisdictional employment control totals
- Incorporation of expected and planned projects from jurisdictional partners

SCENARIO ANALYSIS AND FINAL RESULTS

Scenarios

Back in the RMAP Update process of 2019, PAG developed three future land use scenarios. Of the three scenarios, scenario 3: "Mostly Suburban – Mixed Urban/Suburban" was adopted as the official scenario. The 2055 RMAP Update continues to use this scenario.

Long-range population forecasts from AOEO also include sub-area population controls. The controls force the model to allocate the residential forecast first to areas within assigned jurisdictions. If residential capacity is exhausted for a particular forecast year, the model allocates the remainder to the most suitable lands with capacity in the region. For the initial model run, employment sectors had no sub-regional controls to direct or limit where development can occur.

Housing Unit Growth

The land use model first allocates AOEO jurisdictional population growth forecasts, expressed as housing units, first into known projects and redevelopment, and then into the next most suitable areas in each of the jurisdictions.

The results of the 2055 RMAP precisely allocate the AOEO population forecast for PAG's regional jurisdictions, translated into housing units. Tucson and Pima County together capture a 64.5 percent share of the region's growth (**Table 11**). Over time, the regional pattern of growth shifts toward smaller jurisdictions with remaining capacity. From 2024 to 2055, the City of Tucson and unincorporated Pima County's combined share of regional population drops 3.4 percent while the combined share of the Town of Marana and Town of Sahuarita grows 3.7 percent. These jurisdictions also achieve the highest average compound population growth rates (CAGR) at 2.02 and 1.29 percent annually.

Table 11. Assigned Housing Unit Growth by SAM

Housing Unit Growth						
MAR	OV	SAH	STUC	TUC	PC (Uninc.)	Total East PC
20,844	3,126	7,059	0	30,234	26,036	87,299

2024 Housing Units						
MAR	OV	SAH	STUC	TUC	PC (Uninc.)	Total East PC
24,260	24,554	14,535	2,110	249,154	167,499	482,112

2055 Housing Units						
MAR	OV	SAH	STUC	TUC	PC (Uninc.)	Total East PC
45,104	27,680	21,594	2,110	279,388	193,535	569,411

MAZ-level maps of the scenarios illustrate how the land use model spatially distributes housing units in the region (**Figure 7**). For a closer view of housing growth in Tucson, see **Figure 8**.

Figure 7. **2024-2055 Housing Growth, Mixed Urban/Suburban Scenario**

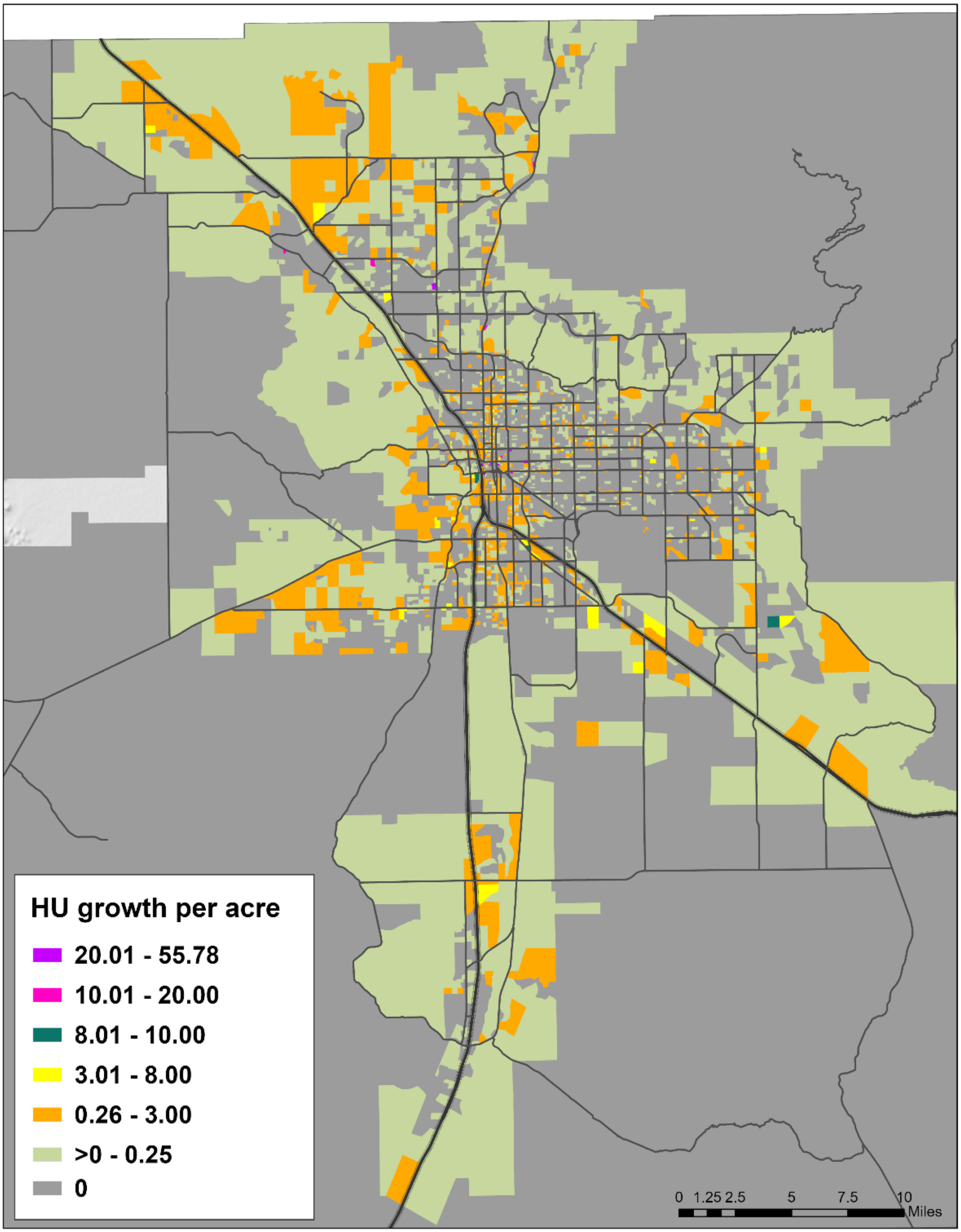
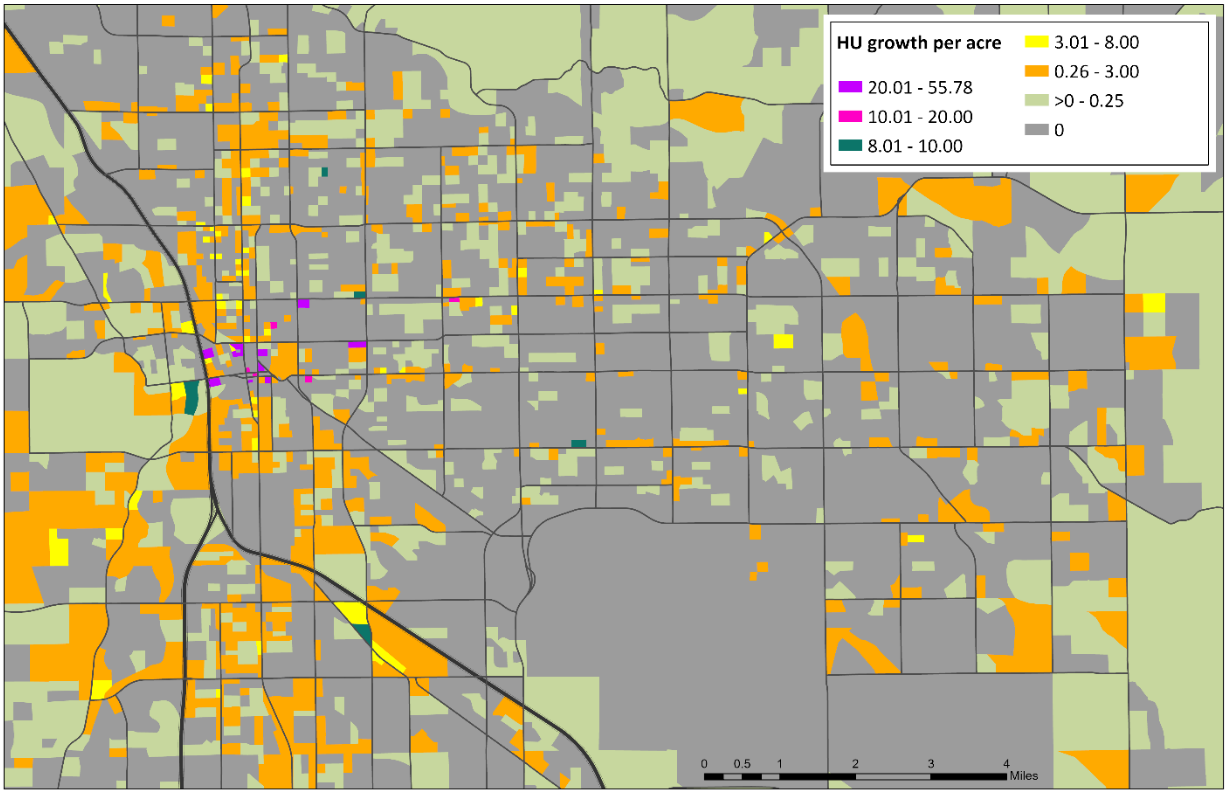


Figure 8. **2024-2055 Housing Unit Growth, Mixed Urban/Suburban Scenario (Tucson)**



In the Mixed Urban/Suburban scenario the principal concentrations of major population growth occur in MAZs:

- In downtown Tucson and near the University of Arizona
- Along Houghton Road, north of I-10
- Along the I-10 corridor between Kino Parkway and Wilmot Road
- Near I-19 and Sahuarita Road in Sahuarita
- Near I-10 and Tangerine Road in Marana
- Near Canoa Ranch on I-19
- Along Ajo Highway and Valencia Road, west of I-19

Within the City of Tucson these growth areas are consistent with planned land use that is comparatively dense, such as that within the Houghton Area Master Plan (HAMP).

Employment Growth

The SAM model allocates employment growth forecasts to the most suitable areas based on assumed jurisdictional minimum growth totals and the regional control total. Jurisdictional minimum growth totals are determined by the ratio of population to employment in the base year. Any residual growth to meet the regional control total is then allocated regionwide, regardless of jurisdiction. Employment growth shows a similar pattern to population at the jurisdictional level, with a modest shift of growth away from the metropolitan core toward the periphery (**Table 12**). Over the 31-year forecast period, together Tucson and Pima County receive the lion's share of regional employment growth (71.8 percent). This large amount of growth is proportionate to Tucson and Pima County's current share of employment in both 2024 (89.8 percent) and 2055 (86.9 percent). The Town of Marana stands out among the smaller jurisdictions, increasing its regional share of employment by 2.7 percentage points, a growth rate of 85.8 percent over the forecast period, with a 2.0 percent compound annual growth rate. As a result, Tucson's regional employment share decreases 2.1 percentage points over the forecast period while that of Pima County decreases by 0.7.

Table 12. Mixed Urban/Suburban Scenario Employment Allocation

Employment Growth						
MAR	OV	SAH	STUC	TUC	PC (Uninc.)	Total East PC
16,034	1,775	2,469	420	41,510	11,216	73,424

2024 Employment						
MAR	OV	SAH	STUC	TUC	PC (Uninc.)	Total East PC
18,689	13,730	5,226	2,346	273,082	78,077	391,150

2055 Employment						
MAR	OV	SAH	STUC	TUC	PC (Uninc.)	Total East PC
34,723	15,505	7,695	2,766	314,592	89,293	464,574

At the MAZ-level, the 2055 RMAP Update shows employment growth in locations with easy access to freeways and major roads (**Figure 9**). The concentrations of major employment growth occur in MAZs:

- Near redevelopment areas inside the City of Tucson and central business district
- Along I-10, near Kino Parkway
- In the Town of Marana, near I-10 and Tangerine Road
- Near the northern extent of the Sonoran Corridor
- Near Sunset Rd and I-10

Figure 9. 2024-2055 Employment Growth per Acre

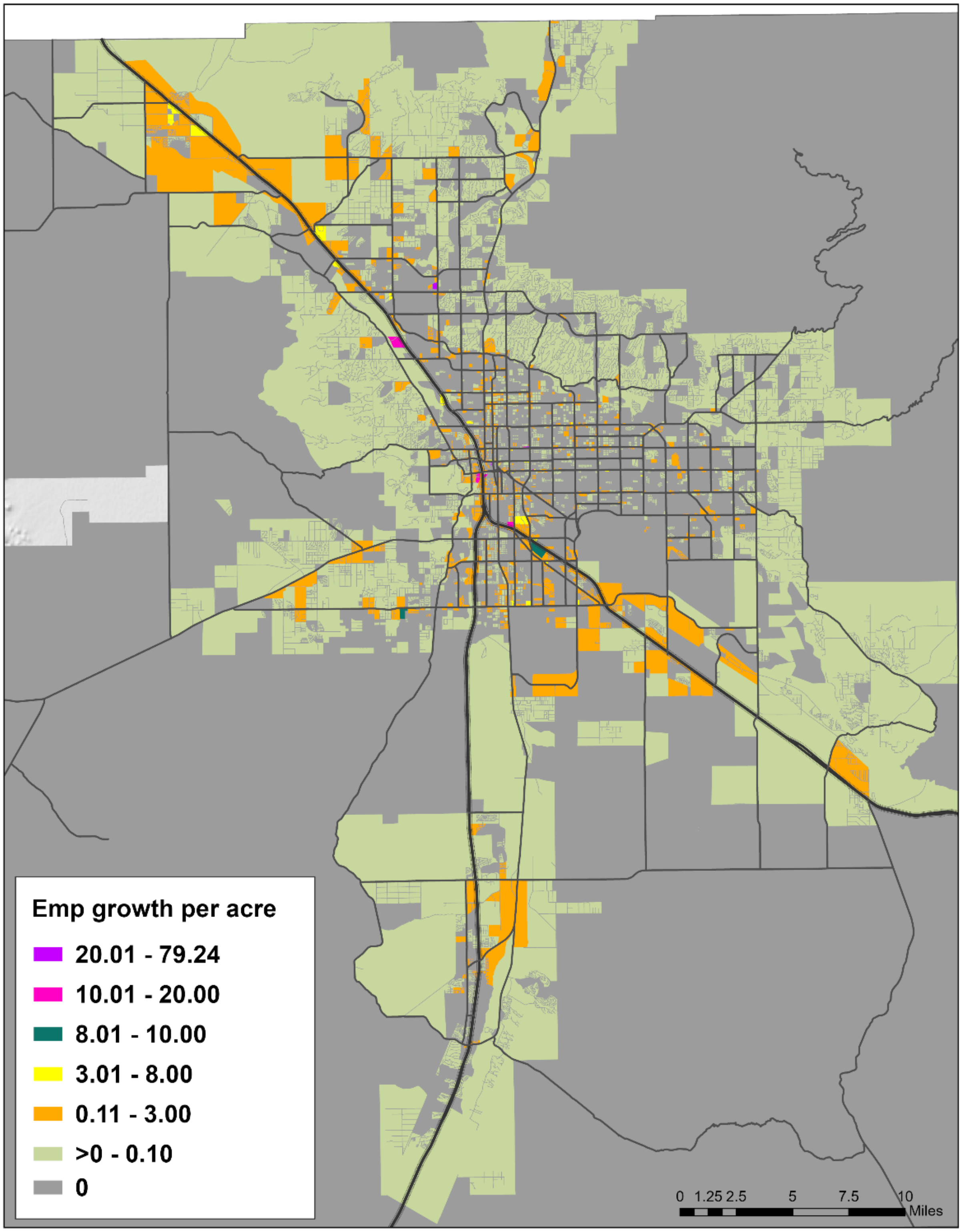
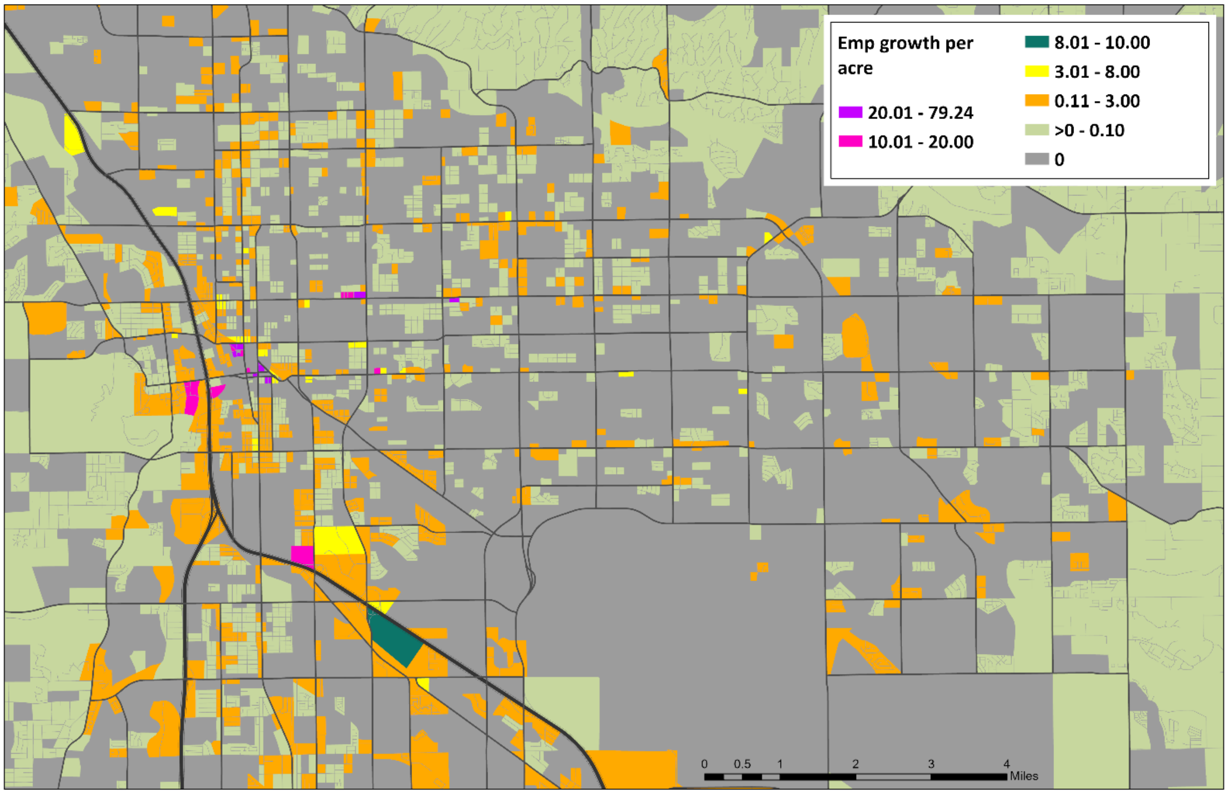


Figure 10. 2024-2055 Employment Growth per Acre (Tucson)

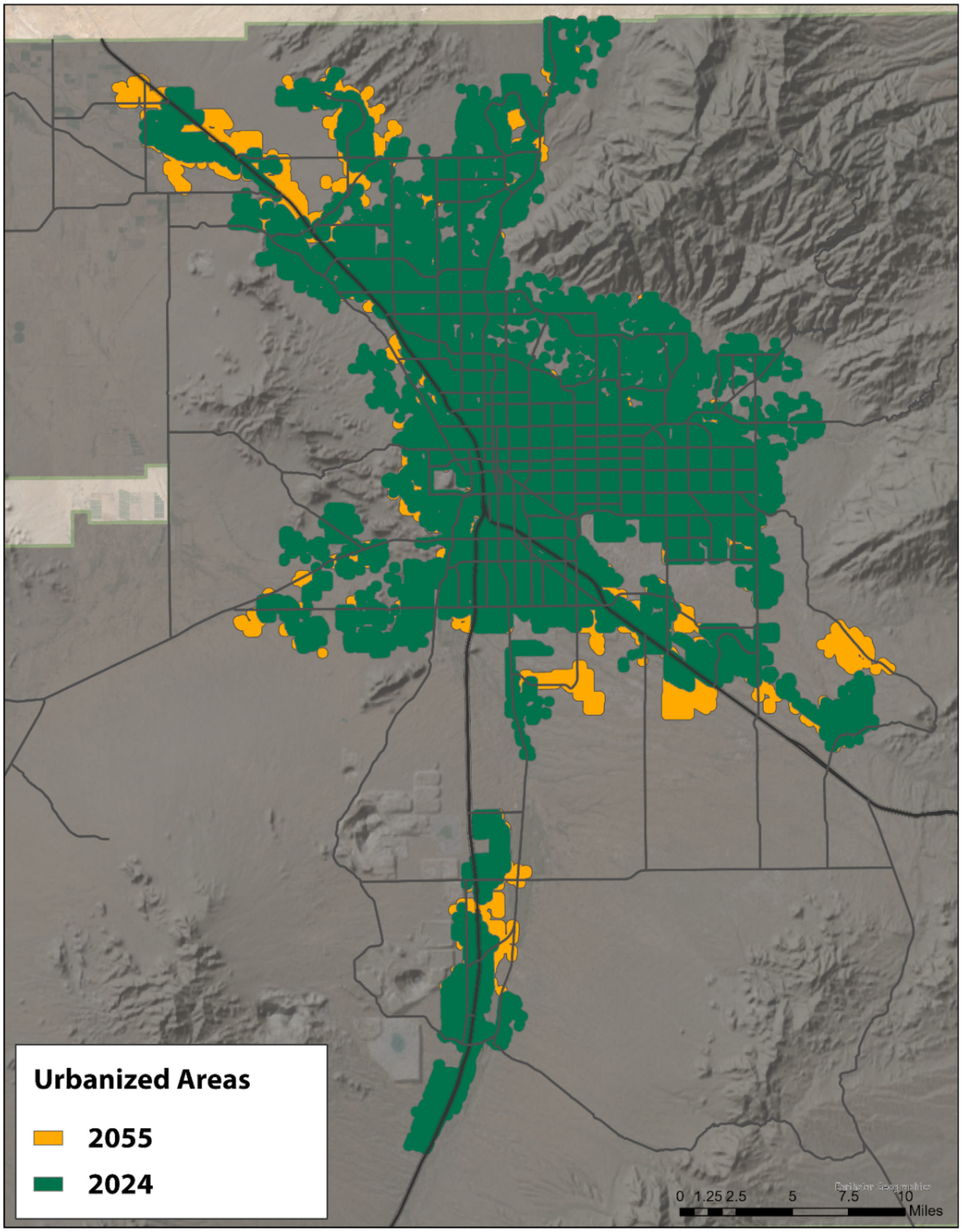


Urbanized Areas

The model differentiates urban areas from rural areas when determining the attractiveness of the land for development. Calibrated model parameters suggest that lands in urbanized areas are relatively more attractive for all growth sectors than rural lands. In the model the urban index-based urban boundary changes as population and employment growth takes place. The urban index estimated in the model accounts for combined population and employment intensity and density and is compared with a predefined threshold to determine the status of lands as either urban or rural.

Figure 11 below shows the 2024 base year urbanized area in green and the expanded 2055 urban boundary in orange for the adopted scenario. In Marana, the urban area expands southeast along I-10 to include Rillito, and east along Tangerine past I-10, and expands to include the Dove Mountain area. In Oro Valley, much of the jurisdiction is already within the urban area, but growth extends westward to include portions of the Tortolita area. Tucson also starts the model period with most of its area within the urban area but sees expansions in the Houghton Area Master Plan (HAMP), south of the airport and Raytheon campus, and south of the UA Tech Park. In Sahuarita, the urban area expands south of Sahuarita Road along I-19 and east around Sahuarita Road and Nogales Highway. In Pima County, urban area growth occurs primarily in Vail and Rocking K on the east, and westward along Valencia Road.

Figure 11. Urbanized Areas, 2045, Mixed Urban/Suburban Scenario



TRAVEL DEMAND MODELING

PAG's travel demand model (TDM) is a tool that allows decision makers, transportation professionals, and interested stakeholders to evaluate the potential impacts of various changes on the performance of the regional transportation system. The model is used to estimate current and future traffic demand on the region's roadways. PAG and PAG's neighbor agency, the Maricopa Association of Governments (MAG, the MPO for the Phoenix region), began cooperatively working on an advanced activity-based model in 2008. The PAG ABM is a simulation applied to a list of synthetically created households, and the synthetic persons living in each household. It retains the core concepts of activities, tours, and trips, as well as long-term, medium-term, and daily decisions. It retains the multi-resolution zone system of select CT-RAMP1 models, using both micro-analysis zones (MAZs) and travel analysis zones (TAZs). And it makes similar simplifying assumptions, such as travel being contained within a simulation day, in which all travelers begin and end their day at home.

The model is a valuable resource in the decision-making process. It generates the likely outcomes of transportation investments based on a series of inputs and allows those outcomes to be evaluated against a set of regionally and nationally established performance criteria or indicators.

This section provides an overview of the travel demand model used for the 2055 RMAP Update. It identifies and explains the socio-economic and roadway information included and used by PAG in the RMAP model, provides a general introduction to the activity-based transportation forecasting model used in the TDM process, and concludes with a review of the performance measures developed for the RMAP report.

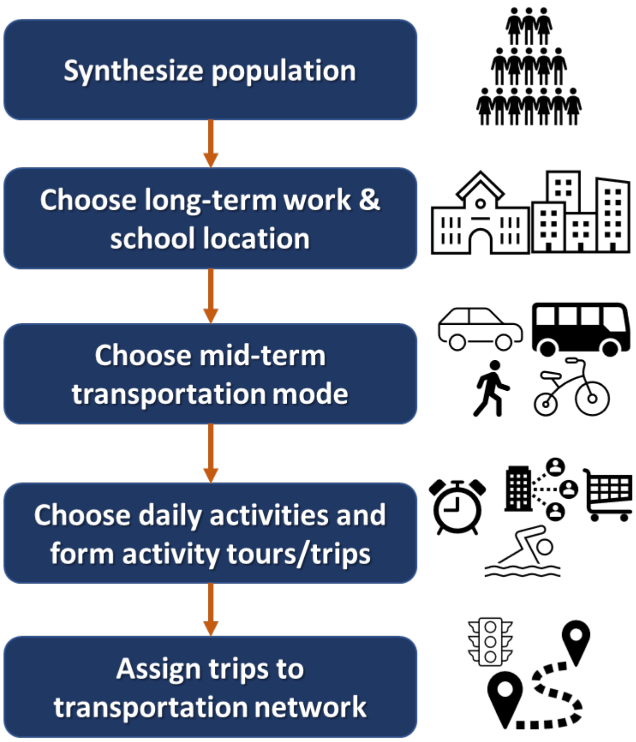
ACTIVITY-BASED MODEL

ABMs have been used in the practice of travel demand modeling in the US since 2001. More than 20 MPOs have been operating and testing ABMs for their transportation planning including PAG. PAG's ABM is a CT-RAMP 2 (Coordinated Travel & Activity Modeling Platform, version 2) and was started with the Phoenix-Tucson megaregion ABM development in early 2010. Since 2019, after a long development in 2010s, PAG added new modules to address the regional planning concerns as follows.

- How to demonstrate for-hire vehicles such as Uber and Lyft?
- How does autonomous vehicle usage impact the regional traffic?
- How to represent e-commerce?
- Does the model demonstrate the land development logically?
- What would be the impact of telecommuting?

The main sub-models of CT-RAMP2 and their primary functions are shown in **Figure 12**. The ABM synthesizes regional households and household members. With the population, the model applies long-term work and school destination and mid-term transportation mode choice models to develop household-level daily activities and interaction and coordination between household members. All household activities are broken down into trips, which are assigned on the transportation and transit networks to estimated roadway volumes and transit ridership.

Figure 12. **PAG Activity-based Model (ABM, CT-RMAP2)**

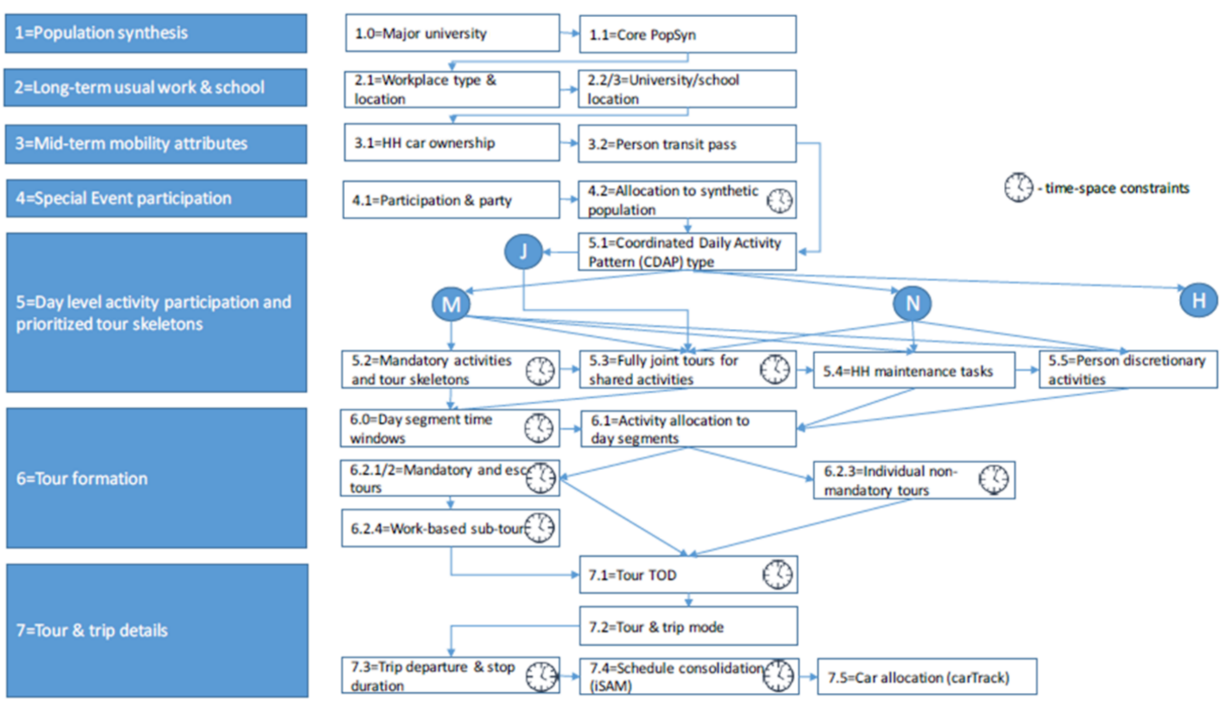


Based on this skeleton, **Table 13** lists multiple functions corresponding to the main variables of the ABM, which are grouped into population characteristics, activity generation, activity location, activity scheduling, tour formation, tour & trip time-of-day choice, and mode and car-use details. Sub-models are grouped into seven major classes as shown in **Table 13** and **Figure 13**. Note that PAG's ABM does not consider Special Event generators although this module is ready for operation. Due to the complexity and multiple sub-models, sub-model classes 5 and 7 are further broken into sub-groups. The matrix of sub-model functionality in CT-RAMP2 is not strictly diagonalized but instead is quite dispersed since multiple sub-models share different aspects of multiple functions to demonstrate the fact that the fundamental functions of activity/trip generation, location, and scheduling are not separated as in the 4-step model or simplified ABM, but are intertwined through time-space constraints and activity prioritizations as summarized in **Table 13.**

Table 13. Sub-model Process

Sub-model	Population	Activity gen.	Locations	Act. schedule	Tour format.	Tour/trip TOD	Mode & car
1.0=Major university	X		X				
1.1=Population synthesizer	X						
2=Usual work & school	X		X				
3=Mobility attributes	X						
4=Special Events (SE)		X	X	X			
5.1=CDAP		X					
5.2.1=Mandatory activities		X	X		X		
5.2.2=Linkage of SE					X	X	
5.2.3=Preliminary TOD				X		X	
5.2.4=School escorting		X	X	X	X	X	
5.3=Fully joint tours		X	X	X	X	X	
5.4=Individual maintenance		X					
5.5=Individual discretionary		X					
6=Tour formation			X		X		
7.1=Tour TOD						X	
7.2=Tour & trip mode							X
7.3=Stop dur. & trip dep.				X		X	
7.4=Schedule consolidation				X		X	
7.5=Car allocation & routing				X		X	X

Figure 13. PAG ABM Flowchart



The general design of the CT-RAMP2 model system and linkages between the sub-models is presented in **Figure 13**. For Step 5, to build a day-level activity participation and prioritized tour skeletons, The Coordinated Daily Activity Pattern (CDAP) included three major individual pattern types: M-mandatary, N-non-mandatory, H-home, and presence of a fully-joint tour (J) for the modeled household day to coordinate shared activities and available household vehicles. Considering the dependency of household members' activity priorities and schedules, Step 6 and 7 form a household tour and assign relevant trips to the tour including departure time and car allocation along with a detailed schedule.

MODEL INPUTS

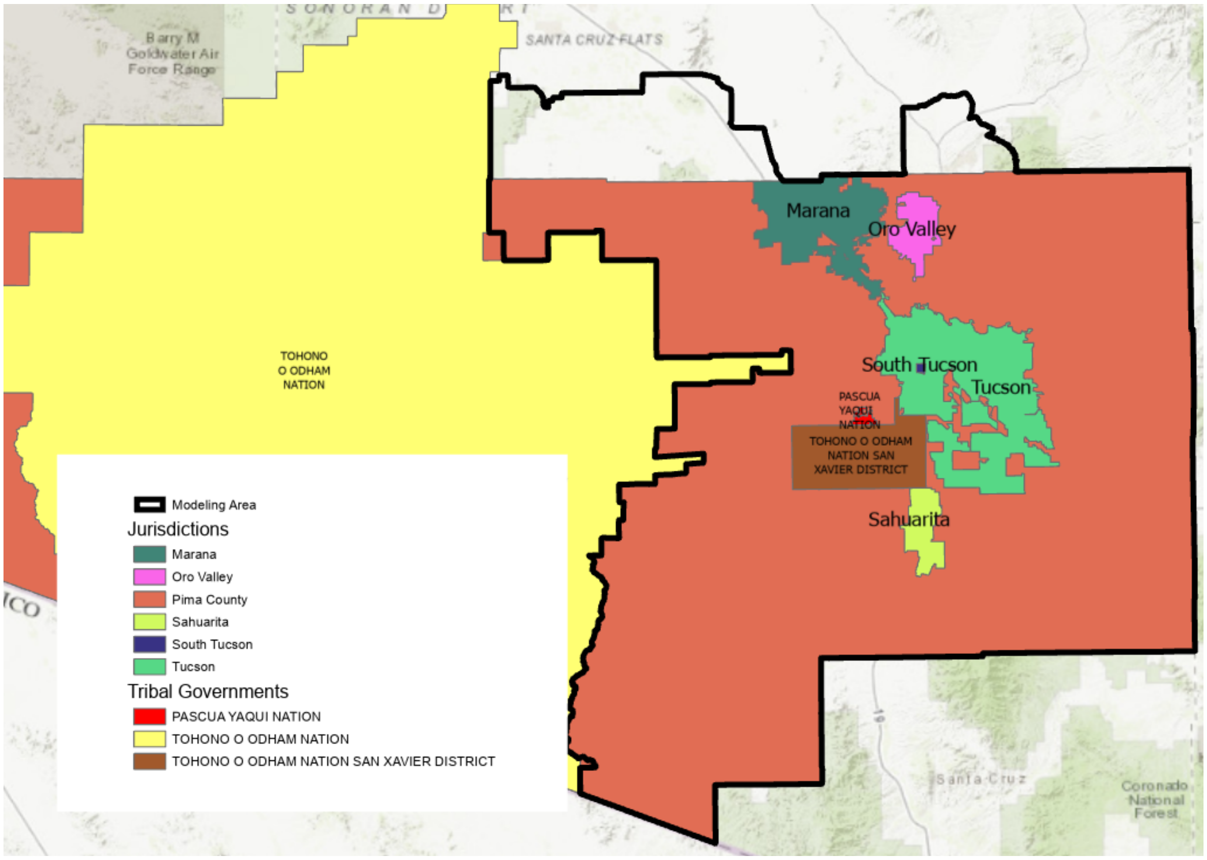
For each analyzed scenario, a full set of model data needs to be assembled. The three major inputs are the Socio-economic Data, Roadway Network, and Transit Network. The model covers the eastern Pima County region and parts of southern Pinal County.

SOCIO-ECONOMIC DATA

Socio-economic data, which describes both demographic and economic characteristics of the region by MAZ, is used as a major input of PAG's ABM. Travel demand analysis is based on the concept that travel is a derived demand of activity participation. Zonal demographic data, such as population, households, and income, is directly related to demand for activity participation in the area, and economic characteristics, such as jobs by industry, are linked with supply of an activity.

PAG's ABM model covers eastern Pima County including 6 jurisdictions and 2 Indian reservations and southern portions of Pinal County as shown in **Figure 14**. Socio-economic data outside Pima County was obtained from Central Arizona Governments.

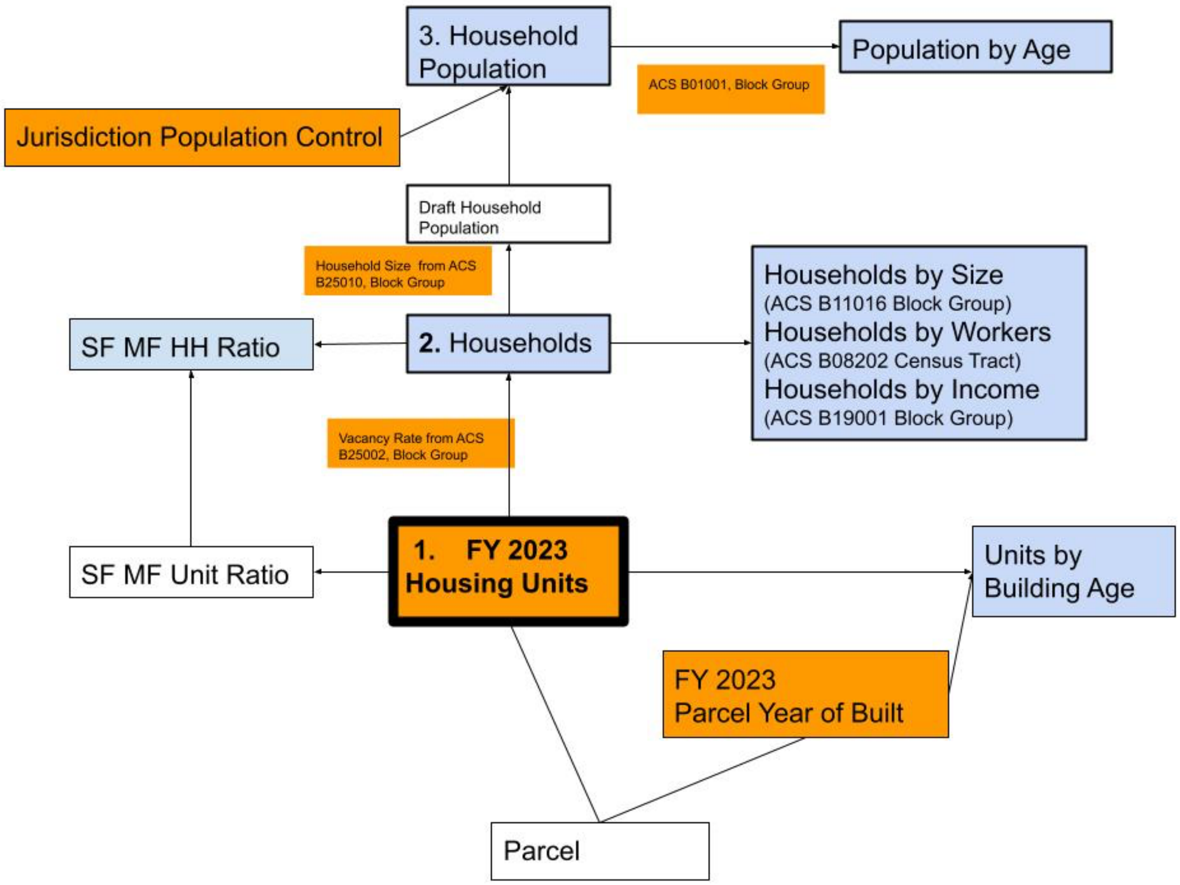
Figure 14. **ABM Modeling Area**



The socioeconomic input data for model base year 2024 consists of zonal control data and the American Community Survey (ACS) Public Use Microdata Sample (PUMS), and sample student data from the University of Arizona. Zonal level control data includes population by type, households by type, housing units by type, school enrollments, school dorms, employment by type, etc.

The base year socioeconomic variables were developed using diverse public and private sources of data and advanced estimation methods. The major data sources include 2020 Census data, 2022 5-yr American Community Survey (ACS) data, 2023 Arizona Office of Economic Opportunity (AOEO) population estimates, 2024 PAG employment data, 2024 Land Use data, jurisdictional building permit data, and the County Assessor's Parcel Database. An overview of the data input preparation process is shown in **Figure 15**.

Figure 15. **ABM Input Data Preparation**



Note:
HU: Housing Unit; MAZ: Micro Analysis Zone; ACS: American Community Survey; SF: Single-family; MF: Multi-family; HH: household; Dist. : Distribution; PPHH: Persons per Household; HH Pop: Household Population; GQ Pop: Group Quarter Population

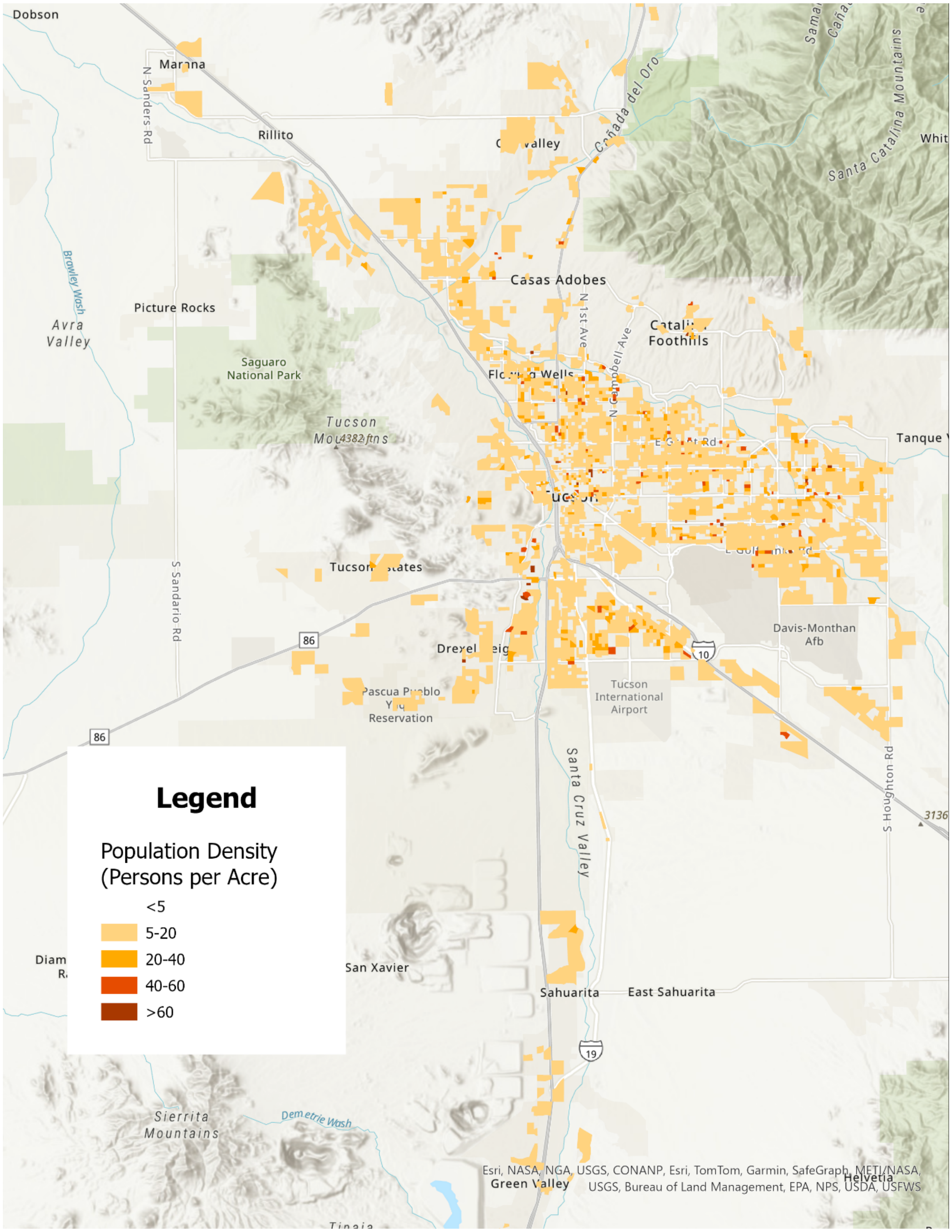
Household and housing unit controls are developed based on Pima County assessor housing unit data and AOEO population estimates. ACS block group level vacancy rates are used to estimate the number of households in each parcel, and ACS block group level household sizes are used to estimate parcel level household population. Parcel level household populations are adjusted based on the jurisdiction level population control data from AOEO. After housing unit, households, and household populations are aggregated at the MAZ level, various types of ACS data are used to classify them to different types of household size, number of workers, income range, building age, person age, and housing types as follows.

Table 14. Demographic Inputs from ACS Data

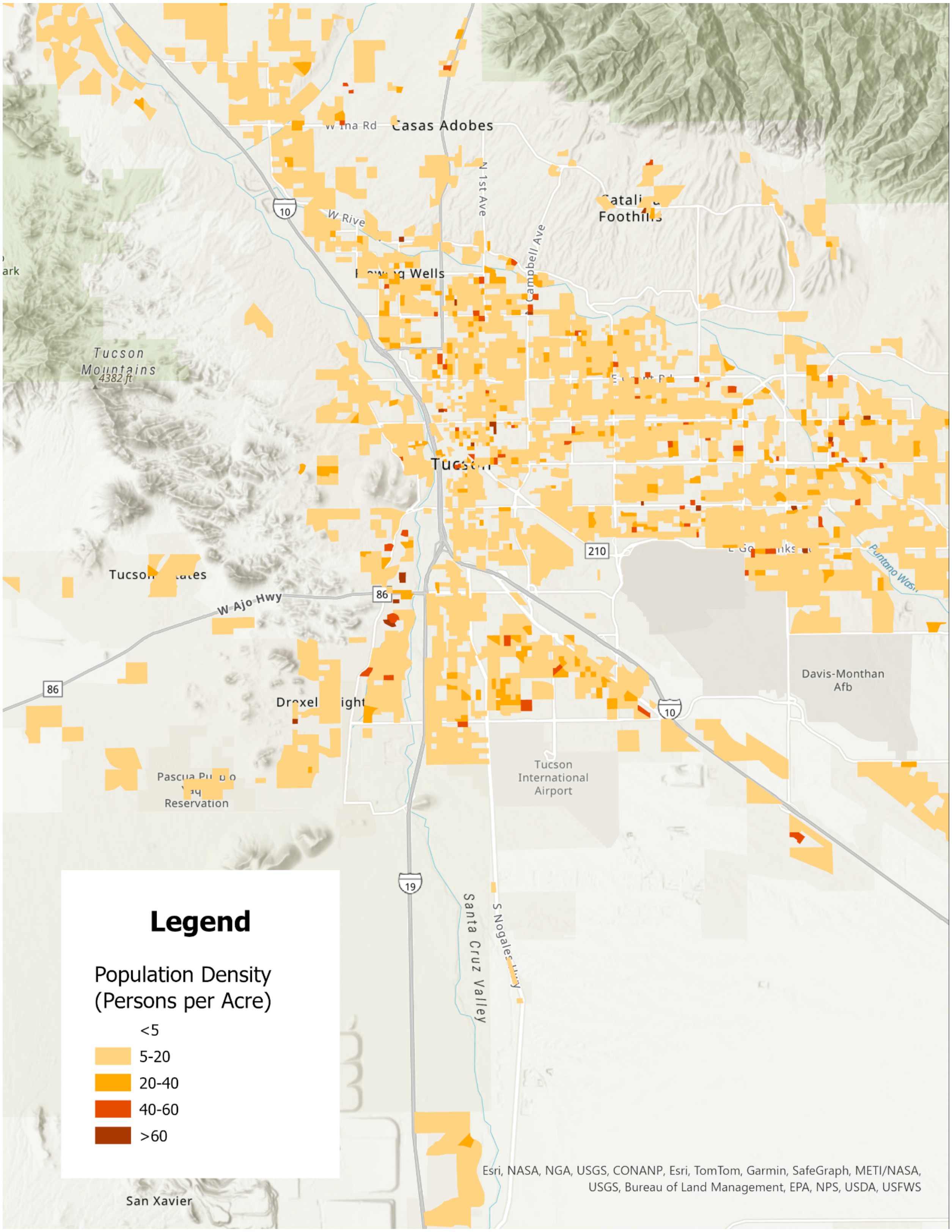
Group	Items
Population	▪ Residential population ▪ Group quarters population
Households	▪ Residential Households ▪ Group quarter Households ▪ Households by Size ▪ Households by Workers ▪ Households by Income ▪ SF/MF households
Housing Units	▪ Housing Units ▪ Housing Units by Building Age

Figure 16 shows the population density of the model area in Micro-Analysis Zone (MAZ). Most of the region is low-density (0 to 20 persons per acre), with some areas of mid- or high-density (40+ persons per acre).

Figure 16. Base Year (2024) Population Density



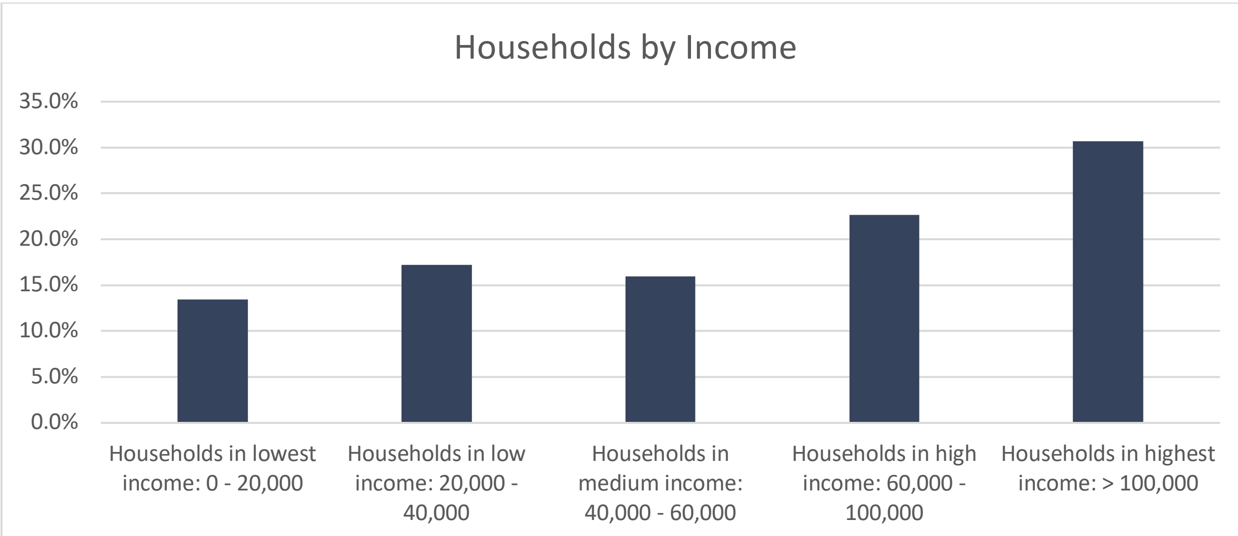
(a) Regional Area



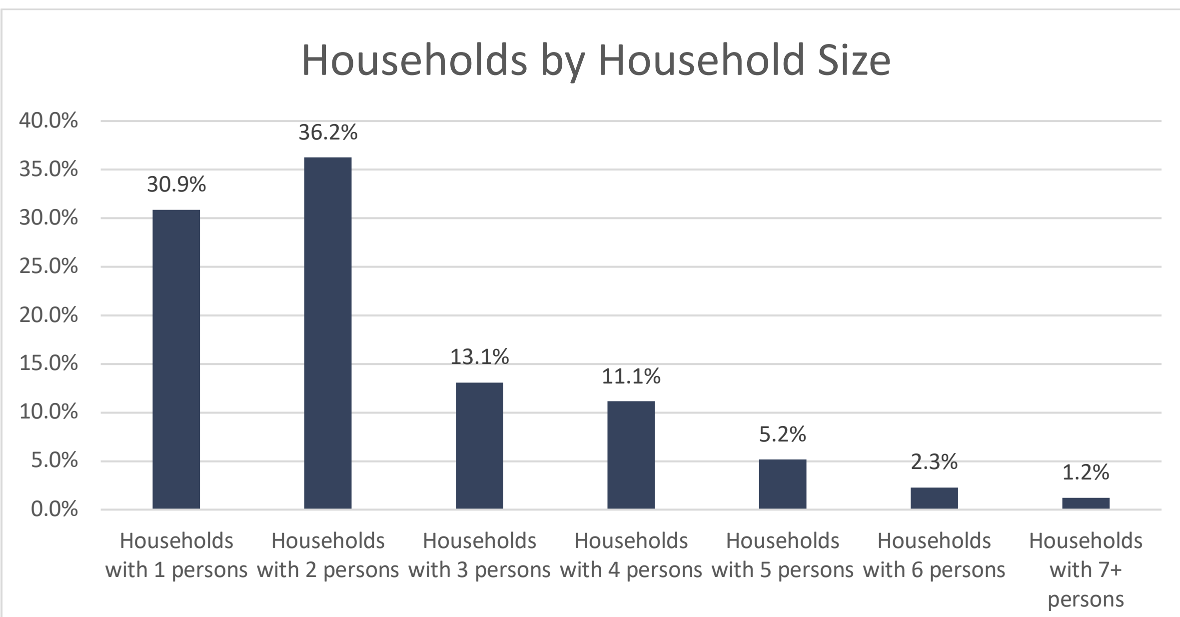
(b) Regional Area (Central Zoom-in)

There are 446,669 households in the model region for the base year, and the distributions of households by income and size are shown in **Figure 17**.

Figure 17. Base Year (2024) Households by Income and Household Size



(a) Households by Income Group



(b) Households by Household Size

In the base year, the distribution of population by age is shown in **Figure 18.**

Figure 18. Base Year (2024) Population by Age Group

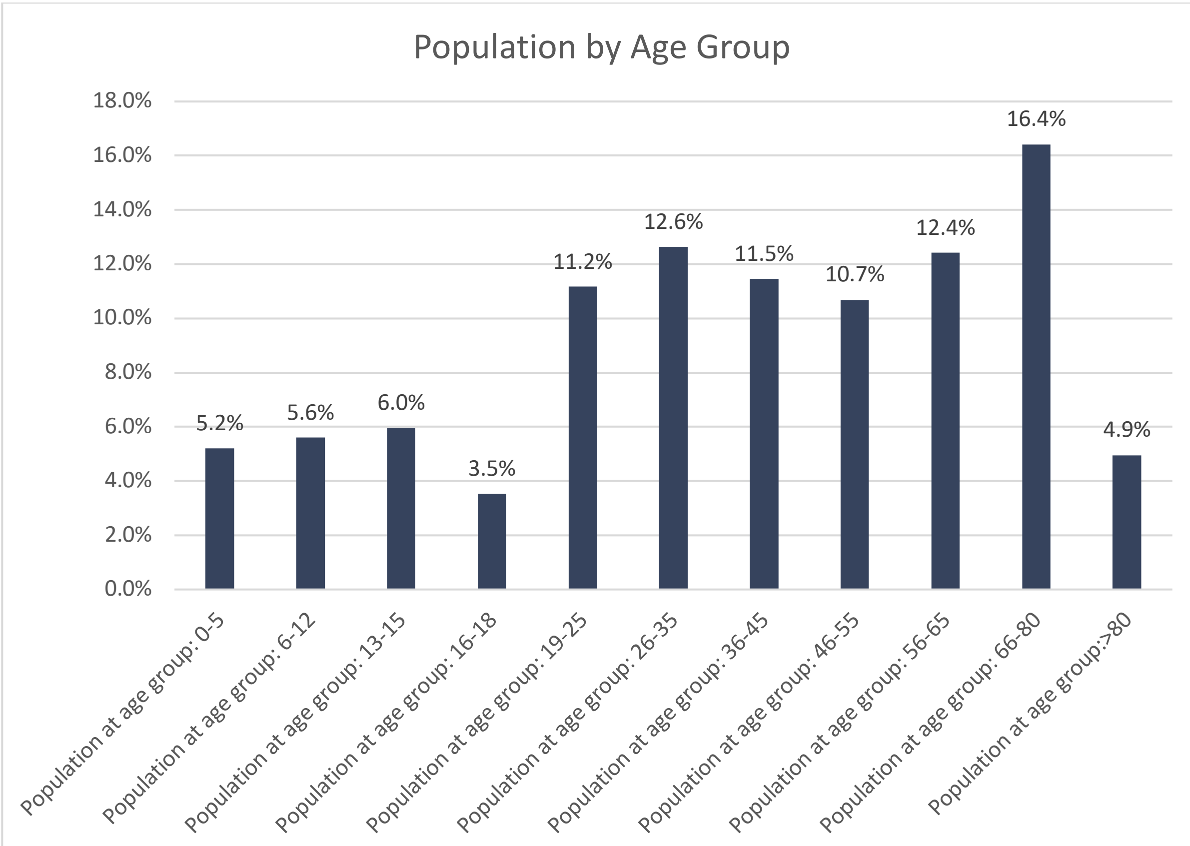
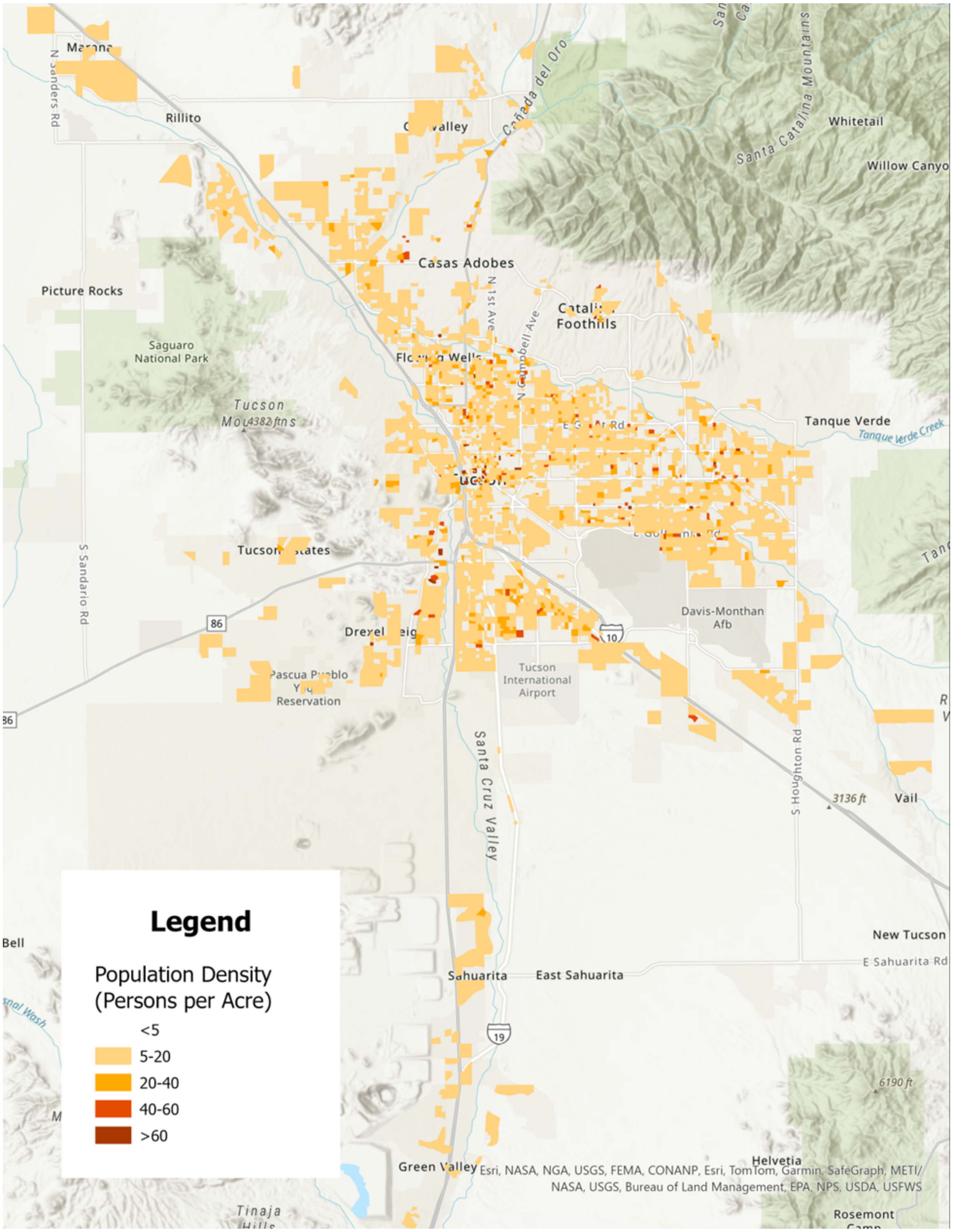
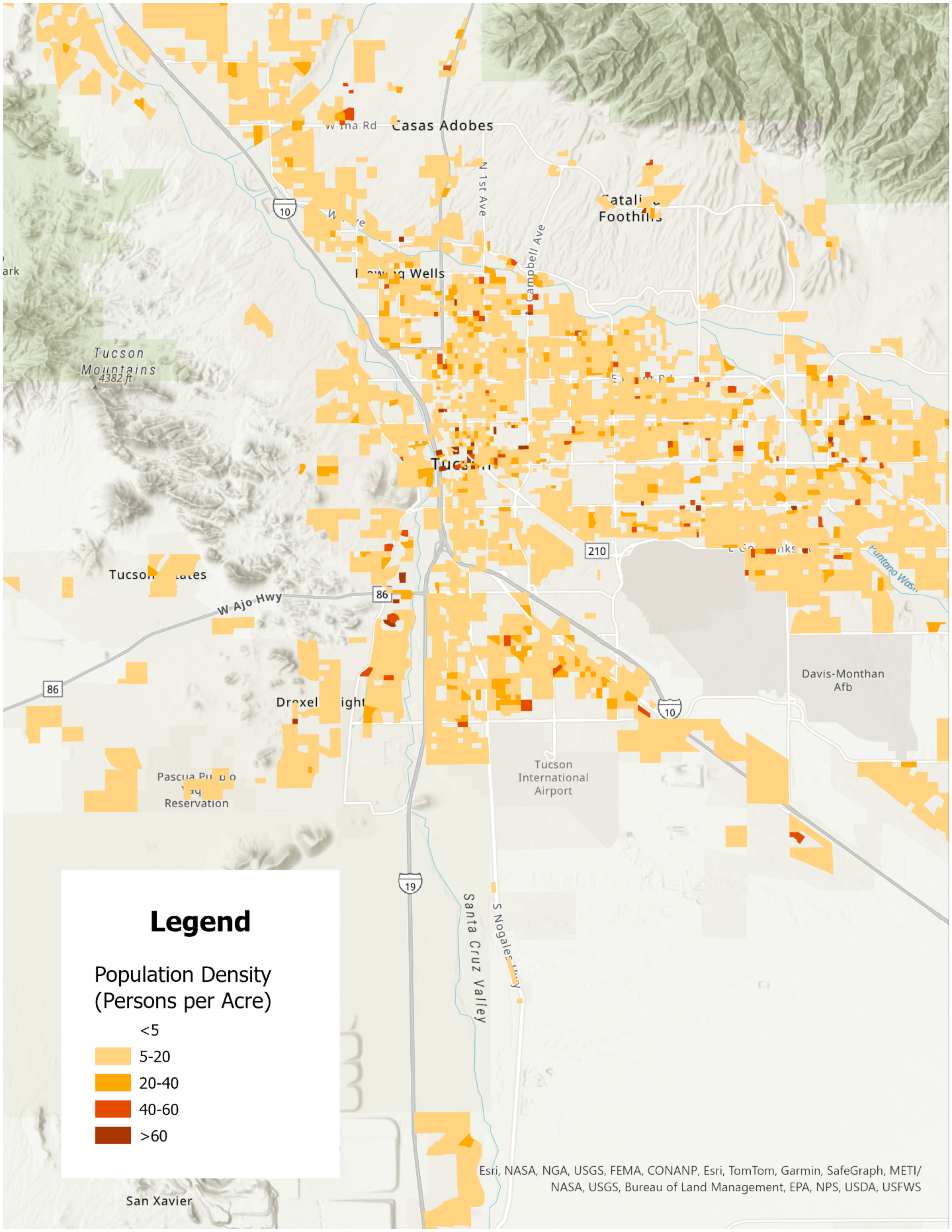


Figure 19 shows the population density of the model area in 2055. Most of the region is low-density (0 to 20 persons per acre), with some areas of mid- or high-density (40+ persons per acre). Downtown Tucson, in particular, has numerous areas of high density development.

Figure 19. Forecast Year (2055) Population Density



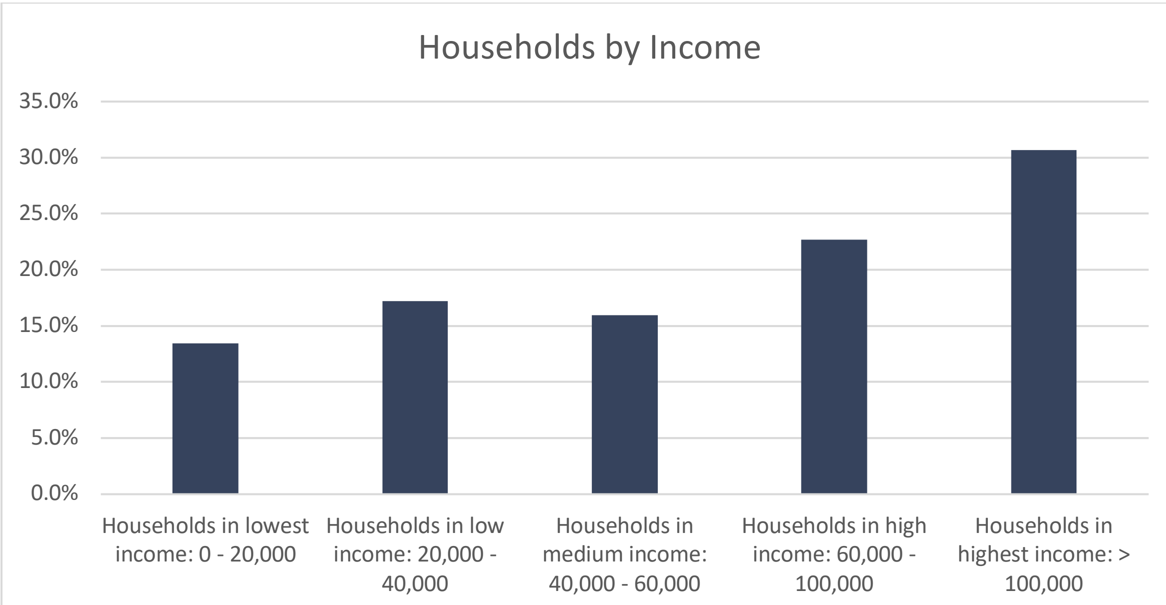
(a) Regional Area



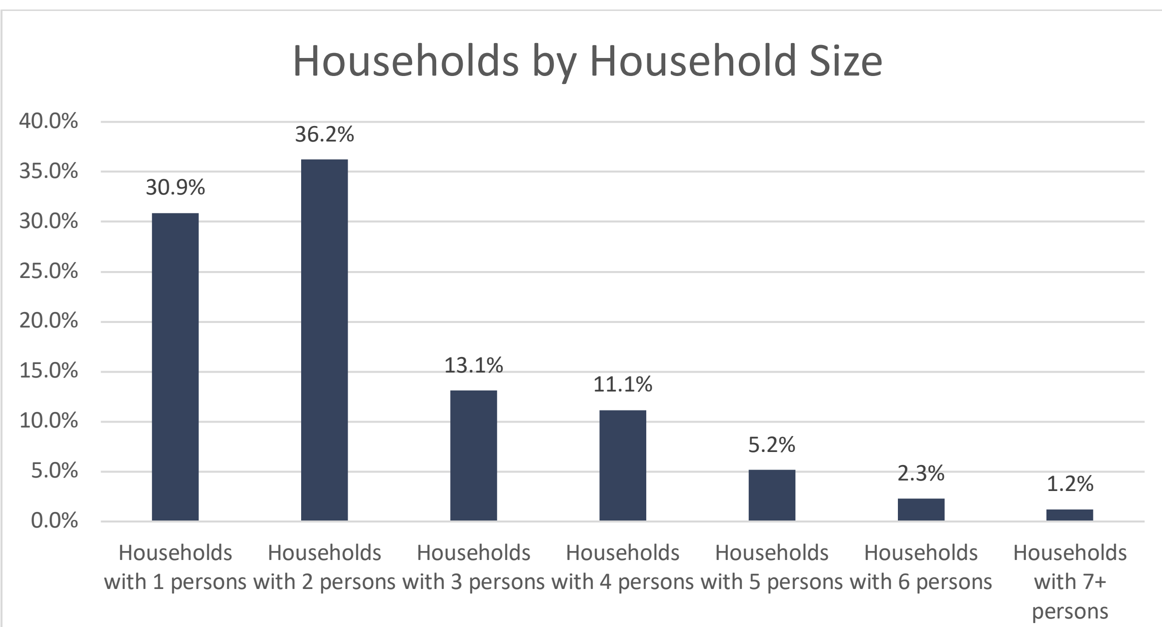
(b) Regional Area (Central Zoom-in)

There are 523,415 households in the model region for the forecast year, and the distributions of households by income and size are shown in **Figure 20**. And the distributions of household by income group and size are like the base year distribution as applying the same household distributions calibrated.

Figure 20. Forecast Year (2055) Households by Income and Household Size



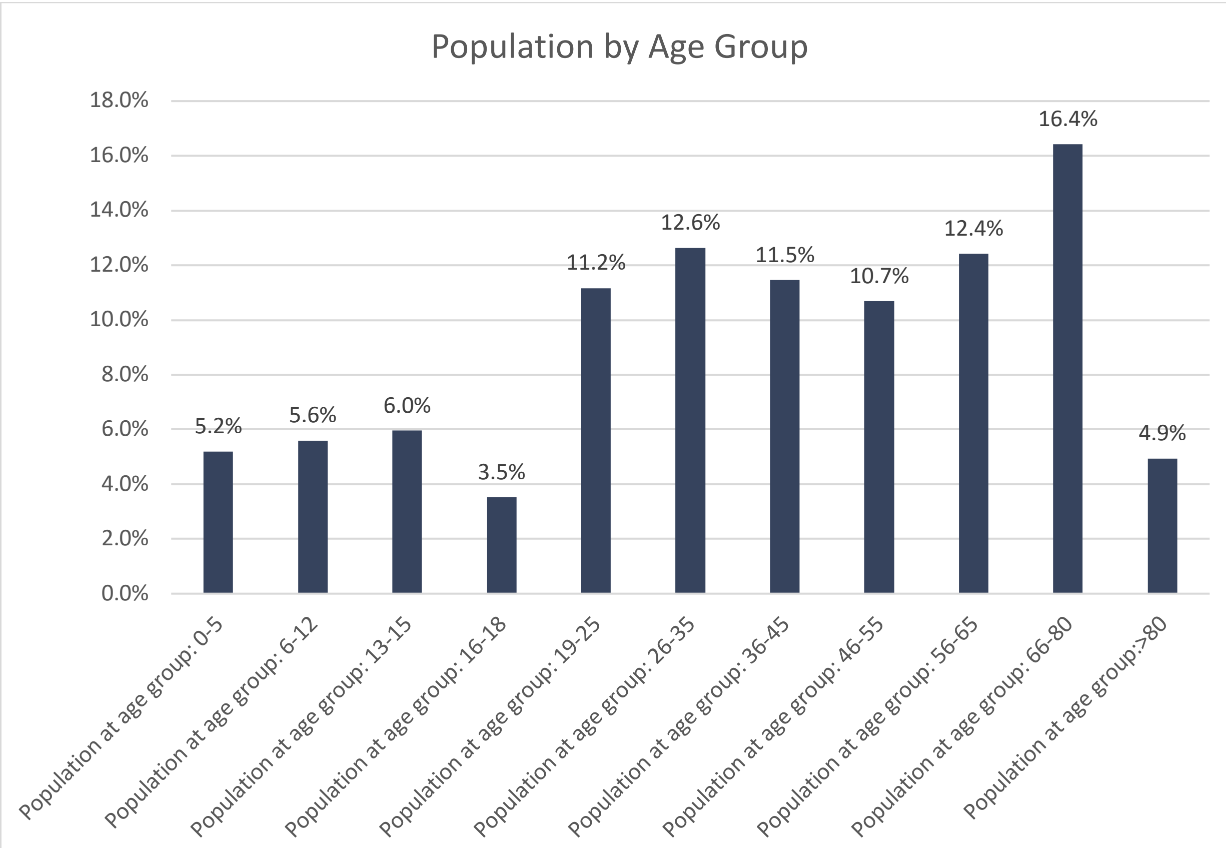
(a) Households by Income Group



(b) Households by Household Size

In the forecast year, the distribution of population by age is shown in **Figure 21**. And population by age groups are like the distribution of the base year as applying the same demographic distribution calibrated.

Figure 21. Forecast Year (2055) Population by Age Group



Regional employment density for the forecast year is shown in **Figure 22**, **Figure 23**, and **Figure 24**. Regional employment is concentrated in the downtown and the university area, along major north-south and east-west corridors such as Oracle Rd, Speedway Blvd., Broadway Blvd., Kolb Rd. and I-10, and south of Tucson International Airport. **Figure 24** highlights Downtown and the UA Area.

Figure 22. **Forecast Year (2055) Employment Density – Regional View**

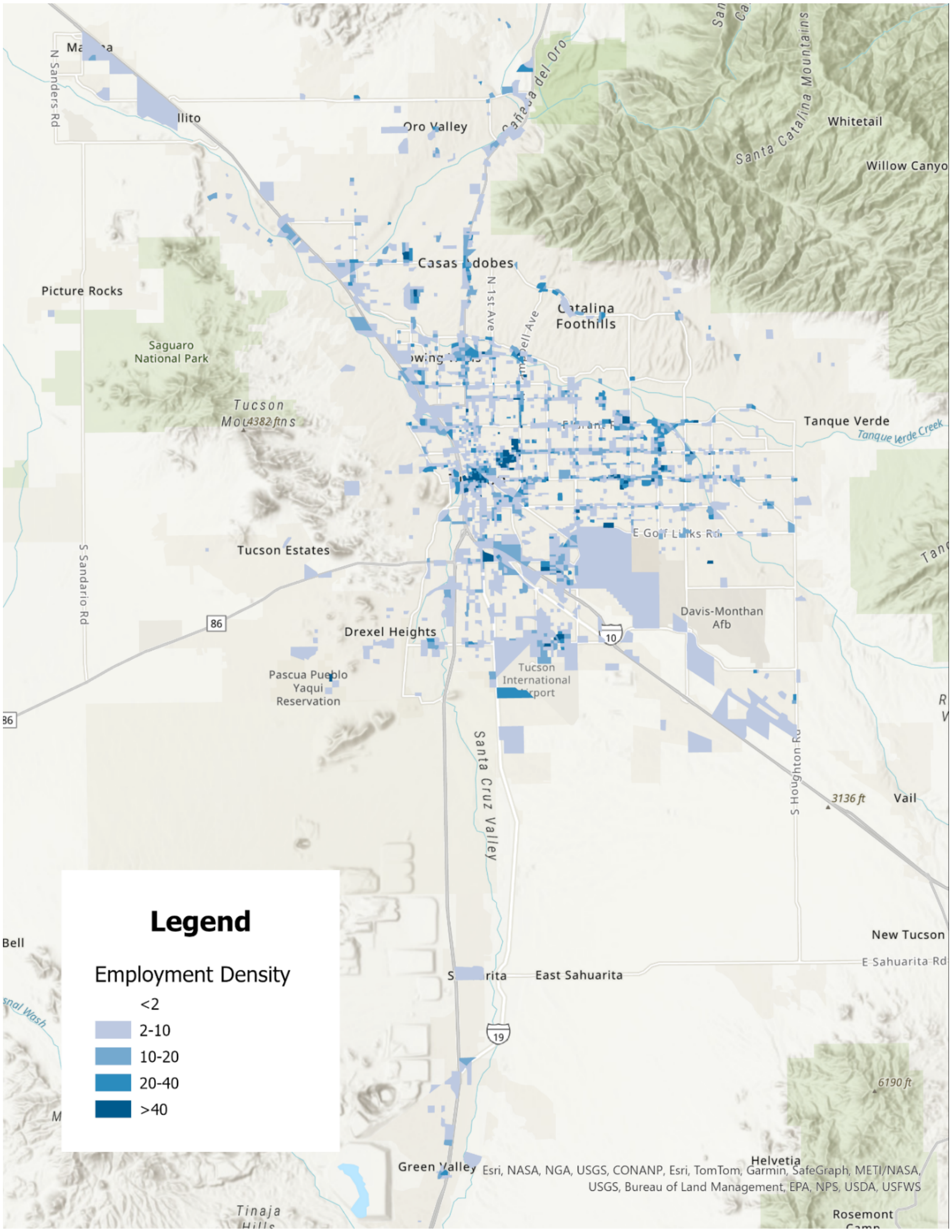


Figure 23. **Forecast Year (2055) Employment Density - Central View**

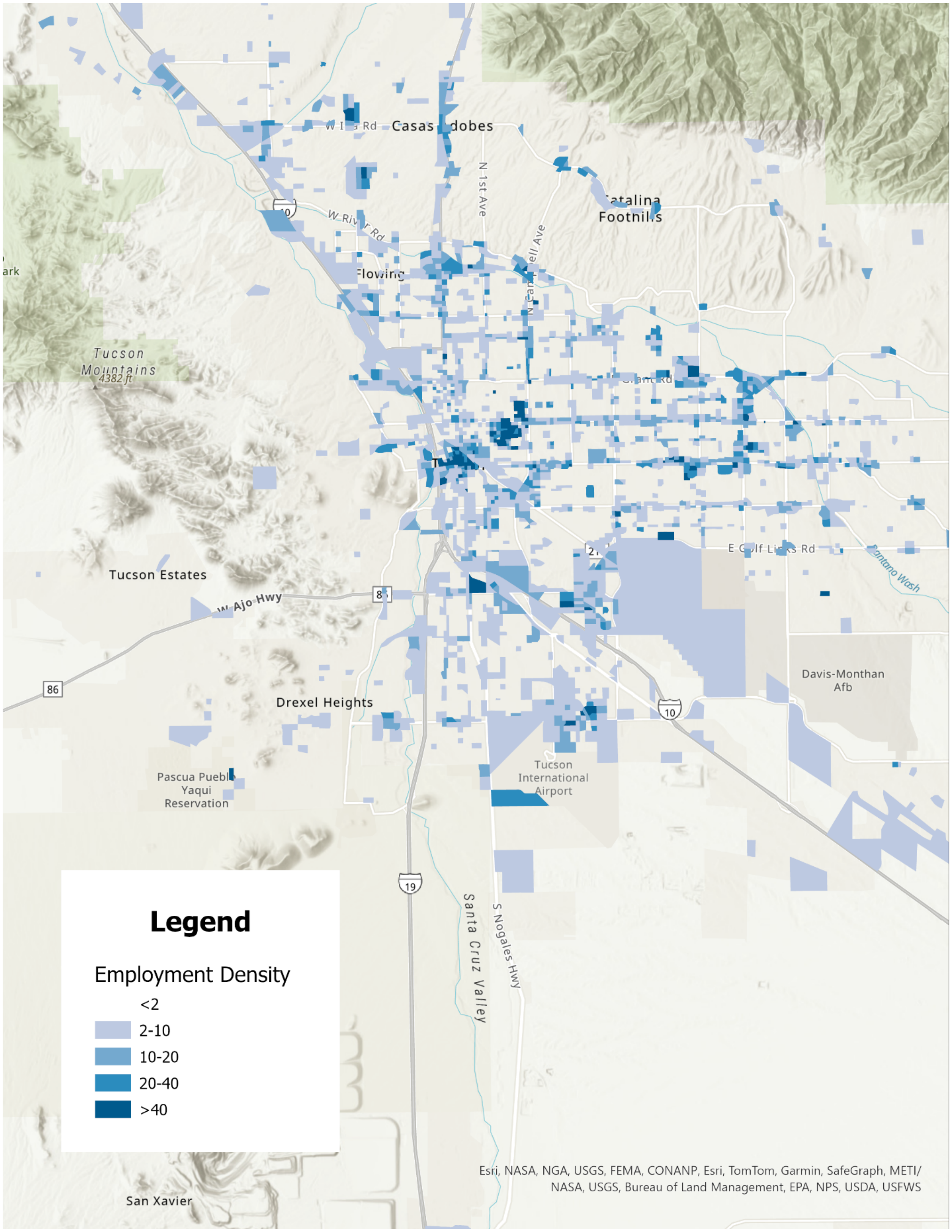
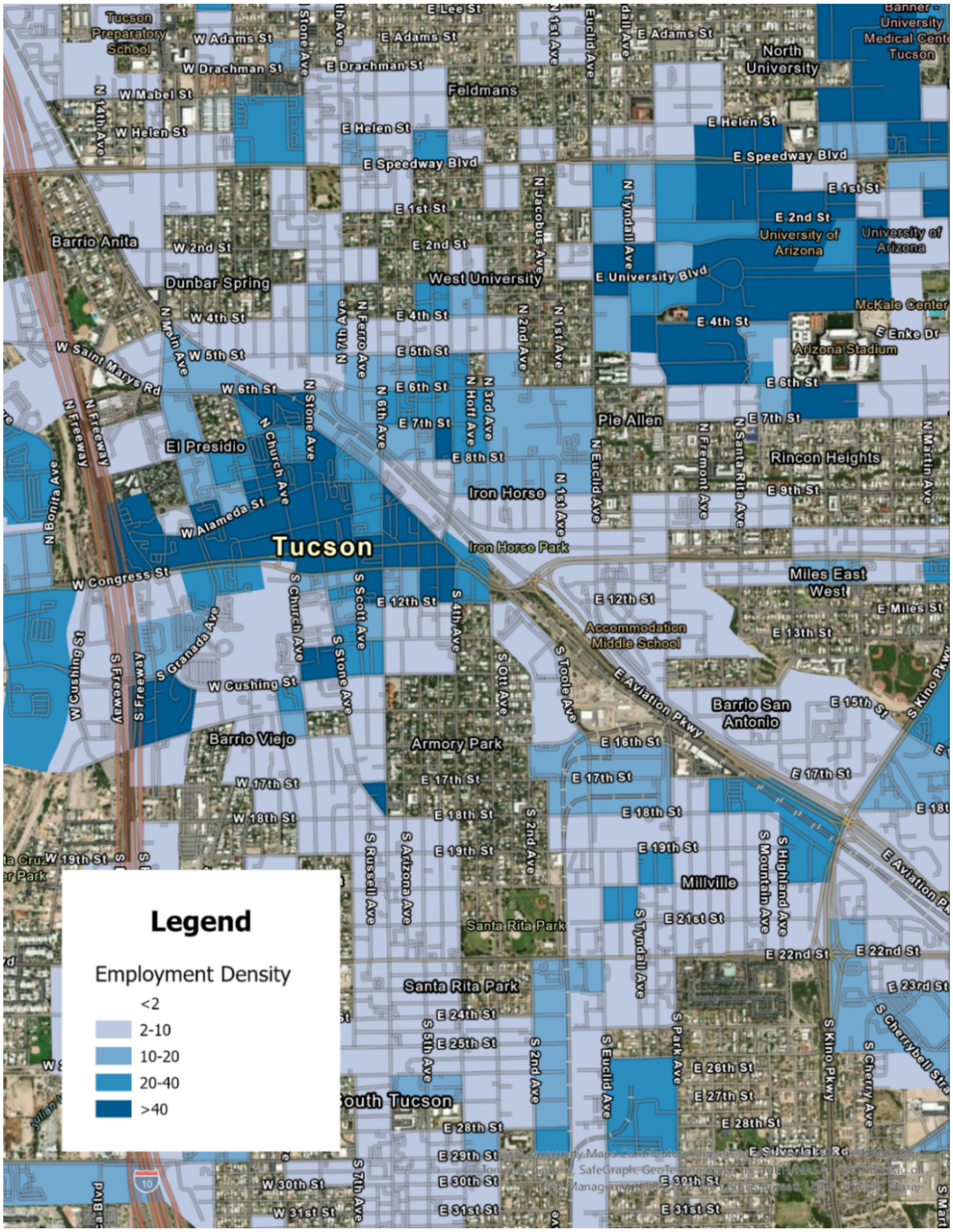


Figure 24. **Forecast Year (2055) Employment Density - Downtown and University Areas**



PAG also collected other population and socio-economic input data for the activity-based model, which includes group quarters/dorms data, school enrollment data, and university enrollment/student data by working with related agencies directly.

There are a total of 104,182 students enrolled in grades K-8 and 46,912 students enrolled in grades 9-12 in the model region. **Figure 25** and **Figure 26** show 2019 grades K-8 and grades 9-12 school enrollment by MAZ.

Figure 25. School Enrollment, Grade K-8

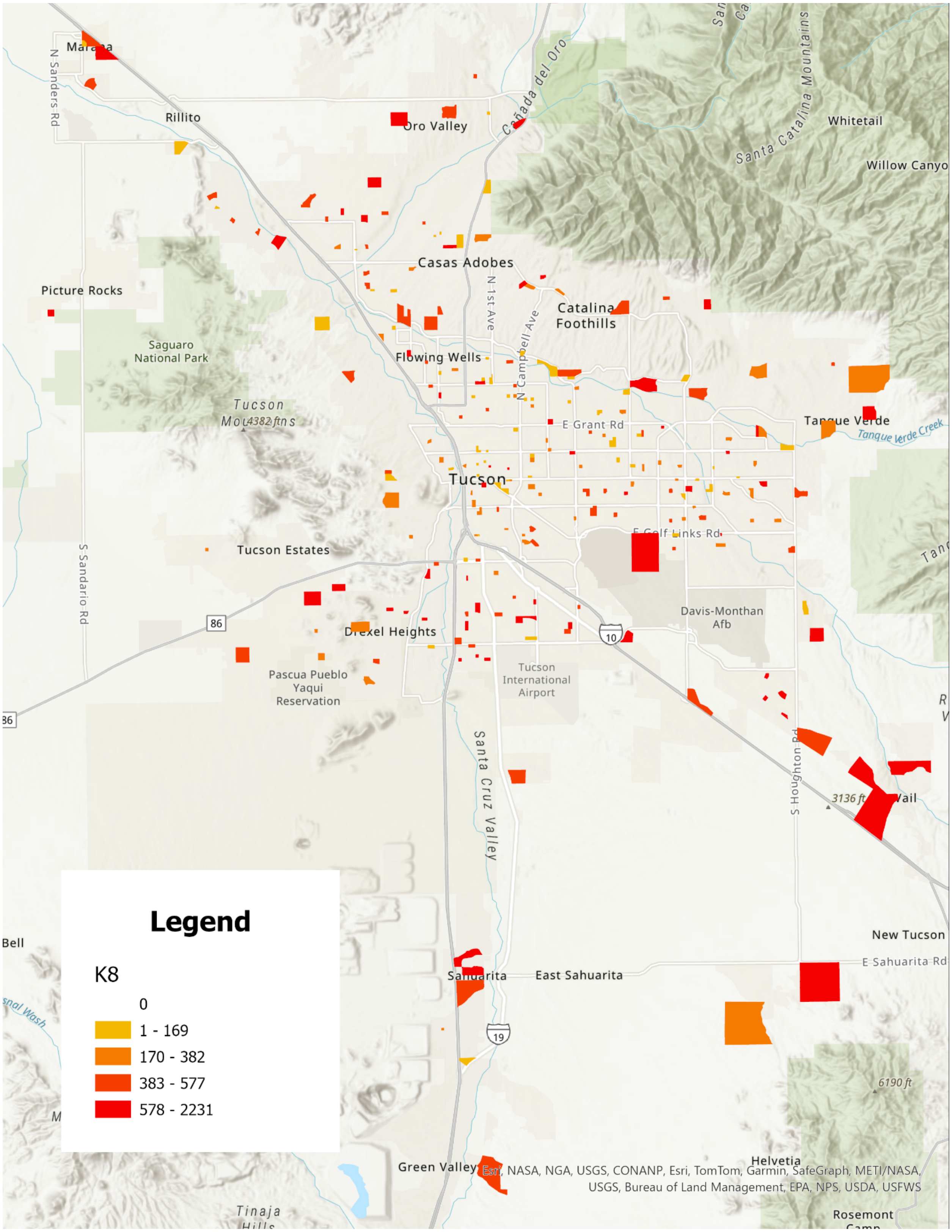
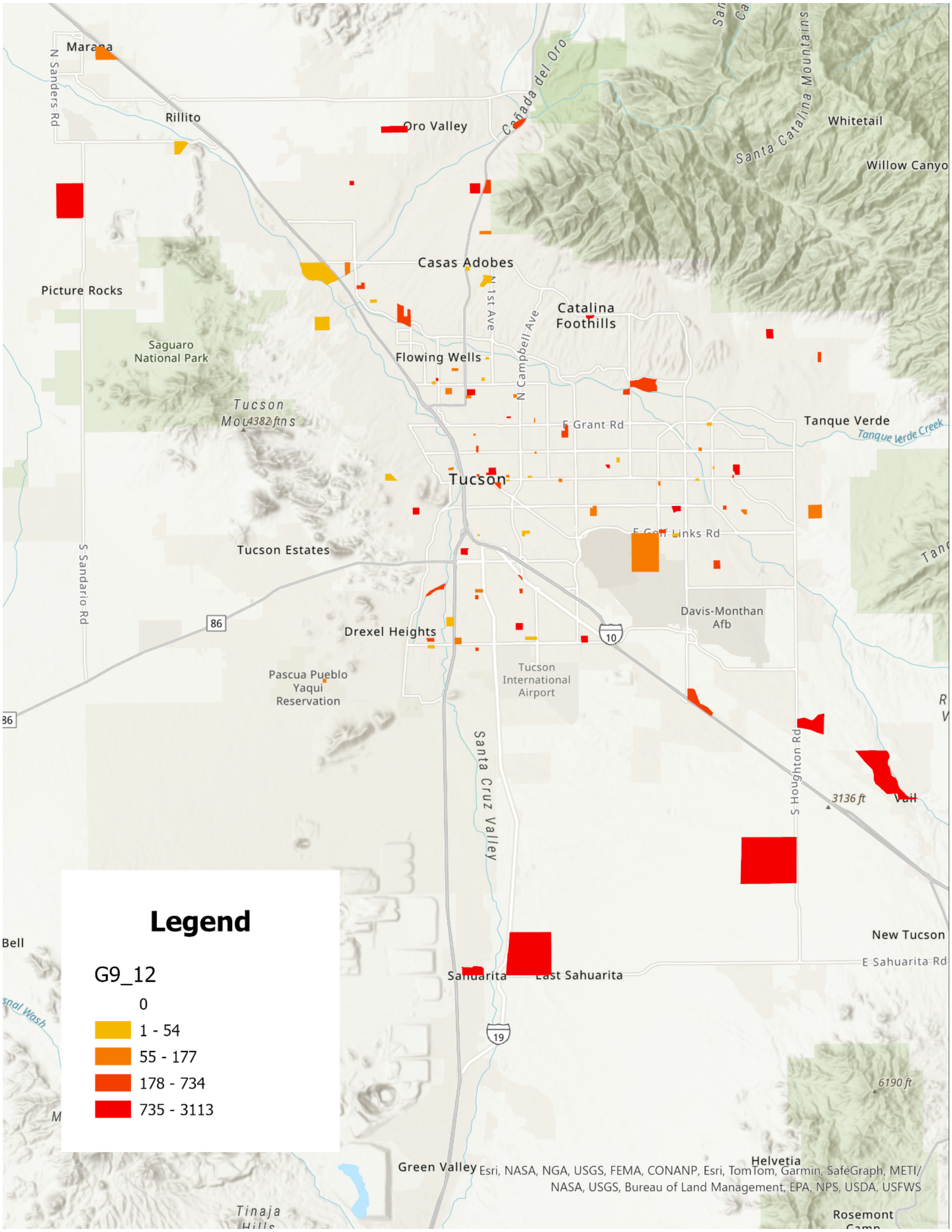
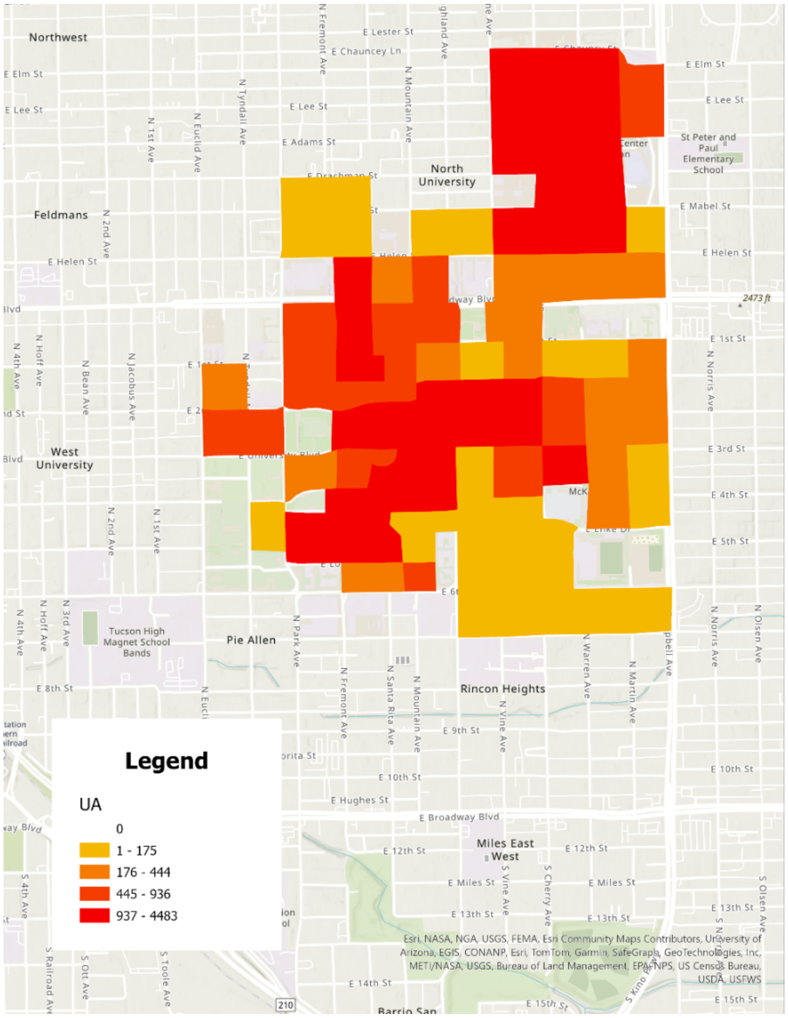


Figure 26. Student Enrollment, Grade 9-12



In 2019, there were a total of 37,981 students enrolled at the University of Arizona. These students are distributed across the campus MAZs, as shown in **Figure 27**.

Figure 27. University of Arizona Enrollment



Roadway Network

The second component of PAG's TDM is the roadway network. PAG's TDM covers all major roads within eastern Pima County. The model roadway network file consists of more than 4,000 links, each containing over 100 data fields, 15 of which are user-defined roadway information. The rest are either model-calculated or information fields. The primary user-defined fields are the area type (high urban, medium urban, low urban, suburban, or rural), which is determined based on land use type and density, number of lanes in each direction, roadway class (e.g. freeway, ramp, major/minor arterial, frontage road), and posted speed limit.

Figure 28. **PAG Roadway Network**

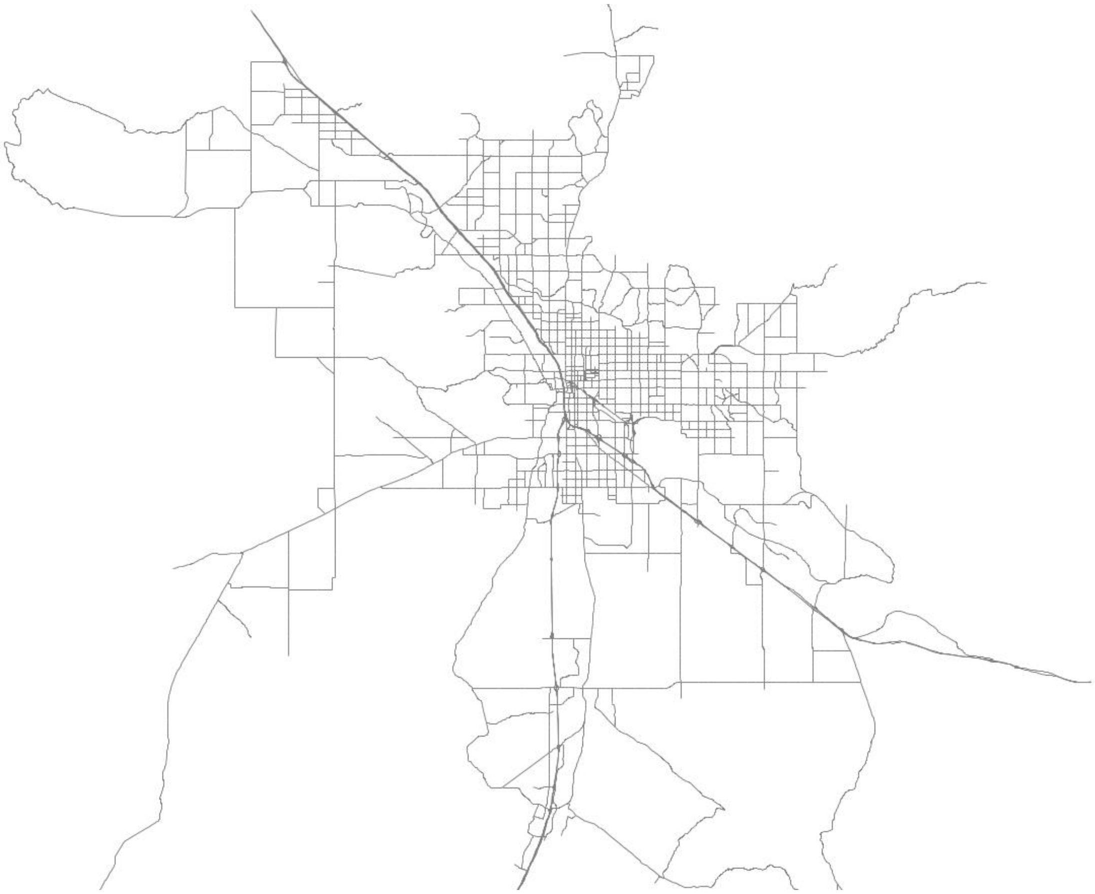


Table 15 represents 501 lane-miles of freeways (I-10 and I-19) and 36 lane-miles of parkways, 3,811 lane-miles of arterial roads, 236 lane-miles of collector roads, 86 lane-miles of ramps, and 170 lane-miles of frontage roads. The 2055 forecast year travel demand model contains a total of 411.57 additional lane-miles over the base year model.

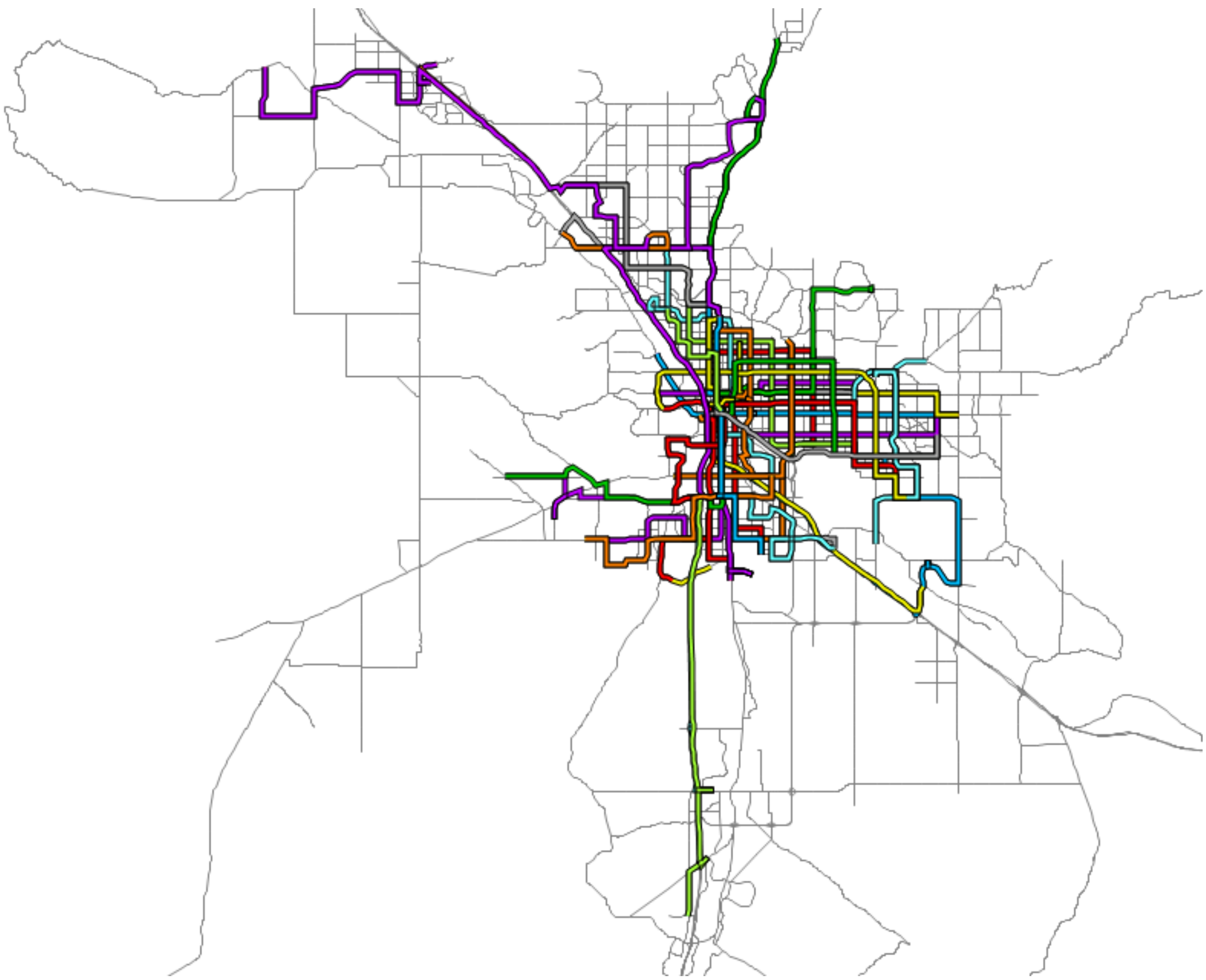
Table 15. Ro**adway Network Lane Miles**

Facility Type	Base Year (2024) Lane-miles	Forecast Year (2055) Lane-miles	Lane-miles Added
Freeway	501.23	612.28	111.05
Parkway	35.85	43.90	8.05
Major Arterial	1,684.60	1,824.47	139.87
Minor Arterial	2,126.56	2,215.16	88.6
Collector	236.20	280.39	44.19
Ramp	86.36	103.73	17.37
Frontage Road	170.10	172.54	2.44
Total	**4,840.90**	**5,252.47**	**411.57**

Transit Network

In addition to the roadway network, the TDM also incorporates transit modes. **Figure 29** represents the 2055 forecast year transit network which includes headway improvement and a new BRT system from Tohono Tadai Transit Center to the Tucson International Airport through the Ronstadt Transit Center. The 2024 transit network contains 77 directional transit routes for the midday and evening hours and 90 directional transit routes for the AM and PM peak periods managed and operated by Sun Tran, which operates Sun Express, Sun Link, Sun Shuttle and the fixed route Sun Tran, and UA Parking and Transportation Services, which operates Cat Tran. All transit routes are coded with their directions, alignments, stops, transit service modes (e.g. standard route, express route, Cat Tran, Sun Link), and headways.

Figure 29. **PAG Transit Network**



For the transit network in the build scenario, a total of 102.2 transit service miles (weighted by frequency) were added (see **Table 16**). The major network modification was the addition of the BRT connecting the Tohono Tadai Transit Center and the Tucson International Airport.

Table 16. Transit Network Update (Frequency-weighted Transit Miles)

Transit Mode	No Build	Build	Change
BRT	0.0	223.6	223.6
Cat Tran	119.1	116.8	-2.4
Sun Express	386.5	334.0	-52.4
Sun Tran	3,124.0	3,057.4	-66.6
Sun Shuttle	352.4	352.5	0.0
Total	**3,982.0**	**4,084.3**	**102.2**

PERFORMANCE MEASURES

With the data provided by the ABM outputs, additional tools developed in house can be utilized to develop various performance measures required by the federal Fixing America's Surface Transportation (FAST) Act, and other PAG and RTA programs, such as the Congestion Management Process (CMP). The performance measures used for the 2055 RMAP can be grouped into two general categories: System and Equity Performance Measures (**Table 17**). The Equity Performance Measures were newly developed for the 2055 RMAP to highlight the regional equity related to PAG's Title VI effort.

Table 17. Performance Measures

	Performance Measures	Description
System Performance Measures	Trips by Mode	Number of person trips by travel mode
	Trips Mode Share	Percent of person trips by travel mode
	Person Miles Traveled by Mode	Person-miles traveled by travel mode
	PMT Mode Share	Percent of person miles traveled by travel mode
	Vehicle Miles Traveled	Total vehicle miles traveled
	VMT per Capita	Vehicle miles traveled per capita
	Vehicle Hours Traveled	Total vehicle hours traveled
	VHT per Capita	Vehicle hours traveled per capita
	Average Commute Time by Mode	Travel time, in minutes, for the average worker to travel to work and return home.
	Average Transit Travel Time	Average travel time for regional transit trips

	Highway Lane miles	Lane-miles by road class
	Transit Miles (Frequency-weighted)	Frequency-weighted transit miles by transit mode
	Population/Jobs within Quarter Mile of Transit	Percent and number of population/jobs within a quarter mile of a transit stop
	Average Transit Speed by Peak/Off Peak	Average speed of transit system vehicles for peak/off peak
	Travel Time Index by Peak/Off Peak	Ratio of travel time during the peak/off peak period to travel time for the same trip during free flow conditions
	Average Travel Speed by Auto (VMT/VHT)	Average auto travel speed calculated by VMT/VHT
Equity Performance Measures	Accessibility to Basic Needs (Hospital, School, and Grocery) by Mode for Vulnerable Populations	Number of basic services (healthcare, educational facilities, essential services, etc.) available by mode
	Accessibility of Jobs by Mode for Vulnerable Populations	Number of jobs available by mode
	Travel Time by Mode for Vulnerable Populations	Daily total travel time of each mode for vulnerable/non-vulnerable populations divided by the total number of vulnerable/non-vulnerable households in the greater Tucson region
	Number of Transit Stops within Quarter Mile Buffer of Vulnerable Population Zones	Percent and number of vulnerable population/jobs within quarter mile of a transit stop
	Average Commute Time by Income Quartile	Average commute time in minutes by income quartile

For the performance measures, the report highlights some system and equity performance measures among 3 scenarios: 2024 base year (2024D2024S), 2055 no-build (2055D2024S), and 2055 build (2055DLateS) to show the 2055 RMAP benefit to the region. Above all, **Figure 30** demonstrates the regional trips by transportation mode. There are significant increases in auto trips in the forecast year. Mode share in **Figure 31**, however, shows a similar percentage in the base year and the forecast year.

Figure 30. Number of Trips by Mode and Scenario

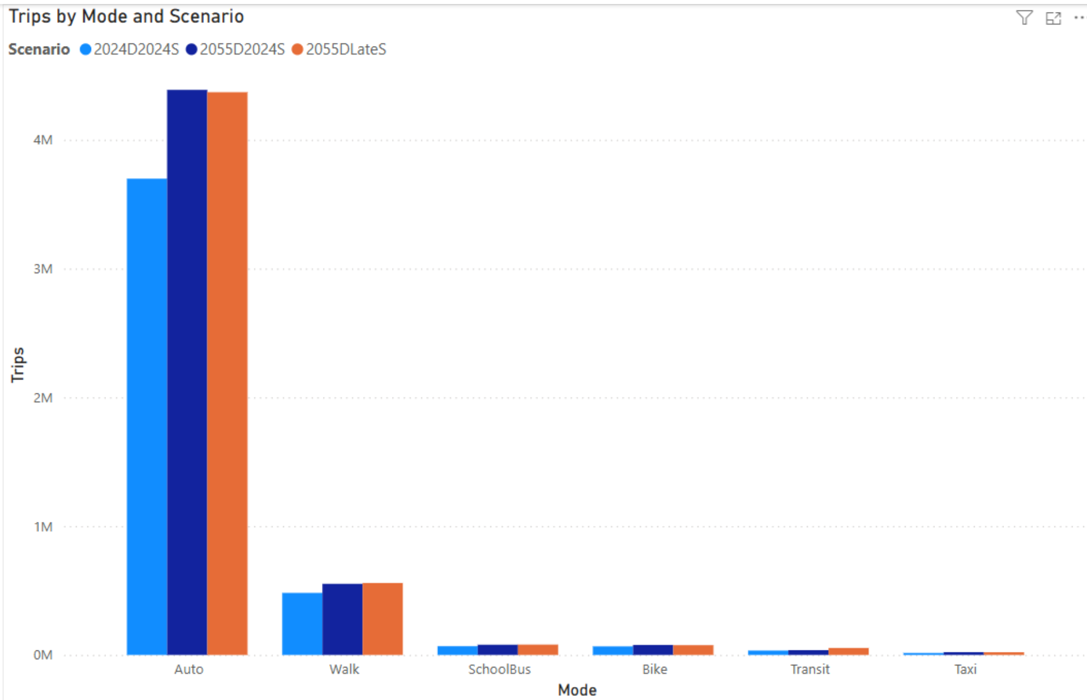
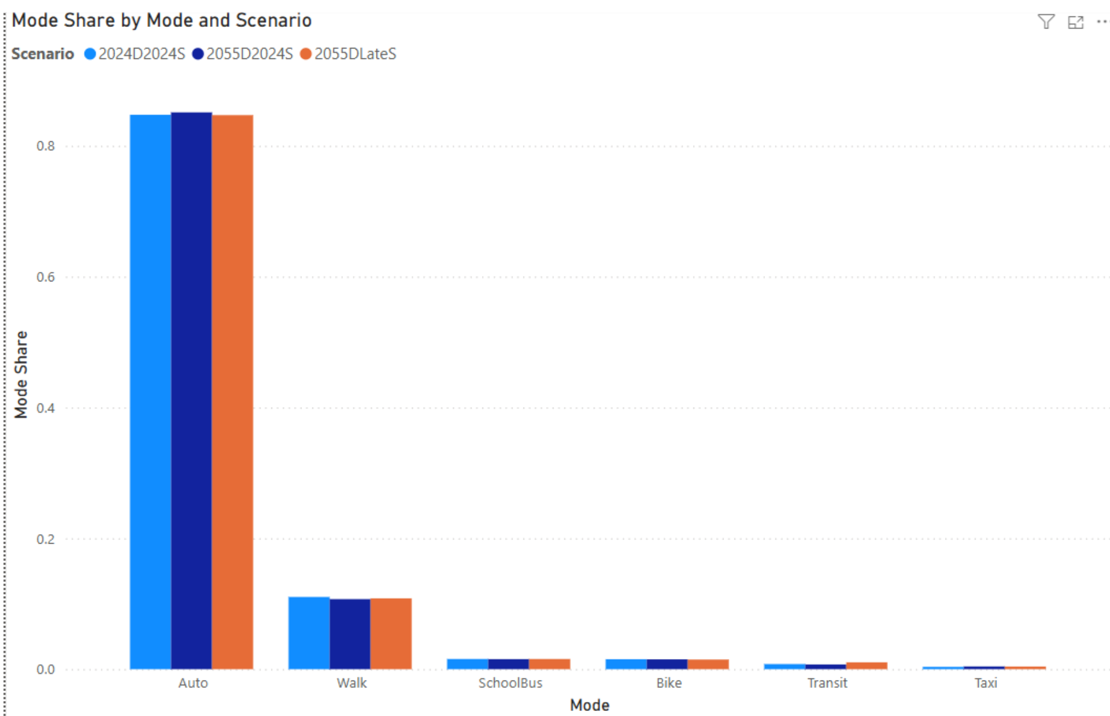
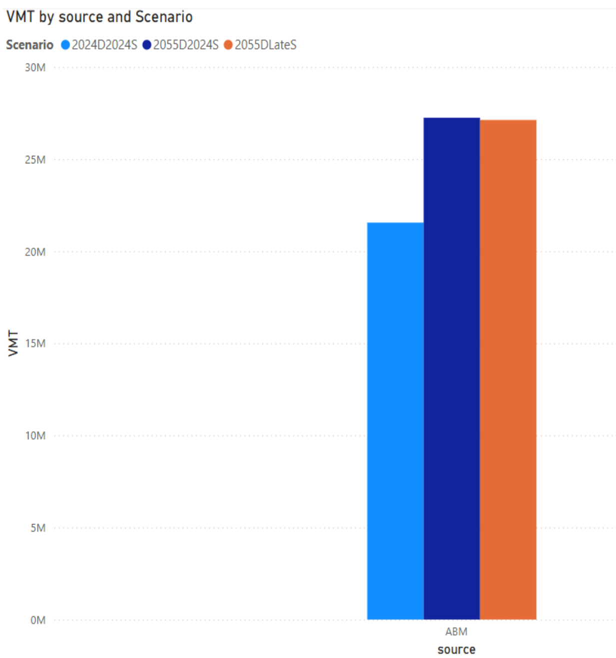


Figure 31. Mode Share by Scenario



Both total regional VMT and average VMT per capita (**Figure 32**) increased in 2055. The population and job growth are the main factors for the increase in VMT as well as the increase in longer OD trips. But the 2055 Build scenario shows VMT and VMT per capita lower than the 2055 No-build scenario.

Figure 32. VMT and VMT per Capita by Scenario



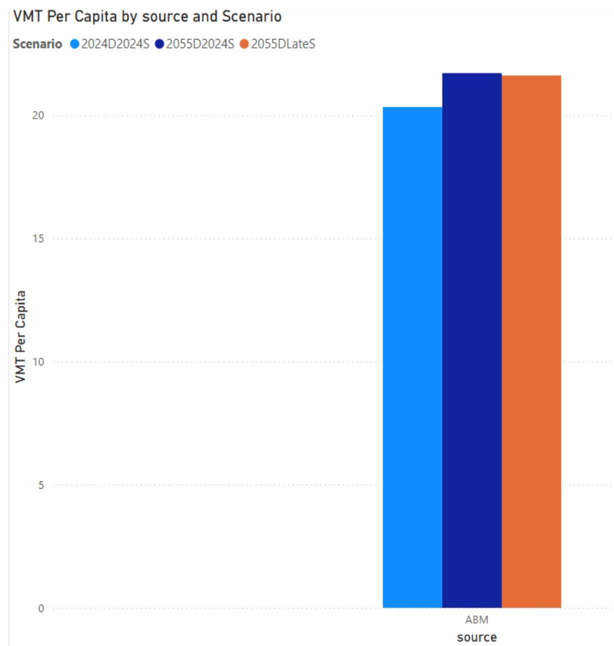
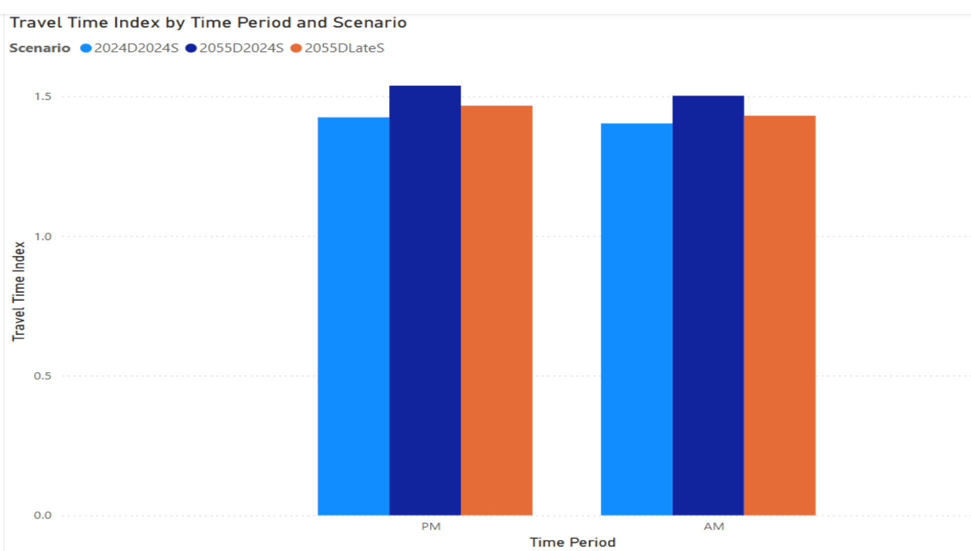


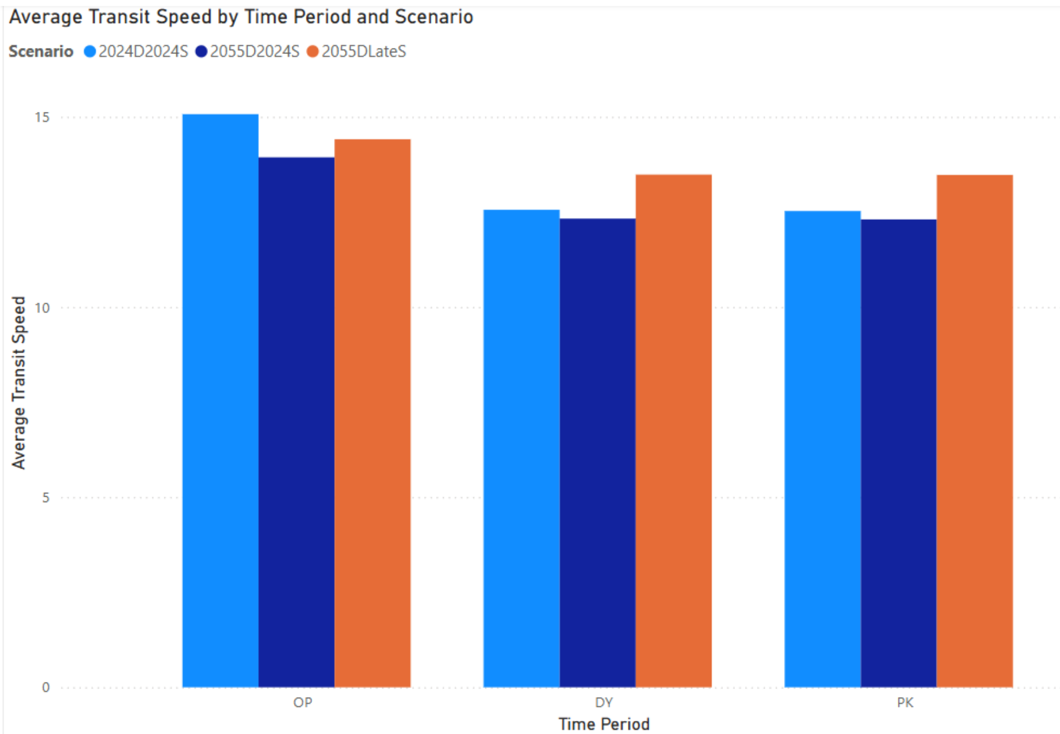
Figure 33. Travel Time Index



As shown in **Figure 33**, the travel time index (=congested travel time/free-flow travel time) indicates that the congestion level in the 2055 Build scenario is better than the 2055 No-build scenario in both the AM (6:30 AM to 8:30 AM) and PM (4 PM to 6 PM) periods.

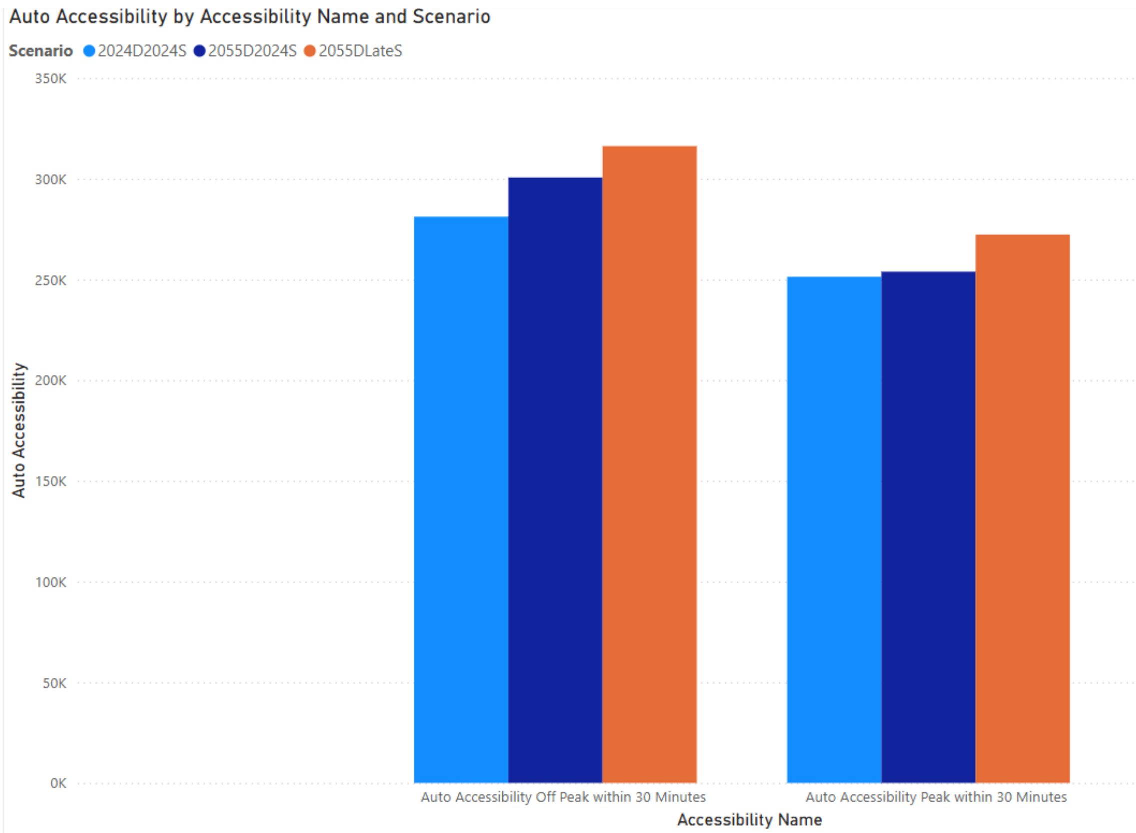
BRT service along Stone and 6th Ave. from Tohono Tadai Transit Center to the Tucson International Airport improves overall average transit speed in the 2055 Build scenario in both peak and off-peak hours and at the daily level compared to the 2055 no-build scenario, as shown in **Figure 34**.

Figure 34. Average Transit Speed



With more jobs and improved transportation services, the 2055 Build scenario shows greater job accessibility (number of jobs accessible within 30 minutes) by auto in both peak and off-peak periods compared to the 2024 base year and the 2055 No-build scenarios in **Figure 35**.

Figure 35. Number of Accessible Jobs by Auto within 30 Minutes



We specified a disadvantaged group area shown in **Figure 36** based on income and other socio-economic data. **Figure 37** represents the travel time between disadvantaged area (1) and non-disadvantaged area (0). It shows the disadvantaged area receives the benefit of the transportation service of the 2055 Build scenario and the overall travel times are shorter than the non-disadvantaged area.

Figure 36. Disadvantaged Group Area

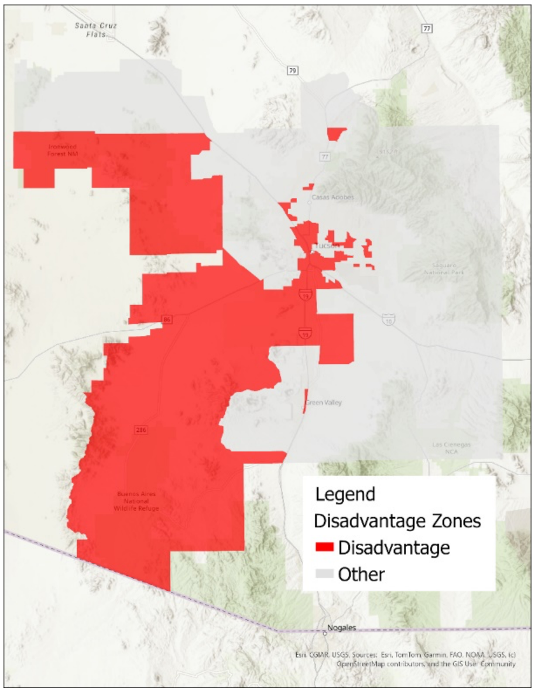


Figure 37. Average Travel Time by Auto for Disadvantaged Area (1) and Non-disadvantaged Area (0)

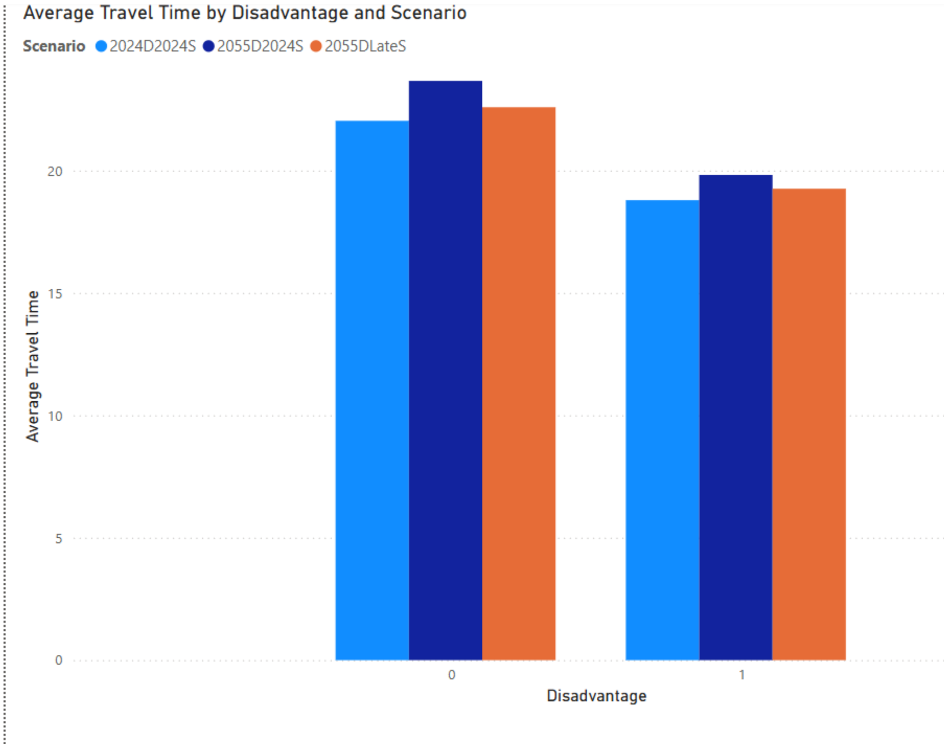


Figure 38 shows that the accessibility of disadvantaged areas is greater than that of non-disadvantaged areas through public transportation, with a greater number of jobs and basic services accessible within 45 minutes in the 2055 Build scenario.

Figure 38. Number of Jobs and Basic Needs Accessible During Off-peak by Transit within 45 Minutes

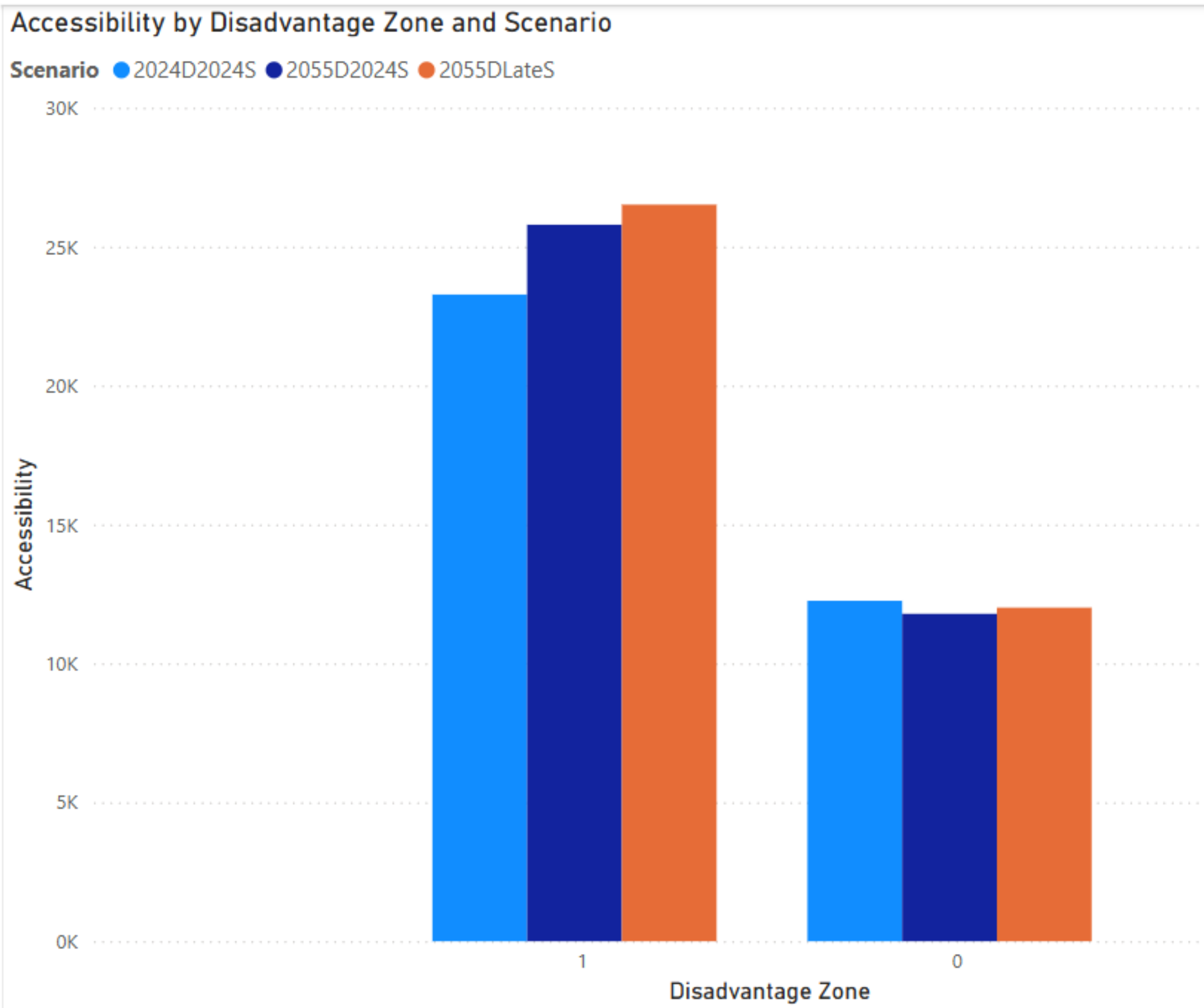
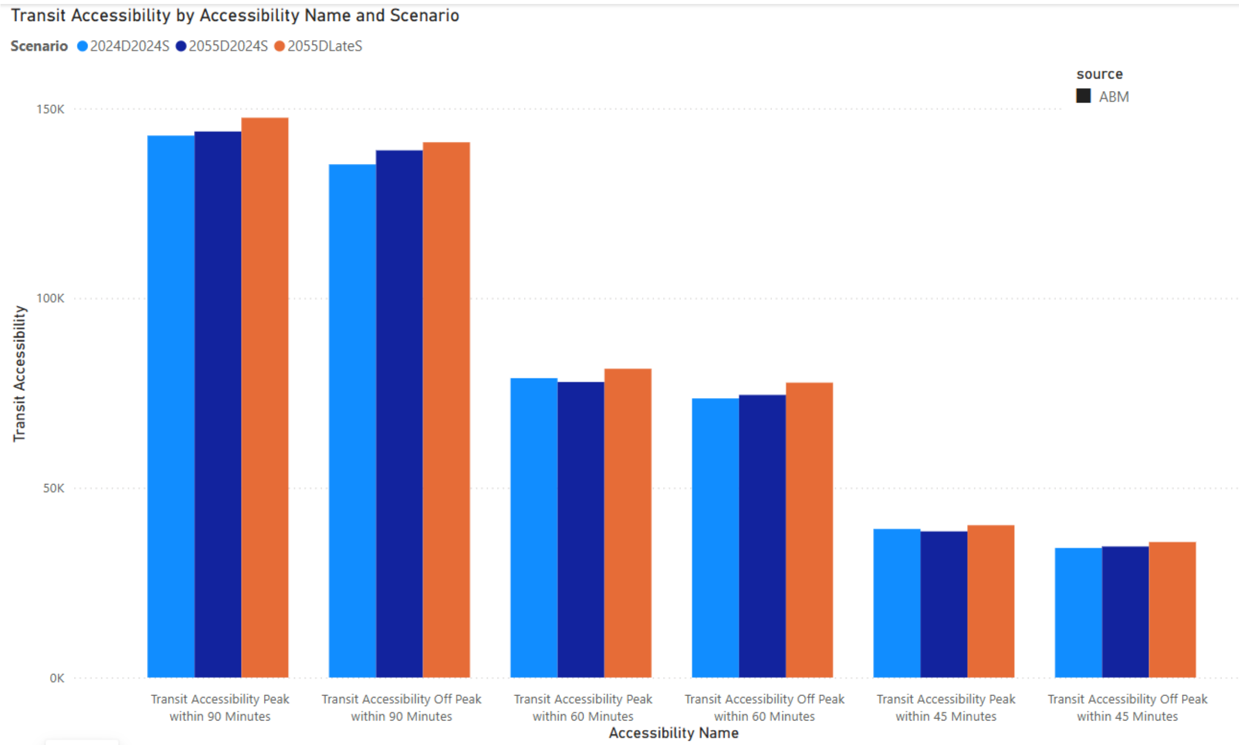


Figure 39 shows that the transit services in the 2055 RMAP provide access to more jobs throughout the region for various travel time durations (90/60/45 minutes).

Figure 39. Number of Accessible Jobs by Transit within 90/60/45 Minutes



TITLE VI ANALYSIS

Title VI of the Civil Rights Act of 1964 protects individuals from discrimination based on race, color, and national origin in programs and activities receiving federal financial assistance.

PAG, as the MPO of the Tucson region, serves as the primary forum where the State DOT, transit providers, local agencies, and the public develop local transportation plans and programs that address the region's needs. Alongside updates to plans and programs, the MPO must maintain and enhance its analytical capabilities to ensure that the long-range transportation plan (2055 RMAP) and the transportation improvement program (TIP) comply with Title VI. The Title VI analysis was conducted for the 2055 RMAP with the 2022 American Community Survey (ACS) to analyze the impact of planned changes to the transportation network on protected populations.

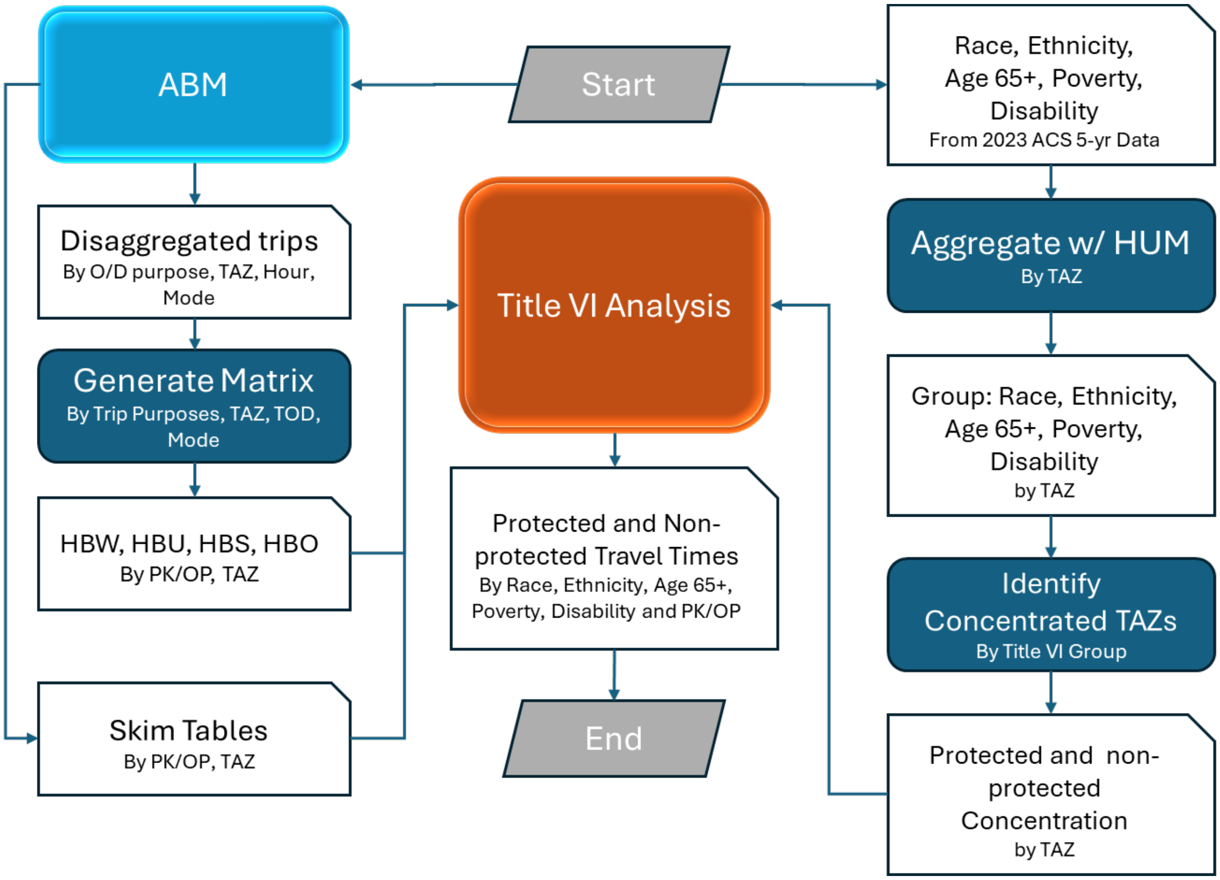
Table 18. Title VI Analysis Inputs from 2022 ACS 5-yr Data

Group	Census Table #	Resolution
Race, Ethnicity	B02001, B03003	Block Group
Age 65+	B01001	Block Group
Poverty	B17020	Tract
Disability	B18101	Tract

After compiling this information at the census block group and tract level as shown in **Figure 40**, the data was allocated to TAZs using the in-house developed methodology and the latest PAG housing unit inventory data. Also for the analysis, the ABM's disaggregated trips are combined into 4 matrices (Home-based Work, HBW; Home-based University, HBU; Home-based School, HBS; Home-based Other, HBO) by Peak (PK) and Off-peak (OP) together with the ABM skim tables.

Of concern are spatial concentrations of protected populations. For a specific geography like a TAZ, an area concentration of a protected population is when the ratio of a protected population to total population exceeds the county average of that measure for all TAZs. To ensure Title VI compliance is achieved, analyses were conducted to assess the impact of the 2055 RMAP project list on the protected populations. The impacts in concentrated areas were compared to the impact on the entire regional population.

Figure 40. Flowchart for Title VI Analysis



*HUM: housing-unit method aggregating based on number of housing units

The Title VI Analysis creates the protected and non-protected travel times by Race, Ethnicity, Age 65+, Poverty, Disability as outputs which are shown in **Table 19**.

Table 19. Outputs of Title VI Analysis

Group			Avg Travel Time 2024 (min/veh) (1)	Avg Travel Time 2055 No-Build (min/veh) (2)	Avg Travel Time 2055 with projects (min/veh) (3)	Comparison of travel time with & without projects (min/veh) (4) =[(3)-(2)]
Peak-Hours	All		13.6	14.6	14.0	-0.6
	African American	Protected	13.2	14.3	13.6	-0.7
		Non-Protected	13.6	14.6	14.0	-0.6
	Asian	Protected	13.0	14.1	13.5	-0.6
		Non-Protected	13.6	14.6	14.0	-0.6
	Disabled	Protected	13.4	14.5	13.9	-0.6
		Non-Protected	13.6	14.6	14.0	-0.6
	Elderly (+65)	Protected	13.6	14.5	14.1	-0.5
		Non-Protected	13.6	14.6	14.0	-0.6
	Hispanic	Protected	13.1	14.3	13.6	-0.7
		Non-Protected	13.8	14.7	14.1	-0.6
	Low Income	Protected	13.0	14.1	13.5	-0.6
		Non-Protected	13.7	14.7	14.1	-0.6
	Native American	Protected	14.1	15.3	14.6	-0.7
		Non-Protected	13.6	14.6	14.0	-0.6
	Pacific Islander	Protected	15.3	16.5	15.9	-0.6
		Non-Protected	13.6	14.6	14.0	-0.6
Off-Peak Hours	All		10.0	10.4	10.1	-0.3
	African American	Protected	9.8	10.2	9.9	-0.3
		Non-Protected	10.0	10.4	10.1	-0.3
	Asian	Protected	9.6	10.0	9.8	-0.2
		Non-Protected	10.0	10.4	10.1	-0.3
	Disabled	Protected	9.7	10.1	9.8	-0.2
		Non-Protected	10.1	10.4	10.2	-0.3
	Elderly (+65)	Protected	9.8	10.2	9.9	-0.2
		Non-Protected	10.1	10.4	10.2	-0.3
	Hispanic	Protected	9.8	10.1	9.8	-0.3
		Non-Protected	10.1	10.5	10.2	-0.3
	Low Income	Protected	9.4	9.8	9.6	-0.2
		Non-Protected	10.1	10.5	10.2	-0.3
	Native American	Protected	10.2	10.5	10.2	-0.3
		Non-Protected	10.0	10.4	10.1	-0.3
	Pacific Islander	Protected	10.9	11.3	11.2	-0.1
		Non-Protected	10.0	10.4	10.1	-0.3

AIR QUALITY MODELING

INTRODUCTION

This Chapter is sourced from CHAPTER 8: AIR QUALITY CONFORMITY AND ENVIRONMENTAL CONSIDERATIONS of the 2055 RMAP document

The EPA's Motor Vehicle Emission Simulator (MOVES) is a modeling system that estimates air pollution and greenhouse gas emissions from motor vehicles. PAG used MOVES4, version 4.0.1, for onroad motor vehicle emissions modeling for PM_{10} from vehicle exhaust, tire wear and brake wear in the Rillito PM_{10} nonattainment area for analysis years 2030, 2035, 2045 and 2055 and modeling CO, CO2e, NOx, VOC, PM_{10}, and $PM_{2.5}$ for the entire PAG region for the same analysis years. Analysis was conducted using the Travel Demand Model (TDM) to estimate average daily Vehicle Miles Travelled (VMT), speeds and travel pattern characteristics for the various road types in the regional roadway network for the following Action scenarios: 2030, 2035, 2045 and 2055. MOVES model inputs included vehicle registration (December 2024, ADOT MVD), speeds, HPMS traffic counts, travel patterns, as well as default gasoline and diesel fuel properties. The vehicle inspection/maintenance program does not affect PM_{10} outputs in MOVES 4, and the default MOVES 4 inspection/maintenance program input for Pima County for the relevant analysis year was used for modeling the 6 pollutants listed above for the PAG region. The MOVES 4 model accounts for all current and future regulatory changes expected over the 2025-2055 period, which extends the full planning horizon of PAG's metropolitan transportation plan, the 2055 RMAP.

On January 13, 2011, EPA released a new method for estimating re-entrained road dust emissions from cars, trucks, buses and motorcycles on paved roads. On February 4, 2011, the EPA published the Official Release of the January 2011 AP-42 Method for Estimating Re-Entrained Road Dust from Paved Roads approving the January 2011 method for use in regional emissions analysis. The AP-42 equation that calculates PM_{10} emission factors for paved roads requires as input: road surface silt loading, the average weight of vehicles traveling on the roads, and the annual number of wet days (with at least 0.01 inch of precipitation). The equation that calculates PM_{10} emission factors for unpaved road fugitive dust requires as input: the road surface material silt content, road surface moisture content, average vehicle speeds, and the annual number of wet days (with at least 0.01 inch of precipitation).

Paved Road Re-entrained PM_{10} Emissions in Rillito PM_{10} nonattainment area

EPA Compilation of Air Pollutant Emission Factors, AP-42, emission factors were used to calculate PM_{10} emissions from re-entrained dust produced by vehicles traveling on paved roads in the Rillito PM_{10} nonattainment area for analysis years 2030, 2035, 2045 and 2055. Equation 2 from section 13.2.1.3 was used to account for annual precipitation. The input values were derived from ADEQ's 2004 Rillito Nonattainment Area Emissions Inventory used in the *Rillito Moderate PM10 Limited Maintenance Plan and Request for Redesignation to Attainment Request*. ADEQ is in the process of completing an updated emissions inventory as part of the SIP development process, which will provide for updated inputs once they become available. VMT was derived from the TDM.

$$E_{ext} = [k(sL)^{0.91} \text{ x } (W)^{1.02}]\ (1 - P/4N)$$

where:

E_{ext} = annual average particulate emission factor in the same units as k

k = particle size multiplier for particle size range and units of interest (1.00 g/mi)

sL = road surface silt loading (0.020 g/m^2 for freeways, 0.085 g/m^2 for arterial, collector & local)

W = average weight of the vehicles traveling the road (derived from TDM and listed below)

P = number of "wet" days with at least 0.254 mm (0.01 in) of precipitation during the averaging period (35 days), and

N = number of days in the averaging period (365 for 2030, 2035, 2045 and 2055)

Unpaved Road Re-entrained PM_{10} Emissions in Rillito PM_{10} nonattainment area

EPA Compilation of Air Pollutant Emission Factors, AP-42, emission factors were used to calculate PM_{10} emissions from re-entrained dust produced by vehicles traveling on unpaved roads in the Rillito PM_{10} nonattainment area for analysis years 2030, 2035, 2045 and 2055. Equation 1b from section 13.2.2 was used and modified to account for annual precipitation. The input values were derived from ADEQ's 2004 Rillito Nonattainment Area Emissions Inventory used in the *Rillito Moderate PM10 Limited Maintenance Plan and Request for Redesignation to Attainment Request*. ADEQ is in the process of completing an updated emissions inventory as part of the SIP development process, which will provide for updated inputs once they become available. VMT was derived from the TDM.

$$E = \left[\frac{k(s/12)^1(S/30)^{0.5}}{(M/0.5)^{0.2}} - C\right]\ (1 - P/N)$$

where:

E = annual average particulate emission factor in the same units as k

k = particle size multiplier for particle size range and units of interest (1.8 lb/mi)

s = surface material silt content (3.51%)

S = mean vehicle speed mph (15 mph for local residential, 25 mph for collectors)

M = surface material moisture content (0.64%)

C = emission factor for 1980's vehicle fleet exhaust, brake wear, and tire wear (0.00047 lb/mi)

P = number of "wet" days with at least 0.254 mm (0.01 in) of precipitation during the averaging period (35 days), and

N = number of days in the averaging period (365 for 2030, 2035, 2045 and 2055)

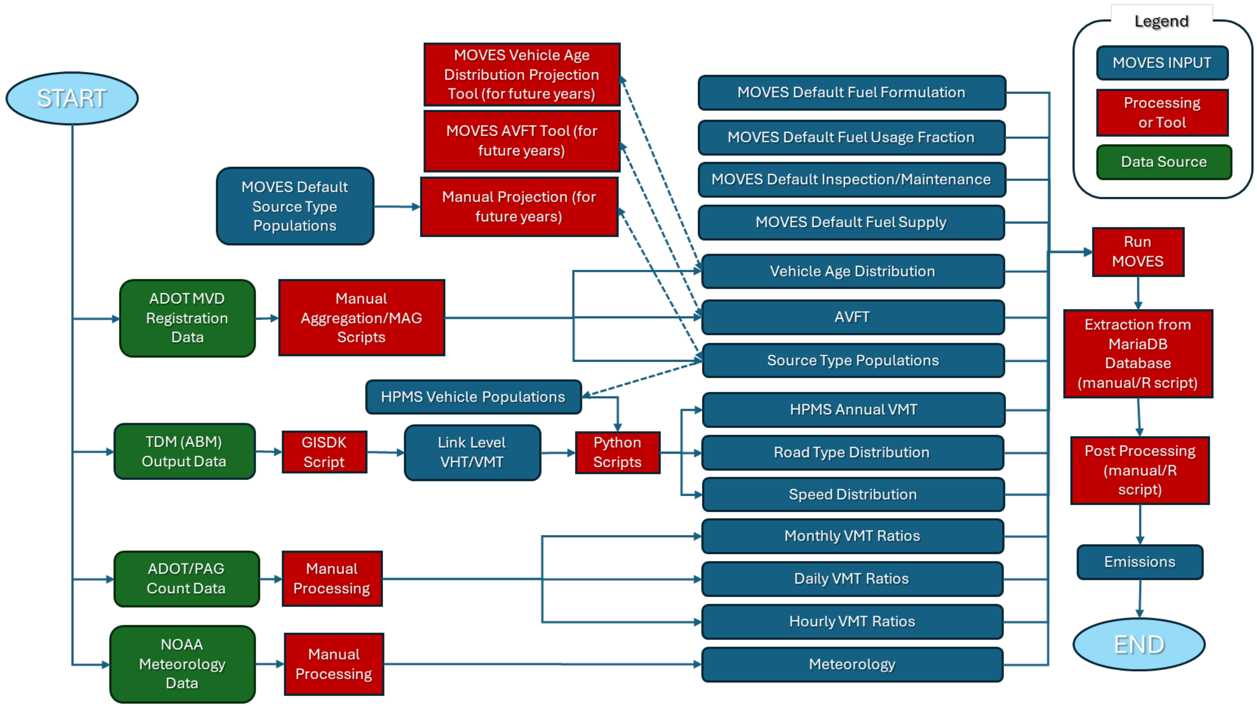
MODEL MECHANISM AND KEY INPUTS

MOVES model inputs include the most recent local data for meteorology, vehicle registration, speeds, travel patterns, inspection/maintenance requirements and gasoline and diesel fuel properties (**Table 20**). The EPA MOVES 4 model accounts for all current and future regulatory changes expected over the 2024-2055 period.

Table 20. MOVES 4 Model Inputs

MOVES 4 Inputs	Data Type	Information Source
Travel related	Vehicle miles traveled (VMT) by HPMS vehicle type	PAG ABM post processing output
	Monthly, daily, hourly VMT ratios	PAG/ADOT/MAG vehicle count data
	Speed ratios by road and vehicle type	PAG ABM post processing output
	VMT ratios by road and vehicle type	PAG ABM post processing output
County related	Meteorology	NOAA 2024 data, Tucson International Airport
Vehicle related	Vehicle registration	ADOT 2024 vehicle registrations for Pima County and MAG custom VIN decoding Python scripts
	Vehicle population, projected 2055	EPA 2055 MOVES 4 default data for Pima County, ADOT 2024 vehicle registrations for Pima County, and MAG custom VIN decoding Python scripts
	Vehicle 30 year age distribution	ADOT 2024 vehicle registrations for Pima County and MAG custom VIN decoding Python scripts
	Vehicle 30 year age distribution, projected 2055	EPA MOVES Age Distribution Projection Tool based on ADOT 2024 vehicle registrations for Pima County and MAG custom VIN decoding Python scripts
	Fuel characteristics	EPA MOVES 4 default data, Pima County

Figure 41. **AQ Modeling Process (MOVES)**



The MOVES software requires numerous inputs, some of which are the default inputs for Pima County for the relevant analysis year and others which are developed from local data. The default inputs include fuel formulation, fuel usage fraction, fuel supply, and inspection/maintenance. ADOT MVD vehicle registration data is processed by custom scripts developed for the Maricopa Association of Governments (MAG) to accurately categorize vehicles based on vehicle identification numbers (VIN). The output of the scripts includes source type populations, vehicle age distribution, and alternative vehicle fuel technology (AVFT) ratios. For future years, the source type populations are projected forward using the ratios of the future year MOVES default source type populations to the default populations for the current or latest year. The MOVES AVFT tool is used to project the AVFT input from the current or latest year to the desired year, and the MOVES Vehicle Age Distribution Projection tool is used to do the same for the vehicle age distribution. The source type populations are aggregated to produce the HPMS vehicle populations, which are an input to the Python scripts that produce the HPMS annual VMT, the road type distribution, and the speed distribution. The link level VHT/VMT produced by a GISDK script from the travel demand model (TDM) output is also an input to the Python scripts. Years ago, ADOT and PAG traffic count data was used to develop monthly, daily, and hourly VMT ratios, and these ratios have been held constant for all MOVES runs since their development. Finally, National Oceanic and Atmospheric Administration (NOAA) data is used to develop the meteorology input. Once all the inputs are ready, MOVES is run. The output is a MariaDB database. The relevant output can be extracted manually or via a script from HeidiSQL and then processed as necessary in R or Excel to produce the emissions for the desired time interval(s) and aggregated (or not aggregated) for the desired source types.

RESULTS

Although the region currently meets the EPA air pollution standards for CO, periodic ozone level exceedances resulted in a violation of the standard in 2018 and high wind days have caused sporadic exceedances of the particulate matter standard locally.

Air emissions modeling is conducted for a typical winter weekday in January, when CO levels are expected to be highest. In addition to estimating CO emissions, modeling and analyses were conducted for two ozone precursor chemicals, volatile organic compounds (VOC) and oxides of nitrogen (NOx), and coarse and fine particulate matter (PM10 and PM2.5, respectively). The same model inputs used in CO analysis were used for these pollutants except that the emissions represent a typical summer day in July when VOC, NOx and ozone/smog contributing particulates are expected to be highest. MOVES output can be obtained at various levels of aggregation. In cases where the output is specified by month and day type (weekday/weekend) and/or source type, the annual emissions, if needed, are calculated by multiplying the daily weekday/weekend day emissions for each month by the number of weekdays/weekend days in that month and summing over all months and/or source types.

Figure 42. MOVES Output

iterationID	yearID	monthID	dayID	hourID	stateID	countyID	zoneID	linkID	pollutantID	processID	sourceTypeID	regClassID	fuelTypeID	fuelSubTypeID	modelYearID	roadTypeID	SCC	engTechID	sectorID	hpID	emissionQuant
1	2024	7	5	\N	4	4019	\N	\N	2	\N	11	\N	\N	\N	\N	\N	\N	\N	\N	\N	1974410
1	2024	7	5	\N	4	4019	\N	\N	2	\N	21	\N	\N	\N	\N	\N	\N	\N	\N	\N	44401500
1	2024	7	5	\N	4	4019	\N	\N	2	\N	31	\N	\N	\N	\N	\N	\N	\N	\N	\N	71714100
1	2024	7	5	\N	4	4019	\N	\N	2	\N	32	\N	\N	\N	\N	\N	\N	\N	\N	\N	3952420
1	2024	7	5	\N	4	4019	\N	\N	2	\N	41	\N	\N	\N	\N	\N	\N	\N	\N	\N	148954
1	2024	7	5	\N	4	4019	\N	\N	2	\N	42	\N	\N	\N	\N	\N	\N	\N	\N	\N	244334
1	2024	7	5	\N	4	4019	\N	\N	2	\N	43	\N	\N	\N	\N	\N	\N	\N	\N	\N	6928.86
1	2024	7	5	\N	4	4019	\N	\N	2	\N	51	\N	\N	\N	\N	\N	\N	\N	\N	\N	7610.39
1	2024	7	5	\N	4	4019	\N	\N	2	\N	52	\N	\N	\N	\N	\N	\N	\N	\N	\N	1450180
1	2024	7	5	\N	4	4019	\N	\N	2	\N	53	\N	\N	\N	\N	\N	\N	\N	\N	\N	70773.5
1	2024	7	5	\N	4	4019	\N	\N	2	\N	54	\N	\N	\N	\N	\N	\N	\N	\N	\N	1203880
1	2024	7	5	\N	4	4019	\N	\N	2	\N	61	\N	\N	\N	\N	\N	\N	\N	\N	\N	694165
1	2024	7	5	\N	4	4019	\N	\N	2	\N	62	\N	\N	\N	\N	\N	\N	\N	\N	\N	1018970

Table 21 below shows additional air pollutant emissions estimated from modeling of the three scenarios in the 2045 RMAP Update. The MOVES model predicts that emissions per mile will decline significantly from 2020 to 2045 primarily due to more stringent vehicle emissions and fuel efficiency standards.

Table 21. Summer Weekday Emissions for the 2045 RMAP Update Scenarios

		VOC	NOx	PM10	PM2.5
Scenario	Average weekday miles traveled	Metric tons per weekday			
2020 RMAP Base Year	23,214,165	10.1	15.4	0.9	0.2
2045 RMAP Build	30,113,825	4.6	3.9	1	0.2
2045 RMAP No-Build	29,731,455	4.6	3.8	1.1	0.2

It is important to keep our air healthy and the region in compliance with the federal air quality standards. Continuing current programs to reduce vehicle miles of travel and promoting the use of alternate modes of transportation and clean fuels will help ensure that our air remains healthy.