ARC PECAS Model System

Atlanta PECAS Model Application for Series Forecast.

FINAL REPORT

HBA Specto Incorporated

Alberta, Canada

"… There is no logic that can be superimposed on the city; people make it, and it is to them, not buildings, that we must fit our plans."

Jane Jacobs, 1916 – 2006

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1. Introduction

This report describes the Atlanta PECAS model developed and applied for the Series 17 Forecast for the Atlanta Regional Commission (ARC). It covers the evolution of the model design and development and its specific form when used to establish the S17 Forecast, while providing a summary of the resulting S17 forecast. It also discusses the potential use of the model in further work exploring the future for the Atlanta Region and suitable areas of further enhancement of the model in support of this further work.

This document is organized into six sections. Section 1 is this introduction. Section 2 describes the two primary roles of the Atlanta PECAS model at ARC, and also provides a brief description of the theoretical foundations of the PECAS model system covering its two modules: Activity Allocation (AA) and Space Development (SD). Section 3 describes the evolution of the ARC PECAS model through seven iterations of development and refinement. Section 4 sets out the current design of the model. Section 5 discusses the establishment of the model's inputs used to produce the ARC Series 17 (S17) Conformity Forecast to support the update to The Atlanta Region's Plan. It also briefly describes two additional scenarios. Section 6 describes the Conformity Forecast Module interactive forecast planning software that works with the model's results and provides guidance for scenario development. Section 7 outlines possible areas of enhancement for the current version of the model.

2. Overview of the ARC PECAS Model

2.1 Dual Role: Forecasting and Regional Growth Scenarios

ARC is responsible for developing and updating the Atlanta Regional Plan, a long-range blueprint that identifies the investments needed to ensure metro Atlanta's future success and enhance the quality of life of its citizens. Forecasts of population and employment and the associated socioeconomic, demographic, and economic characteristics at both the regional and small-area levels are essential components of the Atlanta Regional Plan.

The Research and Analytics Group (RAG) at ARC has been working with HBA Specto Incorporated (HBA) since 2008 in the ongoing development, refinement, and application of the Atlanta PECAS model. This model is based on the PECAS Framework for the simulation of spatial economic systems (like the Atlanta Region) for practical planning application. It is used by ARC for two main types of application:

Use in Forecasting: This is work developing socioeconomic forecasts at the level of Traffic Analysis Zones (TAZ) that form inputs to the ARC Activity Based Model (ABM) transportation model used to establish forecasts of future travel demand. These forecasts of travel demand guide the design of future transportation infrastructure in terms of the capacity requirements implied by the associated transportation flows and resulting system performance.

Use in Policy Analysis and Development: This is work analyzing and refining transportation and land use policy alternatives considering the wider interaction between land use types and intensities, urban form, transportation, and economic impacts – beyond just the required capacities of transportation infrastructure. The primary objective is to understand the wider urban form, social and economic impacts of different policies options involving elements such as zoning rules and development incentives along with transportation infrastructure, operations, and services. The intention is to provide input to planners, decision-makers, and the public to help inform their consideration of options for the future in Atlanta.

In its forecasting work, RAG uses the Atlanta PECAS model to combine data from different sources and at different levels of geography. The model takes indications of region-level and county-level economic and population growth rates by sector provided by the REMI (Regional Economic Model) for the Atlanta Region and loads it onto the spatial land use zoning information provided by the local jurisdictions across the Region. This simulation establishes the resulting locations, interactions, rents and other financial and more general costs and broader conditions – and covers how these all evolve through time as land development and construction respond to the available opportunities and the built form changes. The results include indications of the future spatial allocation of population and employment by type and the interactions among them down to the TAZ level considered by the ABM, and a synthetic version down to individual simulated parcels.

The current version of the ARC PECAS model takes population, household and employment values for 21 counties and allocates them first to a set of 1,034 land use zones (LUZ) broadly aligned with census tracts and then to the set of 5,922 TAZ used by the ABM.

The population, household and employment values for future years are updated every few years, with the last update taking place in 2021. During 2021 and 2022, the AA module of the model was calibrated to fit a) trip length data region-wide, b) proportions of households by type choosing housing types to live in and generating labor occupations region-wide, as well as c) rent data by space type by LUZ. In addition, the space development (SD) module was updated, including updates to the complete parcel database, future zoning data for Dawson County, and further calibration of the development rates by space type by county.

Local jurisdictions contributed to the forecasting process by providing information about planned zoning and local policy objectives, identifying known and anticipated future land development and construction activities, and reacting to forecasting results as they were developed. This ensured that local jurisdictions could be well aware of the forecasting process used by ARC and the instrumental roles of the model in scenario work and forecast development.

2.2 Theory and Background

The Atlanta PECAS model – based on the PECAS Theoretical Framework – is a spatially disaggregate input-output economic model that has two main components: the Activity Allocation (AA) module, which simulates the location of different kinds of households and businesses and the spatial interaction between them; and the Space Development (SD) module, which simulates the development of land with newly built or expanded buildings within which to locate activities as simulated by AA. The current version of the Atlanta PECAS model runs through time year-by-year from 2020 to 2050.

2.2.1 Activity Allocation

The AA module simulates the economic 'activities' in the Atlanta Region. There are eighty-one (81) activities in the Atlanta PECAS model, representing types of households, kinds of business, government activities, and classes of importers and exporters. Households are split into size and income categories, while businesses and government activities are segmented into industries, such as agriculture and forestry, health, and retail.

These activities produce and consume inputs and outputs that quantify their interactions. They are referred to as 'puts', reflecting their dual role as both INputs and OUTputs. (Sometimes puts are called 'commodities', but this can cause confusion given the more limited definition of the term used in classical economics generally. For example, labor is a 'put' in PECAS but it is not a 'commodity' in classical economics.) Households produce labor and consume goods and services. Businesses consume labor, goods and services. Each business produces a specific type of good or service based on their industrial classification, along with some by-products. Space is a special kind of put; in general, each activity consumes some appropriate type of floor space as an input to its production process. A household is an activity that consumes some amount of residential space, a single-detached house or an apartment; and a business is an activity that can use some amount of an appropriate type of space, such as some office or industrial space. Space is non-transportable in that it must be consumed (used or bought) where it is made – buildings are in general not movable.

Each activity allocates the buying and selling of puts to different locations (LUZs) within the Atlanta Region. The activity is located in the LUZ where it consumes space, but it draws inputs from, and supplies outputs to, zones all over the region, as well as from import/export locations. The activity selects these zones based on the unit prices for the puts (higher is worse when buying and better when selling) the costs for transporting the puts (including time and money particularly when people are traveling) and the size of the zone. The relevant transport money costs and travel generalized (time and money and other inconvenience) costs are provided by the ABM (as network 'skims'). Thus, the LUZ with the lowest price or the shortest travel distance is not always used; rather, trade-offs are made considering price, transport cost and zone size.

Puts vary greatly in these considerations: where households sell any labor they make is influenced by travel costs to and from each workday; where the materials come from for factories is influenced by transport costs per unit as well as for storage.

Activities consider these exchange locations and related costs for multiple puts. Consider a sit-down full-service restaurant. It has a single output – served restaurant meals – but requires many inputs. The single output, the served meal, is made and provided at the restaurant, and exchanged from producer to consumer there. The restaurant has multiple inputs: Restaurants hire chefs, engage accountants, use electricity, buy furniture and so on. For spatial economic modeling, the most significantly influential and therefore relevant inputs are labor, various kinds of food products, and appropriate floor space. People are usually not willing to travel far for restaurant meals, so in the model they have a high travel cost. This means that a restaurant – a successful one – will tend to locate near its clients, and will be willing to pay extra in rent to locate somewhere that is convenient to a good customer base.

A food processing business, on the other hand, might supply restaurants and supermarkets with food, but it is generally cheaper for processed food to be shipped than for customers to travel back and forth per unit distance. So, a food processing business will not be as sensitive to the locations of their clients (in this case restaurants) but will likely focus more on concerns about the locations and associated costs for the production labor and industrial floor space they require.

AA simulates the entire process of making these trade-offs and allocating the demands with supplies simultaneously across all activities, puts and LUZs. If the demand for a put in an area is high, the price will go up; the users in that area might get supply from further away and more suppliers might locate in that area. Some puts are elastic; households can choose to produce different kinds and amounts of labor to match that market need, for instance. Space consumption is elastic, allowing more activity in high demand areas even before the SD module can respond by building more space. AA starts with fixed prices for puts in special LUZs that are deemed 'external' and available only to importer and exporter activities, and AA iterates until it finds the unique set of unit prices for all puts in all LUZ that matches the demand with supplies for all puts in all LUZ.

2.1.2 Space Development

The SD module simulates the process and outcomes of land development at the parcel level. It considers all parcels of land in the Atlanta Region individually for each model step from one year to the next.

As SD considers each parcel, it considers several possible events that could take place. The most likely event in most cases, with probabilities in the neighborhood of 0.95, is that nothing happens on the parcel during a given modeled period: if the parcel is undeveloped, it remains as undeveloped land, or if there is a building of a given use on the parcel, the building and its use remain as is. The building on the parcel can be renovated, added to, or demolished. If the parcel is empty, a new building can be created.

These development decisions are guided by two main factors: the zoning for the parcel and the price (rent in units of dollars per square foot per year) of the space. Zoning is a policy input to the model that determines what types of floor space can be built, and at what intensities. These intensities are expressed using the ratio of building area over corresponding land area, which is called the Floor Area Ratio, or FAR. In addition to zoning, greenfield sites can have phasing specified, so that the plans for the order of development are followed.

The higher the potential rent for a development compared to what exists now, the greater the probability that it will be built. The PECAS framework uses the concept of 'imputed rent' when considering floor space. The imputed rent is meant to be the fair market value of the rent. This is generally the amount paid by a tenant to a separate arm's-length landlord established without rent controls. In the case of an owner-occupied building or a family living in a house they own, there is no actual rent paid. The imputed rent represents the opportunity cost that the owner-occupier foregoes by not renting to someone else. Bank loans and mortgages used to finance the purchase of floor space is something different, and should not be confused with the imputed rent.

The base rent for space by type in each LUZ is established by AA. This base rent is intended to capture the impacts of the wider supply and demand pressures in the space markets at the LUZ level, the scale of census tracts or neighborhoods. It is used as an initial value that is further adjusted to reflect the impacts of other 'local effects' on the rents for alternative space types at the parcel-level. These 'local effects' include the proximity of the parcel to major roads, expressway exits, schools, MARTA stations, parks and larger greenspaces. Their impacts vary in strength, direction (increasing or decreasing rents) and distance depending on the space type. For example, with a major road near a parcel, the association with vehicle noise, emissions and dust will act to decrease rents for single detached housing while the association with high exposure to pass-by traffic and greater access will act to increase rents for retail space. The impact of the age of the building is also considered: rents tend to drop as buildings lose their initial lustre. Much older heritage buildings, particularly when renovated, constitute a different space type entirely that will possibly command much higher rents because of their cache.

SD uses these parcel-level adjusted rents in its consideration of each parcel and the possible events. The decision to leave a parcel as is or to develop new space is affected by the potential value of the new space. This includes the basic pro-forma financial analysis used by developers, including rent revenue streams, construction costs, developer fees, along with further cost and inertia terms having values established as part of model calibration. If there is an old building of low value, or if the parcel is vacant and zoned for a higher use, is near local amenities (and not too affected from nearby noxious local effects), and/or if rents in the LUZ are high, development is more likely to occur there.

SD module runs in each year of the simulation, calculating these probabilities for the options permitted by local plans – including what is zoned and potentially what (with greater initial cost) tends to get approved. These probabilities are aggregated across the LUZ to establish changes in space quantities at the LUZ level. In this way, the model predicts the changing quantity of space in a way that is responsive to zoning and approvals, demand, travel system performance, and other things impacting market conditions. Before moving to the next year of the simulation, the changes in space quantities in each LUZ are assigned to the best individual parcels.

This assignment of changes to individual parcels makes the detailed spatial patterns easier to understand and visualize, and gives the entire simulation the information required to establish appropriate results at the LUZ and TAZ levels. But the specific results parcel-by-parcel provide a level of precision at a level of detail that is not justified and should not be used to support planning at the level of a single parcel or even a collection of just a few parcels. A sample of sufficient size needs to be considered; deterministic assignment to the best parcels does not mean we can ignore sample error.

(The same is true for traffic flow microsimulation models: the simulation results for each individual vehicle includes a false precision, and it is only the more aggregate results for groups of individual vehicles that should be considered in application. It is also true more generally in statistical analysis; the useful lifetime of batteries coming off an assembly line is not determined by testing a single battery.)

This method of assignment of changes to individual parcels also means SD is deterministic. That is, SD does NOT use a Monte Carlo process to assign changes to individual parcels and therefore does NOT have issues with variances in its aggregate estimators (so-called 'microsimulation error'). If SD is run again with the same inputs, it produces the exact same result. This contrasts with traffic flow microsimulation models and activity-based microsimulation travel demand models, both of which do have issues with 'microsimulation error'.

2.1.1. Model Interactions – AA, SD and the ABM

The current Atlanta PECAS model simulates the evolution of the Atlanta Region into the future year-by-year from 2020 to 2050. In each simulation year AA establishes the household and employment (activity) quantities and the unit prices for puts including rents for space by type in each LUZ. Between each simulation year and the next, SD uses the rents from AA to generate a year's worth of development, redevelopment and resulting changes in space quantities in each LUZ. These changes in floor space are then used by AA in the next simulation year, which affects household and employment allocations and rents and prices in that year. As the model runs through time, AA and SD interact back and forth.

After 10 simulation years, the household and employment allocations and the flows of puts among them determined by AA are used by the ABM to simulate travel demands and load them to the available networks to establish travel and transport flows and the performance of the transport system in servicing these flows. The resulting congested times, delays and costs 'skimmed' from the ABM networks are then used by AA, which impacts its allocations of households and employment and rents and prices. This provides an explicit representation of the impacts of the transportation system and the policies implemented in its regard on the Atlanta Region spatial economic system, including population and employment distributions and the rents for space and the prices for puts and the changes in the utilities of production and consumption typically considered in benefit cost analysis.

For example, consider a project that expands the capacity of a congested highway in a given part of the Atlanta Region. With this increased capacity, the ABM will establish improved performance, taking account of the changes in routes and modes and times of travel, and provide skims that indicate the distribution of reductions in travel times and costs among zones, modes, times and routes. AA will take these improved skims into account, and in general allocate relatively more activities to the affected locations with new rents higher in these areas and potentially lower in others. In response to these new rents, SD will increase the quantities of space – perhaps more housing at higher densities and more retail and commercial in response to the higher traffic along with the higher rents – to some extent by shifting development from elsewhere in the Atlanta Region (in other LUZs) and also potentially by initiating development that just would not have happened otherwise. AA could shift further growth and SD respond in a similar manner for several years of simulation. When the ABM is run again, the increases in activity will give rise to increased transport and travel that will increase congestion, further impact travel patterns and alter system performance.

Ideally, the integration of the ABM with AA and SD would be done more frequently than once every 10 years, but computer and related processing run times make that impractical.

2.2. Elements of the PECAS model by module

2.2.1. Elements required by the Activity Allocation Module

Thirteen model elements are usually required to develop a PECAS AA module. The complexity of these elements depends on the scope of the simulation needed to respond to the design issues being considered and on the resources and data available. A brief description of the elements is presented in **Error! Reference source not found.**.

Table 1. Elements of a PECAS Activity Allocation Module

Model Element	Description
01: zone system	Locations in AA are represented using a mutually exclusive and collectively exhaustive system of land use zones, or LUZ. Each LUZ contains a given number of Traffic Analysis Zones, or TAZs, that provide a finer level of spatial resolution used in the transportation model.
02: activity category definitions	Activities are of six basic types: households, firms, government, non-profits, importers, and exporters. Accounts for funding allocations, investment spending and factors of production can also be included as activities. Households are categorized by size and income, and firms are categorized based on outputs, technology, and associated input requirements. Firms are often placed into industrial classifications.
03: puts category definitions	Puts are the inputs used and outputs made by activities and include physical items, services, labor, money or credit, (floor) space in buildings, other factors of production, and waste. Puts have varying characteristics regarding form, durability, divisibility, units, values, transportability and transportation costs and requirements. Per-unit market-clearing prices or rents are determined by the AA Module for each put in each LUZ as an exchange location, each year. Physical items include types of raw materials, intermediate products, and manufactured goods. Services include

Model Element	Description
	education, health, professional and technical services, wholesale, retail, management, financial, insurance, policing, information, food and accommodation and broker services. Labor includes categories of occupation, such as managers, administrators, analysts, instructors, drivers, laborers, technicians, etc. Space includes types of residential dwellings, and non-residential buildings and other categories of fixed infrastructure and improvements. The categorization of 'puts' depends on the scope and objectives of the modelling work and may be influenced by data availability.
04: technology options representation and the design diagram	The PECAS design diagram uses a standard layout and set of symbol definitions to present the design of a specific model, as per the puts included in technologies and whether one or multiple technology options and associated sets of technical coefficients are available to an activity. For typical land use transport interaction modelling, households' and firms' technology options have the same coefficient for the make and use of goods and services (making these rates constant), and varying coefficients for the make and use of labor and the use of space (making these rates elastic).
05: aggregate economic flows	The model-wide total flows of puts produced and consumed by activities are set out in the PECAS aggregate economic flows table, which uses a standard layout consistent with the PECAS design diagram. This table is used to establish that the flows are balanced, where, for each put, the total flow into the model and the total amount made by all activities matches the total amount used by all activities and the total flow out of the model area. This table shows the production and consumption of each put by each activity, including labor productivity at firms and consumption by households. It also shows government spending on health and education.
06: space by zone (built form)	Space (or floor space) is a special category of put: It is a fixed capital asset that is a required input for many activities. It is 'non-transportable' in that it must be exchanged and consumed where it was previously constructed (or produced) and remains located. It provides much of the fixedness and inertia in the locations of activities over time. Its production is simulated in the SD module and provided as an input to AA. A representation of the quantities of space by type and LUZ for one or more years is developed as an input to AA. The primary direct measurement is often from the legal ownership records or property tax assessments. However, remote sensing data (imagery, terrain elevation, LIDAR, etc.), population information, vacancy rates, employment summaries, market summaries including rental rates, and other sources are usually used to supplement assessor files.

Model Element	Description
07: spatial distribution of activities	The spatial distribution of activities is represented as quantities in the LUZs. One of the objectives of model calibration is to match the model values to the target values for these quantities for one or more years. Direct observations of these quantities are not available generally, and thus must be synthesized from proxy variables and less than complete observations. The work on their development can be extensive.
08: puts flows	The flows of puts from production activity and location, through exchange location, and on to consumption activity and location are synthesized in AA as flows among the LUZs. Quantification of the corresponding flows in the real world are used as targets in model calibration. In principle, these flows could be full origin-destination matrices developed by observations or synthesis. More typically, corresponding flow length distributions or even related trip length distributions are used as representations.
09: imports and exports	Imports and exports of puts flow across model boundaries to one or more external zones (both domestic and international) that contain put-specific importer and exporter activities. These exporter activities have demand curves, and importer activities have supply curves. The links to the external zones have associated transport costs. These curves and costs establish (a) export markets with price-elastic demand that help drive the model economy and encourage more efficient production and (b) import markets with price- elastic supply that meet requirements and help moderate prices.
10: transport utilities	The transport utility of transporting a unit of a given put among LUZs is calculated using some form of sum of weighted travel times, money costs and mode utilities, provided by the ABM. The mode utilities are generally composite utilities for the full set of available modes connecting the LUZs. The precise form of the sum and the values for the weights vary depending on the nature of the put to be transported. There are four general categories: (1) *physical items* carried once to consumption locations in shipments typically involving flows of vehicles, with drivers providing transport services and possibly involving logistics considerations — transport utilities are calculated using driving times and money costs for vehicle operation and tolls. (2) *labor* requiring the presence of the worker each day; transport utilities are calculated using composite utilities for the available modes for person travel for the trip from home to work and the trip from work to home each workday. (3) *producer delivered services* brought by producers visiting the consumption location; transport utilities include both the arrival trip to the

Model Element	Description
	visit and the departure trip from the visit; when the worker uses a specialized vehicle — transport utilities are calculated using driving times and money costs for the vehicle operation and tolls; otherwise transport utilities are calculated using composite utilities for the available modes for person travel. (4) *consumer obtained services* acquired by consumers visiting the production location; transport utilities are calculated using composite utilities for the available modes for person travel for both the arrival trip to the visit and the departure trip from the visit. The measures of travel conditions used and the values for their weights are established for each put. These weights reflect the different values of time and relative sensitivities involved. They also transform the units from those of the measures output from the transportation model to the 'utils of generalized cost per unit put' of the inputs to AA.
11: observed space rent	One of the objectives of model calibration is to match the model-simulated rents for puts in LUZs to corresponding observed values. Direct observations are possible, and data may be available for many types of puts in many locations. Processing of the observations may be required to separate space rents into components represented in AA and into components represented in the SD Module.
12: space short-run supply functions	Each space put has a short-run supply function that indicates the landlord's willingness to accept lower rents for space as demand decreases and to lease higher proportions of the total space (approaching 0% vacancy rate) at higher rents as demand increases. These functions must extrapolate beyond normal and structural vacancy rates so that the model software can both (a) accommodate extreme situations (approaching 0% or even 100% vacancy rates in LUZs) during its search for market-clearing prices and also (b) provide results for extreme policy scenarios. Usually, these supply functions are developed using observations of local-level rents and occupancy rates. Both residential and non-residential space types are often collected in a census or provided by the real estate industry. Typically, the determination of the central part of the function is informed by observed data, whereas the treatments at the extreme ends (very high rents, very high vacancy rates) are based on expert judgment and extrapolation.
13: observations of technology choice	Elasticities in the rates of production and consumption are incorporated into AA by applying alternative technology options. Typically, in land use transport interaction modelling, households and firms have multiple alternative technology options for the make and use of labor and for the use

Model Element	Description
	of space. In some cases, the alternative technology options have been developed using clustering techniques to classify a dataset of many individual observations into a handful of representative clusters. In other cases, standard 'more' and 'less' options are generated above and below observed rate levels. One of the objectives of model calibration is to match the distributions of make and use rates determined by the model across the LUZ to corresponding observed distributions.

2.2.2. Elements required by the Space Development Module

Thirteen model elements are usually required to develop a PECAS SD module. As with AA, the complexity of these SD elements depends on the scope of the simulation needed to respond to the design issues being considered and on the resources and data available. A brief description of the elements is presented in (Table 2)**Error! Reference source not found.**.

Table 2. Elements of a PECAS Space Development Module

Model Element	Description
01: parcel layer	The parcel layer is a spatial layer containing the shapes of the land parcels in the region, ideally based on land ownership. Each parcel should have some basic attributes defined, including its area, which Traffic Analysis Zone (TAZ) it falls in, and the level of utilities servicing currently available on it. The parcels should never overlap, but do not need to cover the entire region, since it is rarely worth including roads, rivers, cliffs, and other unsuitable building sites.
02: space category definitions	The usable floor space and productive land in the region must be divided into categories. These are usually distinguished by: whether the space is residential, commercial, industrial, or agricultural; finer distinctions of purpose, such as office versus retail; and building height, quality, or location. An additional type represents unimproved land.
03: inherent transition limits	This is the set of rules defining what kinds of changes between space types are physically possible. Each space type should have a minimum and maximum possible intensity, measured as a floor area ratio (FAR), or the ratio of floor area to parcel area. There should also be a list of the allowed change types: new construction, expansion of buildings, renovation, demolition, abandonment, repurposing, etc. In addition, any restrictions on these transitions because of type should be listed; e.g. specifying that high-density residential cannot be demolished to build low-density residential.

Model Element	Description
04: conversions from SD space categories to AA put categories	SD needs to know how to interpret space rents generated by AA, and how to produce floor space amounts that AA can understand. The categories may be different because each model cares about different things: AA cares about the purposes the space can be used for, while SD cares about the type of structure. In such cases, a conversion between SD and AA space categories must be established. It is easiest if the relationship is many-to-one, i.e. multiple SD types can map to the same AA type, but each SD type only maps to one AA type. Many-to-many relationships require weights indicating how relatively common each AA type is in the given SD type(s).
05: base year space inventory	The space inventory is the complete listing of the kinds and quantities of space currently built on each parcel, as well as when that space was built. SD normally only allows one type of space per parcel, so large parcels with a mixture of space types should be divided into smaller parcels. An automated process to perform 'parcel cuts' is included in the PECAS software.
06: zoning policies	Zoning policies are imposed by municipal governments to restrict the kinds and densities of space that can be built in different parts of the municipality. These policies need to be reflected as accurately as possible, specifying the SD space types and range of FARs allowed on each parcel. Each parcel must have a zoning policy in the base year; anticipated future changes in zoning should be included as well.
07: urban fringe release patterns and schedule	If the region includes cities and towns that are expanding onto the surrounding land, areas that are expected to develop should be given small parcels to develop on – otherwise large rural parcels will try to develop all at once, producing large jumps in available space. These parcels should ideally be arranged according to approved neighborhood plans. The expected sequence in which growth areas will develop should also be determined.
08: construction costs	The cost to a developer of physically constructing each type of space should be established. This can include site preparation costs that scale with land area rather than with the built area within the building. Construction costs can vary from location to location within the region. Soft costs and hard costs (labor and materials) are both included here, but regulatory fees and approvals are not (see below).
09: development fees	The fee imposed by the municipality for building each type of space should be established. Like construction costs, fees can vary from location to location, usually at least changing at municipality boundaries.

Model Element	Description
10: local effects and observed prices for estimation	Local effects are the mechanisms, beyond the characteristics of the building itself, via which features of the area around a building may affect the rent its owners can charge. These features can include distances to high-quality transportation options, distances to parks, noise levels, etc. The age of the building is also considered a local effect despite being a property of the building, because age of the building increases every year and usually reduces the value of the building. Local effects consist of two parts – parameters and distances. The parameters that control the strength of the local effect have to be estimated using the observed sale or rental prices for a sample of buildings of different types. The distances require information about the locations of the local effect features.
11: intensity effects	The core of the profit model for developers in SD implies a linear relationship between the size of the building (on a given parcel of land) and expected profit. But this is often not realistic; larger buildings are often more efficient up to a point, but eventually the costs of stronger materials or additional elevators start to outweigh the benefits of the additional space. SD implements a *density shaping function* to address this. Creating the density shaping function requires deciding on a form for the function – how many times does the relationship between space and profit change as the intensity increases, and at which intensities does it change. A preliminary function can be estimated if a sample of observed buildings with known FAR values is available.
12: observed construction	Calibrating SD relies on good observations of past construction in the region. At minimum this should include construction events for each space type, along with the sizes of the buildings produced, over about five years. Better results can be achieved if there is also information on renovations and other types of transitions, as well as information about where each construction event took place.
13: known future construction projects	Any large buildings, such as hospitals, stadiums, or large apartment complexes, that are under construction or approved for construction, should be coded directly into the model as *site specific developments*, which force SD to build in the exact locations indicated. This helps SD produce better short-term forecasts.

3. Evolution of the Atlanta PECAS Model

It has been learned through experience that the successful development of a PECAS model is more assured when the process includes components of the so-called **'Agile Approach'** commonly used in the software development industry. This was done in the development of the Atlanta PECAS model.

Model development was done in cycles. In each cycle a model that included all components and covered all activities and puts was implemented, with acknowledged place-holder forms and simple categorizations used initially in order to keep the time required for a cycle comparatively short, in the order of one or two years, and the resource requirements relatively modest. In subsequent cycles the issues of greatest concern regarding their impacts on model performance, usefulness and practicality were tackled and less suitable place-holder forms and simple categorizations were refined or replaced with more suitable – but still not final – versions.

Seven cycles can be identified as part of the history/evolution of the development and upgrades of the current ARC PECAS model (Figure 1**Error! Reference source not found.**). These cycles are described further below.

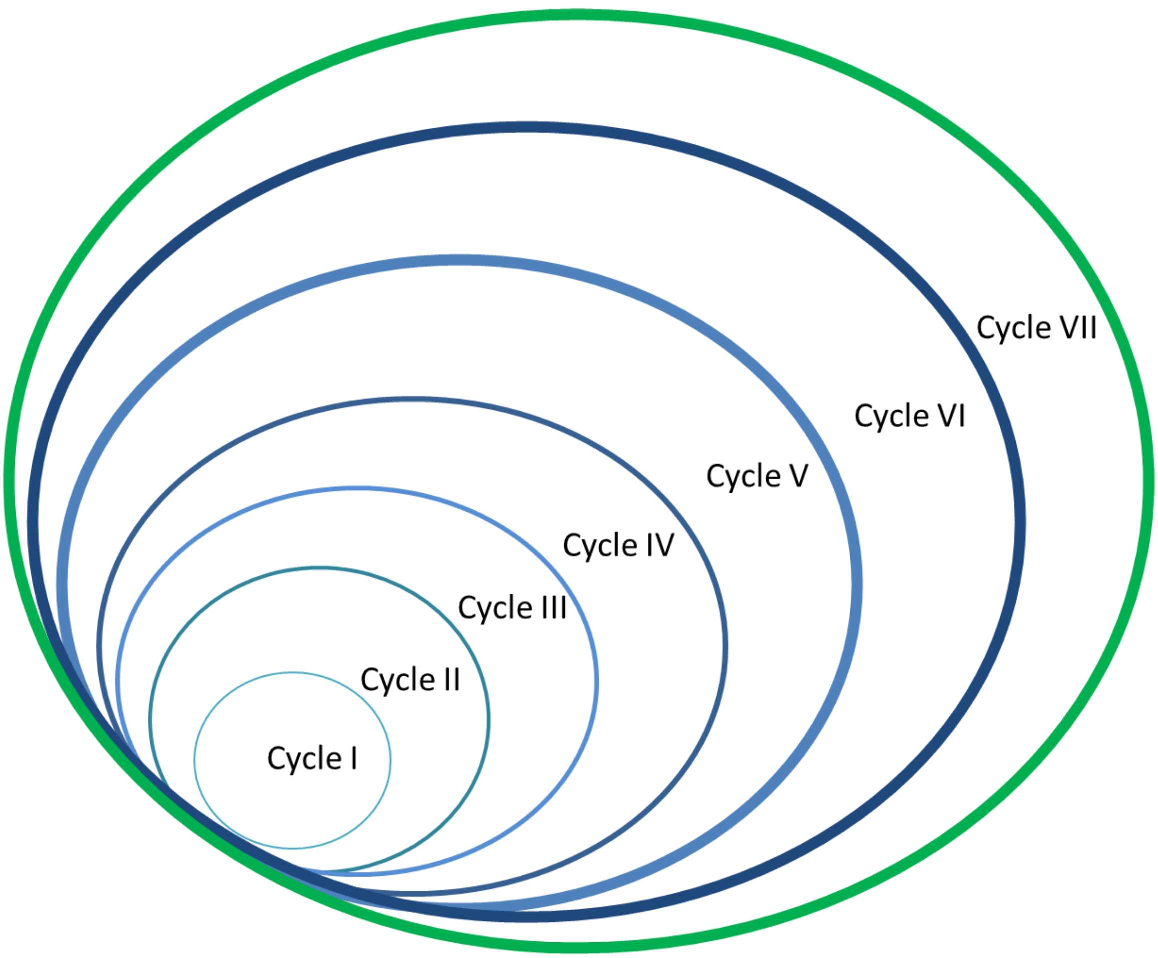


Figure 1. Cycles of Development and Improvements of the Atlanta PECAS Model

3.1. Cycle I – Model Development (2008 – 2010)

Work on the Atlanta PECAS model began in 2008 and included efforts on both AA and SD. The base year was 2005 and the model ran through time to 2040. There was a total of 79 LUZ corresponding to the Super Districts areas used in planning for the Region, one external LUZ, and 2,024 TAZs consistent with the transportation system model in use at the time. The aggregate economic flow (AEF) table defined the production and consumption interactions among 36 categories of activity and 35 type of put. Data from the 2005 US Census were used, including household and labor quantities and commuting flows for LUZ totals and for indications of the spatial patterns of put flows, and the Census Public Use Microdata Sample (PUMS) for samples of patterns of technology choice concerning labor production and residential space. A synthetic population for the Region in 2005 was established using the combinatorial optimization technique and associated software developed by HBA for application in this task.

The distribution of employment by occupation data was used to identify where activities were using office space versus other kinds of non-residential space (retail, industrial, institutional, etc.) together with ARC LandPro land use / land cover data. A separate rent estimation procedure was used to calculate rents per space type, one for residential space and one for non-residential space. Transport utility functions were calculated using data and skims generated by the 4-step transport model, the predecessor to the current ABM model used by ARC. The AA module was calibrated to match average length of commodity flows, choices of residential units by type and observed rents by LUZ.

The parcel database used by SD was enhanced substantially using newly developed GIS layers of municipal tax records and more standardized and/or translated zoning information provided by each of the twenty counties in the Atlanta Region. SD was expanded to make more complete use of this enhanced database in its simulations at the parcel level.

3.2. Cycle II – Model improvements and visualization (2010 – 2014)

During this second cycle, efforts focused on updating the model to use 2010 as the base year instead of 2005. Input files were updated accordingly, including the constraint amounts by TAZ. 2010 Census data were employed for this process. Secondly, a greater consistency between the space (building) data and the employment data was achieved by using a floor space synthesizer. The purpose was to generate a synthetic representation of the built form to assign estimated TAZ-level floor space quantities to parcels, to best match observed parcel conditions. Data from Clayton County was used as a pilot to generate a process that the agency staff applied later to the other 19 counties included in the model area. In addition, new transport skims were obtained which worked better for simulation of the primary school trips. After all these data updates, the model was recalibrated using region-wide trip length, choice of housing types by households, choice of labor generation by households, and simulation of floor space.

The other primary event of this cycle was the creation and installation of MapIt application on the Atlanta PECAS server. MapIt is a visualization tool that allows PECAS users to visualize the model results spatially, as well as export results in several standard formats of any GIS program, including ArcGIS, QGIS and other programs.

3.3. Cycle III - Forecast, planned projects, SD calibration and setting up the interactions with the ABM (2015)

During 2015, the Atlanta PECAS model was refined in several ways. The TAZ system was upgraded, going from an original total of 2,024 zones to 5,873 zones covering a 20-county area. With the development and implementation of the first version of the ABM, an updated and expanded set of transport utility functions and transport cost coefficients were developed to take advantage of the updated and expanded set of skims coming from the ABM. This added more detailed explicit treatment of the specific impacts of transport conditions on more economic interactions, particularly labor commuting flows that affect the allocations of businesses, households, and other institutions. Two main types of improvement were pursued: (a) increasing the resolution and calibration of the model by expanding the numbers of categories and adjusting their associated model parameters and (b) improving the functional performance of the model.

Enhanced model development included (1) updating growth rates for the model-wide activity amounts (households and industries) through time, using data from an updated regional economic forecast, (2) processing previously observed or forecast activity amounts (households and jobs) at the TAZ level to use as calibration targets to align to the most recent observations (2005 to 2015), and updating previous forecasts and comparisons to previous work (2016 to 2050), (3) recalibrating AA to use the updated skims from the transportation model with its new 5,873 TAZ system; this included calibrations for region-wide trip lengths, simulated space rents by type, and technology choice of housing type by an expanded set of household categories, (4) recalibrating SD to better fit updated and expanded development activity targets and to provide more consistent statistical distributions.

Added model functionality included (1) expanding the range of TAZ level targets that can be considered in the SD software in order to make use of an unusual level of local knowledge about existing built form beyond what was available in the parcel database (thereby mitigating the effects of errors in the detailed parcel data available previously), (2) incorporating a treatment of the specification of known and expected developments at various locations before the model is run so that SD could take these into account in its simulation rather than leaving it to *ex post* adjustment, and (3) developing more automated translation of the information flows between AA and the ABM.

3.4. Cycle IV - Initial Exploring of Atlanta City Design scenarios (2016)

In 2016, ARC used the Atlanta PECAS model to explore scenarios where the population in the City of Atlanta reached 1.3 million in the future. A range of scenarios were considered as follows:

- Scenario A: no constraints on the amount of construction through time;
- Scenario B: making the City of Atlanta more attractive than the rest of the region, so more jobs and people move to the city;
- Scenario C: releasing growth constraints in the City of Atlanta, but keeping the model constraints elsewhere;
- Scenario D: making the City of Atlanta more attractive than the rest of the region and increasing jobs in future-year constraints.

The Atlanta PECAS model was used on its own, just AA and SD, without connection to the ABM. This work was revisited with refined models where the connection with the ABM was included.

3.5. Cycle V - Model improvements, calibration, deterministic SD, Technology Scaling, and Atlanta City Design Scenario (2017-2018)

In 2017 and 2018, for the fifth cycle, the inputs to AA were updated using 2015 Census and economic data directly. The LUZ system was expanded to 1,031 zones with the updated census tract boundaries in the model area with the 2015 Census. The categories of activities and puts were expanded and re-defined, allowing some better model fit and providing a much more detailed explicit representation of 4 income by 6 size categories of household. The categories of employment at place of work were adjusted consistent with definitions adopted in the ABM. The AA model parameters were recalibrated for these new categories using the newly available 2015 targets concerning commuting flows, household distributions by type and LUZ, residential and non-residential rents by LUZ and quantities of imports and exports by type).

In 2018, another important improvement was made. The zoning regulations in SD were updated to align better with ARC Regional land use policies as articulated in the Unified Growth Policy Map (UGPM). The UGPM provides directions for future growth in identified areas and places, incorporating local plans as well as PLAN 2040 regional policies and forecasts. The Atlanta PECAS model provides a practical tool for monitoring progress and supporting the development of strategies for pursuing these directions.

The Atlanta PECAS model was used to consider the 'City Design' scenario develop by the City of Atlanta, to assess the impacts and help identify appropriate incentives for pursuing the objectives of increasing the intensity and speed of change in the identified target core areas and corridors while reaching a population of 1.3 million. This analysis provided indications of potential changes in built form, development patterns and intensities, rents and travel from 2015 to 2050, and facilitated the testing new opportunities for development and the ability to alter patterns of development.

Two important features were added to the model during this cycle: (1) SD was updated from the previous Monte Carlo version to the new deterministic version and (2) technology scaling was implemented in AA. Both are significant, and they warrant some further elaboration below:

- SD had traditionally used a Monte Carlo process, where each parcel of land is considered separately with outcomes selected randomly for each unit using probabilities determined by logit-form discrete choice model. This random selection of outcomes leads to different results from different runs, even if no inputs have changed. Investigating the effect of relatively small adjustments in policy can become problematic with this type of model, because the random variation between two runs can be greater than, and hence mask, the policy impact. The new deterministic version avoids this issue of having different results in different runs by accumulating possibilities over each parcel in each LUZ, but then assigning the resulting total development to the parcels in each LUZ that got the highest utility scores in the discrete choice models and thus are identified to be the best according to the model. This avoids the random selection and ensures there is no random variation between two runs that masks the policy impact. Direct comparisons of scenario the results can be made, and visualized as parcel-by-parcel differences, providing a more precise indication of the impacts of the policy itself.
- Technology scaling works to keep the interactions among the industrial and institutional sectors of the economy balanced in future years of the run. In the base year these interactions are balanced and the demand and supply for puts in LUZs are matched. If the future forecasts use different growth rates for different industrial and institutional sectors – that is, if different categories of households and different types of industry are assumed to grow at different rates (which is almost always the case) – then there may be surpluses and shortages of puts model-wide that cannot or should not be absorbed by imports, exports and/or inventories. This can make it difficult for the model to converge on the full LUZ-level market-clearing solution. Technology scaling works to adjust the technology use rates for activities to avoid the surpluses and shortages, sharing the adjustments among the sources of demand from the other activities, the supply of imports, and the demand for exports. This is a mechanical process, with a specific and arbitrary representation. Specifically, the base-year average production rate by activities in the region is used to predict future year production for each put, and then the other three elements, imports, exports, and use, are adjusted. In many cases the result is realistic; for example, a rapidly growing health-care industry likely means higher consumption rates for health care by households as a through-time behavioural shift driven by external factors. But other cases might not match reality or scenario intentions, for example

households growing much faster than industry could lead to large unemployment in reality, but technology scaling will adjust labor use by industry to keep labor markets balanced. Using automated technology scaling is a practical way to represent future-year changes in region-wide technology and behavior, but it is simplistic and arbitrary, and is not intended to replace using the ARC REMI model to forecast or simulate any large regional, national, or global shifts in the nature of future relationships. To this end, the adjustment factors are reported as an output, and can be compared with the outputs from the REMI model to ensure that the shifts in technology and imports/exports aren't misrepresented.

3.6. Cycle VI – Generating S16 Conformity Forecast for the Atlanta Regional Transportation Plan (2019)

In 2019, the focus of the work with the Atlanta PECAS model was its application in support of the development of the S16 Forecast.

Region-level and county-level economic and population growth rates by sector for the years 2015, 2020, 2030, 2040, and 2050 provided by the REMI (Regional Economic Model) for the Atlanta Region were loaded into the Atlanta PECAS model. The Atlanta PECAS model used these to establish LUZ and TAZ-level forecasts of population, households, employment and put flows for each year from 2015 to 2050. These results (for the years 2015, 2020, 2030, 2040 and 2050) were sent to the ABM as they became available, which used them to establish 'skims' of future travel conditions that were input to the Atlanta PECAS model as they became available.

3.7. Cycle VII – Generating S17 Conformity Forecast for the Atlanta Regional Transportation Plan and the forecasting tool.

From 2021 to 2023 the ARC PECAS model has been updated and improved in many dimensions. The base year of the model was updated to 2020, and Dawson County was added in the modelled area, for a total of 21 counties, and as a result the zone system was also updated. New data became available including households' categories by size and income, new and updated parcel data, rent data, as well as updated maps of facilities and services (e.g. parks, schools, MARTA lines and stations, among others), vacancy rates, zoning regulations, among others.

The referred injection of new data propelled several improvements in the model: more detailed representation of the housing market, more accurate rent estimation by zone, updated estimation of the local effects of rents at the parcel level, a better understanding of the behavior of the relationship between rents and buildings' occupancy rates, among other improvements. As part of the model updates the Activity Allocation and the Space Development module were re-calibrated. The ARC PECAS model was run integrated with the ABM, interchanging land use and transport data to and from these two models. MrsGUI, the ARC PECAS model run system was updated and the ARC staff used it to run model scenarios comfortably. In addition, a conformity forecast module was developed to complete the ARC PECAS land-use model framework.

Section 5.1 of this report describes in more detail the data flows among modules used in this process to generate the S17 Forecast results. Section 5.2 presents the resulting forecasts of population, households and employment by county for 2030, 2040, and 2050.

4. Current Model Design and model upgrades

In the AA module, all model inputs are based on updated estimates of population and employment. The current Atlanta PECAS model has 1,034 LUZs.

The following are the main improvements made to ARC PECAS model from 2021 to 2023:

- Base year of the model is now 2020.
- Study area and zone system were expanded to include Dawson County.
- There are new categories for puts (a.k.a. commodities), including more detail in the categorization of housing, while military space was removed.
- Activity amounts, and thus the specified constraints on households and employment for 2020, were updated.
- Relationship between occupancy rates and rents per unit of construction by space type were updated.
- Average zonal rent by space type was updated.
- Updates in the behaviour of employment consuming institutional space.
- Updated parcel data for 2020 from Infutor database and other sources
- Local effects on rents by parcel due to spatial proximity to green spaces, schools, major roads, highway exits and Marta stations.
- Zoning regulations were updated to include Dawson County and using the Unified Growth Policy Map (UGPM).
- The model has gone through major updates including implementation of a new version of AA with more zones and a more direct representation of the job and household categories used in the ABM.
- Calibration data were updated for the Activity Allocation Module, including trip length of put flows (goods, services, and labor), activity use of residential and non-residential space, household provision of labor by type, as well as rent/price data for residential and non-residential space.
- Space development model calibration was updated.
- The PECAS model was run integrated with the accessibility measures provided by the ABM for the years 2030, 2040 and 2050. A detail description of the integration is presented in section 5.1 of this report.
- The scenario development and application included the development of a base scenario to generate the S17 official forecast, a scenario with control totals by county, and a preliminary test scenario for post-pandemic patterns.
- Conformity forecast module.

4.1 Activities and Commodities

Monetary quantities of the flows of production and consumption among the 46 activity types and 31 put types in the model were established in 2020 dollars using data from the 2020 version of the REMI model. The specific categories of activities and puts and their units in the model are shown in Tables 3 and 4 respectively.

Table 3. Activity categories defined in the ARC PECAS Model

No	Activity Name	Description	Units
Industries			
1	AI11AgFor	Agriculture and forestry	Jobs
2	AI21Mining	Mining	Jobs
3	AI22Util	Utilities	Jobs
4	AI23Constr	Construction	Jobs
5	AI313233Manu	Manufacturing	Jobs
6	AI42Whlsale	Wholesale services	Jobs
7	AI4445Retail	Retail and food services	Jobs
8	AI4849Trans	Transportation services	Jobs
9	AI51Info	Information services	Jobs
10	AI52Finance	Finance and insurance services	Jobs
11	AI53RealEst	Real estate services	Jobs
12	AI54ProfTech	Professional and technical services	Jobs
13	AI55Manag	Management services	Jobs
14	AI56Admin	Administrative and business services	Jobs
15	AI61EduServ	Education services	Jobs
16	AI62Health	Health services	Jobs
17	AI71Arts	Arts and cultural services	Jobs
18	AI72Accom	Accommodation services	Jobs
19	AI81Other	Other services	Jobs
20	AI92Gov	Federal, state, and local government services	Jobs
21	AI125GovDemand	Government Spending	2020 US Dollars
22	AI126InvDemand	Capital Investment	2020 US Dollars
Households			
23	I1H1	Households' annual income < $27K; 1 person	Households
24	I1H2	Households' annual income < $27K; 2 persons	Households
25	I1H3	Households' annual income < $27K; 3 persons	Households
26	I1H4	Households' annual income < $27K; 4 persons	Households
27	I1H5	Households' annual income < $27K; 5 persons	Households
28	I1H6	Households' annual income < $27K; 6+ persons	Households
29	I2H1	Households' annual income $27-65K; 1 person	Households
30	I2H2	Households' annual income $27-65K; 2 persons	Households
31	I2H3	Households' annual income $27-65K; 3 persons	Households

No	Activity Name	Description	Units
32	I2H4	Households' annual income $27-65K; 4 persons	Households
33	I2H5	Households' annual income $27-65K; 5 persons	Households
34	I2H6	Households' annual income $27-65K; 6+ persons	Households
35	I3H1	Households' annual income $65-130K; 1 person	Households
36	I3H2	Households' annual income $65-130K; 2 persons	Households
37	I3H3	Households' annual income $65-130K; 3 persons	Households
38	I3H4	Households' annual income $65-130K; 4 persons	Households
39	I3H5	Households' annual income $65-130K; 5 persons	Households
40	I3H6	Households' annual income $65-130K; 6+ persons	Households
41	I4H1	Households' annual income > $130K; 1 person	Households
42	I4H2	Households' annual income > $130K; 2 persons	Households
43	I4H3	Households' annual income > $130K; 3 persons	Households
44	I4H4	Households' annual income > $130K; 4 persons	Households
45	I4H5	Households' annual income > $130K; 5 persons	Households
46	I4H6	Households' annual income > $130K; 6+ persons	Households

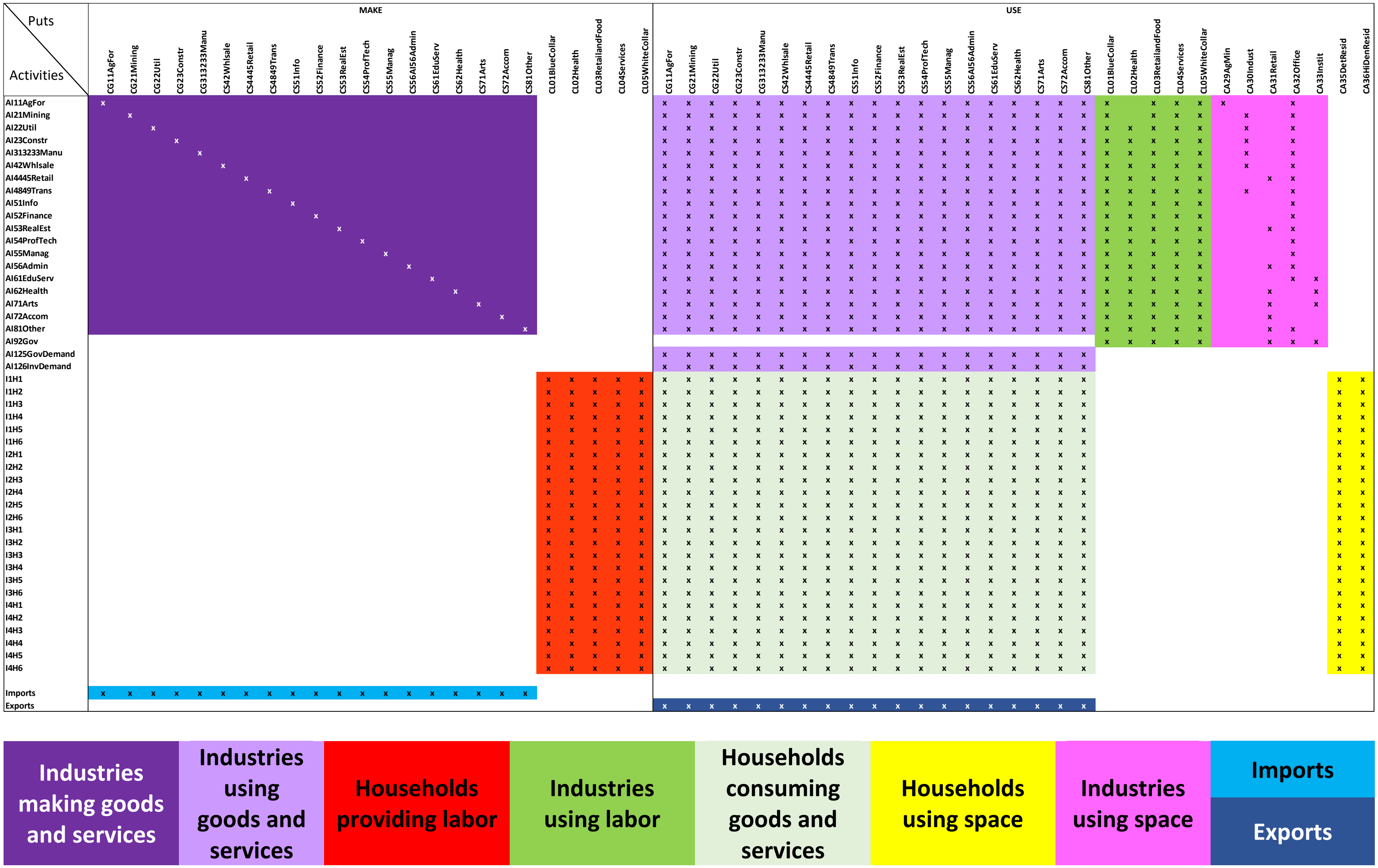
Table 4. Put categories defined in Atlanta PECAS Model

No	Put Name	Description	Units
Goods			
1	CG11AgFor	Agriculture and forestry	Nominal 2020 dollars
2	CG21Mining	Mining	Nominal 2020 dollars
3	CG22Util	Utilities	Nominal 2020 dollars
4	CG23Constr	Construction	Nominal 2020 dollars
5	CG313233Manu	Manufacturing	Nominal 2020 dollars
6	CS42Whlsale	Wholesale services	Nominal 2020 dollars
7	CS4445Retail	Retail and food services	Nominal 2020 dollars
8	CS4849Trans	Transportation services	Nominal 2020 dollars
9	CS51Info	Information services	Nominal 2020 dollars
10	CS52Finance	Finance and insurance services	Nominal 2020 dollars
11	CS53RealEst	Real estate services	Nominal 2020 dollars
12	CS54ProfTech	Professional and technical services	Nominal 2020 dollars
13	CS55Manag	Management services	Nominal 2020 dollars
14	CS56AI56Admin	Administrative and business services	Nominal 2020 dollars
15	CS61EduServ	Education services	Nominal 2020 dollars
16	CS62Health	Health services	Nominal 2020 dollars
17	CS71Arts	Arts and cultural services	Nominal 2020 dollars
18	CS72Accom	Accommodation services	Nominal 2020 dollars
19	CS81Other	Other services	Nominal 2020 dollars
Labor			

No	Put Name	Description	Units
20	CL01BlueCollar	Blue collar (SOC:45,47,49,51,53)	Nominal 2020 dollars
21	CL02Health	Health (SOC:29,31)	Nominal 2020 dollars
22	CL03RetailandFood	Retail and food (SOC:35,41)	Nominal 2020 dollars
23	CL04Services	Services (SOC: 27,33,37,39)	Nominal 2020 dollars
24	CL05WhiteCollar	White collar (SOC:11-23, 25, 43)	Nominal 2020 dollars
Space			
25	CA29AgMin	Agricultural and mining space	Sq ft
26	CA30Indust	Industrial space	Sq ft
27	CA31Retail	Retail space	Sq ft
28	CA32Office	Office space	Sq ft
29	CA33Instit	Institutional space	Sq ft
30	CA35DetResid	Detached residential space	Sq ft
31	CA36HiDenResid	Higher density residential space	Sq ft

An overview of the Aggregate Economic Flow Table for the Atlanta PECAS model is shown in Figure 2. The left half of the Table shows the make or production of puts by the activities, while the right half shows the use or consumption of puts by the activities. Color codes indicate the form of interaction between activities and puts in the model (Figure 2).

Figure 2. Overview of the AEFT for the Atlanta PECAS Model



The total number of households and the split by category were provided by ARC. These amounts are presented in Table 5.

Table 5. Total Number of Households by Household Type for 2020

Household type	Number of households
I1H1	175,679
I1H2	63,139
I1H3	39,635
I1H4	28,387
I1H5	17,791
I1H6	15,413
I2H1	202,594
I2H2	160,878
I2H3	90,338
I2H4	71,792
I2H5	44,287
I2H6	38,704
I3H1	132,771
I3H2	233,809
I3H3	133,084
I3H4	121,364
I3H5	61,250
I3H6	39,052
I4H1	60,763
I4H2	236,866
I4H3	113,041
I4H4	110,139
I4H5	42,543
I4H6	23,933
Total	2,257,252

The total number of jobs was also provided by ARC. The split by industry is presented in Table 6.

Table 6. Total Number of Jobs by Activity for 2020

Activity	Number of Jobs
AI11AgFor	1,782
AI21Mining	2424
AI22Util	11,032
AI23Constr	148,344
AI313233Manu	180,997
AI42Whlsale	149,871
AI4445Retail	318,014
AI4849Trans	146,131
AI51Info	105,422
AI52Finance	190,259
AI53RealEst	98,073
AI54ProfTech	241,327
AI55Manag	80,256
AI56Admin	258,713
AI61EduServ	296,327
AI62Health	295,009
AI71Arts	40,772
AI72Accom	231,492
AI81Other	95,947
AI92Gov	145,214
Total	3,024,751

The amount of Imports and Exports for the Atlanta Region are shown in Table 7. These amounts were used as the targets for the Imports and Exports calibration of the ARC PECAS model.

Table 7. Total Imports and Exports by Put (Goods and Services) for 2020 in 2020 Dollars

Put	Total Imports	Total Exports
CG11AgFor	686,226,111	47,684,496
CG21Mining	9,324,843,987	122,401,415
CG22Util	0	1,277,605,505
CG23Constr	0	898,603,817
CG313233Manu	76,010,003,186	41,608,009,218
CS42Whlsale	5,267,640,561	24,141,761,793
CS4445Retail	81,451,704	1,618,968,740
CS4849Trans	6,814,066,111	24,241,629,486
CS51Info	5,258,358,024	32,661,966,365
CS52Finance	9,640,186,875	19,065,584,534
CS53RealEst	11,499,728,707	29,630,687,842
CS54ProfTech	3,201,489,519	12,577,559,921
CS55Manag	0	3,791,883,143
CS56AI56Admin	1,660,925,157	6,567,854,702
CS61EduServ	1,692,406,352	4,487,651,088
CS62Health	9,422,078,834	10,508,381,617
CS71Arts	2,712,958,266	2,854,654,349
CS72Accom	1,312,649,975	3,037,371,584
CS81Other	2,957,018,312	2,635,904,869

4.2. Updated Land Use Zone System

The Land Use Zone (LUZ) system was updated to 1,034 LUZ system. Figure 3 shows the current LUZ and TAZ system.

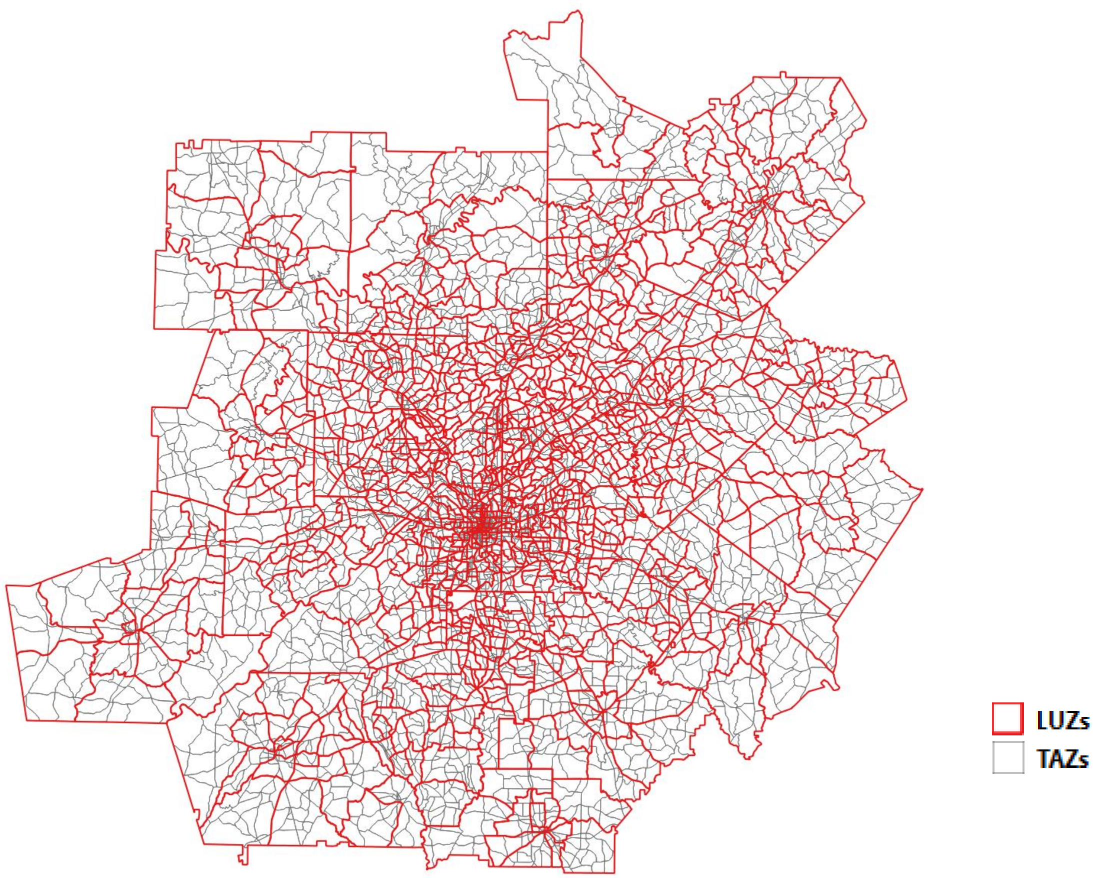


Figure 3. Land Use Zones (LUZs) and Traffic Analysis Zones (TAZs)

4.3. Updated zoning rules in the space development (SD) module

Prior to 2018, the future zoning data developed in 2005 parcel-by-parcel from county assessors were included in SD. In 2018, SD was updated to respect the Unified Growth Policy Map (UGPM). The UGPM provides direction for future growth for defined *areas* and *places* drawing on the plans and objectives of the local jurisdictions and the policies and goals set out in the PLAN 2050 Regional Development Guide for the Atlanta Region.

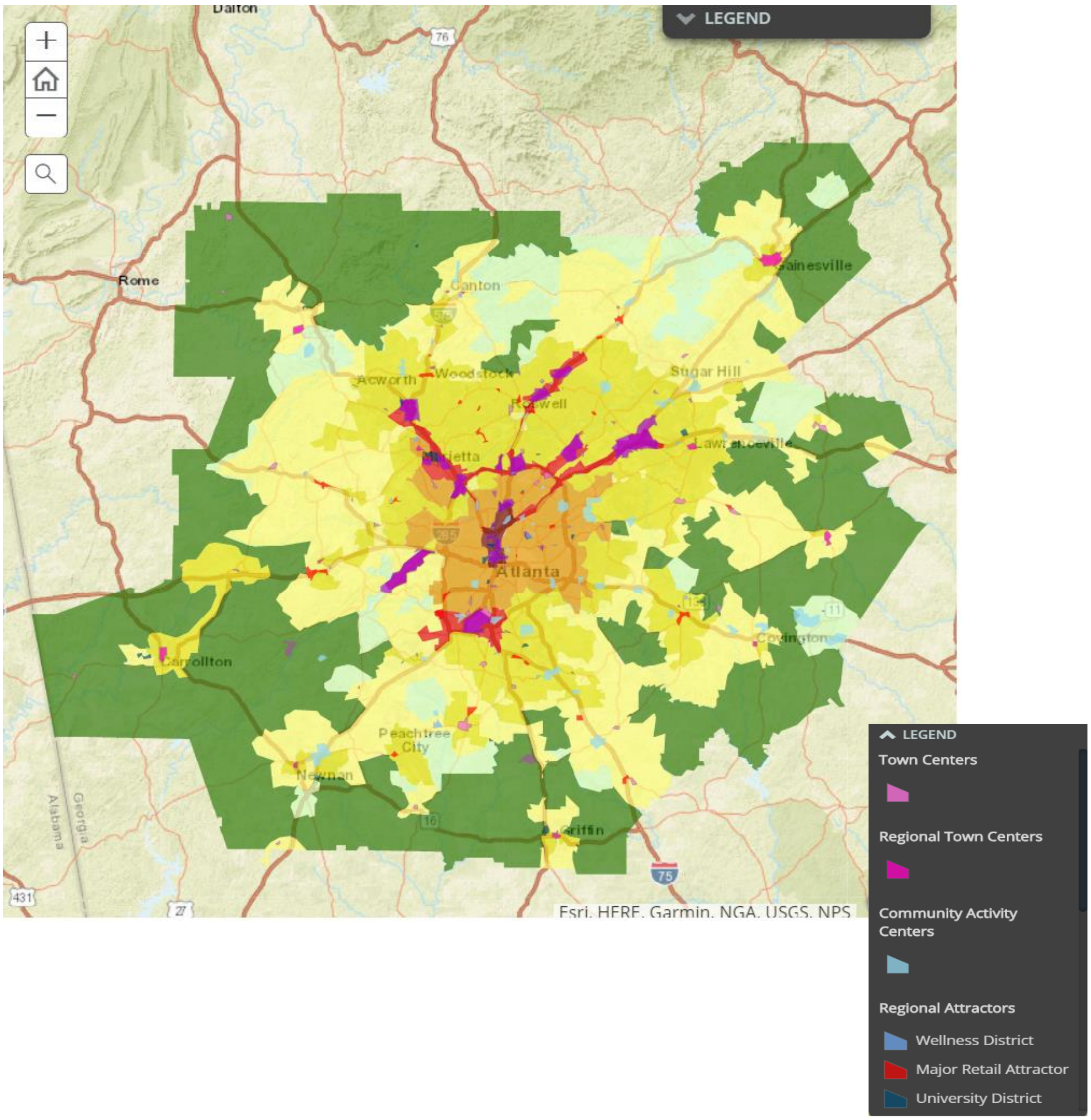


Figure 4. Unified Growth Policy Map for the PLAN 2040 Regional Development Guide for the Atlanta Region

Since the UGPM does not include Dawson County, which was recently added to the simulation area for the ARC PECAS model, the zoning inputs were added to the parcel database employing the Official Zoning Map of the City of Dawsonville (Figure 5) and the Dawson County Land Use Resolution, titled Subpart B – Land Development Ordinances Chapter 121 LAND USE, which is part of an ordinance adopted on August 6, 2020.

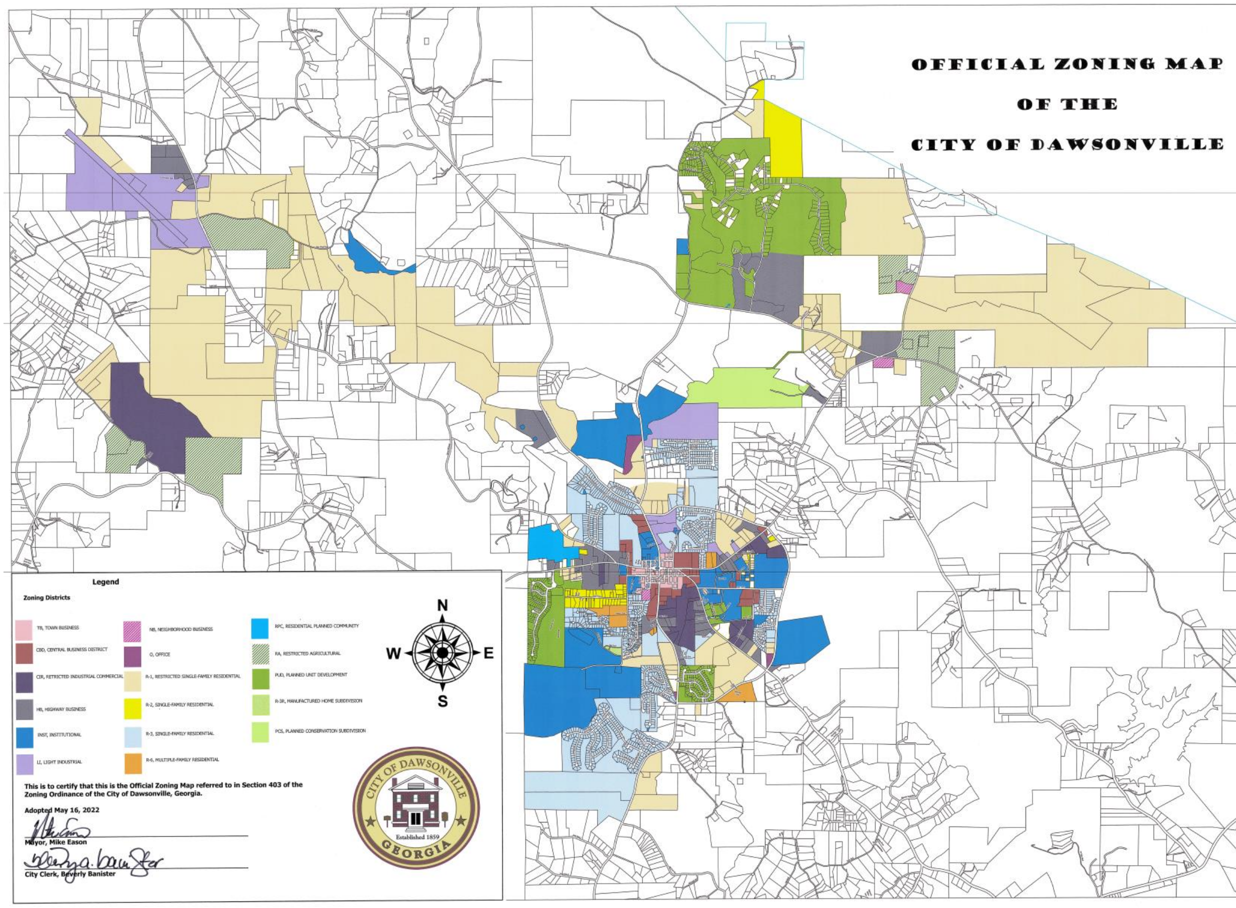


Figure 5.Official Zoning Map of the City of Dawsonville

5. ARC Series Conformity Forecast to support Atlanta Regional Plan

5.1. Forecasting approach for Series 17 Conformity Forecast

The current version of the Atlanta PECAS model accepts inputs from the REMI model and interacts with the ABM. It was used to support development of the Series conformity forecasts for the Atlanta Regional Plan. The official forecast includes population, households and employment by type and by location for the simulation period from 2020 to 2050.

The Atlanta PECAS model has been calibrated using data up to 2020 as available. It starts running for 2020 and simulates values for year-by-year from 2020 to 2050. Each year, AA establishes prices for put categories covering goods, services, labor and floor space. The prices for labor are payments for time, salaries and wages; the prices for floor space are rents. SD runs from each year to the next, using the rents from the previous year to generate a year's worth of development giving rise to changes in floor space quantities for the next year. These new quantities of space, together with the changes in population, households and employment, give rise to changes in AA in the next year. As the Atlanta PECAS model runs its simulation through time from one year to the next, AA and SD interact each year and between years in this manner.

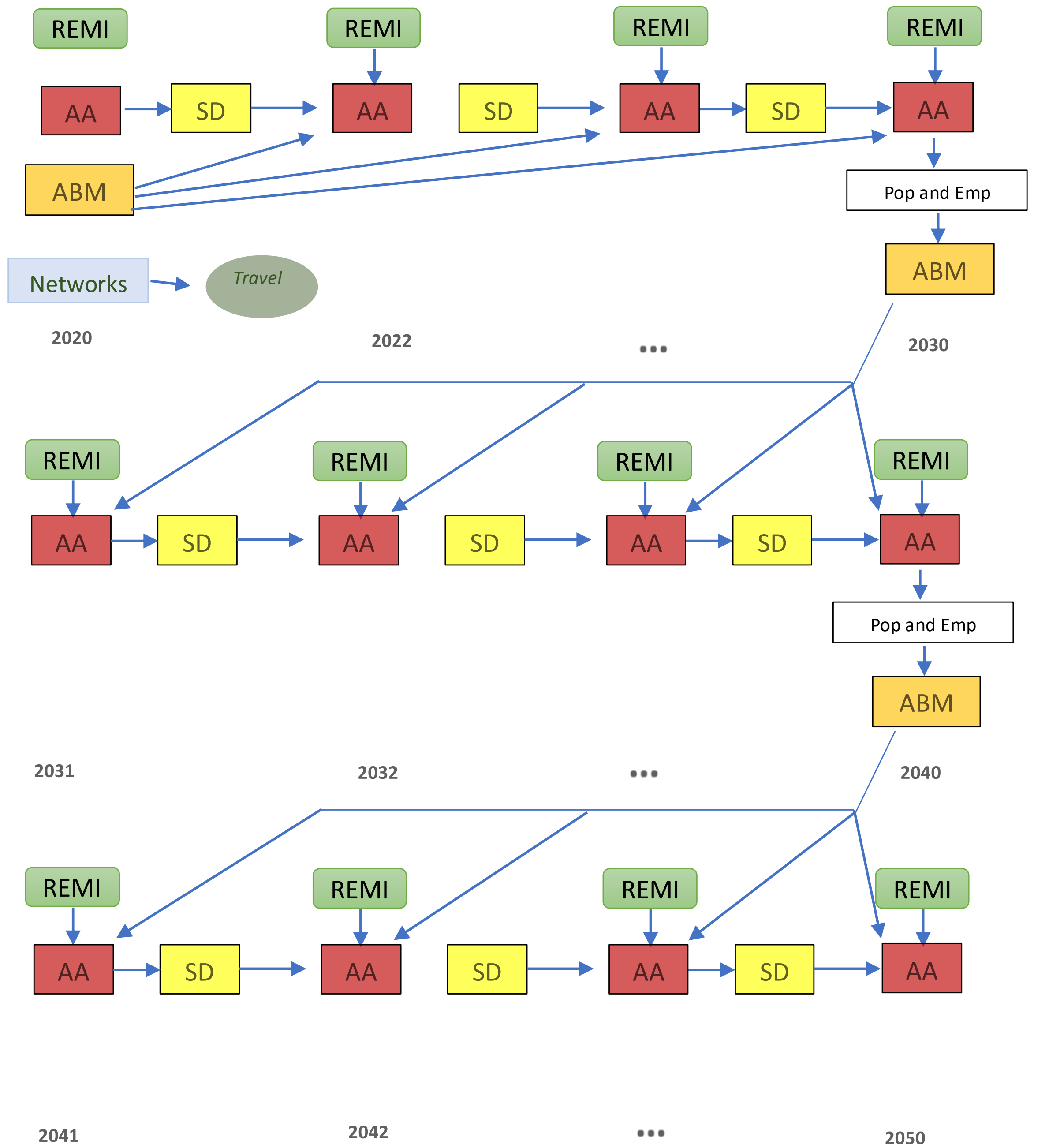
AA runs from 2020 using the skims from the ABM for this year with the activity quantities in the LUZs constrained to observed values – these developed from ABM input data and values from the Census and various other sources. Calibration of this dynamic system involves adjusting model parameters in 2020, the base year of the simulation, so that the additional parameters needed to satisfy the constraints get sufficiently insignificant and a series of model outputs concerning rents, housing demand, development trends and commute distance get sufficiently close to observed (or appropriate 'target') values.

AA was then run from 2020 through to 2030 producing forecasts of employment and households by TAZ for the year 2030. These numbers were input to the ABM to produce skims matrices of travel time, distance, and cost for the year 2030. AA was then run from 2030 through to 2040 with these skims for 2030, and the process repeated for the period from 2040 to 2050.

Figure 6 shows the model run system and its interactions to generate the official forecast.

Using the PECAS and ABM models in this way constitutes an integrated land use transport model system. For every ten-year simulation period, updated population and employment data are generated by the PECAS model, input to the ABM and used by it to generate travel demand and travel and transport skims that are input to the PECAS for use in the next ten-year simulation period. The Land Use System impacts the Transportation System and the Transportation System impacts the Land Use System. If a new freeway is built "in the model system" then both the transportation system and the population and employment distributions are impacted. This is of the essence of an integrated land use transport model system.

The S16 Forecast to 2050 is associated with a specific transportation plan to 2050. What is in the transportation plan influences the locations of population and employment.



ED = Economic Forecast; AA = Activity Allocation Model; SD = Space Development Model

Figure 6. Data flow and model system interactions between REMI, PECAS and the ABM

5.2. Forecasting results

A summary of the forecasts developed to support the Atlanta Regional Plan are presented below. Figure 7 shows the total number of households, employment, and population in the Atlanta Region from 2020 to 2050.

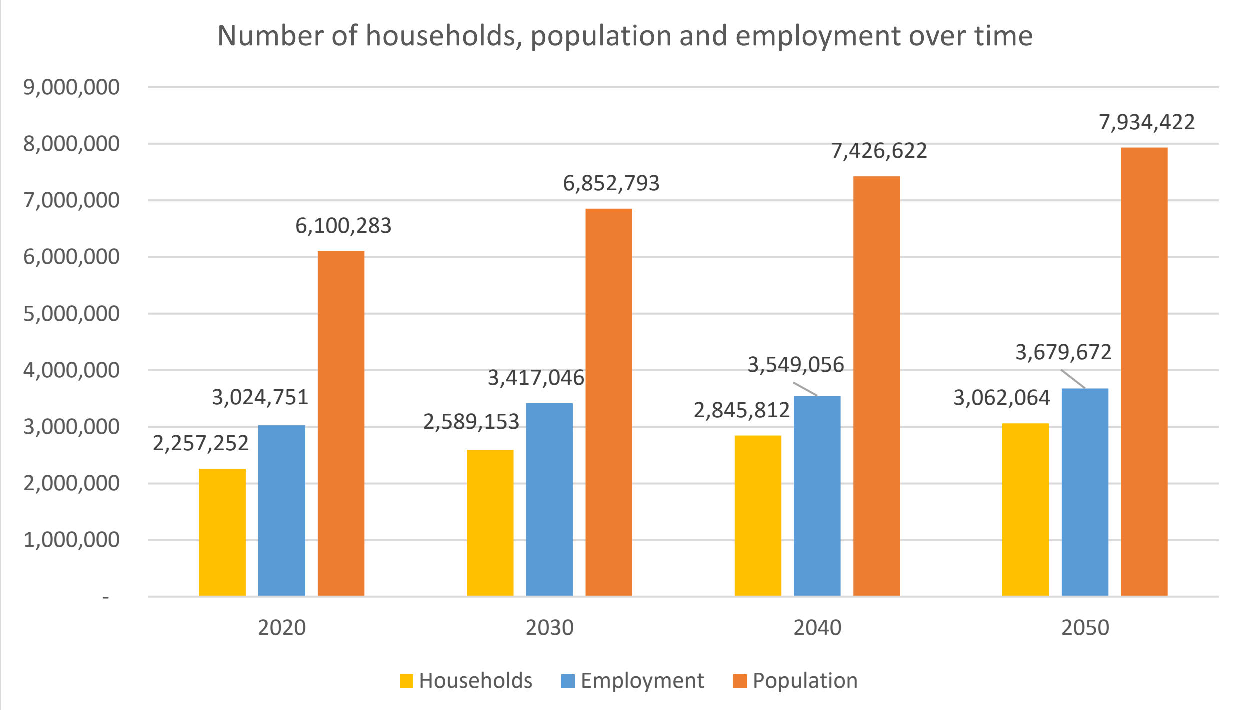


Figure 7. Number of households, employment, and population over time

The forecast for households, population, and employment over time, disaggregated to county level are presented in Figure 8 to Figure 10. The charts show the increase in the total number of households and total population for each county.

It can be noted that that Fulton County and Gwinnet County are similar in size in terms of population, both higher than 1.2 million by 2050. But there are fewer forecast total households in Gwinnet, suggesting a larger average household size. This aligns with the total job forecasts, where Fulton County's jobs are double those in the three next largest job counties: Gwinnett, Cobb and Dekalb. It reflects the differing land use patterns in the two areas: Fulton is a metropolitan center with a greater job base and smaller household's size, while Gwinnett, Cobb and DeKalb are suburban areas with a larger household size and a smaller job base.

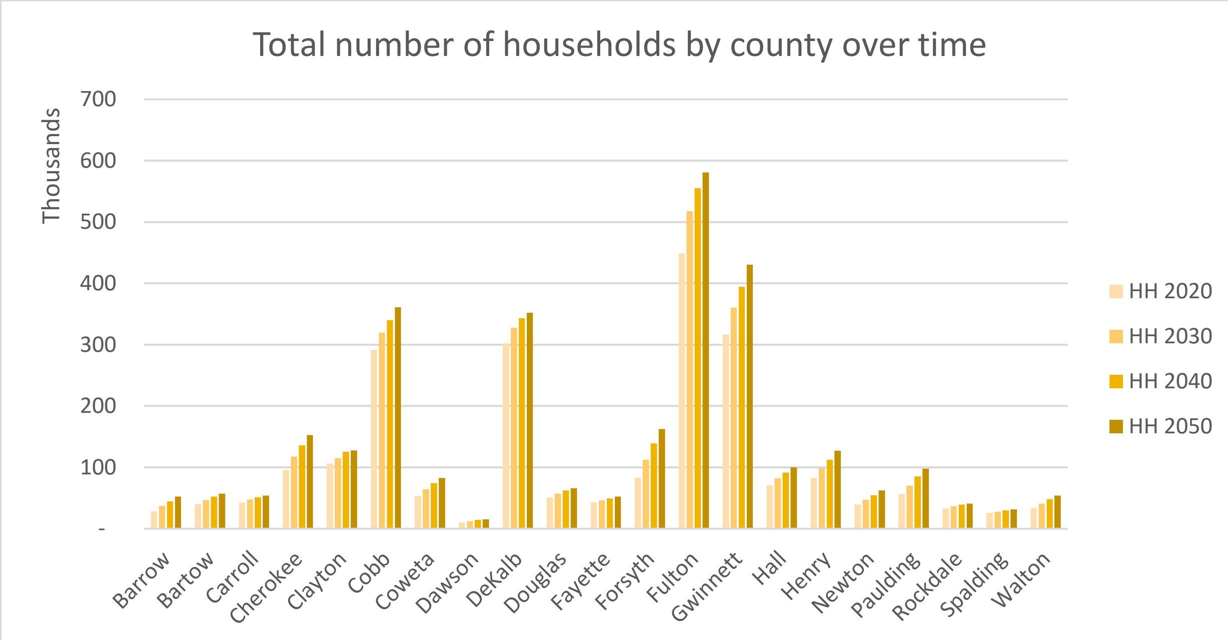


Figure 8. Total number of households by county over time, Series 17

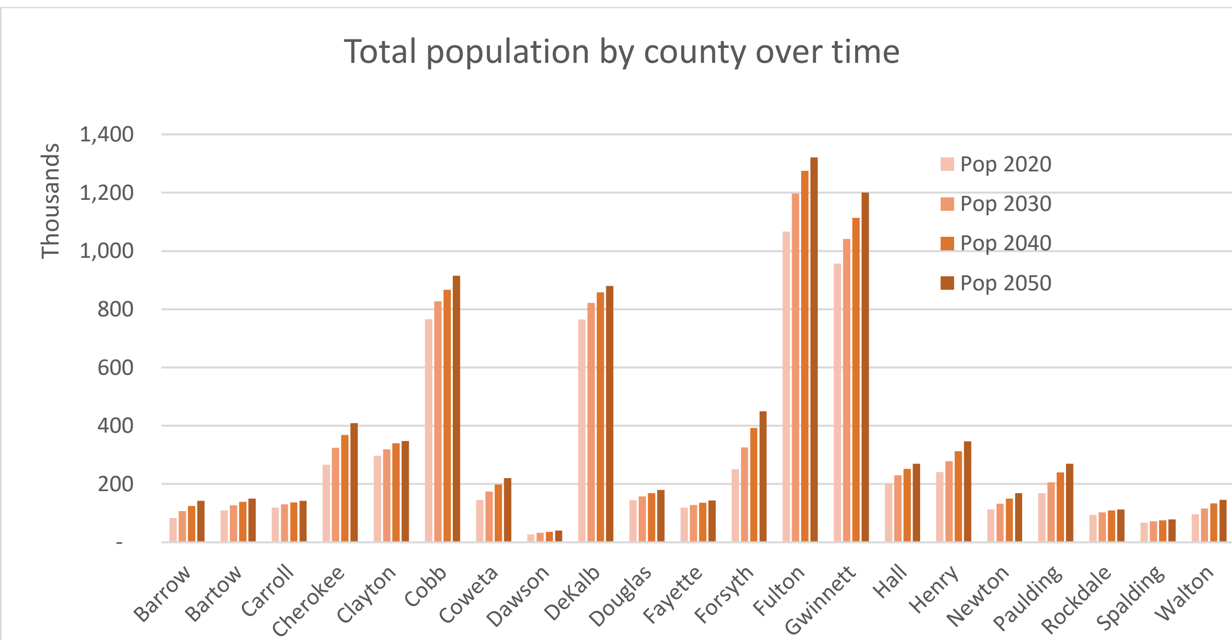


Figure 9. Total population by county over time, Series 17

Total employment shows a slightly different trajectory than households and population, in which the employment totals do not correspond proportionally to future increases in population. Rather, Fulton County remains the dominant employment.

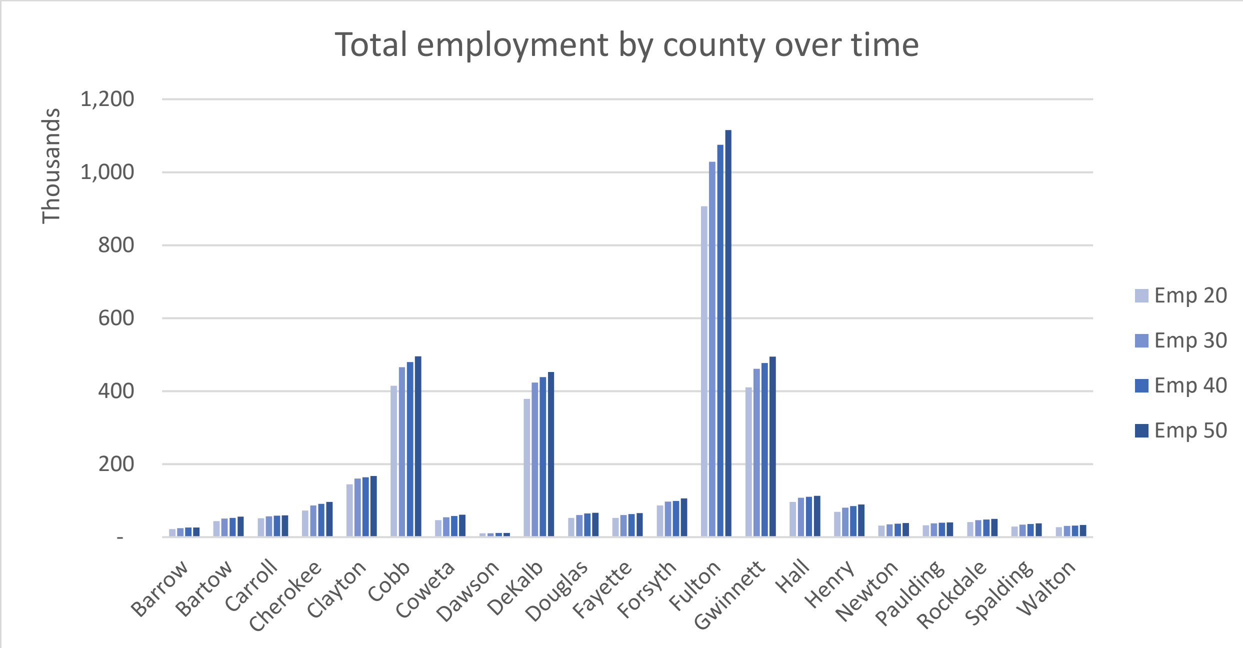


Figure 10. Total employment by county over time, Series 17

The maps in Figures 11 to 13 indicate the spatial distribution of households, population, and employment by county for 2050. Figures 11 and 12 show that while Fulton County has more households than Gwinnett County does, these two counties have similar population totals for 2050. For employment, Figure 12 shows, Fulton is the employment hub of the region, since Cobb, Gwinnett, and DeKalb have close to 50% of Fulton's employment.

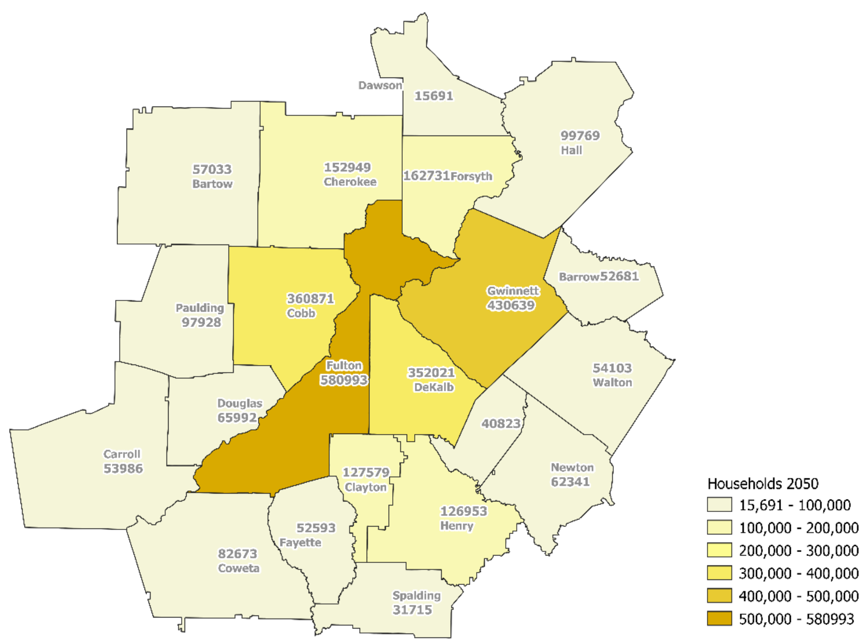


Figure 11. Map of households by county in the Atlanta Region in 2050

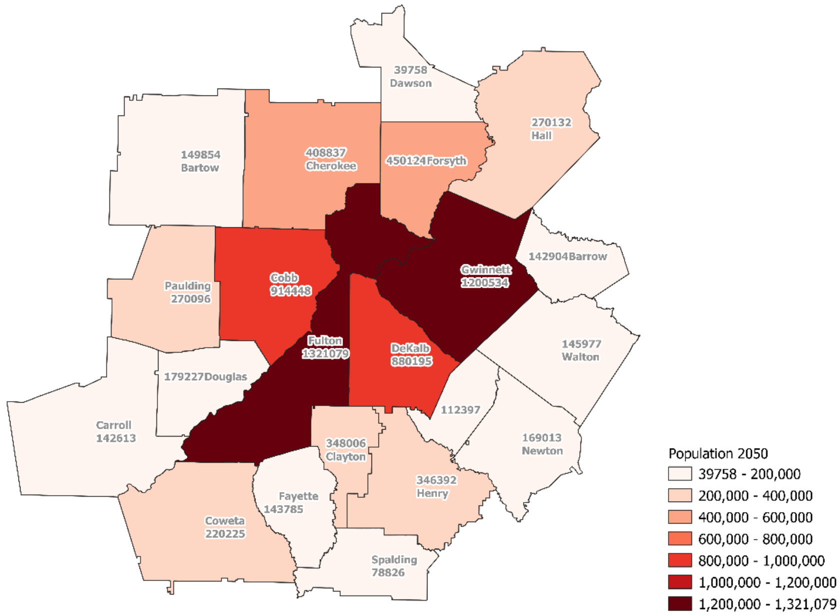


Figure 12. Map of population by county in the Atlanta Region in 2050

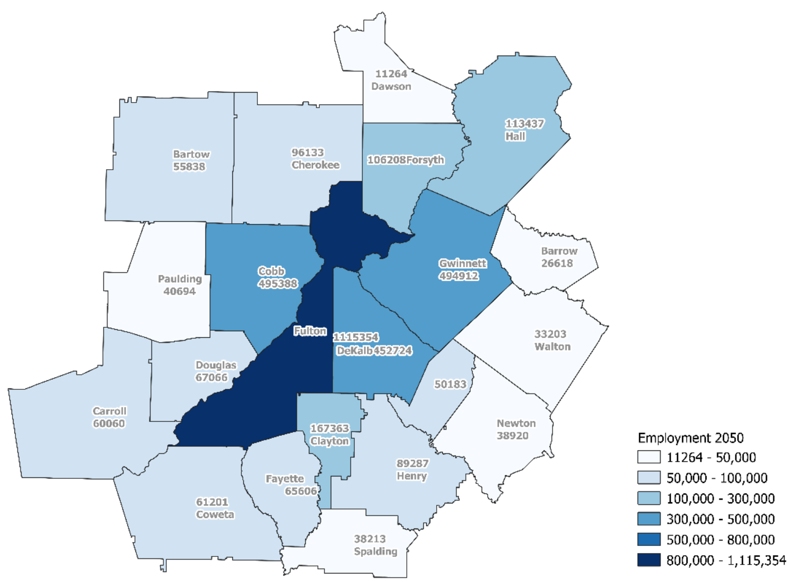


Figure 13. Map of employment by county in the Atlanta Region in 2050

Figure 14 depicts the ratio of jobs to population by County from 2020 to 2050. Some counties show overall decline trends, suggesting their population will increase faster than their employment. Fulton County experiences a slightly decline in this ratio compared to Spalding or Dekalb, suggesting a broader distribution of employment outside the core area over time. This will act to redistribute some transportation demand and corresponding congestion to other corridors or centers outside of that core.

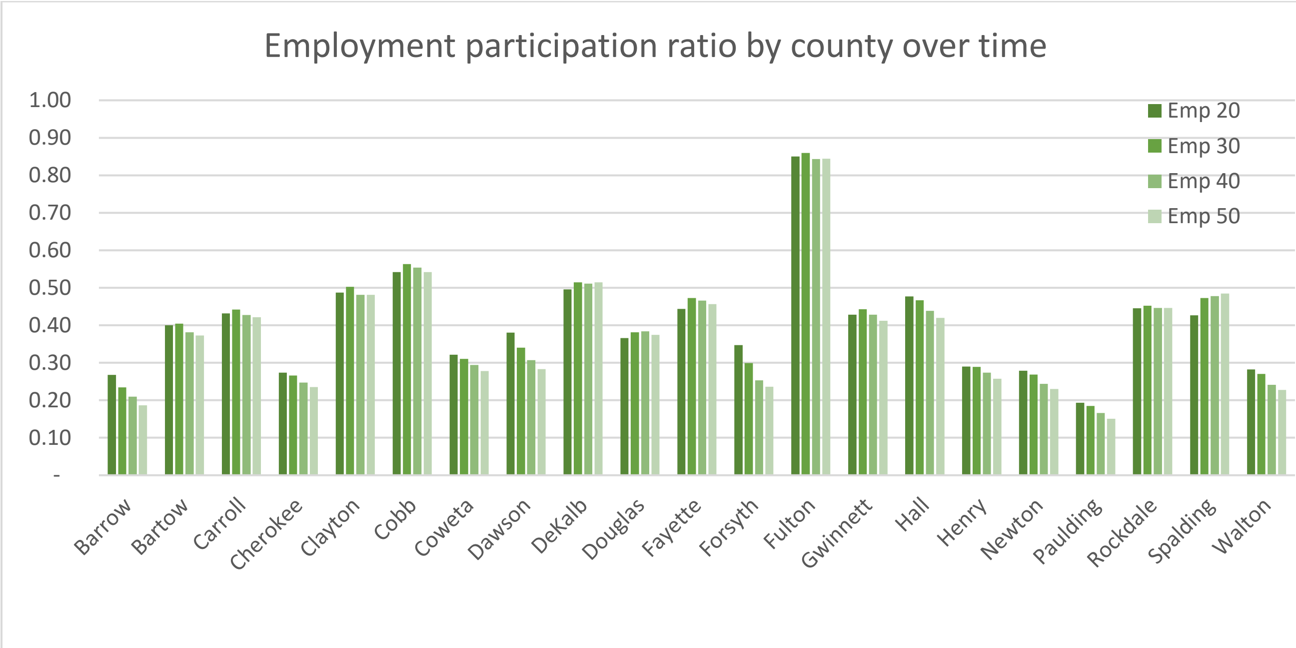


Figure 14. Employment Participation Ratio by county over time

5.3. Regional growth scenarios and policies

Besides generating the official forecast of population, households and employees, the other key role of the Atlanta PECAS Model is to facilitate exploration of potential scenarios or new futures. Previous work was done in 2018 exploring how certain policy elements would act towards the Atlanta Region reaching specific population or employment targets while allowing more intense zoning in certain parts of the Fulton County, to assess the conditions and associated the social and economic impacts of those policy elements. With the most recent model updates, two additional scenarios were explored. The first one is the “County constrained scenario” and the second one is the “Preliminary post pandemic scenario”.

County constrained scenario

A version of the model was run with the job and household total quantity for each county as an exogenous input to the model. The growth amounts over time by county are under continuous discussion by various groups across the region, and in this scenario the Atlanta PECAS Model’s role is to add spatial and categorical detail to these values. The model forecasts the growth in each land use zone and each TAZ as usual, but then the attractiveness of each county is adjusted internally within the model software, and the software iterates until it develops a complete spatial equilibrium that respects the county growth projection. The detailed patterns of people and jobs by LUZ and TAZ, and the parcel-level realization/visualization provide a specific forecast that will be used to inform planning discussions, such as zoning considerations, infrastructure plans, transit service levels, and social services. The economic relationships between zones, and the maps of prices and costs, can be used to identify potential opportunities for services or development.

This scenarios services many purposes. It is especially valuable when discussing detailed patterns between nearby LUZs and TAZs, or reviewing the detailed patterns in the parcel simulation with local governments or other agencies. In high-level planning, discussing and exploring the different growth rate possibilities for different counties is valuable, but in lower-level planning it can be a problematic distraction from the local issues.

Preliminary post pandemic scenario

As many other jurisdictions in the US, Atlanta Regional Commission is aware of the changes we have been going through, during the COVID-19 pandemic and in the post pandemic era. Changes in patterns of behaviour have been observed in cities and regions across the country making it necessary to explore how these changes could impact the urban dynamics affecting different elements. Elements especially relevant to ARC include housing affordability, public transit, employment, climate change, and environmental concerns.

Several changes in patterns of behaviour from the agents involved in making choices in the urban dynamics, such as government, business and households, can be explored with the ARC PECAS model. The purpose of this “Preliminary Post pandemic scenario” was to test the updated ARC PECAS modelling system if white-collar employees had a hybrid work pattern, attending the office an average of 2.5 days a week. The model was adjusted to represent these conditions and was run independently from the ABM for this testing exercise, to perform the analysis and understand the effects of this change in households and business location. To explore the effects of travelling reduction on congestion and emissions, an integrated run with the ABM is necessary.

An objective of preparing and running this scenario was to demonstrate the ARC PECAS model capabilities and response. It is planned to add additional post-pandemic changes to this evolving scenario, reflecting a range of other assumptions, such as:

- Increase the attractiveness of larger homes, to account for adding home offices, as well and a general desire for more non-office space for people spending more time at their home due to working from home and in-home online education. This option could be available for all household categories, or more targeted to those with a higher prevalence of white-collar occupations most suitable to working from home.
- Increase residential construction to account for increased housing demand due to work from home.
- Reduce the demand function for office space per employee at the workplace.
- Increase the effect on rent of the housing located to leisure amenities such as parks, green space, sport facilities and other similar activities that become available due to spending more time at home.

From an institutional point of view, ARC is recognizing many of the wide range of potential types of analysis that can be done with the support of the Atlanta PECAS model and is appropriately pursuing further work to leverage the model’s versatility and flexibility for a variety of purposes.

6. Conformity Forecast Module - development and application.

The Atlanta PECAS Model is designed to assist in the conformity forecasts required by the Federal Highway Administration. A conformity forecast is a detailed set of transportation demand model simulations that predict the regional emissions from on-road mobile sources on the planned (future) transportation system. For conformity forecasting, the Atlanta PECAS Model's outputs are inspected in detail, and compared with many other sources, including potential future planned/announced developments, local government's own forecasts, and internal agency expert knowledge about the likely changes in specific geographic locations.

The Conformity Forecast Module Is a series of programs and algorithms that allow the Atlanta PECAS Model to rapidly assist with developing a detailed conformity forecast. The software generates special maps in a Desktop GIS that are used to visualize patterns of future growth in the model, allowing comparisons of the model's outputs with other sources. Groups of TAZs can be selected as future projects, to enter in planned future development, or as treatments, to adjust the quantities in the future. Expert knowledge and other sources of information can quickly be entered into the system.

The dialog box to enter a treatment or a project Is show In Figure 15. The analyst can names the project and describes it, and explains the years for which the information applies. There are different columns where minimum and maximum amounts can be entered. The first box is where the dwelling units and employees can be constrained for the project or treatment by entering a minimum or maximum. The bottom-left box allows the analyst to control the mix of dwelling types, by adjusting the minimum or maximum amounts. The types of jobs can be finely controlled by entering some maximum or minimum amounts for certain industries.

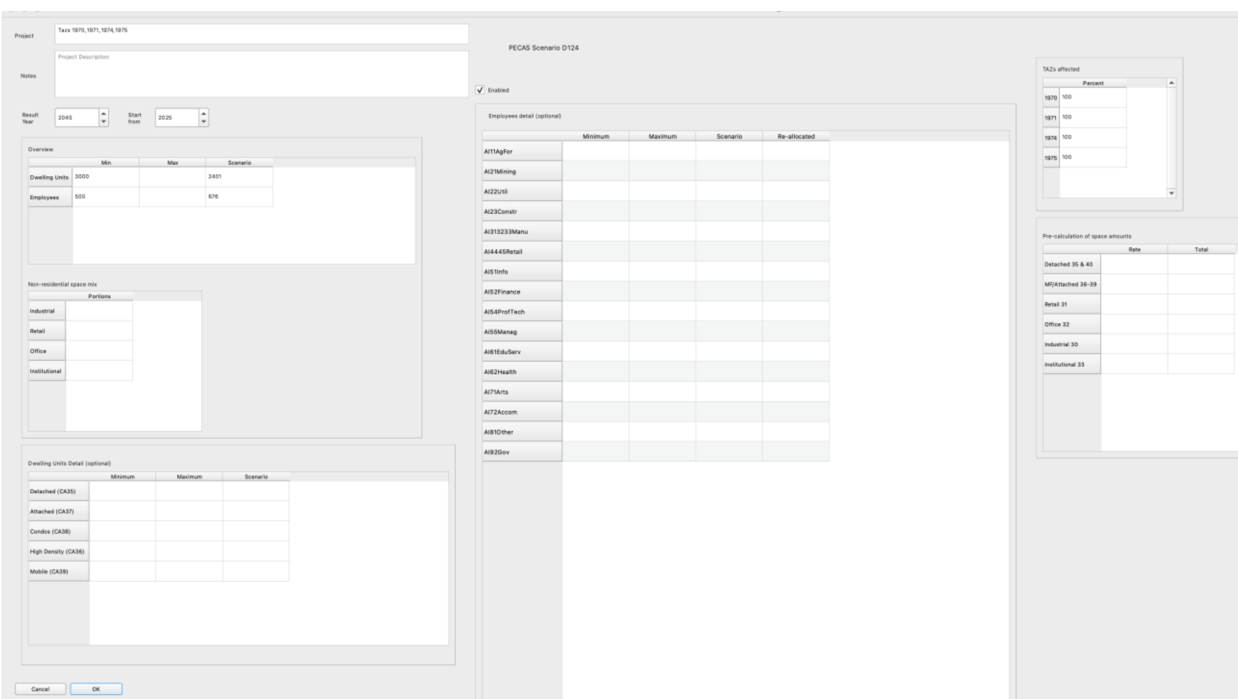


Figure 15. Conformity Forecast Module Treatment Dialog Box

Once a set of projects and treatments are entered, they can be applied to an existing scenario by checking the “enabled” checkbox, and then choosing the “Reallocate Households and/or Employment” tool. This uses a fast constrained least-squares algorithm to shift households and employees from or to other zones in an optimal way, to match the minimum and maximum constraints of all the projects, while still respecting the total amounts across the region. These results can be quickly deployed as maps, or downloaded as output files, for further discussion and comparison with other sources of data, or other forecasts.

The differences between the reallocated amounts and the original model output amounts can then be used to adjust the inputs to PECAS, so that another PECAS scenario can be created and run that is influenced by the constraints from the enabled projects and treatments in the reallocation run. These adjustments can be zoning permissions (allowing or prohibiting certain types and densities of development), site spec (pre-specifying certain amounts of known future development), or zonal attractiveness factors.

The conformity forecasting tool is designed to be a quick-response method, an intermediary system with an easy user interface, in between the model’s outputs from one scenario, the mandatory conformity forecast from the regional transportation plan, and the inputs for the model for another scenario.

7. Potential Future Model Enhancements

RAG, the Research Analysis Group at ARC, wants to continue applying the Atlanta PECAS model to generate forecasts and assess policy scenarios in support of planning policy analysis and development. Possible areas of improvement have been identified to help enhance and expand the Atlanta PECAS model and its ability to contribution to practical analysis work. Some of these areas being considered for the next cycle of the model development and application are:

- Increase the usage of the Population Synthesis procedure. This full synthetic population for each future year has been valuable in analysis, and is an asset that can be of further use at ARC. It can be used as an input to the ABM and/or for various other economic/demographic analysis.
- Enhance Land Use Model Update and Calibration Initiative to make the model ready to develop the S18 conformity forecast.
    a. Revisiting housing categorization to assess if the current one is suitable for the required housing analysis.
    b. Generating a more formal detailed inventory of future projects and schedule of construction (for example: public and private communities, shopping malls, industrial parks, facilities, etc.) as well as an inventory of targeted vacant sites.
    c. Recalibrating the SD module using updated construction costs, development fees, observed rents by space types and observed construction as calibration targets.
    d. Revisit the AA module calibration, to realign the module with the updates in the space data.
- Enhance the model functionality for Scenario Planning, adjusting the model to make it capable of responding to the dynamics of climate change and evolving technology.
- A post pandemic test scenario was performed after the S17 conformity forecast, this can be the starting point to a deeper investigation about the impacts of changes in patterns in the demand of non-residential space, demand of housing space, demand of public transit, among other factors.
- Improve the integration of the ARC PECAS Model with the ABM, for example to improve the response time for investigation of new issues as they arise.
- Maintain the level of training regarding theoretical background, model calibration, and model usability. This includes training in user interface in combination with delivering training on how to use and analyze model results with the current knowledge and programs (MapIt, QGIS plugin, MRS GUI, etc.).
- Keep producing and updating documentation of the ARC Land Use modeling system.