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E APPENDIX METHODOLOGY FOR LAND USE PROJECTIONS IN THE BOSTON REGION

INTRODUCTION

The Metropolitan Area Planning Council (MAPC), the region's land use planning agency, is responsible for preparing detailed transportation analysis zone (TAZ)-level socioeconomic and land use projections out to the year 2040 to support the Long-Range Transportation Plan (LRTP) travel-demand model process. MAPC began this process with the development of regional and municipal population and household projections for the entire Metro Boston model region. Because the model region includes an additional 63 municipalities in adjacent regional planning agencies (RPAs), MAPC convened an advisory team with representatives from neighboring RPAs, along with academic experts, staff from Boston and Cambridge, and state agencies.[1]

MAPC reviewed reports from other regions nationwide to assess the current state of practice and also reviewed prior projections for the Boston region to assess their accuracy and identify opportunities for improvement. Data sources for the demographic projections included decennial census data from 1990, 2000, and 2010; American Community Survey (ACS) data from 2005 to 2011; fertility and mortality information from the Massachusetts Community Health Information Profile; housing production information from the Census Building Permit Survey database; and MAPC's Development Database. For the employment projections, MAPC referred to historic employment data from the US Bureau of Labor Statistics (BLS) and the Executive Office of Labor and Workforce Development, as well as labor force participation data from the US Census Bureau.

Because the future cannot be predicted with certainty, identifying a range of possible futures may prove more useful than a single forecast. Consequently, MAPC prepared two scenarios for regional growth. Each scenario reflects different assumptions about key trends. The "Status Quo" scenario is based on the continuation of existing rates of births, deaths, migration, and housing occupancy. Alternatively, the "Stronger Region" scenario explores how changing trends could result in higher population growth, greater housing demand, and a substantially larger workforce. Specifically, the Stronger Region scenario assumes that in the coming years:

1 A full report, technical documentation, and data downloads are available at www.mapc.org/projections.

- The region will attract and retain more people, especially young adults, than it does today.
- Younger householders (born after 1980) will be more inclined toward urban living than were their predecessors, and they will be less likely to seek out single-family homes.
- An increasing share of senior-headed households will choose to downsize from single-family homes to apartments or condominiums.

Of the two scenarios, the Stronger Region is more consistent with the housing, land use, and workforce development goals of MetroFuture, MAPC's regional plan for sustainable and equitable growth and development in the region. This scenario has been adopted by MAPC for future planning purposes and, as a result, the LRTP socioeconomic data is based on the Stronger Region scenario.

METHODOLOGY

Municipal Population and Household Projections

MAPC first developed regional projections of population by age, gender, and race, utilizing a standard cohort survival methodology with age- and race-specific fertility and mortality rates based on information from the Massachusetts Department of Public Health (DPH). Disaggregated and adjusted age- and race-specific migration rates to and from the region were used, based on migration data available from the US Census Bureau's ACS and Public Use Microdata Sample (PUMS). Household estimates are produced using region-wide age-specific headship rates derived from the decennial census, and they are disaggregated into households by type (family versus nonfamily) and size.

Municipal population projections were initially developed using age- and municipal-specific fertility and mortality rates from the DPH. Net migration by age for each municipality was calculated using the vital statistics method, which compares the actual population in 2010 to the "expected" population, which was derived from Census 2000 counts and recorded deaths during the subsequent ten-year period. Any difference between the observed and expected population is assumed to be the result of migration in or out of the municipality. The independently projected population for each of the 164 cities and towns was calculated and compared to the regional control total in order to produce an adjustment factor that was applied universally to each age cohort so that the municipal sum would match the regional total. After adjusting the municipal totals, they were aggregated to the RPA geographies to derive totals for the Boston Metropolitan Planning Organization (MPO) region.

To estimate change in households, regional headship[2] rates (by household type) were applied to the population in households for 2010 and forecast years, and the difference

2 Headship rates are the number of people who are counted as heads of households.

was calculated. This change in households was added to the actual household counts by age from Census 2010 to produce future-year household estimates by householder age. These households were then disaggregated by household type (family versus nonfamily), income (relative to the area median income defined by the US Department of Housing and Urban Development), and size, based on the distributions observed using decennial census data and ACS microdata. Municipal household projections were allocated to TAZs using the land use model described below.

Employment Projections

MAPC collaborated extensively with the Massachusetts Department of Transportation (MassDOT) to develop employment projections for Massachusetts' MPO regions. An analysis found that as the baby boom generation ages past the age of 65 in the coming decades, a massive wave of retirement is likely to dramatically alter the Massachusetts workforce, making labor availability a major constraint on economic growth. Meanwhile, the state's slow pace of housing construction will make it difficult for younger workers to move into Massachusetts to fill those vacancies. As a result, statewide employment was projected as a function of the available labor force based on demographic projections. In consultation with expert advisors, MAPC also assumed a gradual decrease in the average unemployment rate over the next few decades. Age-specific labor force participation rate was developed for each RPA and applied to the projected population to estimate the number of employed residents. The Stronger Region scenario assumes a gradual decrease in the unemployment rate, from a peak of 8.8% in 2010 to 6.0% in 2020, 5.8% in 2030, and 5.6% in 2040.[3] This scenario is more consistent with long-term unemployment averages (about 5.75% from 1990 to 2015 and from 2000 to 2015), and it also reflects the fact that with likely labor shortages in the coming decades as baby boomers retire, workers will find it easier to get a job. The rate of change in employed residents was then used to estimate total future employment in Massachusetts, assuming that in/out commuting will remain a constant share of total employment. The sectoral distribution of employment in future decades was based on a shift-share analysis[4] of Massachusetts sectoral growth versus the rest of the nation, utilizing BLS forecasts to the year 2020, and then continuing an attenuated rate of change for each sector out to the year 2040.

MAPC then used shift-share methods to analyze how the economic trends of the 164 municipalities in Metro Boston compare to the state. Metro Boston jobs grew an average

3 Estimates of a "non-accelerating inflation rate unemployment" (NAIRU) measure of the "natural" unemployment is in the vicinity of 5.0% to 5.25%. However, this figure is the structural "floor" on unemployment, and any long-term average will also have to account for recessionary periods with higher unemployment.

4 A shift-share analysis is an economic forecasting technique that projects future employment change for a specified area (such as a state or region) as a function of three key factors: a *general growth effect,* reflecting change in employment for a larger reference area (such as the nation); an *industry mix effect,* reflecting differential growth rates for specific sectors; and a *local share effect,* based on the specified area's performance in each sector relative to the reference area.

of 0.66% faster than Massachusetts overall over the last decade. As a result, future employment share for the region was derived based on the total employment projection for the state. Shifts in employment sectors in the region (by the 2-digit North American Industry Classification System [NAICS] sectors) were analyzed to get a composite share of employment for 2020. The logarithmic extrapolation using the shift in share from 2001, 2010, and 2020 was used to determine the respective sectoral shares for 2030 and 2040. Municipal and TAZ allocation of employment was done using the land use model described below.

TAZ Allocation

MAPC worked collaboratively with MPO staff to procure and develop a regional Land Use Model, which distributes households and employment to TAZs based on a variety of zonal attributes, including access to employment and labor, development capacity, and new real estate development already "in the pipeline." After reviewing the wide variety of land use modeling software tools currently available, MAPC and CTPS procured Citilabs "Cube Land" software. Based on the bid-rent model at the core of the software, the model "agents" (households or employers) compete for available real estate. The agent's location is a result of interaction with other agents, the agent's ability to afford a location, the attractiveness of a location based on neighborhood characteristics, transportation connectivity and other attributes, and other factors. MAPC defined the agents to be consistent with the previously developed population and household projections as well as employment projections.

A total of 24 model agents were defined, composed of 13 household agents and 11 employment agents. The household agents are defined in terms of the age of the householder, the household type, the household size, and income level. Table E-1 summarizes the 13 household agent types by their characteristics.

TABLE E-1
Land Use Model Household Agent Description

HH Agent Code	Age Range	HH Type	HH Size	Income	Agent Description
1	15-34	Nonfamily	2-4+ Persons	All income levels	15-34 Nonfamily 2-4+ persons HH all income
2	15-34	Nonfamily	1 Person	All income levels	15-34 Nonfamily single person HH all income
3	15-44	Family	2-4+ Persons	Above 80% AMI	15-44 Family 2-4+ persons HH high income
4	15-44	Family	2-4+ Persons	Below 80% AMI	15-44 Family 2-4+ persons HH low income
5	35-64	Nonfamily	2-4+ Persons	All income levels	35-64 Nonfamily 2-4+ persons HH all income
6	35-64	Nonfamily	1 Person	Above 80% AMI	35-64 Nonfamily single person HH high income
7	35-64	Nonfamily	1 Person	Below 80% AMI	35-64 Nonfamily single person HH low income
8	45-64	Family	2-4+ Persons	Above 80% AMI	45-64 Family 2-4+ persons HH high income
9	45-64	Family	2-4+ Persons	Below 80% AMI	45-64 Family 2-4+ persons HH low income
10	65+	Both family and nonfamily	2-4+ Persons	Above 80% AMI	65+ Family and nonfamily 2-4+ persons HH high income
11	65+	Both family and nonfamily	2-4+ Persons	Below 80% AMI	65+ Family and nonfamily 2-4+ persons HH low income
12	65+	Nonfamily	1 Person	Above 80% AMI	65+ Nonfamily single person HH high income
13	65+	Nonfamily	1 Person	Below 80% AMI	65+ Nonfamily single person HH low income

AMI = average median income. HH = household

MAPC created a residential location choice model based on responses from the Massachusetts Travel Survey.[5] Travel survey responses were assigned to an agent category based on household type, householder age, household size, and reported income, and they were geocoded to individual parcels based on the reported home address. These observations of actual households formed the basis for estimating location choice preferences used in the bid-rent model.

5 http://www.massdot.state.ma.us/planning/Main/MapsDataandReports/Reports/TravelSurvey.aspx

While the Cube Land software is most commonly used to allocate regional totals to zones, MAPC chose to set up the model in such a way that the previously developed municipal population and household totals would be maintained, so as to preserve LRTP consistency with the Regional Housing Plan and other policy documents. Therefore, the model's primary role was to determine the distribution of household agents to TAZs *within* each municipality, not to forecast regional-scale population movement.

The regional travel-model land use inputs are more detailed than the 13 agents reflected in Table E-1. The regional model inputs include:

- Households by four income groups
- Households by household size (one-person households, two-person households, three-person households, and households with four or more persons)
- Households by workers (zero-worker households, one-worker households, two-worker households, and households with three or more workers)

In addition, the regional travel model requires information on households by auto availability (zero-auto households, one-auto households, two-auto households, and households with three or more autos).

MAPC and the MPO staff have jointly developed a methodology to convert the zonal Cube Land output to the needed regional model input. This methodology makes extensive use of the existing census data and uses a methodology known as iterative proportional fitting. Simply stated, the households by income, size, and workers are proportionally scaled to match MAPC-predicted community control totals for population, households, and workers. Once completed, the results of the proportional fitting were manually checked so that all community control totals established by MAPC were precisely matched.

For the auto-owner projections, the MPO staff had developed an auto ownership model. This auto ownership model was estimated from the 2011 Massachusetts Travel Survey data. The model was then calibrated to known Massachusetts Registry of Motor Vehicle data. The auto ownership model uses households by income, households by size, and households by worker as the basis for predicting auto ownership.

The 11 employment agents were defined based on the 2-digit NAICS sector, with an adjustment to move retail employment firms from the Trade, Transportation, and Utilities sectors as grouped in NAICS; the Retail sector was grouped with the Leisure and Hospitality sector. This was done because the location choice of retail jobs and firms more closely follows that of jobs in the Leisure and Hospitality sectors than those in the Wholesale and Transportation sectors. Table E-2 summarizes the grouping of employment by NAICS sector to the 11 employment firms.

Table E-2
Land Use Model Employment Agent Description

NAICS 2-Digit Sector	NAICS Description	Model Firm Number	Model Firm Description
11	Agriculture, Forestry, Fishing and Hunting	8	Natural Resources and Mining
21	Mining, Quarrying, and Oil and Gas Extraction	8	Natural Resources and Mining
22	Utilities	11	Trade, Transportation, and Utilities
23	Construction	1	Construction
31	Manufacturing	7	Manufacturing
32	Manufacturing	7	Manufacturing
33	Manufacturing	7	Manufacturing
42	Wholesale Trade	11	Trade, Transportation, and Utilities
44	Retail Trade	6	Retail, Leisure and Hospitality
45	Retail Trade	6	Retail, Leisure and Hospitality
48	Transportation and Warehousing	11	Trade, Transportation, and Utilities
49	Transportation and Warehousing	11	Trade, Transportation, and Utilities
51	Information	5	Information
52	Finance and Insurance	3	Financial Activities
53	Real Estate Rental and Leasing	3	Financial Activities
54	Professional, Scientific, and Technical Services	10	Professional and Business Services
55	Management of Companies and Enterprises	10	Professional and Business Services
56	Administrative and Support and Waste Management and Remediation Services	10	Professional and Business Services
61	Educational Services	2	Education and Health Services
62	Health Care and Social Assistance	2	Education and Health Services
71	Arts, Entertainment, and Recreation	6	Retail, Leisure and Hospitality
72	Accommodation and Food Services	6	Retail, Leisure and Hospitality
81	Other Services (except Public Administration)	9	Other Services
92	Public Administration	4	Public Administration
99	Not Applicable	9	Other Services

NAICS = North American Industry Classification System

MAPC created an employment location choice model by geocoding establishment data from InfoGroup to land parcels, with information about land use, density, and

accessibility. These observations of actual establishment formed the basis for estimating the location choice preferences used in the bid-rent model.

The 13 household agents and the 11 employment agents compete to occupy different types of real estate. The model has a total of 12 real estate types, including single family and multifamily for residential agents, as well as various commercial real estate types, including high- and low-density retail office, warehouse, and institutional real estate. Mixed-use real estate is occupied by both residential and employment agents. In the case of employment, the model also accounted for commercial real estate built since 2000 or proposed for construction. This information was derived from MAPC's Development Database,[6] an online inventory of 3,000 recently completed or anticipated residential and commercial development projects that was compiled based on inputs from municipal planning staff in MAPC's 101 cities and towns, information provided by neighboring RPAs, and MAPC research. The database provided the supply side of real estate that is likely to be available for employment firms to occupy in the future.

The zonal employment data needed by the regional travel model is not as detailed as the 11 employment agents forecast by Cube Land. The regional travel model requires zonal employment for three categories (basic employment, retail employment, and other employment). However, as seen in Table E-2, components of these three categories are parsed throughout the 11 categories used by Cube Land. Consequently, MAPC and the MPO staff developed a methodology for distributing the 11 Cube Land categories across the three categories needed for model input.

Based on the allocation of households from the land use model, additional household attributes that were needed for the travel model were estimated. These included school-age population, workers, and total household population. MAPC provided municipal control totals for these inputs, which were a part of the demographic projections work that had been done previously. PUMS data was used to estimate the population younger than 20 years old in households and was controlled at the municipal level for consistency with the projections. Labor force participation rate and the share of employed residents (both for current and future years) in the municipalities were used to estimate the change in workers.

6 dd.mapc.org