A Gross Migration Optimization Technique of Developing In- and Out-Migration Assumptions for regional Population Projections

By

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Abstract

Gross migration approach may produce more adequate population projections than net migration approach for several reasons. But, gross migration approach was not popular due to the limited availability of gross migration data and its difficult applicability. This study proposes a gross migration optimization technique to develop reasonable gross migration assumptions.

The gross migration optimization technique is designed to produce reasonable gross in-migration and out-migration assumptions by efficiently optimizing traditional adjustment factors used in the plus-minus method. The major advantage of the gross migration optimization technique is to immediately develop the size of in-migration and out-migration, while maintaining acceptable age and sex specific in-migration and out-migration schedules.

The gross migration optimization technique was applied to develop gross in- and out-migration assumptions of multiple counties in the Southern California in the following order. First, the optimization technique could successfully optimize the size of regional in-migration and out-migration to achieve the balance between labor force demand and labor force supply at the regional level. Second, the optimization technique could effectively allocate the regional domestic migration into county net domestic migration, using different base periods and local input. Third, the optimization technique could disaggregate the county net migration into the county domestic in-migration and out-migration.

1. Introduction

Gross migration approach has been found to produce more adequate population projections than net migration approach (Isserman, 1993; Smith, 1987). There are many reasons why gross migration approach is better than net migration approach. Key reasons include: 1) gross migration is closer to the true migration process; 2) gross migration traces gross migration flows; 3) gross migration rates are based on population at risk; 4) gross migration can account for differences in growth rates between origin and destination populations (Smith & Swanson, 1998; Smith, 1987).

Although net migration approach is criticized as a theoretical concept and as a measure of population movement (Isserman, 1993; Plane, 1993; Rogers, 1990; Smith, 1987), it is still widely used in developing local (counties and metropolitan areas) population projections. Smith and Swanson (1998) summarize the strengths of net migration: 1) net migration provides a summary measure of one component of population change; 2) net migration can be used when gross migration data are unavailable and unreliable; and 3) net migration provides a low-cost alternative to the use of gross migration data.

With availability of county-to-county migration data from the Census and the US Internal Revenue Services (IRS), regional and county demographers and planners have a choice of using a theoretically sound gross migration approach. But, they still prefer net migration approach to gross migration approach. One major reason is that gross migration is difficult to apply due to its more complicated nature. The difficulty comes from two-way adjustment process of in-migration and out-migration. There is much need to develop easily applicable gross migration assumptions for local or metropolitan population projections.

This study proposes a gross migration optimization technique (an expanded plus-minus method) to develop gross migration assumptions for population projections of multiple counties in the Southern California region. There are two steps of developing migration assumptions in an economic-demographic framework. The first step is to develop regional gross migration assumptions. The second step is to develop multiple counties' gross migration assumptions, given the regional gross migration flows.

The gross migration optimization technique optimizes the size of regional in-migration and out-migration to achieve the balance between labor force demand and labor force supply at the regional level. The gross migration optimization technique also allocates the regional domestic migration into county net domestic migration, and further disaggregates county net domestic migration into domestic in-migration and out-migration.

2. Issues of Gross Migration Estimation

There are several issues developing gross migration assumptions.

1) Domestic Migration vs. International Migration

Developing regional migration component assumptions always has been challenging as observed in traditional population models due to the volatile nature of the migration component. Gross migration can be processed using two components or three components. Two components are in-migration and out-migration. International in- and out-migration are included in in-migration and out-migration data. International out-migration is usually estimated and projected using a certain percentage of immigrants based on sample survey and modeling result. Three components are domestic in-migration, domestic out-migration, and international net migration.

International migration has a very limited relationship with employment change, in particular, unemployment rate of the region or the nation. The correlation between net international migration and employment rate (e.g., 1-unemployment rate) is found to be very small and negative (*r=-0.058*), if California Department of Finance (CA DOF) data sets for 1990/01-2004/05 are used (see figure 1). A small, but positive correlation *(r= 0.114*) between the legal immigration and the unemployment rate is found, if the legal immigration data sets (1984-2004) are used. International migration assumption tends to depend on the past trends and the future national immigration policy. A trend extrapolation method might include using the past regional trends or the regional share of the nation reflecting the past trends.

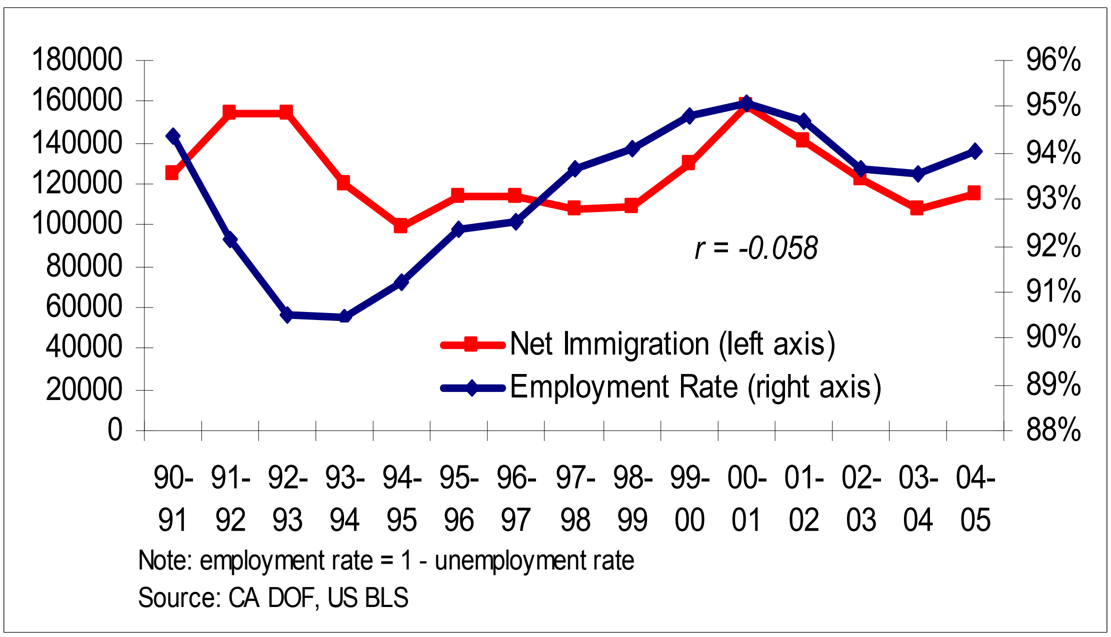


Figure 1. Net Immigration and Employment Rate, 1990-2004: SCAG Region

In contrast to developing international migration assumptions, development of domestic in- and out- migration assumptions is more challenging. Domestic in- and out-migration are also volatile and fluctuating over time along with the economy cycle. The linkage of domestic migration with the economy cycle could be used as a basis for developing domestic migration, given the unemployment rate assumption. Domestic migration is empirically found to show a strong positive correlation (*r= 0.922*) with the regional employment rate (see figure 2). IRS county to county migration flows confirm that the higher the employment rate, the more the net positive domestic migration is induced (see figure 3).

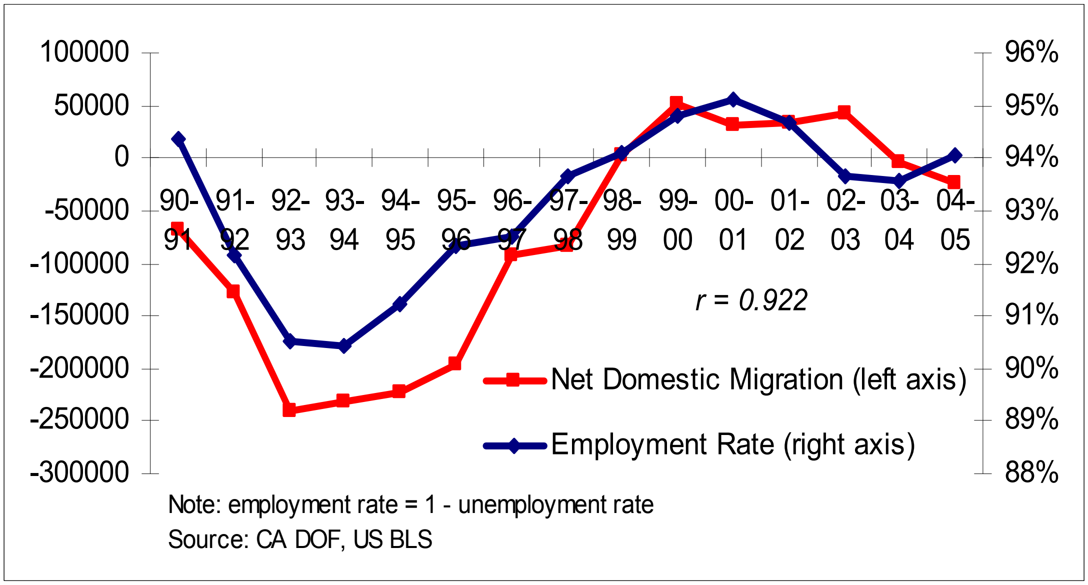


Figure 2 . Net Domestic Migration and Employment Rate, 1990-2004: SCAG Region

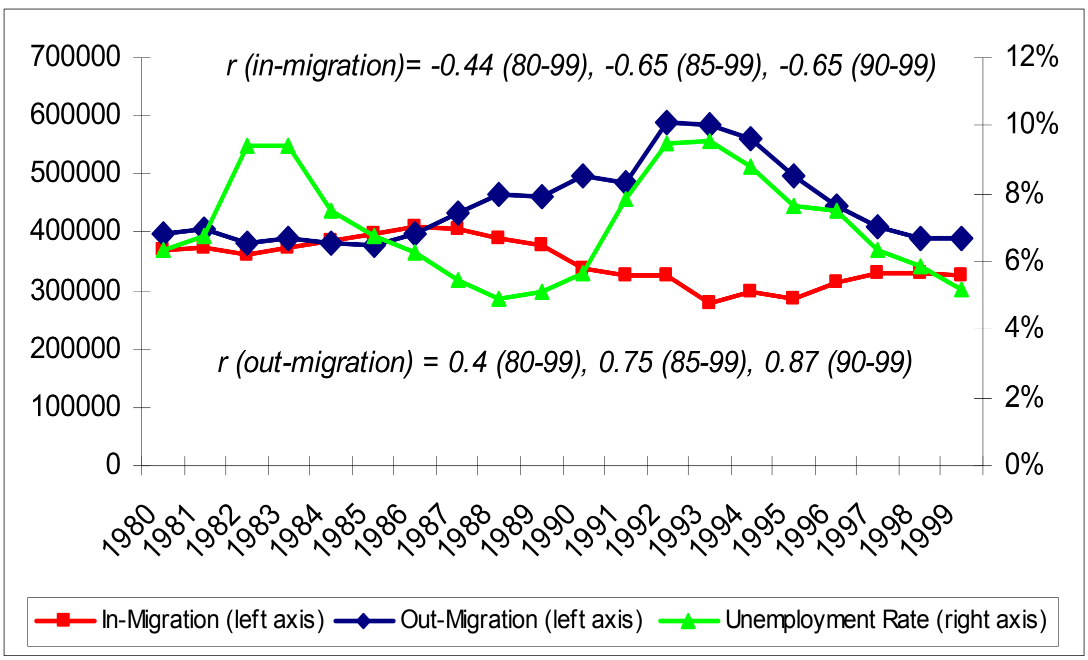


Figure 3: Domestic In- and Out-Migration and Employment Rate, 1980-1999: Sum of Counties in the SCAG Region

Three component approach seems conceptually sounder because of different nature of international migration and domestic migration. Domestic in- and out-migration could be developed by linking with economic changes, while international migration assumptions can be developed using the past trends and the future national immigration polices.

2) Extrapolation vs. Structural Model

The traditional way of projecting migration flows is the extrapolation method. The first important consideration is which base periods to use (Smith, 1987). The length of base periods would be recent five years, recent ten years, or recent fifteen years, etc. The second consideration is which migration rates to select (Isserman, 2002). The migration projection would vary depending on the length of base periods or migration rates.

Since domestic migration and employment change are strongly related, an approach toward developing domestic migration can focus on the linkage of domestic migration to employment rate. For example, the creation of excessive (moderate) jobs in the region could be followed by positive (negative) net migration (more in-migration than out-migration) under reasonable unemployment rate assumptions. This kind of equilibrium model is relatively less costly and easy to implement (George et al, 2004).With externally derived employment projections and assumed unemployment rates, the future migration flows would be easily calculated. The linkage between migration and employment would play a most important role in the future migration flows, which would not be consistent with historical trends.

The linkage of population dynamics to economic trends can be based on 1) the "recursive" assumption that patterns of migration into and out of the region are influenced by the availability of jobs, or 2) the "nonrecursive" assumption that patterns of migration into and out of the region are influenced by (and influence) the availability of jobs. The nonrecursive assumption seems to have sounder theoretical and statistical basis and be supported by a lot of the empirical findings (Borts and Stein, 1964; Greenwood, 1981; Muth, 1971;Plane, 1993). The recursive migration model is still the most widely used econometric model of migration. Although this model does not reflect the full range of interactions between migration and the economy, it has proven successful for projecting migration (George et al, 2004).

3) Top-Down vs. Bottom-Up

The traditional top-down approach focuses on estimates of total net migration rather than separate estimates for each sex-age cohort (Smith et al, 2001). The traditional top-down approach is, first, to develop the size of total net migration using recent trends or linkages to employment patterns, etc., second, to develop the demographic characteristics (e.g., age, sex) of in- and out-migrants using migration rates. The traditional bottom-up approach is, first, to develop the demographic characteristics (e.g., age, sex) of in- and out-migrants using migration rates, second, to aggregate demographic specific migrants to derive total net migration.

The spatial top-down or bottom-up approach emphasizes the relationship between the region and subregions (counties). The spatial top-down approach focuses on the regional estimates of gross migration rather than subregional estimates of gross migration. The spatial top-down approach is, first, to develop in- and out-migration by demographic characteristics, second, to allocate in- and out-migration into subregions (counties). The spatial bottom-up approach is, first, to develop subregions(counties) in- and out-migration by demographic characteristics (e.g., age, sex), second, to aggregate county specific migration to derive total net migration. The spatial top-down and bottom-up approach are sometimes interactively used to produce consistent migration flows of the region and subregions(counties).

4) Two Region Model vs. Multiple Region Model
Gross migration of multiple regions can be developed for projecting multiple regions' populations. Economic-demographic modeling framework emphasized the fixed or changing transition probability (Goetz, 1999; Plane & Rogerson, 1994; Isserman, 1985). The use of the fixed transition probabilities is oftentimes an accepted projection practice, but it is criticized for not representing a correct behavioral representation of a migration system (Plane & Rogerson, 1994). There have been efforts to measure the changing transition probabilities by linking migration to "destination weights"(Plane & Rogerson, 1994). Destination weights include population, economic opportunities, etc. of destination areas. The weights are still hard to project because of their forecasting uncertainty and the changing and unpredictable relationship between these weights and migration.

Two-region based gross migration approach, a simplified version of multiple region model, focuses on gross migration of two regions: the study region and the rest of the country. Two-region based approach retains many of the benefits of full-blown multiregional models (Smith et al, 2001). Major benefits include use of proper migration rates, less data need, fewer calculations, and less cost (Isserman, 1993; Smith et al, 2001).

3. Southern California Gross Migration Model

1) Background and the Structure of the Model
Southern California Association of Governments (SCAG) is the largest of nearly 700 councils of government in the United States, functioning as the Metropolitan Planning Organization for six counties: Los Angeles, Orange, San Bernardino, Riverside, Ventura and Imperial. The region encompasses a population exceeding 18 million persons in an area of more than 38,000 square miles. As the designated Metropolitan Planning Organization, the SCAG is mandated by the federal and state governments to research and draw up plans for transportation, growth management, hazardous waste management, and air quality, housing, hazardous waste management, and waste treatment management.

According to California Health and Safety Code Section 40460 (b), SCAG, with the assistance of counties and cities, is responsible for preparing and approving the portions of the Air Quality Plan related to regional demographic projections on which emission of pollutants are based. SCAG prepares a consistent socioeconomic data set for Cities, Counties, and other government agencies in the region.

Population projections are required as key input to develop federal and state mandated plans and programs. Employment projections are also developed along with population projections because of their importance in developing regional economic strategy and measuring traffic attractiveness of the destination areas. As a result, the future population and employment size should be determined considering the relationship of two variables. An example is to use population to employment (P/E) ratio to develop population or employment projections. The P/E ratio can be effectively used to link population to employment.

Given the requirements of developing both population and employment projections, SCAG has developed a type of economic-demographic models. The following is a brief description of SCAG regional population projection model (SCAG, 1998) (see figure 4).

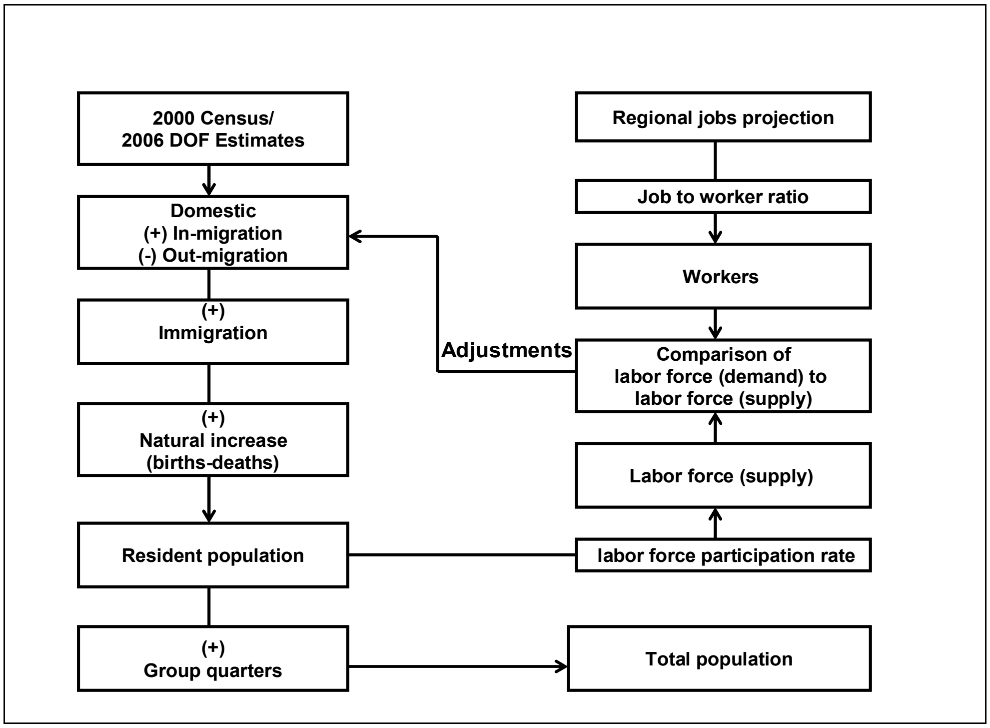


Figure 4. Population Projection Model in an Economic-Demographic Model

Two major components (five minor components: births, deaths, net international immigration, domestic in-migration, domestic out-migration) account for population growth: natural increase (which is the balance between births and deaths) and net migration (which is the balance between the number of people coming and leaving the region). Net migration is further divided into three components: domestic in-migrants (people moving into the region from the rest of the country), domestic out-migrants (people moving into the rest of the country from the region), and net international immigrants (legal and undocumented immigrants minus legal and undocumented international emigrants).

SCAG initially develops regional population projections using the cohort-component model. The model computes the population at the future point in time by adding to the existing population the number of group quarters population, births and persons moving into the region during a projection period, and by subtracting the number of deaths and the number of persons moving out of the region. Two region gross migration approach is used to develop two domestic migration components for its theoretical soundness, less data needs, and easy applicability. This process is represented as the demographic balancing equation.

$$P_t = P_0 + B - D + DIM - DOM + NIM$$

where P_t is the population at time t, P_0 is the population at time 0, B is births between times 0 and 1, D is deaths between times 0 and 1, DIM is domestic in-migrants, DOM is domestic out-migrants, and NIM is net international migrants.

The fertility, mortality and migration rates are projected in five year intervals for eighteen age groups, for two sexes, for four mutually exclusive ethnic groups: Non-Hispanic White, Non-Hispanic Black, Non-Hispanic Asian and Others, and Hispanic. The birth rates are also projected by population classes: residents (domestic migrants) and international immigrants.

As discussed in the previous section, the key approaches toward developing "regional" gross migration are 1) three component approach (domestic in-migration, domestic out-migration, net international migration), 2) structural model for domestic migration, extrapolation for international migration, 3) bottom-up model linked to employment assumptions, and 4) two region model.

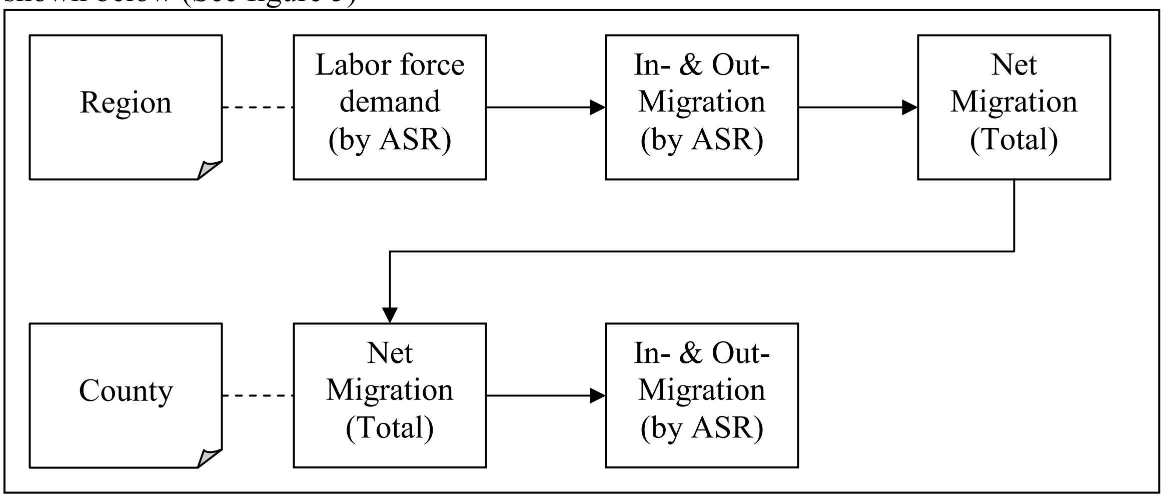
The future labor force supply is computed from the population projection mode by multiplying civilian resident population by projected labor force participation rates. This labor force supply is compared to the labor force demand based on the number of jobs by the shift share employment projection model.

The labor force demand is derived using three step processes. The first step is to develop independent job projections using diverse economic models, including export-base models, input-output models, or shift-share techniques (Smith et al, 2001). The second step is to convert jobs into workers using the worker to job ratio. The application of the worker to job ratio is intended to reflect the proportion of workers holding two jobs or more. The third step is to convert workers into labor force demand using the ideal implied unemployment rate. If any imbalance occurs between labor force demand and labor force supply, it is corrected by adjusting the migration assumptions of the population projection model. This kind of equilibrium model is relatively less costly and easy to implement (George et al, 2004). Adjustment of migration assumption is translated into total population changes using the established conversion ratio.

Three key assumptions are developed to link population projection to employment projection. They include labor force participation rates, implied unemployment rates, and worker to job ratio. Labor force participation rates and worker to job ratio are based on the historical trends and the national projections, while implied unemployment rates are set at 5%-7%. Two high or too low unemployment rates are not assumed in developing reasonable population projections.

The county population projections are based on the traditional cohort-component model. Births are projected using county specific fertility rates by age, ethnicity, and migration status (immigrants or others), while deaths are projected using the adjusted regional survival rates (used for the regional model).

The county model uses some regional modeling approaches: 1) three component approach and 2) two region model, but it emphasizes 1) the county allocation algorithm of net international and domestic migration instead of structural model, 2) the top-down approach. Net international and domestic migration by county is derived by allocating the regional net migration into counties using the historical trends (with different base periods). The derived net domestic migration is further disaggregated into in- and out-migration. The linkage of regional and county level migration projection modules are shown below (See figure 5)



Note: ASR = age, sex, and race/ethnicity

Figure 5. Linkage of Region and County Migration Modules

The preliminary population projections are developed by reviewing the sum of initial county population projections and the regional independent population projections. If the difference of both results is significantly large and unacceptable, input data at the county level is adjusted to bring the sum of counties projections close to the regional independent projections. In the end, the sum of counties makes up the regional population projections.

In summary, the SCAG population projection is based on a cohort component model in the context of an economic-demographic model framework. The SCAG gross migration model is characterized as 1) it is two region gross migration model, 2) domestic migration is processed as a separate category from international migration, 3) regional domestic migration is derived by using the structural linkage with employment projections, and the derived regional domestic migration is allocated to counties using the projected county's share of regional domestic migration, 4) regional domestic migration is derived using a bottom-up approach: from domestic in- and out-migration by demographic characteristics to total net domestic migration, while county domestic migration is derived using a top down approach: from total net domestic migration to domestic in- and out-migration by demographic characteristics.

2) Gross Migration Optimization[1]

(1) Regional Model

What would be most effective way of developing regional gross in- and out- migration assumptions in an economic-demographic modeling framework? The first step is to develop key demographic and economic assumptions of "baseline" fertility rate, mortality rate, gross domestic in- and out- migration rates (or transition probabilities), international migration, labor force participation rates, worker to job ratio, and implied unemployment rates through trend extrapolation techniques, econometric and demographic projection models, professional judgment, expert review, and approval process.

The second step is to adjust gross domestic in- and out-migration rates in order to match labor force supply with labor force demand, derived from independent employment projection. The size of domestic in- and out-migration is difficult to derive because of fluctuating size with business cycles and its nature of two way adjustments.

The regional gross migration optimization technique is intended to minimize the absolute difference between labor force demand and labor force supply by using two derived migration adjustment factors, s_1 and s_2. The gross migration optimization technique is represented as follows:

$$\text{Minimize } \left|\overline{LFS_t} - LFD_t\right|$$

$$\text{Subject To } \overline{LFS_t} = \Sigma_a l_{(a,t)} \overline{P_{(a,t)}}, \quad \text{where } \overline{P_{(a,t)}} = P_{(a,0)} + B_{(a,t-0)} - D_{(a,t-0)} + I_{(a,t-0)} + \overline{N_{(a,t-0)}}$$

$$LFD_t = \frac{1}{(1-\tilde{u}_t)} w_t E_t$$

$$\overline{N_{(a,t-0)}} = \overline{s_1} M_{(a,t-0,in)} - \overline{s_2} M_{(a,t-0,out)} \quad \Leftarrow \forall a$$

$$M_{(a,t-0,in)} = \overline{s_1} r_{(a,0-t,in)} P^{n-r}_{(a,0)} \quad \Leftarrow \forall a$$

$$M_{(a,t-0,out)} = \overline{s_2} r_{(a,0-t,out)} P^{r}_{(a,0)} \quad \Leftarrow \forall a$$

$$\overline{s_1} = \frac{[\Sigma_a (M_{(a,0-t,in)} + M_{(a,0-t,out)}) + (\overline{N_{t-0}} - N_{0-t})]}{\Sigma_a (M_{(a,0-t,in)} + M_{(a,0-t,out)})}$$

$$\overline{s_2} = \frac{[\Sigma_a (M_{(a,0-t,in)} + M_{(a,0-t,out)}) - (\overline{N_{t-0}} - N_{0-t})]}{\Sigma_a (M_{(a,0-t,in)} + M_{(a,0-t,out)})} = 2 - \overline{s_1}$$

$$\overline{N_{t-0}} = \Sigma_a \overline{N_{(a,t-0)}}$$

$$M_{(a,0-t,in)} = r_{(a,0-t,in)} P^{n-r}_{(a,0)} \quad \Leftarrow \forall a$$

$$M_{(a,0-t,out)} = r_{(a,0-t,out)} P^{r}_{(a,0)} \quad \Leftarrow \forall a$$

where (1) the variable with a horizontal bar (¯) will be derived through the optimization

[1] We propose a gross migration optimization technique, an expanded version of the plus-minus method (Judson, D.H., & Popoff, C. L. Popoff, 2004; Klosterman, 1990; U.S. Bureau of the Census 1975), to achieve the balance between labor force supply and demand. The plus-minus method is well known in the field of demography, and is very useful in adjusting distributions with both positive and negative frequencies.

process, (2) the variable with a caret (^), an implied unemployment rate, is subject to change along with scenarios, (3) subscripts 0-t, 0, t, t-0 represent time. 0-t represents the specified period of duration in the past, while t-0 represents the specified period of duration in the future. 0 and t represent the base year and the target year, respectively, (4) a subscript a represents age, sex, and race/ethnicity, (5) $\overline{LFS_t}$ is the labor force supply projection at the target year (*t*), which is determined by the projected population and assumed labor force participation rate (*l*), (6) Population projection during the projection period (*t-0*) is derived by adding births (*B*), subtracting deaths (*D*), adding net international migration (*I*), and adding net domestic migration (*N*), (7) LFD_t represents labor force demand projection at the target year (*t*), which is determined by the projected employment, the assumed worker to job ratio (*w*), and the assumed implied unemployment rate (*u*), (8) $\overline{N_{(a,t-0)}}$ is the regional domestic net migration projections by age-gender-race/ethnicity, (9) $M_{(a,t-0,in)}$ is the regional domestic in-migration projections by age-gender-race/ethnicity, (10) $M_{(a,t-0,out)}$ is the regional domestic out-migration projections by age-gender-race/ethnicity, (11) $r_{(a,0-t,in)}$ is the regional domestic in-migration rate by age-gender-race/ethnicity, observed during the base period, (12) $r_{(a,0-t,out)}$ is the regional domestic out-migration rate by age-gender-race/ethnicity, observed during the base period, (13) $P^{n-r}_{(b,0)}$ is the difference between the age-gender-race/ethnicity specific national population and the age-gender-race/ethnicity specific regional population at the base year 0, (14) $P^{r}_{(b,0)}$ is the age-gender-race/ethnicity specific regional population at the base year 0, (15) $\overline{s_1}$ is the adjustment factor positive net domestic migration values by age-gender-race/ethnicity, (16) $\overline{s_2}$ is the adjustment factor for negative net domestic migration values by age-gender-race/ethnicity, (17) $M_{(b,0-t,in)}$ is the regional domestic in-migration values by age-gender-race/ethnicity, observed during the base period, (18) $M_{(b,0-t,out)}$ is the regional domestic out-migration values by age-gender-race/ethnicity, observed during the base period. The sum of two migration adjustment factors, $\overline{s_1}$ and $\overline{s_2}$, is assumed to be 2, as implied in the plus-minus method.

In addition to its easy application, the gross migration optimization technique also reflects proper demographic process due to gross migration approach and maintains an acceptable range of age/sex distribution and race/ethnic composition of projected in-migrants, out-migrants, and population with different assumptions of base periods and unemployment rates assumptions.

Figure 6 shows a changing pattern of domestic in- and out-migration by age with different unemployment rates as resulted from gross migration optimization process. For example, the higher unemployment rates decrease more in-migration, while they increase more out-migration. Age specific in- and out-migration shows a proportionate effect of unemployment rates on population by age group.

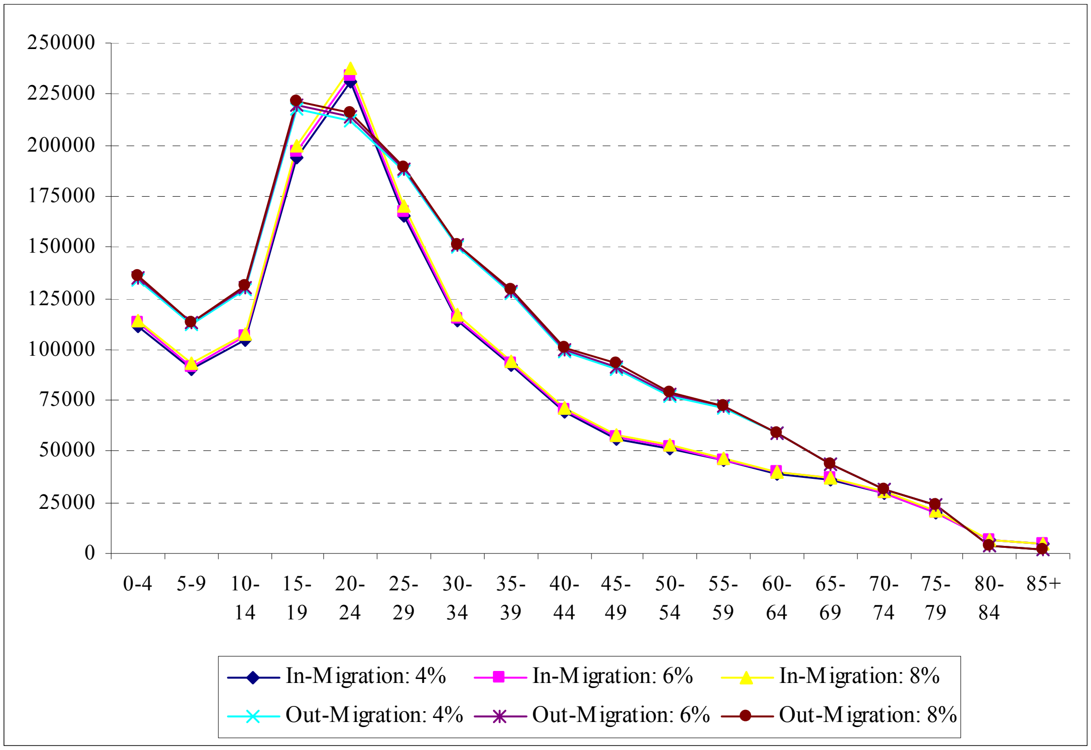


Figure 6 . Adjustment of Domestic In- and Out-Migration with Different Unemployment Rates

This study relies on the Microsoft Excel Solver to determine the changing size of in- and out-migration, given the independently developed employment projections and the implied unemployment rate. The gross migration optimization technique efficiently finds two optimal adjustment factors: one for in-migration and the other for out-migration. Two factors are similar to those of the plus-minus method (Akers and Siegel, 1965), widely used to adjust net migration composed of the positive and negative frequencies.

Table 1 demonstrates the procedure of deriving in- and out-migration by using the gross migration optimization technique. The baseline model, a traditional cohort-component model, can produce net domestic migration (-0.7 million), domestic in-migration (0.9 million), and domestic out-migration (1.6 million) without the introduction of linking with employment forecasts and key economic assumptions. If necessary, we could estimate labor force supply with labor force participation rate. This labor force supply forecast might be used to derive the future optimal employment forecast.

Table 1. Application of Gross Migration Optimization (Example)

	Baseline	Economic-Demographic Model	difference
adjustment factor (1)	1.103	1.658	
adjustment factor (2)	0.897	0.342	
net domestic migration	-701,603	955,231	1,656,834
in-migration	907,712	1,505,214	597,502
out-migration	1,609,316	549,983	-1,059,333
labor force supply	8,182,709	8,950,089	767,380
population projections	18,136,000	19,727,000	1,591,000
labor force demand	n/a	8,950,089	n/a
implied unemployment rate	n/a	5.00%	n/a
workers	n/a	8,502,585	n/a
job to worker ratio	n/a	0.94	n/a
employment projections	n/a	9,012,740	n/a

Note: adjustment factor (1) is for in-migration and adjustment factor (2) is for out-migration.

The economic-demographic model uses a linkage of labor force demand (8.95 million) and labor force supply (8.95 million) with a few additional key assumptions (labor force participation rate, job to worker ratio, implied unemployment rate, independent employment projections), to produce domestic in-migration (1.5 million) and domestic out-migration (550,000). Key assumptions including labor force participation rate, implied unemployment rate (5.0%), job to worker ratio (0.94), and employment projections are generally developed through an independent projection process. Implied unemployment rate are oftentimes set with a certain range (e.g., 5%-7%). Employment projections (9 million) might be adjusted to maintain consistent (not fluctuating) population growth patterns in a long term perspective. Adjustment factor 1 (1.658) for age and sex specific domestic in-migration distribution and adjustment factor 2 (0.342) for age and sex specific domestic out-migration distribution are derived using the gross migration optimization technique. Adjusted age-sex specific in- and out-migration rates for the economic-demographic model are provided in table 2.

Table 2. Age-Sex Specific In- and Out-Migration Rates: Baseline vs. Economic-Demographic Model (Example)

		Baseline				Economic-Demographic Model			
		In-Migration Rates		Out-Migration Rates		In-Migration Rates		Out-Migration Rates	
Age in 2000	Age in 2005	Male	Female	Male	Female	Male	Female	Male	Female
0-4	5-9	0.00372	0.00380	0.08734	0.08431	0.00559	0.00572	0.03329	0.03213
5-9	10-14	0.00295	0.00312	0.07300	0.07218	0.00444	0.00469	0.02782	0.02751
10-14	15-19	0.00355	0.00391	0.08469	0.08785	0.00533	0.00587	0.03228	0.03348
15-19	20-24	0.00745	0.00745	0.15200	0.13933	0.01120	0.01120	0.05793	0.05310
20-24	25-29	0.00982	0.00929	0.14763	0.12870	0.01477	0.01396	0.05626	0.04905
25-29	30-34	0.00754	0.00613	0.12465	0.11299	0.01133	0.00921	0.04751	0.04306
30-34	35-39	0.00516	0.00418	0.10787	0.09355	0.00775	0.00628	0.04111	0.03565
35-39	40-44	0.00381	0.00315	0.08958	0.07652	0.00572	0.00473	0.03414	0.02916
40-44	45-49	0.00299	0.00262	0.07175	0.06566	0.00449	0.00393	0.02734	0.02502
45-49	50-54	0.00258	0.00233	0.06834	0.06926	0.00387	0.00351	0.02604	0.02640
50-54	55-59	0.00231	0.00223	0.07314	0.06860	0.00347	0.00334	0.02788	0.02615
55-59	60-64	0.00206	0.00204	0.07184	0.06809	0.00309	0.00307	0.02738	0.02595
60-64	65-69	0.00200	0.00184	0.06694	0.05691	0.00301	0.00277	0.02551	0.02169
65-69	70-74	0.00174	0.00179	0.05018	0.04590	0.00262	0.00268	0.01912	0.01749
70-74	75-79	0.00152	0.00171	0.04150	0.04499	0.00228	0.00257	0.01582	0.01715
75-79	80-84	0.00139	0.00170	0.04287	0.04832	0.00208	0.00255	0.01634	0.01842
80-84	85+	0.00067	0.00076	0.01084	0.01492	0.00101	0.00114	0.00413	0.00568
85+	85+	0.00043	0.00070	0.00764	0.01404	0.00065	0.00105	0.00291	0.00535

(2) County Model[2]

The regional net domestic migration total is developed into age-gender-race/ethnicity

[2] It should be emphasized that the development process of acceptable county net migration requires strong collaboration between regional demographers and county demographers and planners. They review essential economic and demographic assumptions needed to develop population projections together. The collaboration of regional and county demographers and planners was strengthened by the enactment of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991. The ISTEA emphasized more coordination among local governments, other regional agencies, stakeholders, and citizens during the regional plan preparation process.

The similar collaboration effort is found in developing and updating population projections of all counties in the State of California by California Department of Finance (DOF) Demographic Research Unit (DRU). California DOF DRU released the most recent population projection in April 2004. The California DOF DRU introduced a new method, not a traditional demographic method, for developing net migration assumptions of counties in California during the development of this set of population projections. The California DOF DRU used net migration input from local and regional agencies in developing county net migration assumptions. The annual average of the county net migration assumptions resulting from local input was 186,000 over the 50-year projection horizon (http://www.dof.ca.gov/HTML/DEMOGRAP/ReportsPapers/Projections/P1/P1.asp).

Although the California DOF DRU applies its own developed birth and death rate assumptions, the new method of developing migration helped to keep California DOF DRU county population projections close to population projections by local and regional planning agencies. As a result, the state agency's population projections were more acceptable to local jurisdictions. The approach toward reflecting local input in developing net migration is a professionally retreated, but politically proper initiative of the state demographic agency in the long history of population projection in California. Development of local population projections becomes understood not as a scientific inquiry of the future but as a decision making process of interested parties.

specific gross migration of counties by using two step processes (see figure 5).

The first step is to allocate regional net domestic migration into each county using the county's share of the projected regional domestic net migration. The county's share can be assumed constant or dynamic during the projection period. If assumed constant, the choice of base periods will influence the future countywide distribution of in-migration.

The gross migration optimization technique is to develop county domestic net migration, in particular, adjustment factor 1 (f_1) and adjustment factor 2 (f_2), by using the gross migration optimization technique. The gross migration optimization technique is intended to minimize the absolute difference between the sum of county domestic net migration projections and the desired regional net domestic migration projection, which is the desired sum of county domestic net migration projections by using two derived adjustment factors, f_1 and f_2. The gross migration optimization technique is represented as follows;

$$\text{Minimize } \left| \Sigma_c \overline{N_{t-0}^c} - \overline{N_{t-0}} \right|$$

$$\text{Subject To } \overline{N_{t-0}^c} = \overline{f_1} N_{0-t}^c \text{ , where } \overline{f_1} = \frac{\Sigma_c |N_{0-t}^c| + (\overline{N_{t-0}} - N_{0-t})}{\Sigma_c |N_{0-t}^c|} \text{ , if } N_{0-t}^c > 0$$

$$\overline{N_{t-0}^c} = \overline{f_2} N_{0-t}^c \text{ , where } \overline{f_2} = \frac{\Sigma_c |N_{0-t}^c| - (\overline{N_{t-0}} - N_{0-t})}{\Sigma_c |N_{0-t}^c|} \text{ , if } N_{0-t}^c < 0$$

$$\overline{f_2} = 2 - \overline{f_1}$$

Where $\overline{N_{t-0}^c}$ is the county domestic net migration projection, $\overline{N_{t-0}}$ is the desired regional net domestic migration projection, which is the desired sum of county domestic net migration projections, N_{0-t}^c is the county domestic net migration recognizing signs, observed during the base period, $|N_{0-t}^c|$ is the absolute domestic net migration observed during the base period, N_{0-t} is the observed regional net domestic migration, which is the sum of observed county net domestic migrations during the base period, $\overline{f_1}$ is the adjustment factor for counties with positive net domestic migration values, $\overline{f_2}$ is the adjustment factor for counties with negative net domestic migration values. The sum of two migration adjustment factors, $\overline{f_1}$ and $\overline{f_2}$ is assumed to be 2, as implied in the plus-minus method.

The adjustment factors can be developed using county distribution based on specific base periods for the baseline migration flows. Which base periods to use? The use of different base periods, such as recent five years (2000-2005), recent ten years (1995-2005), or recent fifteen years (1990-2005), would result in a wide range of county gross in- and out-migration as well as county net migration.

Table 3 shows a changing distribution of county net domestic migration with different base periods. Los Angeles county shows a biggest range of domestic net migration

(120,000), while Imperial county shows a smallest range of domestic net migration (9,000).

Table 3. Net Domestic Migration with Different Base Periods (in thousands)

County	Five Year Average (Estimates)			Five Year Average: Projections, 2005-2035			Range of projections
	2000-2005	1995-2005	1990-2005	2000-2005*	1995-2005*	1990-2005*	
Imperial	-1	-7	-3	-3	-11	-4	9
Los Angeles	-251	-337	-515	-445	-519	-564	120
Orange	-50	-20	-44	-89	-31	-49	59
Riverside	260	174	145	60	80	131	72
San Bernardino	125	74	52	29	34	47	18
Ventura	0	-1	-9	0	-1	-10	10
Total	82	-117	-375	-449	-449	-449	0

Note: * base periods

It is worth noting that four counties including Imperial, Los Angeles, Orange, and Ventura counties showed negative net migration flows during the projection period of 2005-2035, while Riverside and San Bernardino counties showed positive net migration flows during the same period. Those migration distribution patterns observed in the selected base periods are expected to remain the same during the projection period.

The question would be how much the domestic net migration flows of each county would be in the future. The county model focuses on how to allocate "regional" net international and domestic migration into counties. The county allocation factors are oftentimes determined using different base periods or average of those base periods. There are no best criteria toward choosing most proper base periods to produce accurate net domestic migration flows. Local input is proposed as a supplemental tool for estimating the future county share of net domestic migration, given the changing nature of historical and projected county share of net domestic migration.

The acceptable allocation of future domestic net migration flows by county might be possible by establishing several assumptions that: 1) the past historical trends of the county net migration are reflected in the future net migration patterns to some degree; 2) the future county net migration is functionally constrained by the region-wide net migration projection; 3) the size of the future county net migration is generally agreed upon by a variety of experts, local and regional planners, elected officials, interested parties, etc.

The second step is to disaggregate county net domestic migration total into age-gender-race/ethnicity specific in- and out-migration using the gross migration optimization technique. The gross migration optimization technique is intended to minimize the absolute difference between the sum of county domestic net migration projections by age-gender-race/ethnicity and the desired county net domestic migration projection total by using two derived adjustment factors, y_1^c and y_2^c. The gross migration optimization technique is represented as follows;

$$\text{Minimize } \left| \Sigma_b \overline{N^c_{(b,\, t-0)}} - \overline{N^c_{t-0}} \right|$$

$$\text{Suject To } \overline{N^c_{(b,\, t-0)}} = M^c_{(b,\, t-0,\, in)} - M^c_{(b,\, t-0,\, out)} \quad \Leftarrow \forall\, b$$

$$M^c_{(b,\, t-0,\, in)} = \overline{y^c_1}\, r^c_{(b,\, 0-t,\, in)} P^{n-c}_{(b,\, 0)} \quad \Leftarrow \forall\, b$$

$$M^c_{(b,\, t-0,\, out)} = \overline{y^c_2}\, r^c_{(b,\, 0-t,\, out)} P^c_{(b,\, 0)} \quad \Leftarrow \forall\, b$$

$$\overline{y^c_1} = \frac{[\Sigma_b (M^c_{(b,\, 0-t,\, in)} + M^c_{(b,\, 0-t,\, out)}) + (\overline{N^c_{t-0}} - N^c_{0-t})]}{\Sigma_b (M^c_{(b,\, 0-t,\, in)} + M^c_{(b,\, 0-t,\, out)})}$$

$$\overline{y^c_2} = \frac{[\Sigma_b (M^c_{(b,\, 0-t,\, in)} + M^c_{(b,\, 0-t,\, out)}) - (\overline{N^c_{t-0}} - N^c_{0-t})]}{\Sigma_b (M^c_{(b,\, 0-t,\, in)} + M^c_{(b,\, 0-t,\, out)})} = 2 - \overline{y^c_1}$$

Where $\overline{N^c_{(b,t-0)}}$ is the county domestic net migration projections by age-gender-race/ethnicity, $\overline{N^r_{t-0}}$ is the desired county net domestic migration projection total, $M^c_{(b,t-0,in)}$ is the county domestic in-migration projections by age-gender-race/ethnicity, $M^c_{(b,t-0,out)}$ is the county domestic out-migration projections by age-gender-race/ethnicity, $r^c_{(b,0-t,in)}$ is the county domestic in-migration rate by age-gender-race/ethnicity, observed during the base period, $r^c_{(b,0-t,out)}$ is the county domestic out-migration rate by age-gender-race/ethnicity, observed during the base period, $P^{n-c}_{(b,0)}$ is the difference between the age-gender-race/ethnicity specific national population and the age-gender-race/ethnicity specific county population at the base year 0, $P^c_{(b,0)}$ is the age-gender-race/ethnicity specific county population at the base year 0, $\overline{y^c_1}$ is the adjustment factor for counties with positive net domestic migration values by age-gender-race/ethnicity, $\overline{y^c_2}$ is the adjustment factor for counties with negative net domestic migration values by age-gender-race/ethnicity, $M^c_{(b,0-t,in)}$ is the county domestic in-migration values by age-gender-race/ethnicity, observed during the base period, $M^c_{(b,0-t,out)}$ is the county domestic out-migration values by age-gender-race/ethnicity, observed during the base period,

The sum of two adjustment factors, $\overline{y^c_1}$ and $\overline{y^c_2}$, is assumed to be 2, as implied in the plus-minus method.

According to the recent migration and unemployment statistics, historical patterns, the relationship between in-migration and unemployment is much weaker than that of out-migration and unemployment rate (see Figure 3), and the variability of regional domestic in-migration is smaller than that of domestic out-migration (see Table 4). The county level variability of in- and out-migration except Los Angeles county is generally small.

Table 4. Variability of Domestic In- and Out-Migration Flows, 1980-2000: SCAG Region and Counties

County	Migration Type	Mean	Standard deviation	Coefficient of variation (%)	Minimum	Maximum	Range
Imperial	In-migration	7116	2468	34.7%	4688	12299	7611
	Out-migration	7446	2528	34.0%	4697	12386	7689
	In/out Ratio*	1.13	0.36	32.1%	0.79	1.91	1.12
Los Angeles	In-migration	187193	21848	11.7%	150613	213545	62932
	Out-migration	281665	39048	13.9%	236223	352472	116249
	In/out Ratio*	0.75	0.06	7.8%	0.66	0.84	0.19
Orange	In-migration	114597	10515	9.2%	97999	130752	32753
	Out-migration	125168	11616	9.3%	107380	151008	43628
	In/out Ratio*	1.04	0.09	8.2%	0.94	1.21	0.27
Riverside	In-migration	76521	15776	20.6%	53220	116286	63066
	Out-migration	54139	11429	21.1%	38873	69274	30401
	In/out Ratio*	1.62	0.25	15.5%	1.32	2.24	0.92
San Bernardino	In-migration	88942	14870	16.7%	72014	119379	47365
	Out-migration	74190	12691	17.1%	58818	98338	39520
	In/out Ratio*	1.37	0.18	13.2%	1.14	1.71	0.57
Ventura	In-migration	34325	3609	10.5%	28953	40640	11687
	Out-migration	33952	3570	10.5%	29244	42235	12991
	In/out Ratio*	1.15	0.08	7.2%	0.96	1.31	0.35
Total	In-migration	508893	48195	9.5%	430798	604382	173584
	Out-migration	576561	70465	12.2%	484820	697501	212681
	In/out Ratio	0.89	0.12	13.5%	0.67	1.06	0.39

Note: * standardized in/out ratio = county in/out ratio / regional in/out ratio
Source: US IRS, County to county migration, 1980-2000.

The model results are evaluated for their reasonableness and consistency using several criteria: 1) the county's relative attractiveness, measured by the ratio of the county's ratio of in-migration to out-migration to the regional ratio of in-migration to out-migration, 2) annual average growth of projected population 3) annual average growth rate of projected population, and 4) projected county share of regional population (See Table 5,6,7).

Table 5. County's Share of Regional Population Projections

County	Estimates, 2000-2005	Projected, 2030-2035			Range of projections
		2000-2005*	1995-2005*	1990-2005*	
Imperial	1%	1%	1%	1%	0%
Los Angeles	56%	52%	50%	49%	4%
Orange	17%	16%	18%	17%	2%
Riverside	11%	13%	14%	15%	2%
San Bernardino	11%	13%	13%	13%	0%
Ventura	4%	5%	5%	5%	0%
Total	100%	100%	100%	100%	

* Base periods

Table 6. County's Share of In- and Out-Migration: Projections with Different Base Periods

County	Estimates, 2000-2005	Projected, 2030-2035			Range of projections
		2000-2005*	1995-2005*	1990-2005*	
	In-Migration				
Imperial	1%	2%	1%	1%	1%
Los Angeles	36%	36%	32%	30%	6%
Orange	18%	18%	22%	21%	4%
Riverside	22%	19%	21%	24%	4%
San Bernardino	17%	17%	17%	18%	1%
Ventura	6%	8%	8%	7%	1%
Total	100%	100%	100%	100%	
	Out-Migration				
Imperial	1%	1%	1%	1%	0%
Los Angeles	49%	46%	45%	45%	1%
Orange	21%	18%	19%	19%	1%
Riverside	10%	15%	15%	16%	1%
San Bernardino	12%	13%	13%	13%	0%
Ventura	6%	7%	6%	6%	0%
Total	100%	100%	100%	100%	

Note: * base periods

Table 7. County's Relative Attractiveness

County	Estimates, 2000-2005	Projected, 2030-2035			Range of projections
		2000-2005*	1995-2005*	1990-2005*	
Imperial	0.90	1.13	0.77	1.08	0.36
Los Angeles	0.73	0.79	0.71	0.66	0.13
Orange	0.86	0.99	1.13	1.09	0.14
Riverside	2.09	1.33	1.39	1.52	0.19
San Bernardino	1.42	1.27	1.30	1.34	0.06
Ventura	0.96	1.20	1.19	1.13	0.07
Total	1.00	1.00	1.00	1.00	

Note: * base periods. standardized relative attractiveness = (county in-migration / county out-migration) / (regional in-migration / regional out-migration)

4. Evaluation of the Model Outcomes

The gross migration optimization model is divided into two models: the regional optimization model and the county optimization model. The model results are compared using different scenarios of migration size and unemployment rates. Other key demographic and economic assumptions needed to run the economic-demographic projection model remain unchanged for different scenarios. Those assumptions include birth rates, survival rates, net international migration, labor force participation rates, and worker to job ratio.

1) Regional Model

Six scenarios (S1-S6) are prepared to understand the implication of different population projections models and of introducing additional economic assumptions (e.g., implied unemployment rates) on migration. Two scenarios (S1 and S2) are based on a traditional cohort-component model. Net domestic migration is developed using the historical trends, and is disaggregated into domestic in- and out-migration using the gross migration optimization method. Two different base periods (1995-2005, 1990-2005) are used to see their impacts on total population projections. Four scenarios (S3 though S6) are based on the economic-demographic model. Net domestic migration, in-, and out-migration are developed using the linkage of migration with employment projections. Unemployment rate plays an important role in determining the size of domestic in- and out-migration. Other key demographic and economic assumptions being equal, high unemployment rate generates more net domestic migration, while low unemployment rate generates less net domestic migration. The gross migration optimization method will be used to develop domestic in- and out-migration. Six scenarios are summarized in the table below. (see table 8)

Table 8. Six Scenarios of Developing Regional Gross Migration Assumptions

Scenario	Model	Net Domestic Migration: Base Period	Unemployment Rate	Key Economic Assumptions
S1	Cohort-Component	1995-2005	n/a	n/a
S2	Cohort-Component	1990-2005	n/a	n/a
S3	Economic-Demographic	n/a	constant at 4%	- Labor force participation rate - Worker to job ratio
S4	Economic-Demographic	n/a	constant at 6%	- Labor force participation rate - Worker to job ratio
S5	Economic-Demographic	n/a	constant at 8%	- Labor force participation rate - Worker to job ratio
S6	Economic-Demographic	n/a	varying at 5%-7%	- Labor force participation rate - Worker to job ratio

As expected, scenarios S1 and S2, as a pure application of the cohort-component model, show a constant amount of net migration during the projection period. The annual net domestic migration of the scenario S1 is -24,000, equivalent to an annual average of 1995-2005, while the annual net domestic migration of the scenario S2 is -75,000, equivalent to an annual average of 1990-2005.

Scenarios S3, S4, and S5 assume a changing size of net domestic migration along with three different unemployment rates: 4%, 6%, and 8%. It is interesting to note that the first five year period shows a wide range of net domestic migration from -134,000 annual net domestic migration of the scenario S3 to -6,000 annual net domestic migration of the scenario S5.

Scenario S6 assumes a changing size of net domestic migration along with different unemployment rate ranging from 5% to 7% during the projection horizon. This scenario emphasizes the reasonable trends in five year population growth during the projection period. The growth rate of population will gradually slow down over time. It does not fluctuate as found in the scenarios S3-S6.

The gross migration optimization technique produced domestic in- and out-migration of the six scenarios (see table 9). All of the six scenarios generate “more” in- and out-migration along with additional population during the projection period. The increasing population size of the region and the rest of the country are reflected in the increasing in- and out-migration size. It also produced an acceptable range of age/sex distribution and race/ethnic composition of projected population along with different scenarios (see figures 7 and 8).

Table 9. Migration Scenarios with Summary Measures of Gross Migration and Population Growth: Estimated (2000-2005) and Projected (2005-2035) (in thousands)

Scenario	2000-2005	2005-2010	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035
Annual Net Domestic Migration							
S1	17	-23	-24	-24	-23	-24	-24
S2	17	-75	-75	-75	-75	-75	-74
S3	17	-134	-104	-104	-78	-74	-62
S4	17	-70	-104	-102	-77	-74	-61
S5	17	-6	-104	-102	-76	-73	-59
S6	17	-54	-87	-103	-95	-102	-97
Annual Domestic In-Migration							
S1	256	257	272	285	298	311	326
S2	256	236	249	259	270	281	293
S3	256	212	234	243	263	275	292
S4	256	238	237	247	266	278	296
S5	256	264	240	250	270	282	300
S6	256	245	245	248	260	267	280
Annual Domestic Out-Migration							
S1	239	280	296	309	321	335	350
S2	239	311	324	334	345	356	367
S3	239	346	338	347	341	349	354
S4	239	308	341	349	343	352	357
S5	239	270	344	352	346	355	359
S6	239	299	332	351	355	369	377
Attractiveness:Ratio of Domestic In-Migration to Domestic Out-Migration							
S1	1.1	0.9	0.9	0.9	0.9	0.9	0.9
S2	1.1	0.8	0.8	0.8	0.8	0.8	0.8
S3	1.1	0.6	0.7	0.7	0.8	0.8	0.8
S4	1.1	0.8	0.7	0.7	0.8	0.8	0.8
S5	1.1	1.0	0.7	0.7	0.8	0.8	0.8
S6	1.1	0.8	0.7	0.7	0.7	0.7	0.7
Annual Average Growth of Population							
S1	314	273	281	285	281	272	262
S2	314	215	219	220	214	204	192
S3	314	150	181	182	204	199	202
S4	314	222	187	187	208	202	206
S5	314	293	192	192	212	205	210
S6	314	239	207	190	190	171	163
Annual Average Growth Rate of Population							
S1	1.9%	1.5%	1.4%	1.4%	1.3%	1.1%	1.0%
S2	1.9%	1.2%	1.1%	1.1%	1.0%	0.9%	0.8%
S3	1.9%	0.8%	1.0%	0.9%	1.0%	0.9%	0.9%
S4	1.9%	1.2%	1.0%	0.9%	1.0%	0.9%	0.9%
S5	1.9%	1.6%	1.0%	0.9%	1.0%	0.9%	0.9%
S6	1.9%	1.3%	1.1%	0.9%	0.9%	0.8%	0.7%

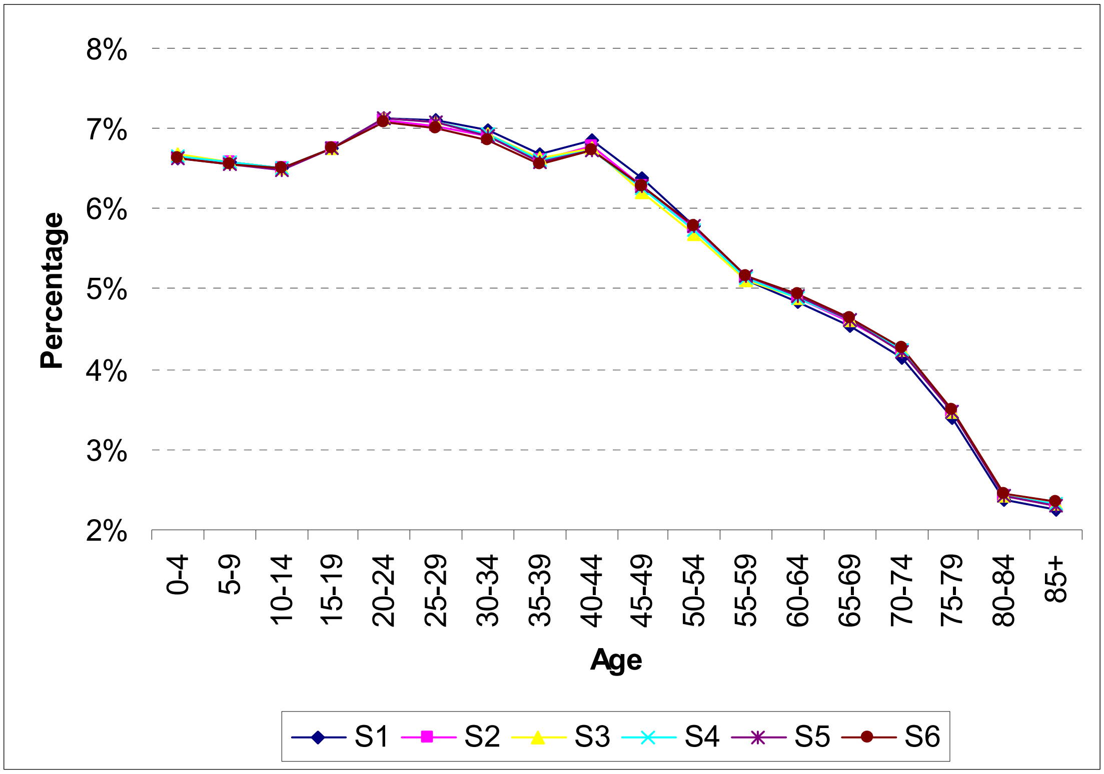


Figure 7. Age Distribution of Regional Population for Year 2035

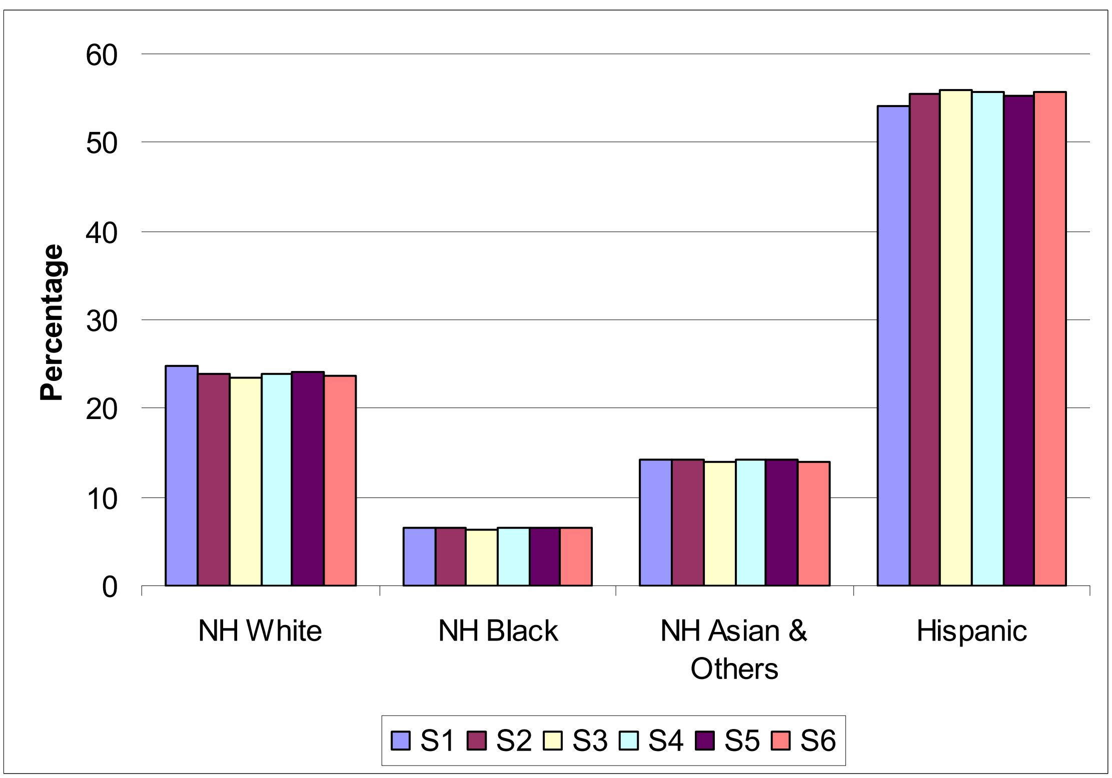


Figure 8. Ethnic Composition of Regional Population for Year 2035

A way of assessing the relationship between domestic in-migration and out-migration is to use the regional attractiveness, measured by the regional domestic in-migration to regional domestic out-migration as an indicator. The relatively high regional attractiveness implies more domestic in-migration than domestic out-migration. In contrast, the relatively low regional attractiveness implies less domestic in-migration than domestic out-migration. All of scenarios show the regional attractiveness of less than 1. The scenario 1 shows the highest attractiveness (0.9), while the scenario S6 shows the lowest attractiveness (0.7). Scenarios from 2 to 6 generally show attractiveness ranging from 0.7 and 0.8.

Another way of assessing migration assumption is to look at the growth patterns of derived population projections. Annual average growth of population and annual average growth rate of population are popularly used indicators for the analysis. Scenario 6, among scenarios, shows a reasonable and consistent pattern of future population growth over time in the long term projection schedule (30 year period). Three major indicators of the scenario 6 show a temporally consistent (monotonous) growth pattern: 1) change of attractiveness from 0.8 (2005-2010) to 0.7 (2030-2035), 2) change of annual average population growth from 239,000 (2005-2010) to 163,000 (2030-2035), and 3) change of annual average growth rate of population from 1.3% (2005-2010) to 0.7% (2030-2035).

The stability of the domestic in- and out-migration can be analyzed to see if the projected pattern is consistent with the historical pattern (see table 10). Scenario S1 and S2 show that in-migration is less stable than out-migration. Scenarios S1, S2, and S3 reflect the changing relationship between in- and out-migration. The higher the unemployment rate, the more varying the out-migration is (or the less varying the in-migration is). Scenario S6, reflecting local input, show more variability of the out-migration than that of in-migration. The coefficient of variation of the in-migration is 5.5%, while the coefficient of variation of out-migration is 8.1%. It is found that unemployment rates assumption influences the variability of in- and out-migration. High unemployment rates assumption affects more out-migration than in-migration, and vice versa.

Table 10. Variability of Projected Regional Domestic In- and Out-Migration Flows, 2005-2035

Scenario	Average	Standard deviation	Coefficient of variation (%)	Minimum	Maximum	Range
Annual Domestic In-Migration						
S1	292	25.4	8.7%	257	326	69
S2	265	21.0	7.9%	236	293	57
S3	253	29.1	11.5%	212	292	80
S4	260	23.8	9.2%	237	296	59
S5	268	21.7	8.1%	240	300	60
S6	258	14.2	5.5%	245	280	35
Annual Domestic Out-Migration						
S1	315	25.6	8.1%	280	350	70
S2	340	20.7	6.1%	311	367	56
S3	346	5.7	1.7%	338	354	16
S4	342	17.5	5.1%	308	357	49
S5	338	33.6	10.0%	270	359	89
S6	347	28.3	8.1%	299	377	78

2) County Model

The county migration assumptions are developed using the top down approach: from the net domestic migration to domestic in- and out-migration. Four scenarios (C1-C4) of domestic net migration by county are prepared to analyze their impacts on in-migration, out-migration, and population projections. Three scenarios (C1, C2, and C3) of net domestic migration are based on the county growth distribution using three different base periods (2000-2005, 1995-2005, 1990-2005).

The scenario C4 of net domestic migration is developed considering both the past historical trends of growth distribution and local input. The future relative attractiveness of each county is hard to measure due to uncertain economic and other opportunities of each county. Local demographers and planners provide input about each county's future growth potentials. This local input is considered as one of criteria measuring the future relative attractiveness of the county.

The regional net migration was allocated to counties using four different distributions (three different base periods and local input) through the plus-minus method. As a result, the annual average of net migration of four scenarios for 2005-2035 ranges from -2,000 to -1,000 (Imperial), from -113,000 to -89,000 (Los Angeles), from -23,000 to -6,000 (Orange), from 12,000 to 26,000 (Riverside), from 6,000 to 9,000 (San Bernardino), and from -4,000 to 0 (Ventura). (see table 11). The net migration assumptions of the scenario C4 reflects how the future migration and population growth are perceived by local input. Riverside county (22,000) maintains the fast growth of net migration, and Los Angeles (-96,000) and Imperial (-1,000) counties show the relatively small amount of negative net migration, given the historical patterns. San Bernardino county (6,000) reflects the slow growth of net migration, and Orange (-23,000) and Ventura (-4,000) counties show the relatively large amount of negative net migration, given the historical patterns.

Table 11. County Net Domestic Migration Scenarios: Estimated (2000-2005) and Projected (2005-2035) (annual average in thousands)

Scenario	2000-2005	2005-2010	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035
Imperial							
C1	0	0	-1	-1	-1	-1	-1
C2	0	-2	-2	-2	-2	-2	-2
C3	0	-1	-1	-1	-1	-1	-1
C4	0	-1	-1	-1	-1	-1	-1
Los Angeles							
C1	-50	-76	-88	-94	-91	-93	-92
C2	-50	-84	-103	-111	-107	-111	-108
C3	-50	-89	-111	-121	-117	-121	-118
C4	-50	-99	-101	-99	-97	-93	-89
Orange							
C1	-10	-15	-18	-19	-18	-19	-18
C2	-10	-5	-6	-7	-6	-7	-6
C3	-10	-8	-10	-10	-10	-10	-10
C4	-10	-4	-17	-23	-30	-32	-30
Riverside							
C1	52	26	13	7	10	7	9
C2	52	26	17	12	14	12	14
C3	52	33	27	24	25	24	25
C4	52	31	25	22	21	17	14
San Bernardino							
C1	25	12	6	3	5	3	4
C2	25	11	7	5	6	5	6
C3	25	12	10	9	9	9	9
C4	25	10	5	5	5	6	6
Ventura							
C1	0	0	0	0	0	0	0
C2	0	0	0	0	0	0	0
C3	0	-2	-2	-2	-2	-2	-2
C4	0	-3	-4	-4	-5	-5	-4

Variations of coefficients of both domestic in-migration and domestic out-migration indicate moderately strong correlation (0.775). This implies that the county with domestic in-migration of high variation of coefficients tends to show domestic out-migration with high variation of coefficients. The projected county domestic in- and out-migration show much smaller variation of coefficients during the projection period than the historical county domestic in- and out-migration pattern between 1980 and 1999 (see tables 12 and 13). The variation of coefficients of projected county domestic in-migration is generally smaller than that of projected county domestic out-migration. 75% of 24 cases (four scenarios for six counties) show higher variation of coefficients of domestic out-migration than that of domestic in-migration. The average coefficient of variation of the in-migration is 7%, while the coefficient of variation of out-migration is 8.5%. This is consistent with historical variation of coefficients of both domestic in-migration and domestic out-migration.

Table 12. Variability of Projected Domestic In-Migration Flows by County, 2005-2035 (in thousands)

Scenario	Average	Standard deviation	Coefficient of variation (%)	Minimum	Maximum	Range
Imperial						
C1	6	1.18	19.3%	5	8	3
C2	4	0.38	10.6%	3	4	1
C3	6	1.02	17.8%	4	7	3
C4	5	0.78	14.6%	4	6	2
Los Angeles						
C1	162	6.82	4.2%	155	172	17
C2	149	3.02	2.0%	145	153	8
C3	142	3.46	2.4%	138	148	10
C4	154	9.85	6.4%	143	169	26
Orange						
C1	85	2.39	2.8%	81	88	6
C2	98	6.02	6.1%	90	106	16
C3	94	4.87	5.2%	87	100	13
C4	81	6.23	7.7%	75	90	16
Riverside						
C1	86	4.50	5.2%	81	93	12
C2	90	5.91	6.5%	85	100	15
C3	103	9.51	9.3%	92	117	25
C4	98	5.78	5.9%	90	105	15
San Bernardino						
C1	76	2.76	3.6%	73	80	7
C2	77	3.44	4.5%	73	81	8
C3	80	4.71	5.9%	74	85	12
C4	75	3.77	5.0%	71	80	9
Ventura						
C1	34	2.71	7.9%	30	38	7
C2	34	2.62	7.7%	30	37	7
C3	31	1.78	5.7%	29	34	5
C4	28	0.67	2.4%	27	29	2

Table 13. Variability of Projected Domestic Out-Migration Flows by County, 2005-2035 (in thousands)

Scenario	Average	Standard deviation	Coefficient of variation (%)	Minimum	Maximum	Range
Imperial						
C1	7	1.21	18.2%	5	8	3
C2	6	0.53	9.1%	5	6	1
C3	6	1.08	16.7%	5	8	3
C4	6	0.99	15.5%	5	8	3
Los Angeles						
C1	251	11.86	4.7%	231	264	33
C2	253	9.74	3.9%	235	261	26
C3	255	9.63	3.8%	237	262	25
C4	251	5.97	2.4%	241	258	17
Orange						
C1	102	3.49	3.4%	97	106	10
C2	104	6.48	6.2%	95	112	18
C3	104	5.60	5.4%	95	111	15
C4	103	4.77	4.6%	94	107	13
Riverside						
C1	74	8.64	11.7%	60	84	24
C2	74	9.42	12.7%	60	86	26
C3	76	12.00	15.7%	59	92	33
C4	76	11.66	15.3%	59	91	32
San Bernardino						
C1	70	5.18	7.4%	62	75	14
C2	70	5.13	7.3%	62	75	13
C3	70	5.68	8.1%	62	77	15
C4	70	4.66	6.7%	62	74	12
Ventura						
C1	34	2.71	7.9%	30	38	7
C2	34	2.64	7.7%	30	37	7
C3	33	1.96	5.9%	30	36	5
C4	32	1.14	3.5%	30	33	3

The county's relative attractiveness is a good measure of measuring a relative gross migration pattern of each county. Different base periods generate the range of each county's relative attractiveness during the projection period. For example, the relative attractiveness of the Riverside county for 2030-2035, a rapidly growing county in the region, ranges from 1.33 to 1.52, depending on which base periods to use. In contrast, Los Angeles county for 2030-2035 maintains stable relative attractiveness between 0.68 and 0.76. Table 14 shows a range of relative attractiveness of each county.
For each scenario during the projection period (see table 14).

Table 14. County's Relative Attractiveness: Estimated (2000-2005) and Projected (2005-2035)

Scenario	2000-2005	2005-2010	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035
Imperial							
C1	0.9	1.0	1.1	1.1	1.1	1.1	1.1
C2	0.9	0.7	0.7	0.7	0.7	0.8	0.8
C3	0.9	1.0	1.0	1.1	1.1	1.1	1.1
C4	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Los Angeles							
C1	0.7	0.8	0.8	0.8	0.8	0.8	0.8
C2	0.7	0.7	0.7	0.7	0.7	0.7	0.7
C3	0.7	0.7	0.7	0.7	0.7	0.7	0.7
C4	0.7	0.7	0.7	0.7	0.8	0.8	0.8
Orange							
C1	0.9	0.9	1.0	1.0	1.0	1.0	1.0
C2	0.9	1.1	1.1	1.2	1.1	1.1	1.1
C3	0.9	1.0	1.1	1.1	1.1	1.1	1.1
C4	0.9	1.1	1.0	1.0	0.9	0.9	0.9
Riverside							
C1	2.1	1.6	1.4	1.4	1.4	1.3	1.3
C2	2.1	1.6	1.5	1.4	1.4	1.4	1.4
C3	2.1	1.8	1.7	1.6	1.6	1.6	1.5
C4	2.1	1.7	1.7	1.6	1.6	1.5	1.4
San Bernardino							
C1	1.4	1.3	1.3	1.3	1.3	1.3	1.3
C2	1.4	1.3	1.3	1.3	1.3	1.3	1.3
C3	1.4	1.3	1.4	1.4	1.4	1.4	1.3
C4	1.4	1.3	1.3	1.3	1.3	1.3	1.3
Ventura							
C1	1.0	1.1	1.2	1.2	1.2	1.2	1.2
C2	1.0	1.1	1.2	1.2	1.2	1.2	1.2
C3	1.0	1.1	1.1	1.2	1.1	1.1	1.1
C4	1.0	1.0	1.1	1.1	1.1	1.1	1.1

In addition to relative attractiveness, three other indicators including 1) annual average growth of population (see table 15), 2) annual average growth rate of population (see table 16), and 3) the county share of regional population (figure 9 and table 17) are also useful indicators in assessing population projections resulting from different domestic migration assumptions. An interesting example is Orange county. According to figure 9, the scenario C3 for Orange county shows a linear growth of the county share during the projection horizon, while C4 and DOF projections for Orange county show logistic growth curves of the county share during the projection horizon.

Table 15. County Population Growth: Estimated (2000-2005) and Projected (2005-2035) (annual average in thousands)

Scenario	2000-2005	2005-2010	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035
Imperial							
C1	4	4	5	5	5	5	5
C2	4	3	3	2	2	2	2
C3	4	4	4	4	4	4	4
C4	4	4	4	4	4	4	4
Los Angeles							
C1	128	100	87	80	78	68	63
C2	128	87	65	53	52	40	35
C3	128	85	60	46	45	32	27
C4	128	75	71	70	67	65	63
Orange							
C1	40	33	30	29	28	25	23
C2	40	43	42	42	42	40	38
C3	40	40	39	38	37	35	33
C4	40	45	31	24	15	9	8
Riverside							
C1	76	52	41	36	38	35	36
C2	76	52	45	41	43	41	42
C3	76	59	56	54	56	55	56
C4	76	57	54	52	51	46	43
San Bernardino							
C1	52	41	36	34	34	33	33
C2	52	39	37	35	35	34	35
C3	52	40	39	38	39	38	38
C4	52	38	33	34	33	34	34
Ventura							
C1	12	12	12	12	12	11	11
C2	12	12	12	12	12	11	11
C3	12	10	10	10	9	9	8
C4	12	9	8	7	6	5	5

Table 16. County Population Growth Rate: Estimated (2000-2005) and Projected (2005-2035) (annual average)

Scenario	2000-2005	2005-2010	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035
Imperial							
C1	3.0%	2.6%	2.4%	2.2%	2.0%	1.8%	1.7%
C2	3.0%	1.7%	1.4%	1.2%	1.1%	1.0%	1.0%
C3	3.0%	2.5%	2.2%	2.0%	1.8%	1.7%	1.6%
C4	3.0%	2.4%	2.1%	1.9%	1.7%	1.5%	1.4%
Los Angeles							
C1	1.3%	1.0%	0.8%	0.7%	0.7%	0.6%	0.5%
C2	1.3%	0.8%	0.6%	0.5%	0.5%	0.3%	0.3%
C3	1.3%	0.8%	0.6%	0.4%	0.4%	0.3%	0.2%
C4	1.3%	0.7%	0.7%	0.6%	0.6%	0.6%	0.5%
Orange							
C1	1.4%	1.1%	0.9%	0.8%	0.8%	0.7%	0.6%
C2	1.4%	1.4%	1.3%	1.2%	1.1%	1.0%	0.9%
C3	1.4%	1.3%	1.2%	1.1%	1.0%	0.9%	0.8%
C4	1.4%	1.5%	1.0%	0.7%	0.4%	0.3%	0.2%
Riverside							
C1	4.9%	2.7%	1.9%	1.5%	1.5%	1.2%	1.2%
C2	4.9%	2.7%	2.0%	1.7%	1.6%	1.4%	1.4%
C3	4.9%	3.1%	2.5%	2.1%	2.0%	1.8%	1.7%
C4	4.9%	2.9%	2.4%	2.1%	1.8%	1.5%	1.3%
San Bernardino							
C1	3.0%	2.1%	1.7%	1.4%	1.3%	1.2%	1.1%
C2	3.0%	2.0%	1.7%	1.5%	1.4%	1.2%	1.2%
C3	3.0%	2.0%	1.8%	1.6%	1.5%	1.4%	1.3%
C4	3.0%	1.9%	1.5%	1.4%	1.3%	1.2%	1.2%
Ventura							
C1	1.6%	1.5%	1.4%	1.3%	1.2%	1.1%	1.0%
C2	1.6%	1.5%	1.4%	1.3%	1.2%	1.0%	0.9%
C3	1.6%	1.3%	1.2%	1.1%	1.0%	0.8%	0.8%
C4	1.6%	1.1%	0.9%	0.8%	0.7%	0.5%	0.5%

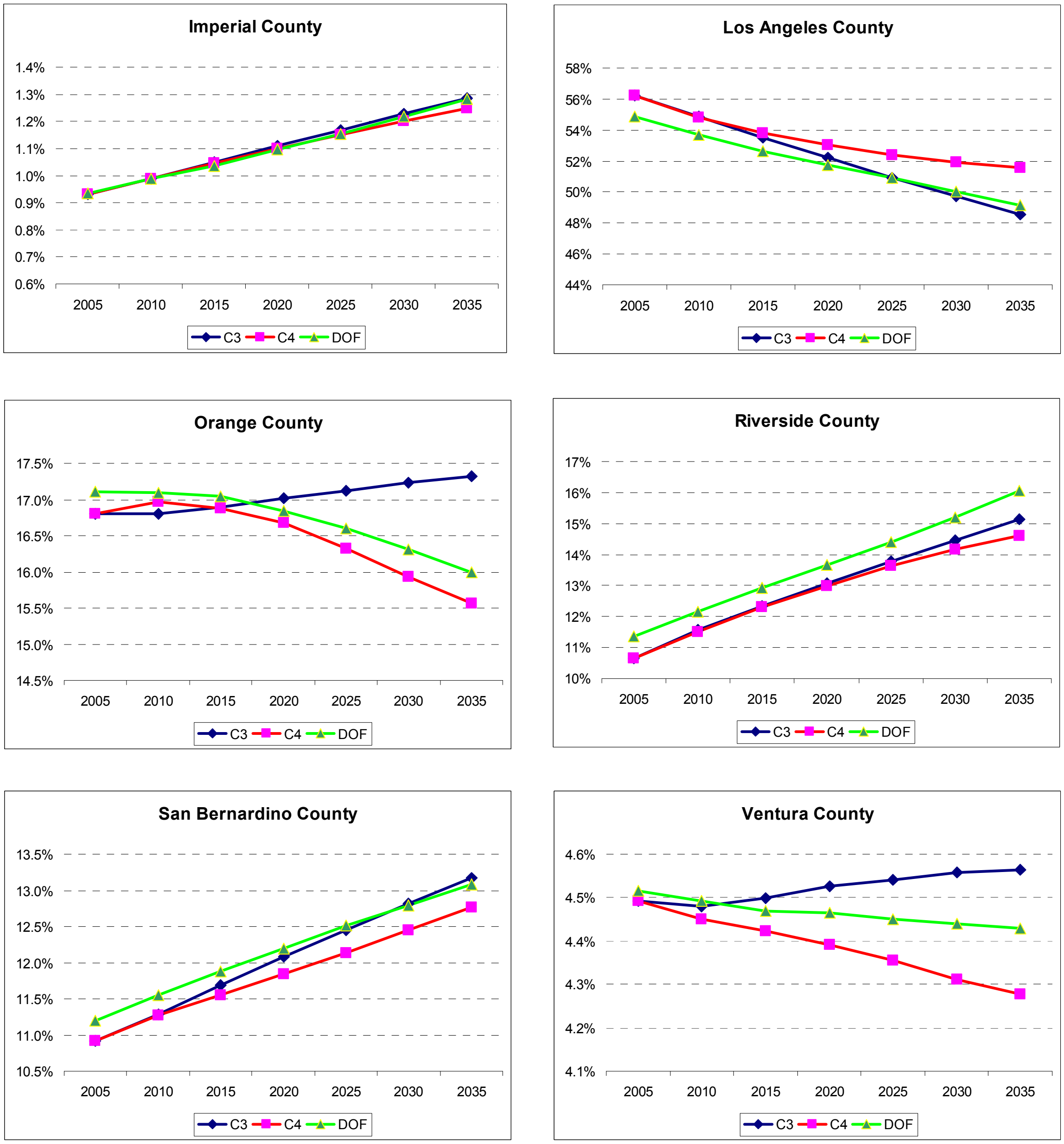


Figure 9. County Share of Regional Population: Scenario C3, Scenario C4, and CA DOF Population Projections (2004)

Table 17. County Share of Regional Population: Estimated (2005) and Projected (2010-2035)

Scenario	2005	2010	2015	2020	2025	2030	2035
Imperial							
C1	0.9%	1.0%	1.1%	1.1%	1.2%	1.3%	1.3%
C2	0.9%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
C3	0.9%	1.0%	1.1%	1.1%	1.2%	1.2%	1.3%
C4	0.9%	1.0%	1.0%	1.1%	1.2%	1.2%	1.2%
Los Angeles							
C1	56.2%	55.2%	54.5%	53.8%	53.2%	52.6%	52.1%
C2	56.2%	55.0%	53.8%	52.7%	51.6%	50.6%	49.6%
C3	56.2%	54.9%	53.5%	52.2%	50.9%	49.7%	48.5%
C4	56.2%	54.8%	53.8%	53.0%	52.4%	51.9%	51.5%
Orange							
C1	16.8%	16.6%	16.5%	16.4%	16.3%	16.2%	16.1%
C2	16.8%	16.9%	17.1%	17.3%	17.5%	17.7%	17.9%
C3	16.8%	16.8%	16.9%	17.0%	17.1%	17.2%	17.3%
C4	16.8%	17.0%	16.9%	16.7%	16.3%	15.9%	15.6%
Riverside							
C1	10.7%	11.4%	11.8%	12.1%	12.4%	12.7%	13.0%
C2	10.7%	11.4%	11.9%	12.4%	12.8%	13.2%	13.7%
C3	10.7%	11.6%	12.3%	13.1%	13.8%	14.5%	15.1%
C4	10.7%	11.5%	12.3%	13.0%	13.6%	14.2%	14.6%
San Bernardino							
C1	10.9%	11.3%	11.6%	11.9%	12.2%	12.4%	12.7%
C2	10.9%	11.3%	11.6%	12.0%	12.3%	12.6%	12.9%
C3	10.9%	11.3%	11.7%	12.1%	12.4%	12.8%	13.2%
C4	10.9%	11.3%	11.5%	11.8%	12.1%	12.4%	12.8%
Ventura							
C1	4.5%	4.5%	4.6%	4.7%	4.7%	4.8%	4.8%
C2	4.5%	4.5%	4.6%	4.7%	4.7%	4.8%	4.9%
C3	4.5%	4.5%	4.5%	4.5%	4.5%	4.6%	4.6%
C4	4.5%	4.5%	4.4%	4.4%	4.4%	4.3%	4.3%

5. Conclusion

Gross migration approach has been found to produce more adequate population projections than net migration approach for several reasons. This study proposes a gross migration optimization technique to develop gross migration assumptions for population projections of multiple counties in the Southern California region.

The gross migration optimization technique was used to develop the Southern California multi-county population projection in an economic-demographic forecast framework. Using a two-region gross migration model, several regional and county migration scenarios produced a wide range of regional and multi-county population projections. The four major indicators including the county's relative attractiveness, annual average growth of population, annual average growth rate of population, and county share of regional population are suggested to assess regional and multi-county population projections.

The gross migration optimization technique successfully optimized the size of regional in-migration and out-migration to achieve the balance between labor force demand and labor force supply at the regional level. The gross migration optimization technique effectively allocated the regional domestic migration into county net domestic migration and further disaggregated the county net migration into domestic in-migration and out-migration. The gross migration optimization technique could maintain the baseline demographic characteristics of domestic in-migrants, domestic out-migrants, and the resulting population. Gross migration approach can be recommended for the proper reflection of migration processes and its easy applicability.

There are future research needs to improve the gross migration approach. First, the region-county gross migration framework needs to find a better way of reflecting the "changing" county allocation of the regional net migration. Local input was proposed as a supplemental tool for estimating the relative attractiveness of the destination area, given the changing nature of the county allocation of net domestic migration. Efforts to properly translate local input into county share of net domestic migration might be needed.

Second, gross migration approach in a region-county migration modeling framework needs to convert county domestic net migration into county domestic in- and out-migration. We assume that this conversion process would reflect demographic processes better than net migration approach with no in- and out-migration information. This can be generalized by applying the gross migration optimization technique to other large metropolitan areas and assessing the model results.

Third, baseline gross migration schedules by demographic characteristics (e.g., age, sex, and race/ethnicity) are assumed to remain fixed during the projection period. The migration schedules are expected to change over time, as observed in the past and recent empirical analysis.(Rogers & Castro, 1981; Rogers and Watkins, 1987; Raymer & Rogers, 2006). The changing migration schedules might reflect the better demographic process along with projected gross migration patterns.

Fourth and last, gross migration approach could be used to understand and influence the current and future urban growth pattern (e.g., sprawl). The changing demographic characteristics of projected in- and out-migrants could be used to understand and meet community needs (e.g., apartment development for increasing younger in-migrants). The gross migration approach, in particular, multi-regional migration approach, might tell us more about demographic characteristics of origin-destination specific domestic in- and out-migrants in the region.

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