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Integrating Demographic Microsimulator (DEMOS) into Regional Planning: Insights from SCAG

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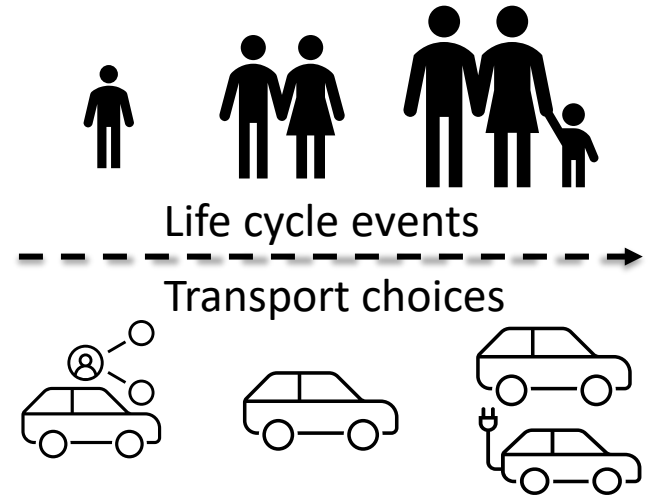
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Background and Need

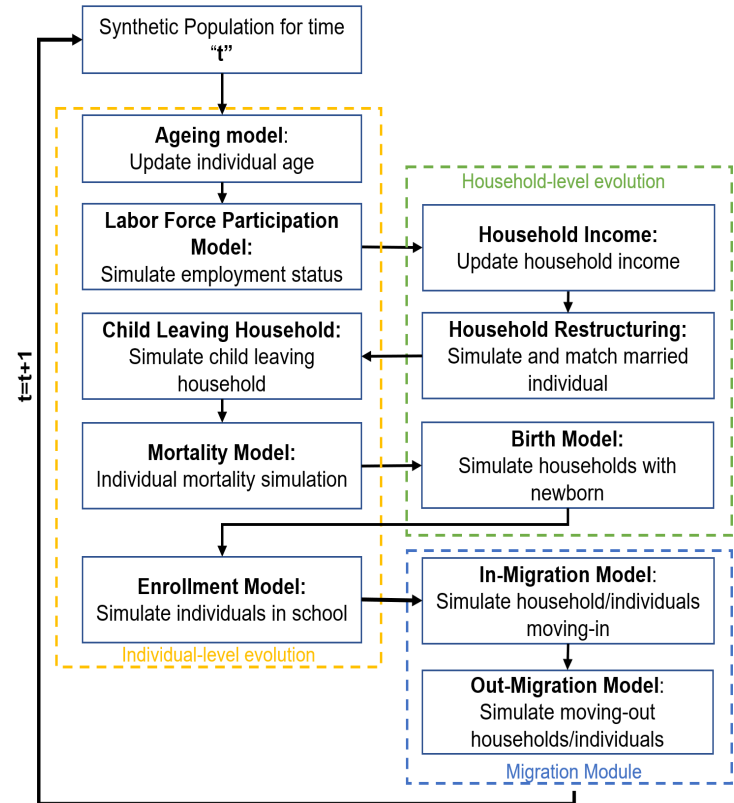
- Travel demand forecasting models often rely on **cross-sectional (or slice in time) synthetic population** information to forecast travel demand and evaluate transportation policies.
- **Timing and sequence of life cycle events** are found to have a significant impact on peoples' travel-related decisions.
- Existing population evolution models have limitations:
 - Developed from cross-sectional data (do not reflect sequence of life cycle events).
 - Based on panel dataset but do not cover all demographic events or capture more complicated interrelationships.
- The Panel Study of Income Dynamics (PSID) is a panel dataset covering a wide range of socioeconomic and demographic data



- Jin et al. (2020) highlighted the role of life cycle events (e.g., **getting married, becoming employed, having a newborn**) on **mode usage patterns**.
- Scheiner and Holz-Rau (2013) show that a **newborn** may change the household maintenance tasks and increase both **car acquisition probability and vehicle use**.

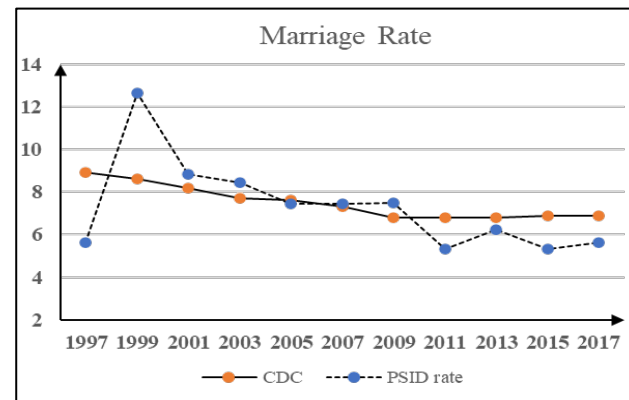
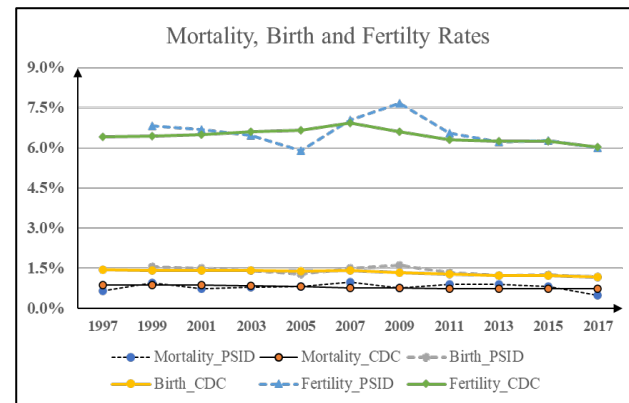
Demographic Microsimulator (DEMOS)

- Proposed an advanced dynamic **DEMOS** that captures the interdependencies between short-term and long-term life cycle events.
- Initiated with a baseline year (t) synthetic population and advances individuals and households through a host of life cycle events.
- Household- and individual-level characteristics are updated and provided as inputs to subsequent year's ($t + 1$) population evolution.



Panel Study of Income Dynamics (PSID)

- Longitudinal, long-running survey (1968-present)
- Wide range of socioeconomic, demographic, health, and attitudinal characteristics
- The dataset used for this study was from year 1997-2017
- High quality data
 - Matching CDC patterns for key lifecycle events (mortality, birth, marriage)



Model Specification and Calibration Approach

Model Outcome Predictors

Individual Level Models

Household Level Models

Exogenous Attributes	Individual Level Models				Household Level Models			Birth	
	Mortality	Education Enrollment	Leaving Parental Home	Labor Force Participation		Household Restructuring			
				Employed-to-X	Unemployed-to-X	Single-to-X	Cohabitate-to X	Married-to-X	
Gender	✓		✓	✓	✓	✓			
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓
Employment Status	✓	✓	✓			✓			
Education Attainment	✓	✓	✓	✓	✓	✓	✓	✓	
Marital Status	✓	✓							
Number of Workers								✓	
Household Size									✓
Household Head Race			✓	✓	✓	✓	✓	✓	✓
Household Income							✓		
Interaction of Employment and Age			✓						
Interaction of Education and Age			✓						

Flexible Calibration Approach

Flexible calibration approach to allow for transferability of the model to different geographical contexts

Individual model calibration

- Calibrating ASC within each simulation run
- Used in models with data on observed outcome each year
- E.g., Birth and Mortality Model: projecting the births and deaths, and calibrating with the yearly birth and mortality statistics from census records

Simultaneous model system calibration

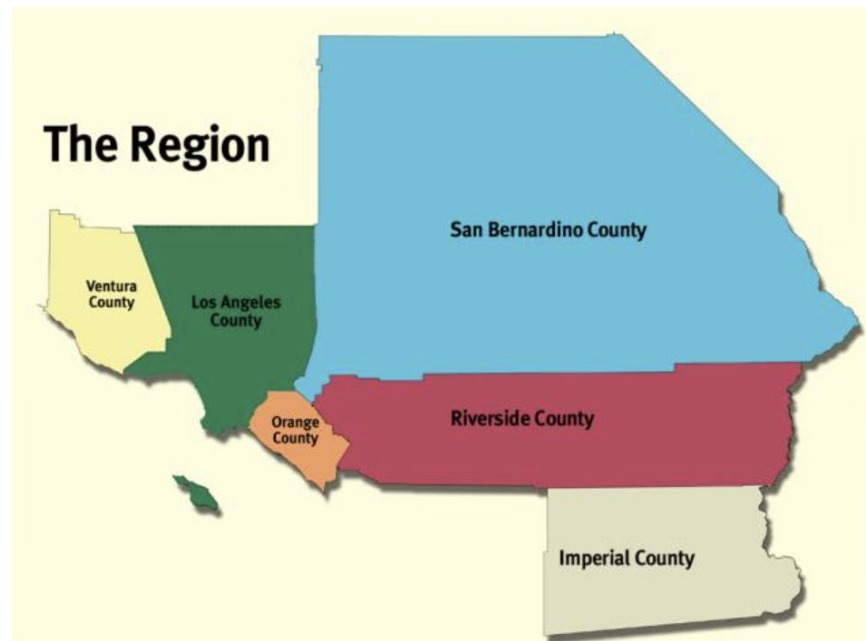
- Calibrating ASC to match predicted distribution of observed distribution of outcome
- Used when data on detailed outcome distribution is not available
- E.g., household restructuring models: projecting the **transitions** between marital statuses, and calibrating with the yearly statistics on marital status from census records

ASC= Alternative Specific Constant

DEMOS Deployment in SCAG Region: Insights and Results

SCAG Region

- **Timeline:**
 - 2019 to 2050
- **Input (Baseline) population:**
Approx. 18.2M individuals and
6.5M households generated by synthetic
population



Source: https://ops.fhwa.dot.gov/freight/detroit/appendix/appendix_d/scag.htm

Automating Data Integration & Filling Input Data Gaps

- DEMOS evolved from a manual setup → to a scalable, automated pipeline that can adapt to diverse MPO datasets and handle missing or inconsistent inputs.

Synthetic Population

- **Challenge:** SCAG-provided data wasn't in a DEMOS-ready format.
- **Solution:** Built an automated pre-processing script.

Variable Group	Examples
Demographics	Education, Age, Race
Socioeconomics	Person Income
Household Structure	Relationship to Reference Person, Household Size
Status Flags	Worker, Student, Hispanic

Marginal Control

- **Challenge:** Some key variables only available every 5 years → gap for annual calibration
- **Solution:** Developed an interpolation method to generate reliable control totals for in-between years.

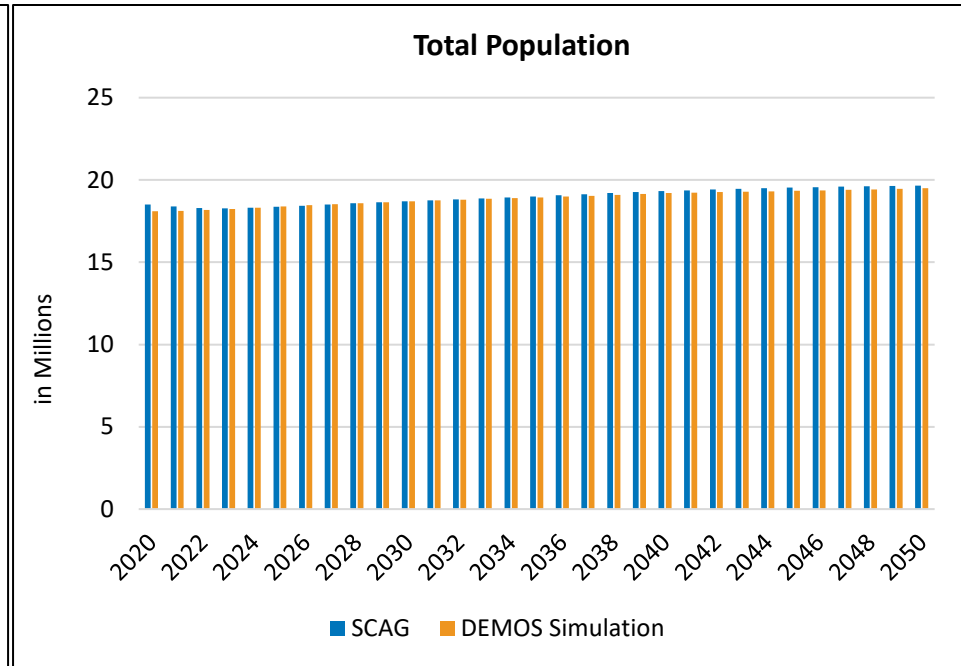
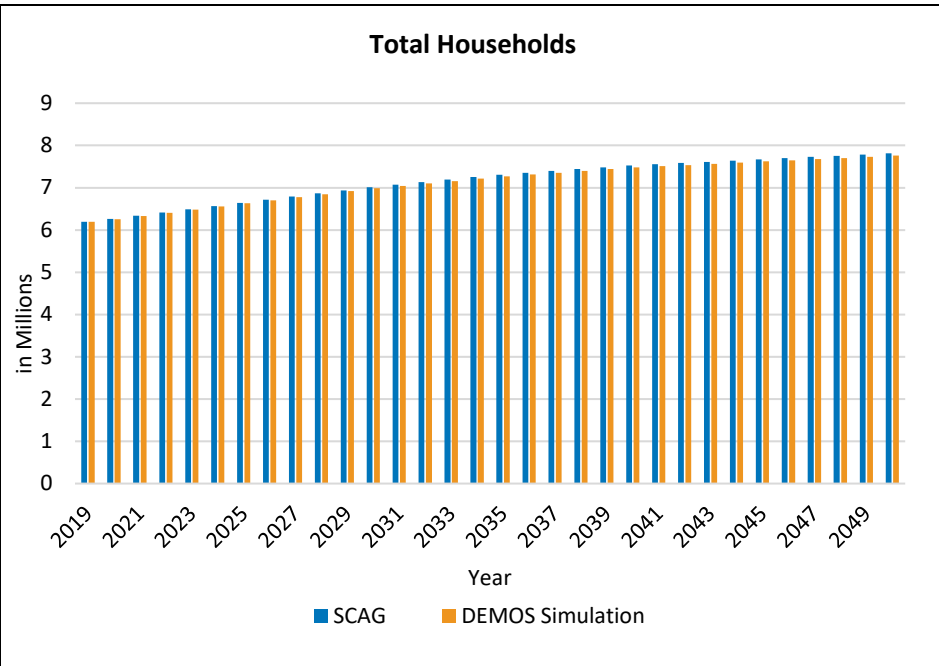
Variable Group	Examples
Vital Stats	Births, Mortality
Households	Household counts by size
Population & School	Total population, K–12 enrollment
Economics	Income growth, Employment transitions

DEMOS Simulation Results and Computational Performance Metrics

Baseline year 2019, simulated through year 2050

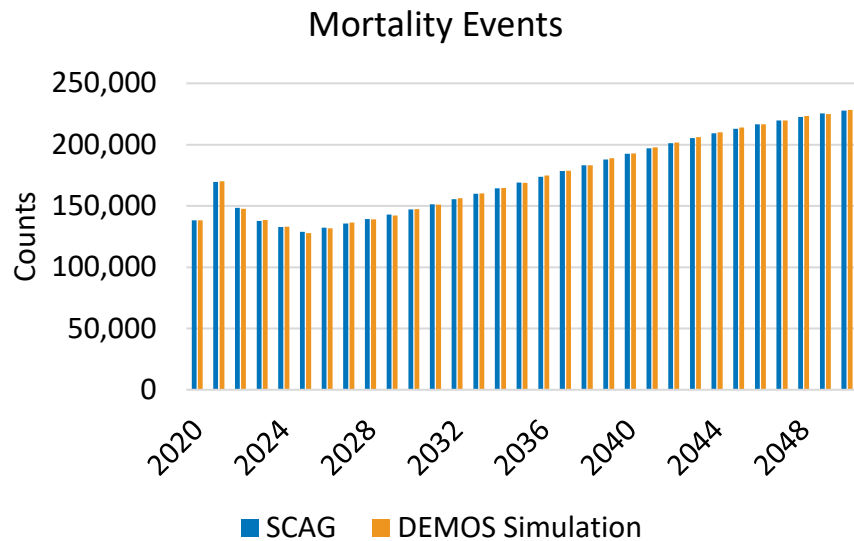
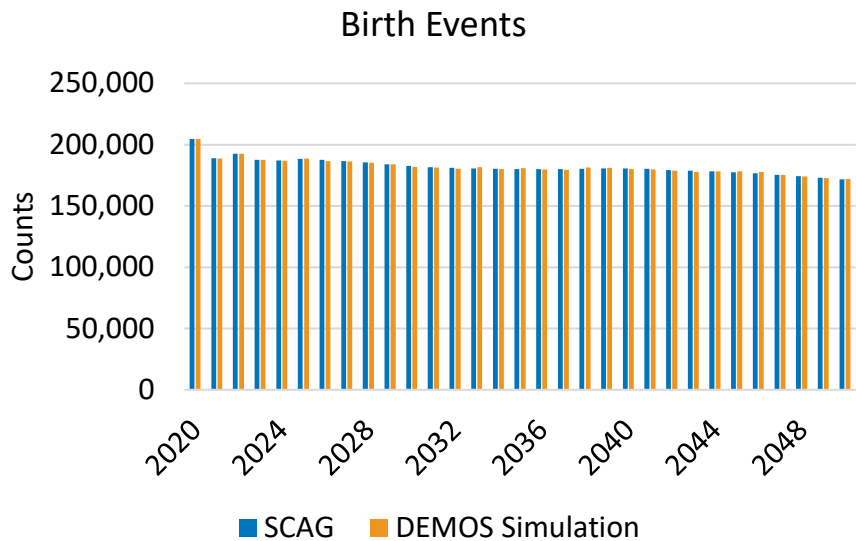
DEMOS Simulation Results: Total Households and Population

- DEMOS closely tracks SCAG forecasts, with slightly higher growth after the mid-2030s.
- DEMOS can be reliably used for scenario testing, policy evaluation, and linking demographic shifts to energy, transportation, housing prices, and land-use outcomes.

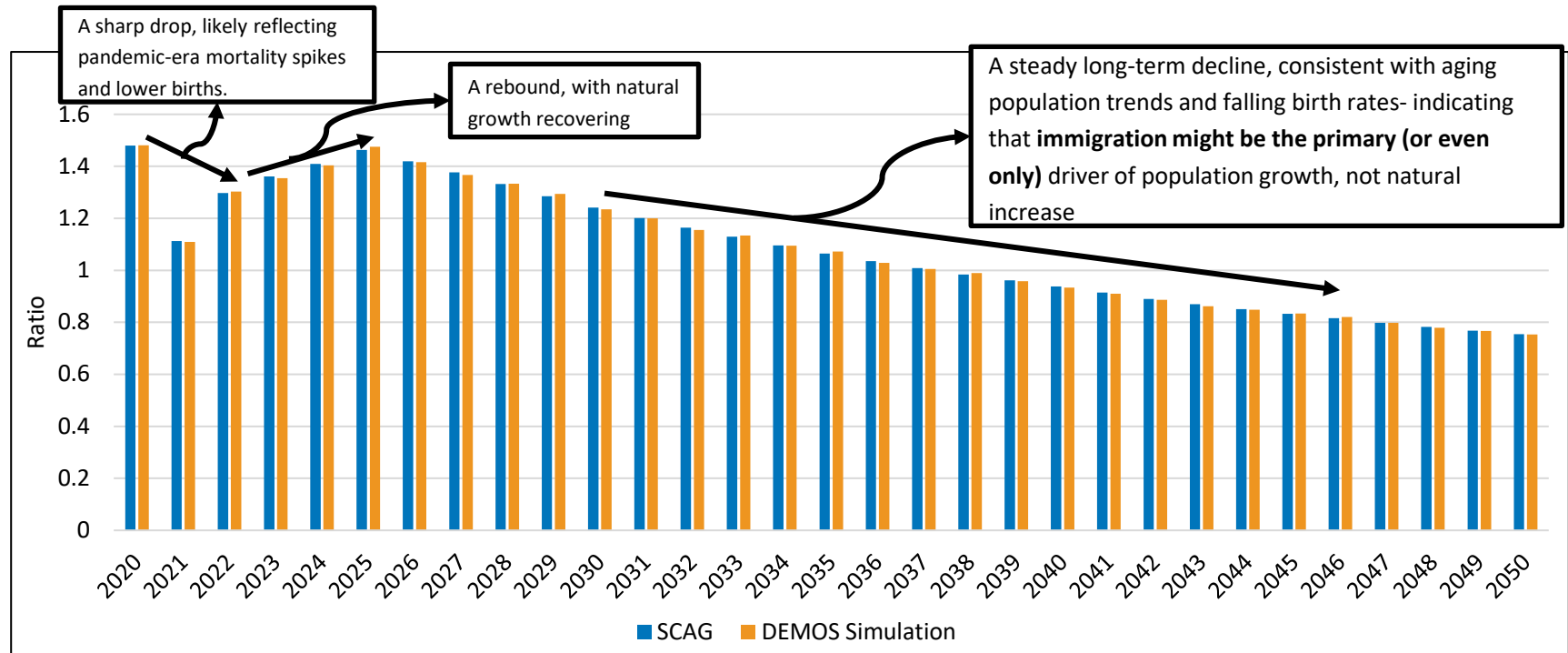


DEMOS Simulation Results: Total Birth and Mortality Events

- Declining births and rising mortality point to an aging population story, increasing dependence on migration and long-term implications for housing demand, mobility patterns and workforce availability—DEMOS aligns closely with SCAG in capturing these dynamics.



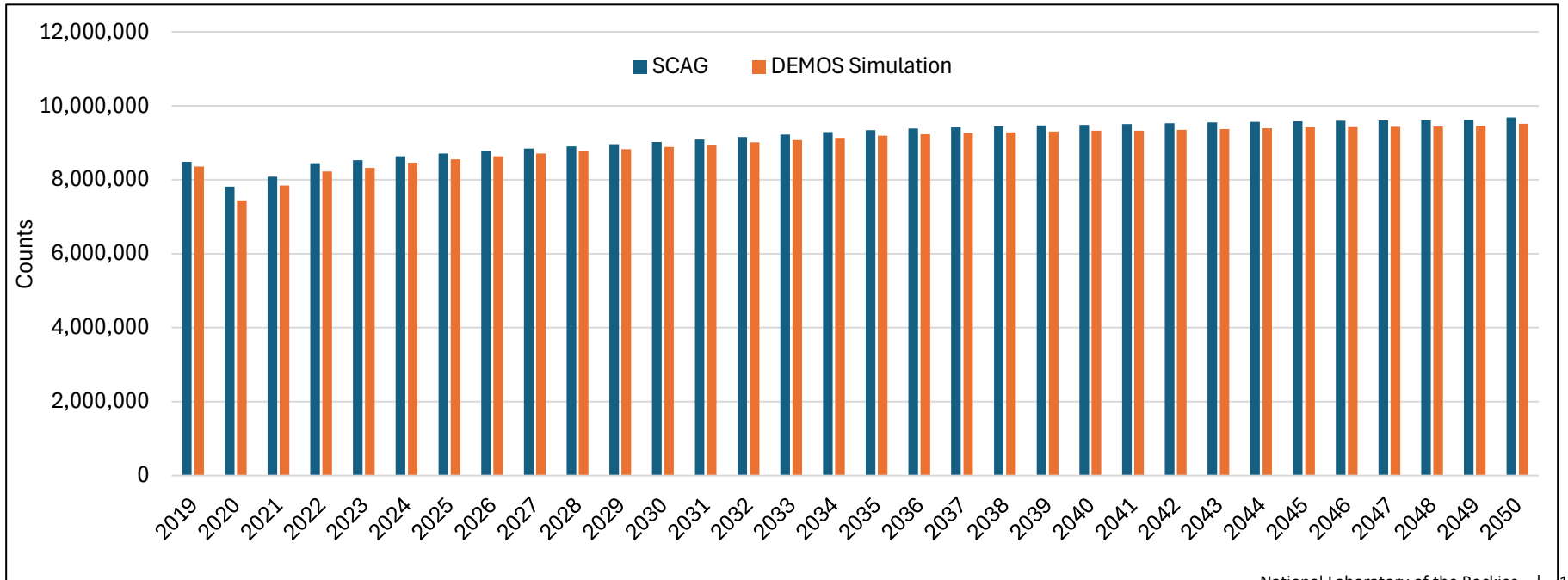
DEMOS Simulation Results: Birth to Death Ratio



- According to Census data, most U.S. counties saw more deaths than births in 2021 (due to the spike in mortality during COVID).
- Pew Research indicated that over the decades, birth rates have declined and the gap to death rates has narrowed, contributing to slower population growth

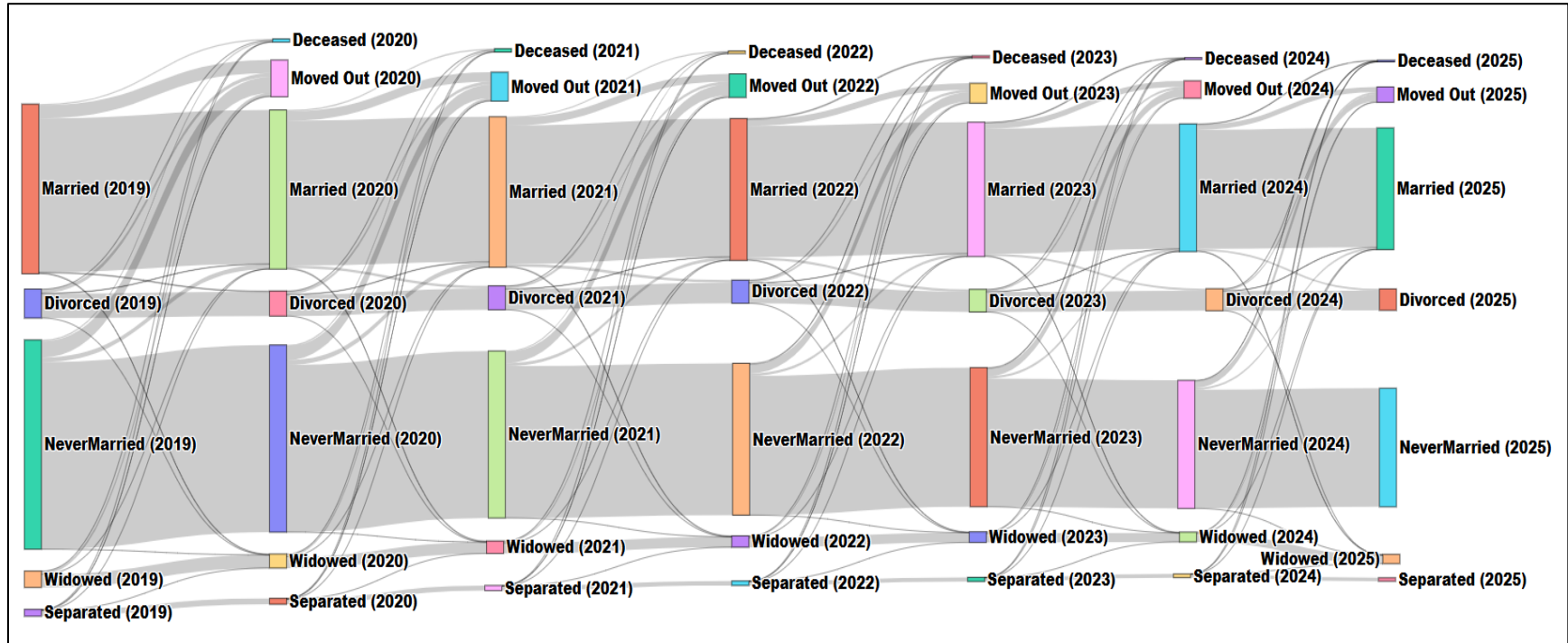
DEMOS Simulation Results: Employed Total Population

- Employment growth in the region is expected to be modest, and DEMOS tracks the SCAG forecast closely. With the enhanced simulation capabilities, it will be interesting to explore how AI, automation, or other technological disruptions could reshape labor demand over time



Key Capability of DEMOS: Capturing Evolution Over Time

- Longitudinal patterns reveal that while most remain in their initial status, a measurable portion of never married and divorced transition to marriage or move out.
- Such life cycle events transition play an important role in individual mobility choices and transport decisions



** Preliminary Result*

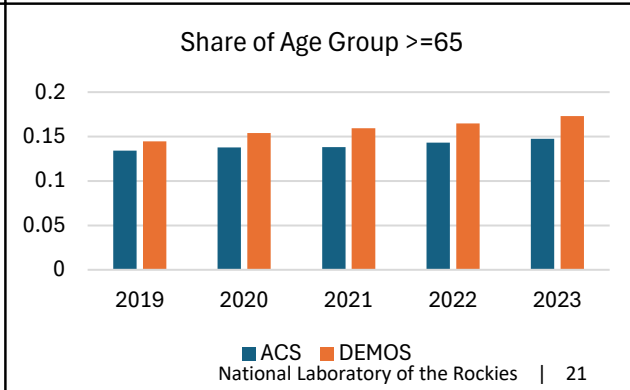
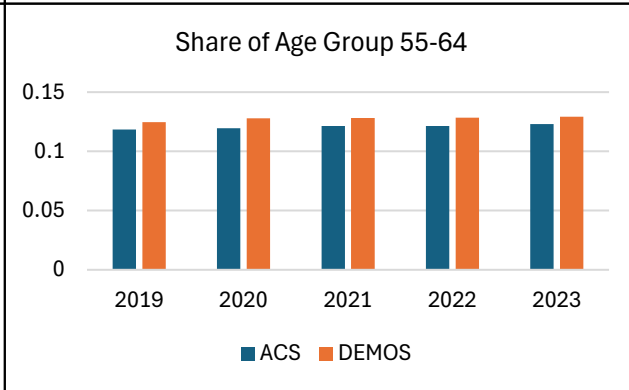
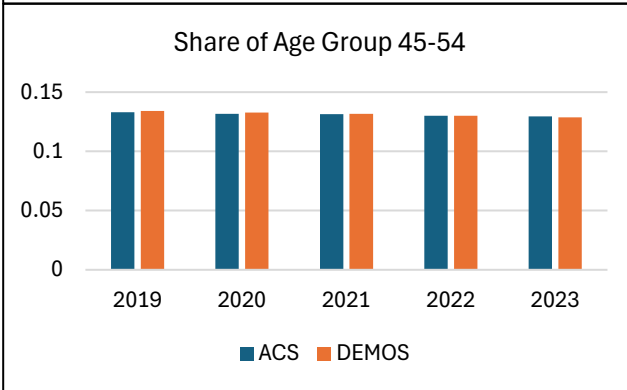
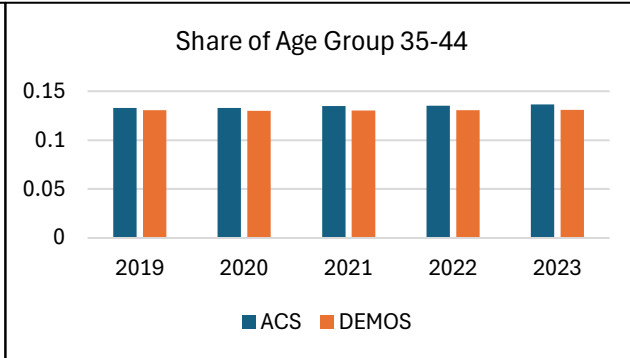
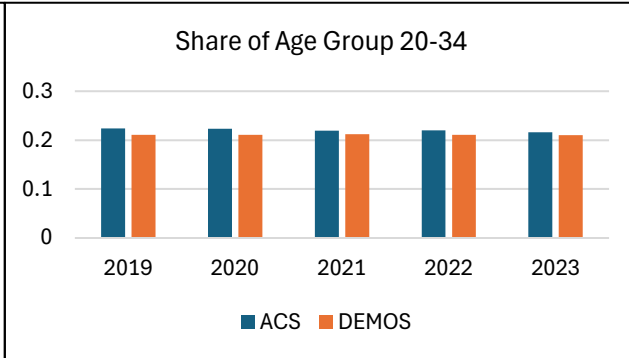
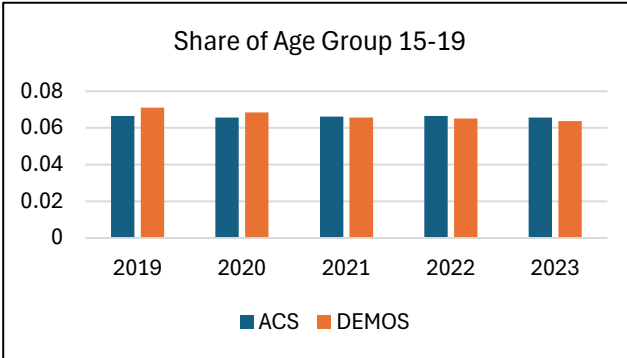
Computational Performance Benchmark in SCAG Region

Total Households	~6.5 million households
Total population	~18.2 million individuals
Simulation time	~18 minutes per year on average
Operating System	Windows
Processor	13th Gen Intel(R) Core(TM) i9-13900H
RAM	48 GB

DEMOS Validation

Validation with ACS: Share of Age Group

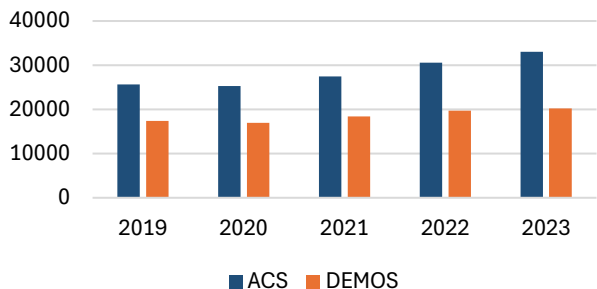
- DEMOS closely replicates ACS age-group trends over time (small decline in the 20–34 share, gradual increase in the 65+ share, and stability in middle-age groups)



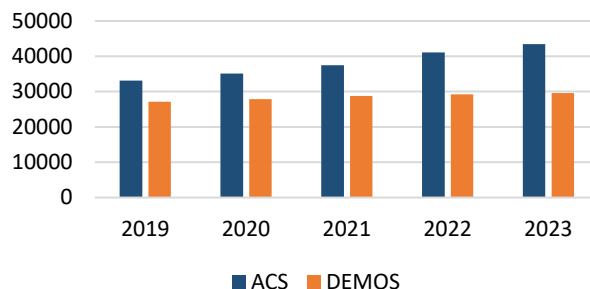
DEMOS Simulation Results: Validation with ACS

- Most differences between DEMOS and ACS arise because non-workers are assigned zero earned income—understating income for some retirees with pensions – ongoing updates to address this issue.

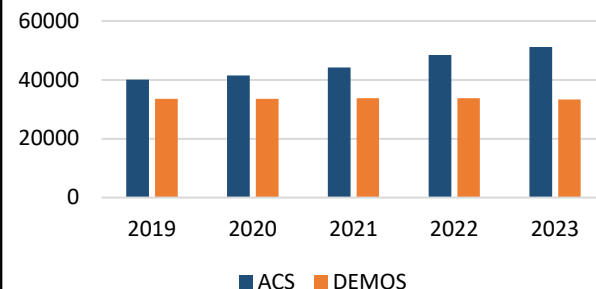
Median Earning, Imperial County



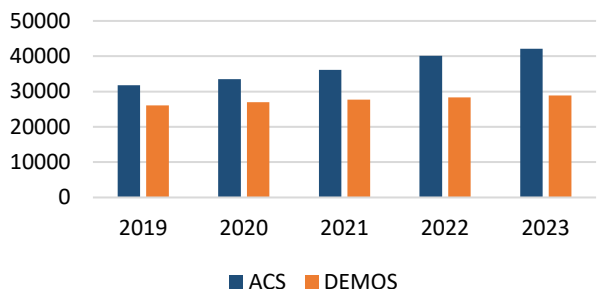
Median Earning, Los Angeles County



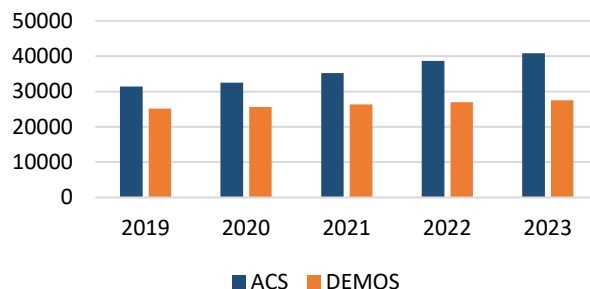
Median Earning, Orange County



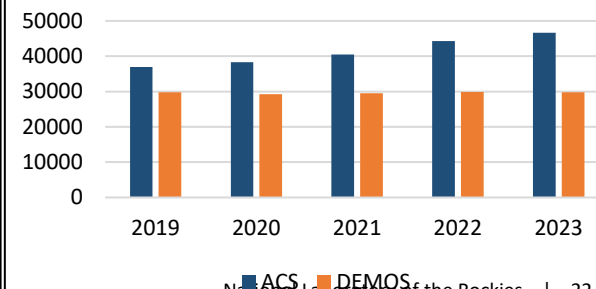
Median Earning, Riverside County



Median Earning, San Bernardino County



Median Earning, Ventura County

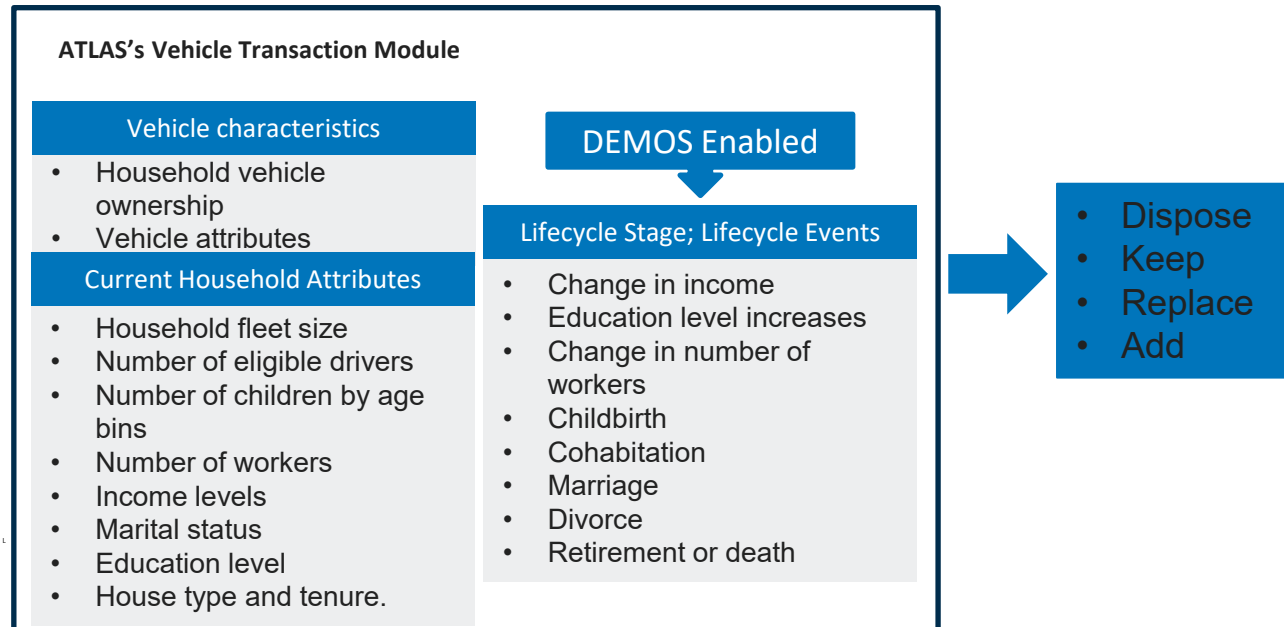


Additional DEMOS Use Cases

- Vehicle Transaction Model
- Mandatory Location Choice Model

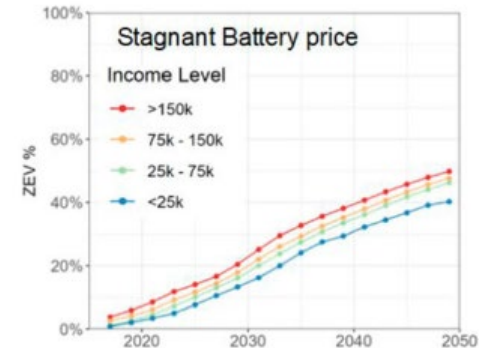
DEMOS Use Case → Vehicle Transaction Framework in SF Bay Area

- DEMOS enables scenario analysis which supports regional planning

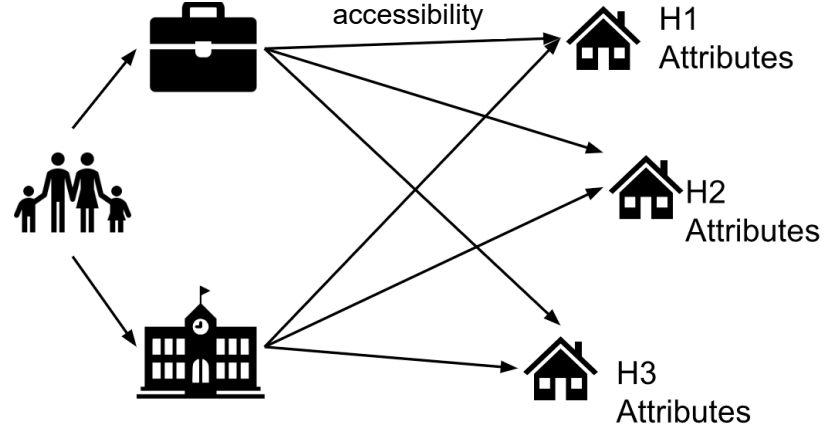
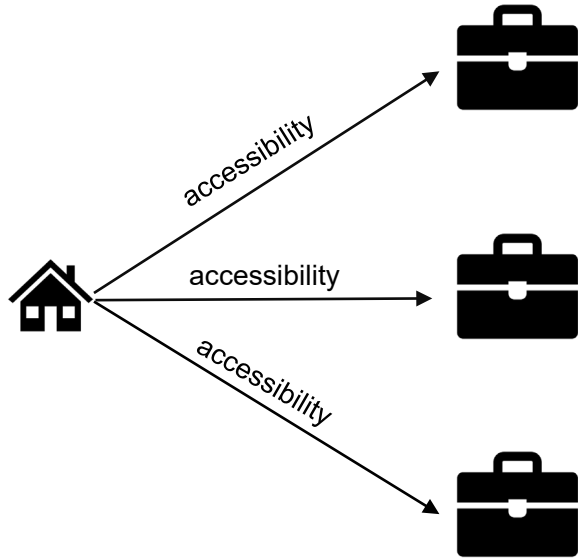


Regional Planning

E.g., how policies and technology progress may shape future vehicle fleets across different household types



DEMOS Use Case → Mandatory Location Choice Model



Conclusion and Future Work

- DEMOS **captures a host of life cycle events** including individual-level events (e.g., education attainment, marriage, mortality), and household-level events (e.g., childbirth, family formation/dissolution) **to inform transportation planning and policy evaluation**
- All DEMOS life cycle event models have statistically significant parameters and show behaviorally intuitive trends
- The **SCAG collaboration** highlights DEMOS's ability to scale to large MPO datasets, automate synthetic population integration, and adapt to challenges such as data rebalancing at fine geographic resolutions
- **Future work and Ongoing Discussions with SCAG**
 - Enhance DEMOS to capture spatial movement to support land use planning scenarios
 - Further refine methods for rebalancing and marginal control to improve accuracy at fine geographic levels
 - Continue discussions with SCAG on integrating DEMOS with the Synthetic Population Generator
 - Test DEMOS outputs within the activity-based model to assess improvements in model performance



Thank you!
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