

Uncertainty in Forecasting

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Topics

1. Quandary facing forecasters
2. Value of understanding forecast uncertainty
3. Characteristics of forecast uncertainty
4. Words Matter- Forecast error versus utility
5. Current approaches to forecast uncertainty
6. Survey of state and regional agencies

Key Points

- Knowledge of the behavior of forecast uncertainty is important for users and producers of forecasts
- Characteristics of forecast uncertainty is known for states and counties; information for subcounty areas lacking
- Options for incorporating uncertainty into forecasts vary in resource requirements and political sensitivity
- 96% of state and regional agencies surveyed currently or plan to incorporate uncertainty into their forecasts

Quandary Facing Forecasters

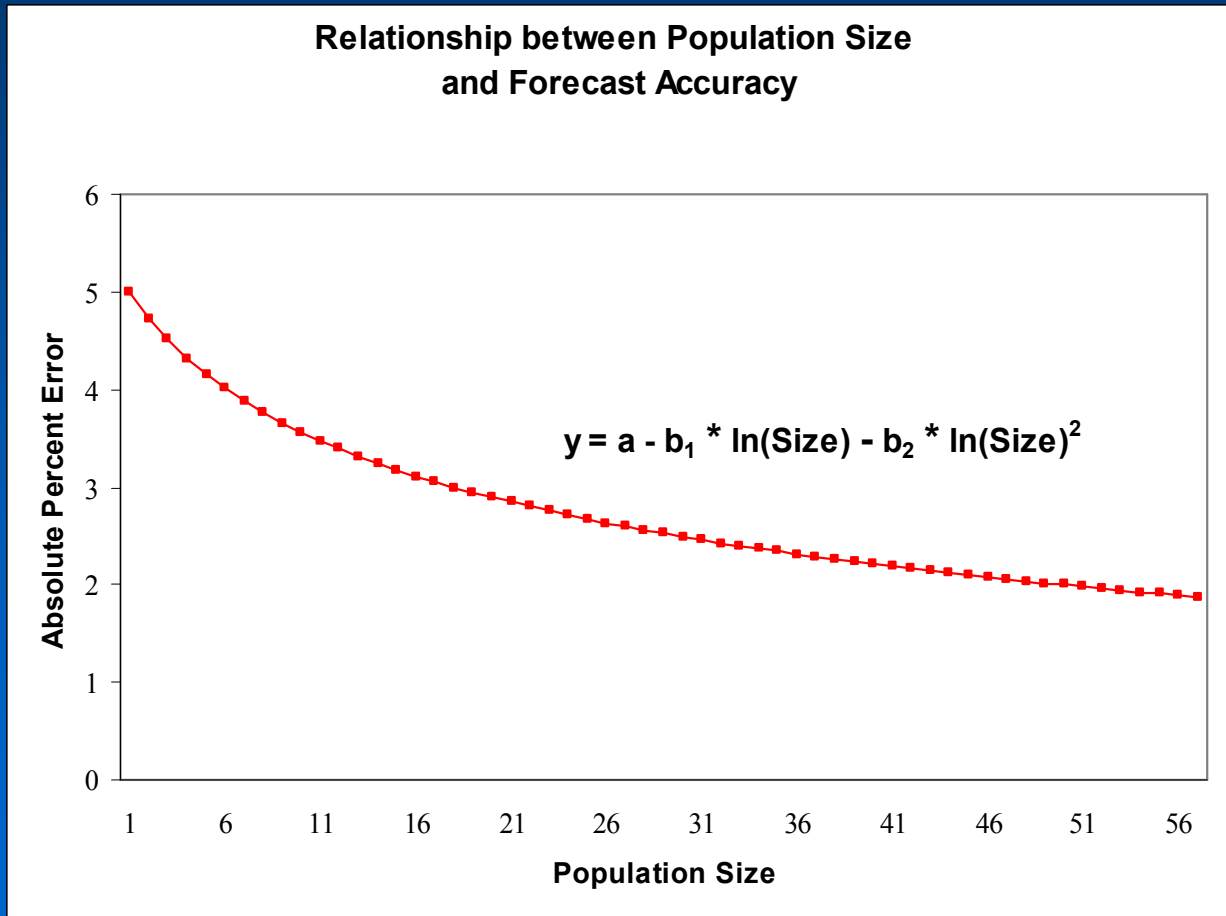
- Forecasting is impossible yet unavoidable
- Forecasts are needed for decision-making and must be in the form of numbers
- Forecasts invariably turn out to be different than the numbers that occur
- Users demand that forecasts meet standards of accuracy that exceed those commonly accepted as reasonable by forecasters

Value of Understanding Forecast Uncertainty

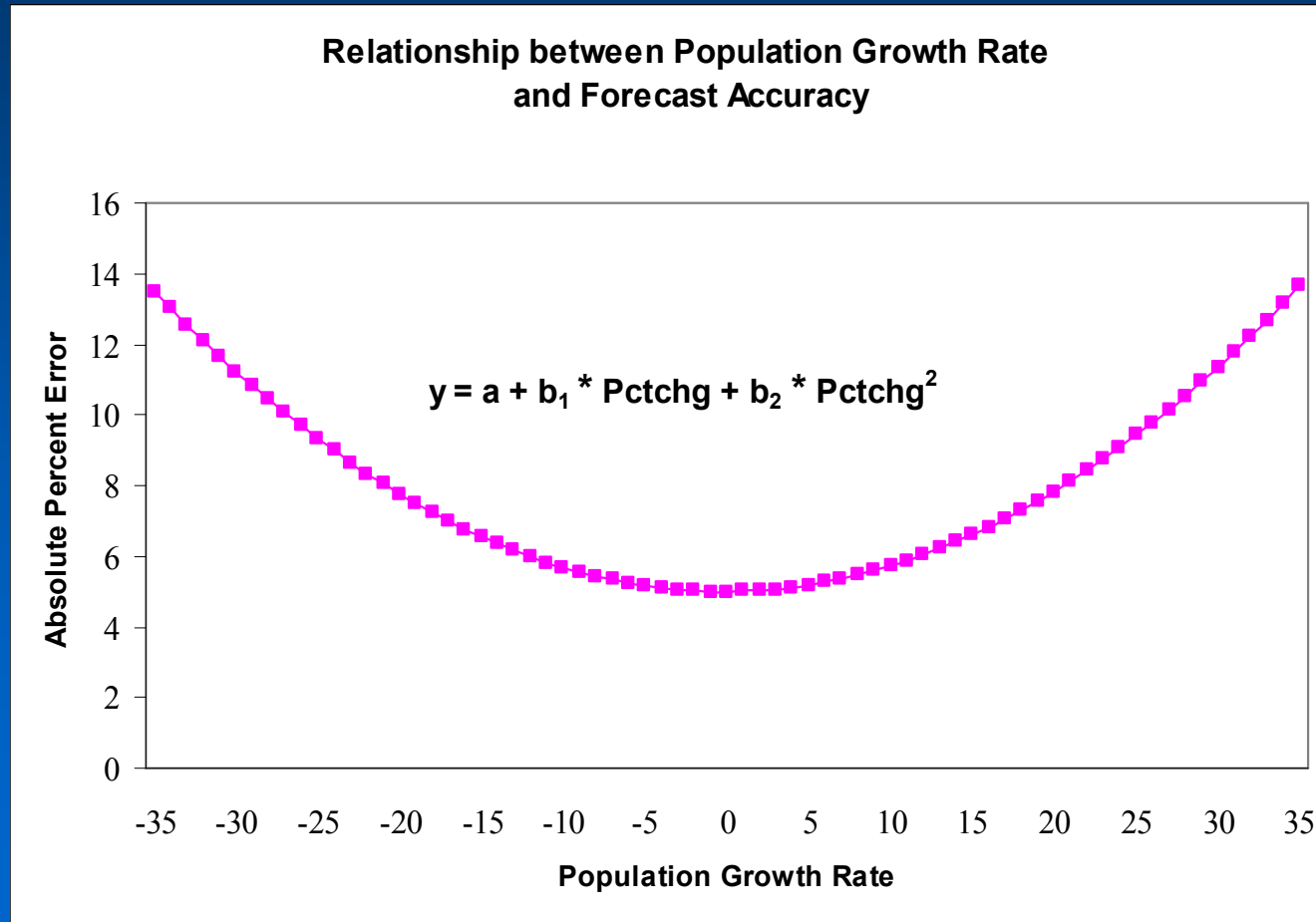
- Forecasting is an uncertain business
- Presence of uncertainty is inherent in management or policy decisions
- Make forecasts more valuable to planners, policy makers, and the public
- Better decisions regarding potential costs and benefits that rely on forecasts
- Improve forecasting methods and processes

General Characteristics of Forecast Error and Uncertainty

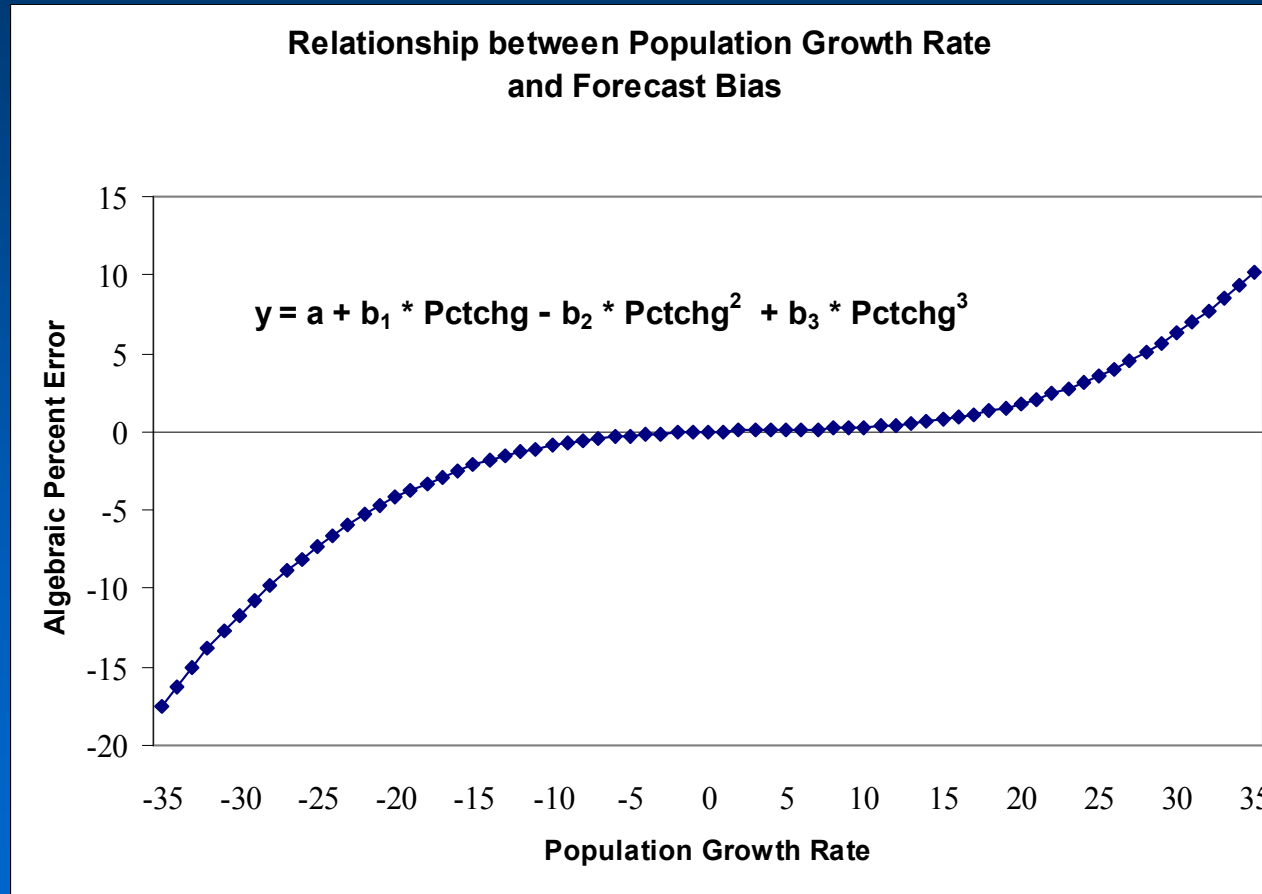
Forecast Error Decreases with Size



Forecast Error Increases with Increasing Rates of Change



Forecast Bias is Lowest for Stable/Slow Growing Areas



Complex Methods Do Not Out Perform Simpler Methods

Average Error Across Age Groups

States	Launch Year	Target Year	MAPE	MALPE
CCM	1980	1990	7.7	3.6
HP			7.0	2.3
CCM	1980	2000	12.6	-0.1
HP			10.7	-1.3
CCM	1990	2000	4.9	-1.6
HP			5.6	-2.3
Florida Counties	Launch Year	Target Year	MAPE	MALPE
CCM	1980	1990	10.4	0.4
HP			10.6	0.7
CCM	1980	2000	15.2	-5.7
HP			15.4	-5.0
CCM	1990	2000	10.9	-3.8
HP			9.5	-3.8

S. Smith and J. Tayman. 2003. An Evaluation of Population Projections by Age. *Demography* 40: 741-757

Forecast Error Increases Linearly with Length of Forecast Horizon

Table 13.7. "Typical" MAPEs for Population Projections by Level of Geography and Length of Horizon

Level of Geography	Length of Projection Horizon (Years)					
	5	10	15	20	25	30
State	3	6	9	12	15	18
County	6	12	18	24	30	36
Census Tract	9	18	27	36	45	54

Source: S. Smith, J. Tayman, & D. Swanson. 2001. *State and Local Population Projections: Methodology and Analysis*. Kluwer/Plenum Publications.

Words Matter

Used Car – Pre-owned Car

Cheap – Inexpensive

Quick and Dirty – Cost Effective

Budget Cut – Right Sizing

Forecast Error – Forecast Utility

Current Approaches to Forecast Uncertainty

- **Alternative Scenarios**
 - Range of values
 - Evaluation of policies and relevant factors
- **Statistical Probability Intervals**
 - Model-based
 - Empirically-based
- **Role of Experts**

Alternative Scenarios

Land Use Distribution Scenarios

- ***Current Plans*** – 19 local plans
- ***County Targets*** – 18 cities local plans, County targets & footprints
- ***Smart Growth*** – County targets & footprints, San Diego and Chula Vista plan updates, commitments from remaining 16 cities

Housing Unit Growth, 2000-2030

- Current Plans
- County Targets
- Smart Growth

Western
Riverside

Urban/
Suburban

East
County

■ Increases
growth in
rural East
County

Baja
California

Housing Unit Growth, 2000-2030

- Current Plans
- County Targets
- Smart Growth

**Western
Riverside**

**Urban/
Suburban**

**East
County**

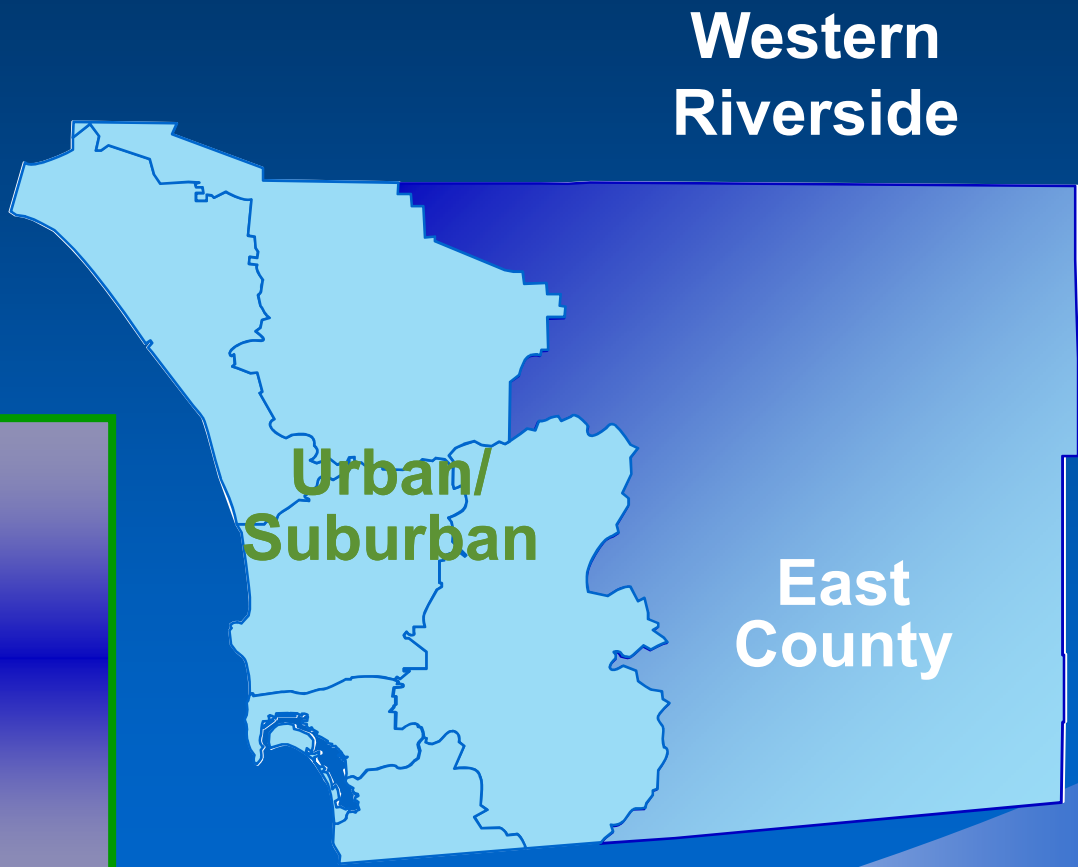
■ **Increases
inter-
regional
commuting**

**Baja
California**

Housing Unit Growth, 2000-2030

- Current Plans
- County Targets
- Smart Growth

Focuses growth in urban/suburban



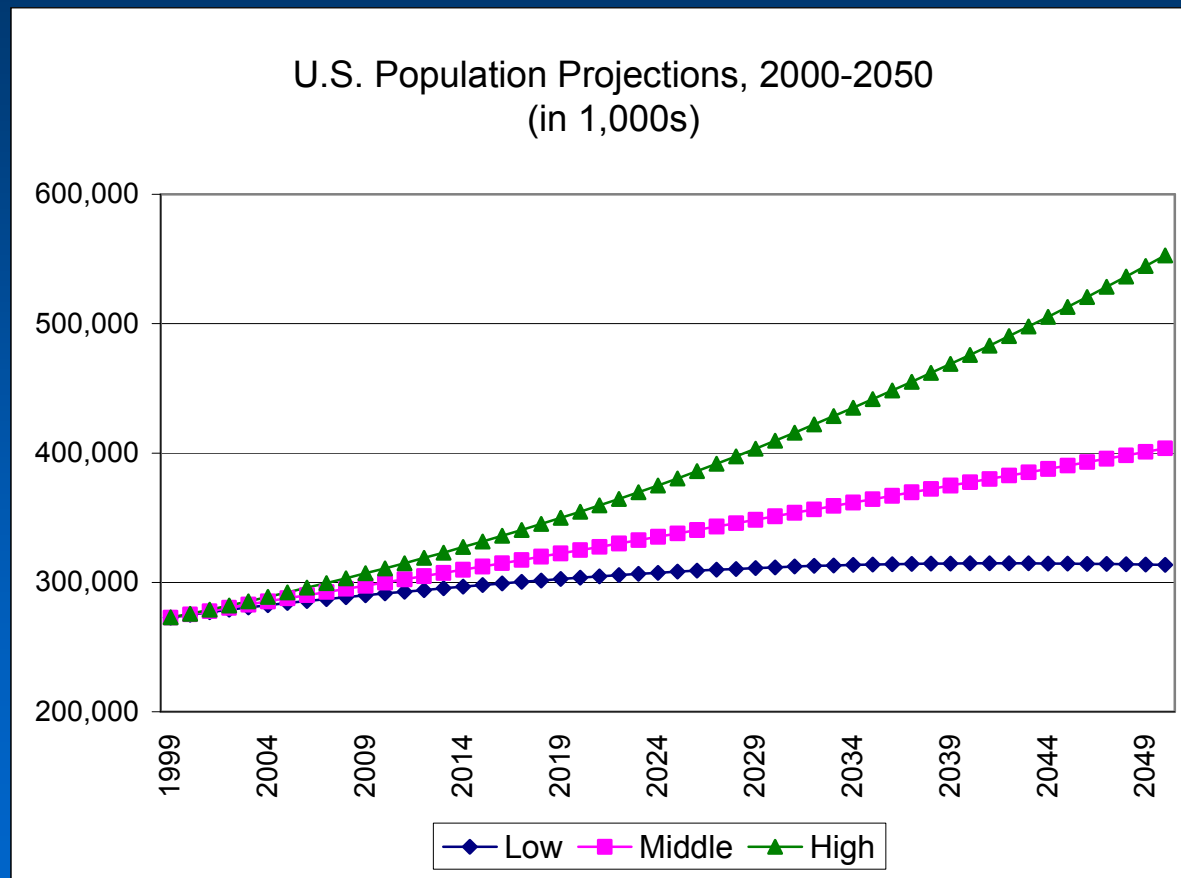
Western Riverside

Urban/
Suburban

East County

Baja California

Range of Projections



Internet Release Date January 13, 2000, U.S. Census Bureau
<http://www.census.gov/population/www/projections/natproj.html>

Alternative Scenarios

- Easy to see effects of different assumptions/policies
- Does not require new models or expertise
- Gives users choices
- Least costly way to examine uncertainty
- No measure of likelihood of occurrence
- May understate true level of uncertainty
- Fail to capture real world fluctuations

Model-Based Probability Intervals

ARIMA Models: States

68 % Prediction Intervals, Forecasts of Selected States

Average of Half-Widths ¹

Model		Base Period Length (in Years)			
		10	30	50	
ARIMA (1,1,0)	Forecast	10	9.1	7.3	6.0
	Horizon (in Years)	20	14.3	10.8	8.9
		30	18.5	13.5	10.9
ARIMA (2,2,0)	Forecast	10	35.5	22.2	16.4
	Horizon (in Years)	20	93.8	54.2	39.4
		30	169.8	90.1	64.9
ARIMA ln(0,1,1)	Forecast	10	9.7	8.5	7.5
	Horizon (in Years)	20	17.2	13.6	11.7
		30	25.3	18.5	15.4

Percent of Observed Population Counts Within Interval

Model		Base Period Length (in Years)			
		10	30	50	
ARIMA (1,1,0)	Forecast	10	50%	50%	33%
	Horizon (in Years)	20	42%	42%	17%
		30	42%	42%	42%
ARIMA (2,2,0)	Forecast	10	83%	92%	83%
	Horizon (in Years)	20	100%	92%	92%
		30	100%	100%	100%
ARIMA ln(0,1,1)	Forecast	10	50%	58%	58%
	Horizon (in Years)	20	67%	67%	58%
		30	58%	67%	67%

¹ Half-Width = ((Upper Limit - Lower Limit) / 2) / Point Forecast

J. Tayman, S. Smith, & J. Lin. 2007. Precision, Bias, and Uncertainty for State Population Forecasts: An Exploratory Analysis of Time Series Models. Population Research and Policy Review 26: 347-369

Model-Based Probability Intervals

- Provide explicit probability statements to measure forecast uncertainty
- Intervals often exceed low and high ranges; provide an important reality check
- Valid only to extent underlying assumptions hold
- Models are complex; require expertise beyond in-house capabilities; users find difficult to understand
- Alternate models imply different levels of uncertainty
- Netherlands only agency using probabilistic intervals in official projections

Empirically-Based Probability Intervals

Empirical Intervals: Counties

Absolute % Error Distributions for U.S. Counties				
Target Year	Horizon Length	Absolute % Error		
		Mean	Std. Dev.	90 th PE
1930	10	12.2	13.9	29.1
1940	10	11.2	12.4	23.3
1950	10	11.2	11.1	24.9
1960	10	10.3	9.9	23.2
1970	10	9.6	9.7	21.0
1980	10	13.2	10.2	26.3
1990	10	7.8	6.6	15.6
2000	10	6.2	6	13.9
Average	10	10.2	10	22.2
Std. Dev.	10	2.3	2.7	5.2
1950	30	33.1	37.4	78.7
1960	30	32.9	34.5	68.1
1970	30	31.9	31.1	68.3
1980	30	22.1	19.9	49.3
1990	30	29.3	23	60.6
2000	30	27.8	20.3	55.3
Average	30	29.5	27.7	63.4
Std. Dev.	30	4.2	7.6	10.5

S. Rayer, S. Smith, & J. Tayman.
 Empirical Prediction Intervals for County
 Population Forecasts. Forthcoming
 Population Research and Policy Review

Empirical Intervals: Subcounty

95% Confidence Intervals for Average Errors in 1990
for Selected Population Sizes, San Diego County

Size	MAPE			
	Lower Limit	Point Estimate	Upper Limit	Interval Width
500	67.4	72.0	80.3	12.9
1,000	50.5	56.5	59.7	9.2
1,500	42.7	46.2	50.2	7.5
3,000	31.9	33.4	37.4	5.5
5,000	25.7	27.9	30.1	4.4
7,500	21.7	24.4	25.4	3.7
10,000	19.2	20.7	22.5	3.3
20,000	14.3	16.3	16.8	2.5
30,000	12.0	12.4	14.2	2.2
40,000	10.6	11.5	12.6	2.0
50,000	9.7	10.5	11.5	1.8

**Elasticity for
Population Size and
MAPE = -0.442**

J. Tayman, E. Schafer, & L. Carter.
1998. The Role of Population Size in
the Determination and Prediction of
Population Forecast Errors: An
Evaluation Using Confidence Intervals
for Subcounty Areas. Population
Research and Policy Review 17: 1-20

Empirically-Based Intervals

- More useful for small areas than model-based intervals
- Less complex modeling; within capabilities of in-house staff
- Can accommodate alternate error distribution shapes
- Availability and usability of past forecasts may be an issue in many agencies, especially those doing subcounty forecasts

Expert Panels

San Diego County Water Authority Probabilistic Water Demand Forecasts

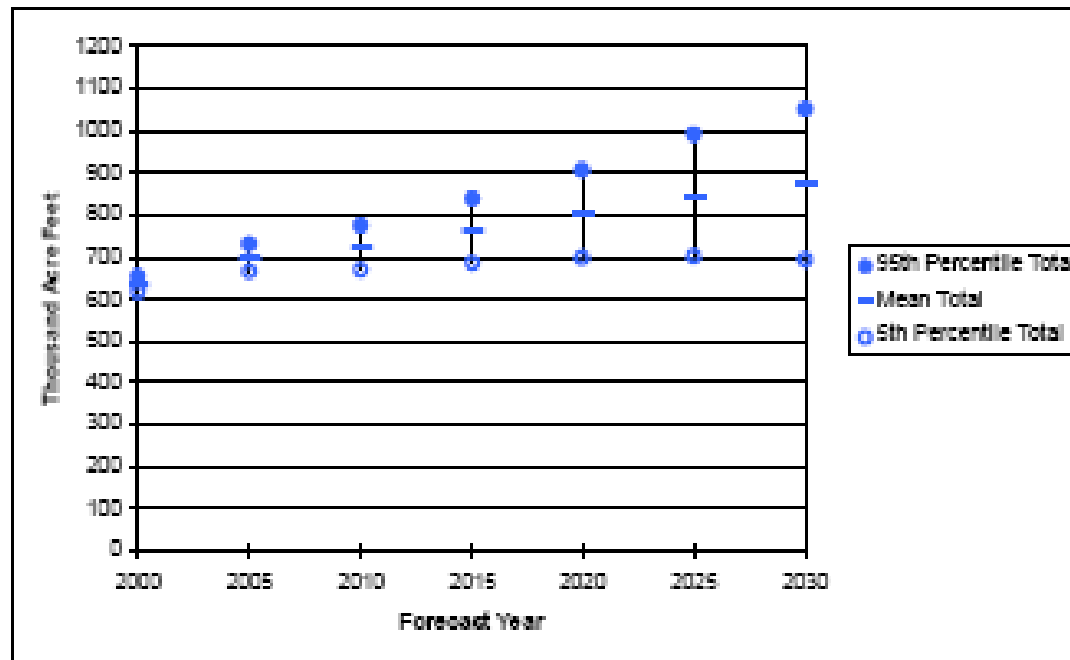
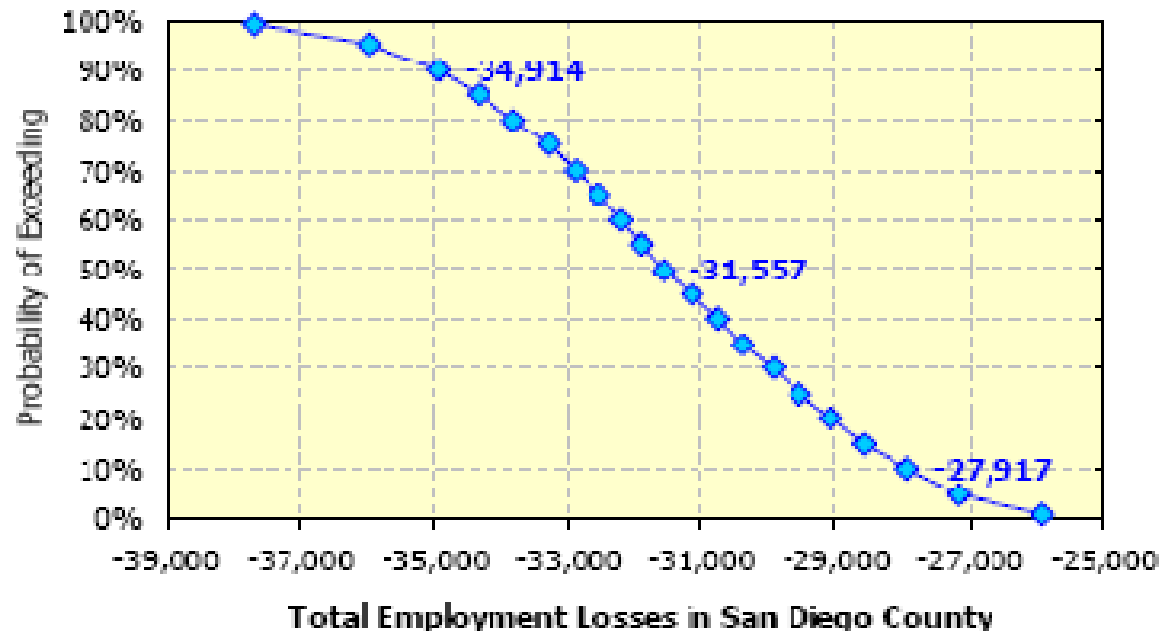


Figure 1. SDCWA Forecast Confidence Intervals

San Diego County Water Authority. 2002. Draft
Regional Water Facilities Master Plan: Appendix C

Economic Impacts of Border Wait Times

Figure 18: Personal Trips – Risk Analysis of Employment Losses in San Diego County



SANDAG & Caltrans District 11. 2006. Economic Impacts of Wait Times at the San Diego-Baja California Border.

Expert Panels

- Use same models, assumptions, and committee structure as “official forecast”
- Maybe the least costly alternative to producing probabilistic forecasts
- Aid in the acceptance and understanding of forecast uncertainty by stakeholders
- Defining who is an expert
- Need rigorous procedures (e.g., Delphi) to challenge status quo views
- Can be influenced by dominant personalities

Survey of State and Regional Agencies

Survey Respondents

- Non-Probability Sample
- Agencies have long standing and respected programs similar in stature to MAG
- 12 of 19 regional agencies responded
- 12 of 18 state agencies responded
- Conducted during Dec. 2008
- Three general topics
 - How forecast adequacy is assessed
 - How uncertainty is incorporated into the forecasting process
 - General characteristics of the forecasting process

Migration is the Highest Ranked Source of Uncertainty

Major Sources of Uncertainty in the Long-range Forecast¹

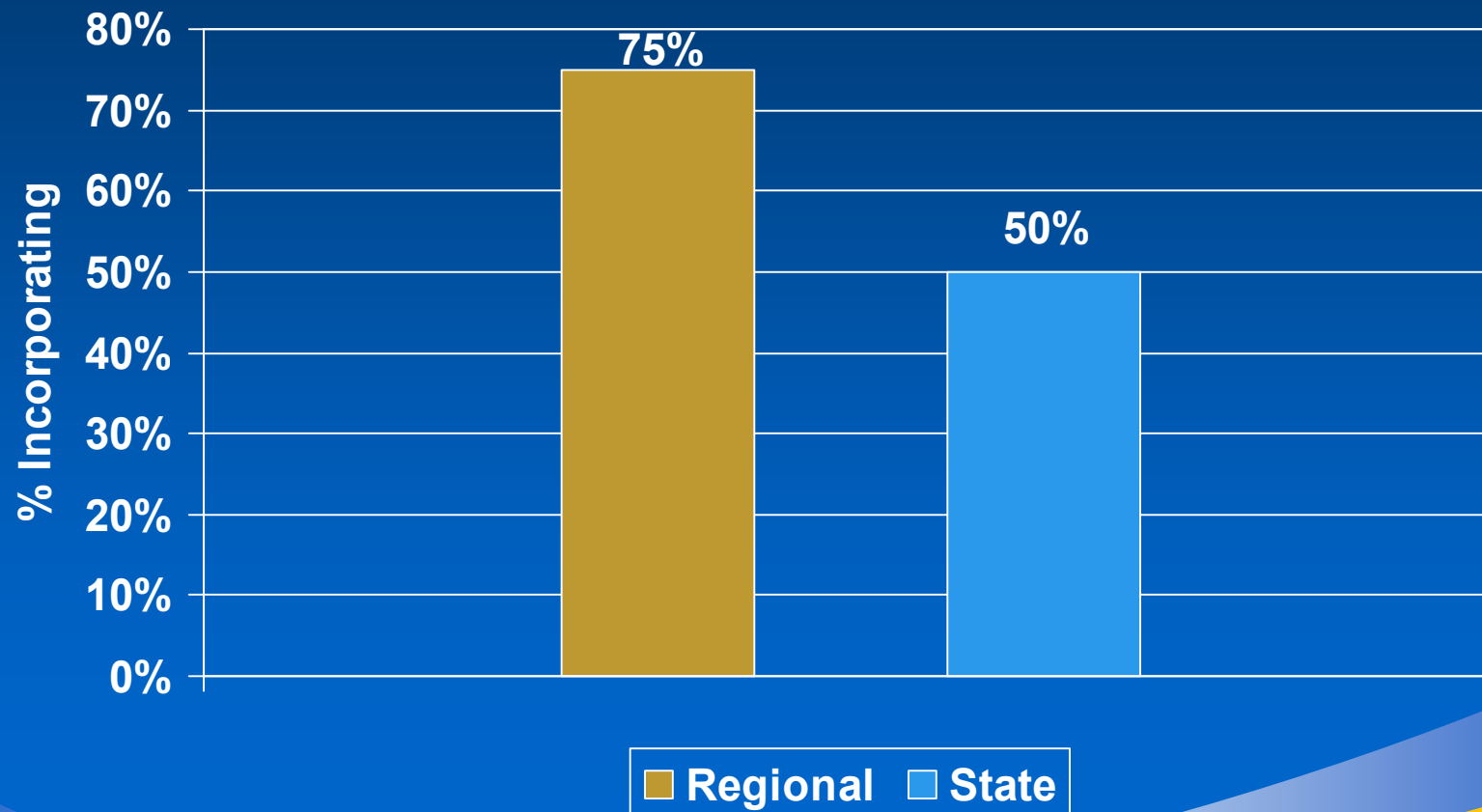
Uncertainty Sources	Rank (1 Highest) ²		Percent of Responses	
	Regional	State	Regional	State
Migration	1.6	1.0	23%	46%
Fertility	4.0	2.0	3%	23%
Mortality	2.0	3.0	6%	15%
Economy/Labor Force	1.8	2.0	14%	4%
Land Uses	1.9	–	23%	0%
Administrative/Regulatory	2.0	2.0	3%	8%
Commuting Patterns	2.0	3.0	3%	4%
Model Specification	3.0	–	6%	0%
Availablility of Infrastructure	2.0	–	3%	0%
U.S. Forecasts	3.0	–	3%	0%
Prices, Costs	4.0	–	3%	0%
Household Size/VR	4.0	–	6%	0%
Aging of Households	3.0	–	3%	0%
Changes in Technology	4.0	–	3%	0%
All Responses			100%	100%

¹ Respondents could select more than one variable.

² Average of ranks

Source: 2008 survey of state and regional agencies.

More Regional than State Agencies Currently Incorporate Uncertainty



Only 1 Agency Not Currently or Planning to Incorporate Uncertainty

Table C-7. Current Status by Anticipated Changes to Incorporating Uncertainty

Currently Incorporated	Changes Anticipated			Currently Incorporated	Changes Anticipated		
	Yes	No	Total		Yes	No	Total
Yes	38%	91%	63%	Yes	5	10	15
No	62%	9%	38%	No	8	1	9
All Responses	100%	100%	100%	All Responses	13	11	24

Source: 2008 survey of state and regional agencies.

Regional Agencies Use Multiple Methods for Incorporating Uncertainty

Table C-6. Uncertainty in Current Forecasting Process: Approach¹

Approach	Percent			Number		
	Regional	State	Total	Regional	State	Total
Alternative Scenarios	33%	33%	33%	6	2	8
Range of Values	22%	17%	21%	4	1	5
Expert Panel	33%	0%	25%	6	0	6
Empirical Intervals	6%	17%	8%	1	1	2
Model Intervals	6%	17%	8%	1	1	2
Past Forecasts	0%	17%	4%	0	1	1
All Responses	100%	100%	100%	18	6	24

¹ Respondents could select more than one variable.

Source: 2008 survey of state and regional agencies.

Alternate Scenarios/Range of Values Most Likely New Approaches to Uncertainty

Table C-8. Uncertainty in Future Forecasting Process: Approach^{1,2}

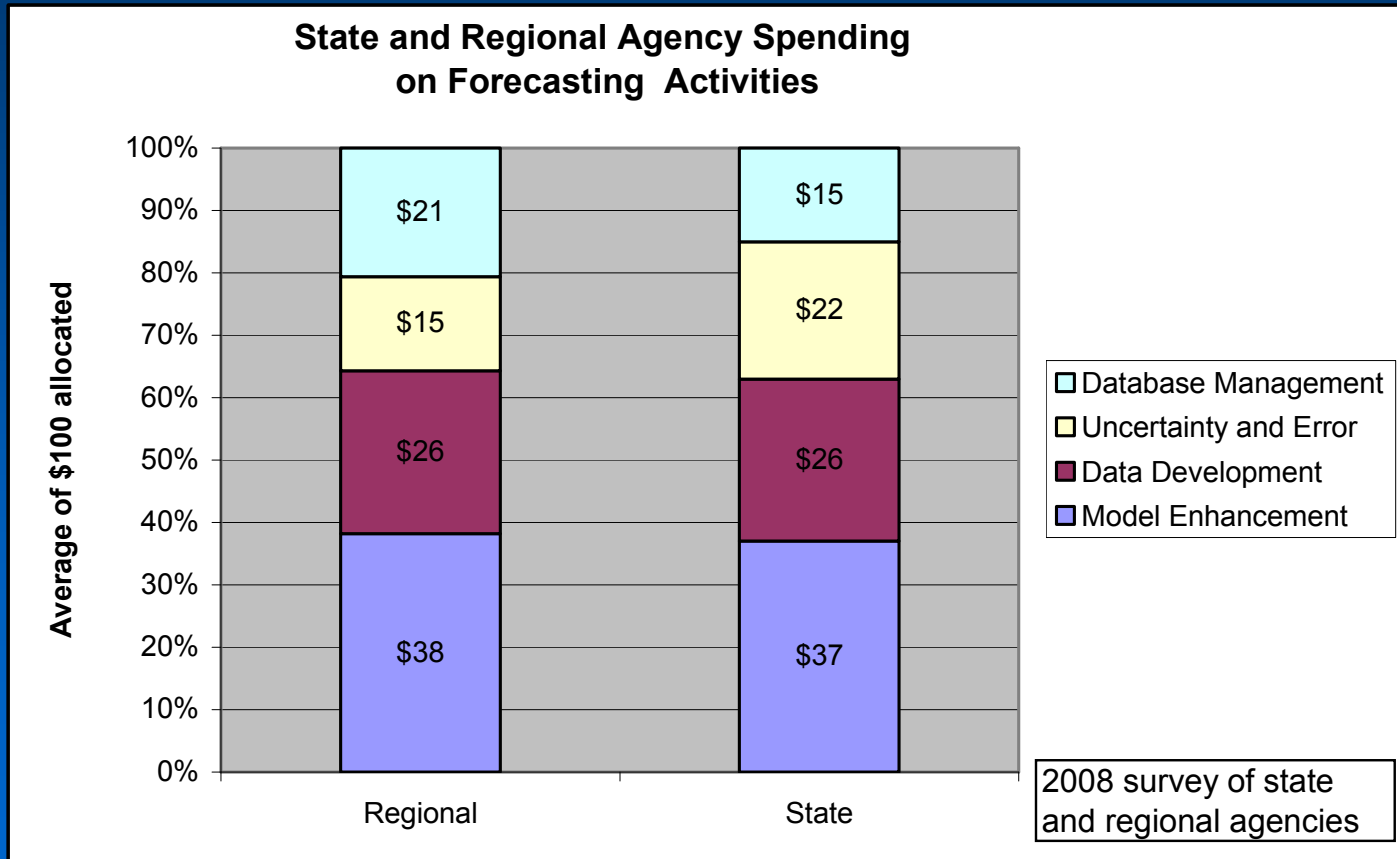
Approach	Percent			Number		
	Regional	State	Total	Regional	State	Total
Alternative Scenarios	50%	17%	38%	5	1	6
Range of Values	20%	33%	25%	2	2	4
Expert Panel	20%	0%	13%	2	0	2
Empirical Intervals	0%	0%	0%	0	0	0
Model Intervals	10%	0%	6%	1	0	1
Do Not Know	0%	50%	19%	0	3	3
All Responses	100%	100%	100%	10	6	16

¹ Respondents could select more than one variable.

² Includes respondents who indicated a change in practices and new approaches not currently being used.

Source: 2008 survey of state and regional agencies.

State and Regional Agency Spending Priorities Differ



Website URL of Uncertainty Report

<http://www.mag.maricopa.gov/detail.cms?item=10300>