SOCIETY OF ACTUARIES

Article from:

# Forecasting & Futurism

September 2009 – Issue 1

# **Introduction** to Forecasting Methods for Actuaries

*By Alan Mills*

Nearly all actuaries employ some form of forecasting: Life insurance actuaries forecast population mortality and company assets over lifetimes; retirement actuaries forecast pension plan payouts and plan assets during retirement; and health insurance actuaries forecast medical expenditures and premium income for two or three years. But actuaries employ only a small subset of the forecasting methods used by the general business community. This article provides a brief introduction to forecasting methods that are potentially relevant to actuarial work.

## RELEVANT FORECASTING METHODS

Table 1 on page 7 and 8 provides an overview of forecasting methods potentially applicable to the work of actuaries, with references for further study. It is organized as follows:

**A. Extrapolative methods:** methods based on data patterns rather than explanatory variables.
**B. Explanatory variable methods:** methods incorporating causal variables to forecast (explain) dependent variables.
**C. Simulation modeling methods:** methods using the computer to simulate real-world agents, behaviors and events.
**D. Judgmental methods:** methods based on expert opinion or intuition.
**E. Composite methods:** methods involving a combination of the above.

Alan Mills

The table describes each method and its preferable application. The table also includes an assessment of each method's current usage both among actuaries and within the general business community. For further study, it cites references with basic information about the method, as well as references covering more advanced information and applications. For each method, there is at least one reference that can be easily accessed online. A current version of the table and its references will be found on the Forecasting and Futurism Section's Web site, accessed through "Find a Section" on the SOA home page, *www.soa.org*. As our understanding of actuarial forecasting methods and usage evolves, the table and references will be updated.

**M competitions**
In several places, Table 1 refers to forecasting competitions. These are the "M forecasting competitions." Sponsored by the *International Journal of Forecasting*, and inspired by Spiros Makridakis (thus, the M in their name), these competitions (of which there have been three—M1, M2 and M3—in 1982, 1993 and 1998) compared the forecast accuracy of dozens of forecasting methods applied to thousands of historical data sets.

The table highlights an interesting observation: It appears that actuaries typically do not use forecasting methods that the general business community finds useful. Examples are:

- Exponential smoothing
- Autoregressive moving average
- Econometric modeling
- System dynamics simulation
- Multi-agent simulation

In an upcoming survey of actuaries, the Forecasting and Futurism Section will seek to substantiate and better understand this observation.

Perhaps one reason that actuaries use a limited range of forecasting methods is that the actuarial exams do not cover the forecasting methods that are potentially applicable to actuarial work. For example, it appears that the only comment about simulation models for health actuaries on the exam syllabus is, "Simulation is less commonly used for forecasting due to its complexity and time constraints. There are often strong competing priorities between the level of detail at which forecasting is necessary and the ability to apply simulation techniques successfully." This is perhaps practical advice, but will hardly encourage actuaries to explore the powerful simulation forecasting methods. ▼

**Alan Mills, FSA, MAAA, ND,** is a family practice physician. He can be reached at *alan.mills@earthlink.net*.

## TABLE 1: OVERVIEW OF FORECASTING METHODS

| Forecasting method | Description/preferred application | Current usage | | References | |
|---|---|---|---|---|---|
| | | Among actuaries | Within business generally | Basic | More advanced |
| **A. Extrapolative methods** | | | | | |
| 1. Simple moving average | This method averages the last n observations of a time series. It is appropriate only for very short or very irregular data sets, where features like trend and seasonality cannot be meaningfully determined, and where the mean changes slowly. | Widely used | Widely used | [1, 2] | |
| 2. Exponential smoothing, such as the Holt-Winters method | A more complex moving average method, involving parameters reflecting the level, trend and seasonality of historical data, usually giving more weight to recent data. Widely used in general business because of its simplicity, accuracy and ease of use. This method's robustness makes it useful even when historic data are few or volatile. It is a frequent winner in forecasting competitions. | Generally not used | Widely used for time-series analysis. | [2-5] | [6] |
| 3. Autoregressive moving average (ARMA)—aka Box-Jenkins | An even more complex class of moving average models, capable of reflecting autocorrelations inherent in data. It can outperform exponential smoothing when the historical data period is long and data are nonvolatile. But it doesn't perform as well when the data are statistically "messy." | Generally not used | Widely used | [2, 7] | [6] |
| **B. Explanatory variable methods** | | | | | |
| 1. Regression analysis | Fitting a curve to historical data using a formula based on independent variables (explanatory variables) and an error term. Although these methods are relatively simple, and are helpful both in analyzing patterns of historical data and for correlation analysis, they are not generally recommended for forecasting. They have performed poorly in forecasting competitions. | Widely used | Widely used | [2, 8, 9] | [6, 10] |
| 2. Predictive modeling | An area of statistical analysis and data mining, that deals with extracting information from data and using it to predict future behavior patterns or other results. A predictive model is made up of a number of predictors, variables that are likely to influence future behavior. | Gaining in popularity | Widely used | [11-13] | |
| 3. Artificial neural networks | Patterned after the neural architecture of the brain, these methods allow for nonlinear connections between input and output variables, and for learning patterns in data. | Generally not used | Sometimes used | [2, 14-16] | |
| 4. Econometric modeling | Systems of simultaneous equations to represent economic relationships. | Generally not used | Widely used | [17, 18] | [19] |

CONTINUED ON **PAGE 8**

INTRODUCTION TO FORECASTING … | FROM PAGE 7

## TABLE 1: OVERVIEW OF FORECASTING METHODS continued

| Forecasting method | Description/preferred application | Current usage | | References | |
|---|---|---|---|---|---|
| | | Among actuaries | Within business generally | Basic | More advanced |
| **C. Simulation modeling methods** | | | | | |
| 1. Cell-based modeling | Modeling of individual homogeneous units (cells) over time, such as age/sex cells in pension forecasting. These models are usually deterministic, but may be stochastic. They are useful to model large systems. | Frequently used | Frequently used | [20] | |
| 2. System dynamics simulation | Simulation of a system as a whole over time, incorporating feedback loops as well as stocks and flows. Such methods are useful for complex systems. | Generally not used | Becoming more widely used | [21] | [22] |
| 3. Multi-agent simulation | A computer representation that employs multiple interacting agents and behavioral rules to mimic the behavior of a real system. This method is especially useful for modeling complex adaptive systems. | Generally not used | Becoming more widely used | [23-25] | [26, 27] |
| **D. Judgmental methods** | These methods rely on expertise and intuition, rather than on statistical analysis of historical data. Such methods are particularly useful when historical data is scarce. Many of the methods of "futurism"—such as the Delphi method, visioning and scenario building—fall under this category. | Frequently used, usually on an informal basis | Frequently used, often on a structured basis | [2, 28-30] | |
| **E. Composite methods** | | | | | |
| 1. Bayesian forecasting | This family of methods combines statistical methodology with structured integration of human judgment: new evidence is used to update a statistical forecast, based on application of Bayes' theorem. These methods are good for highly seasonal data with short history. | Generally not used | Generally not used | [31] | [32] |
| 2. Other | Combinations of forecasting methods usually perform better in forecasting competitions. The use of composite methods will increase as decision makers are increasingly called on to combine their intuitions with data-based decision making from forecasting models. | Generally not used | Generally not used | [2, 33, 34] | |

## REFERENCES (refer to last two columns in the references section in the chart)


[1] Wikipedia. Moving average. Retrieved June 1, 2009, from *http://en.wikipedia.org/wiki/Moving_average*

[2] Makridakis, S. G., Wheelwright, S. C., & Hyndman, R. J. (1998). *Forecasting: Methods and Applications* (3rd ed.). New York: John Wiley & Sons.

[3] Armstrong, J. S. (2001). *Principles of Forecasting: A Handbook for Researchers and Practitioners* (Section 8: "Extrapolation of time-series and cross-sectional data"). Boston, MA: Kluwer Academic.

[4] Gardner, E. S. (1985). "Exponential Smoothing: the State of the Art," *Journal of Forecasting*, 4(1), 1-28.

[5] Wikipedia. "Exponential Smoothing." Retrieved June 1, 2009, from *http://en.wikipedia.org/wiki/Exponential_smoothing*

[6] Montgomery, D. C., Jennings, C. L., & Kulahci, M. (2008). *Introduction to Time Series Analysis and Forecasting*. Hoboken, N.J.: 34.: Wiley-Interscience.

## REFERENCES continued


[7] Wikipedia. "Autoregressive Moving Average Model." Retrieved June 1, 2009, from *http://en.wikipedia.org/wiki/Autoregressive_moving_average_model*

[8] Sykes, A. O. "An introduction to Regression Analysis." Retrieved June 1, 2009, from *http://www.law.uchicago.edu/Lawecon/WkngPprs_01-25/20.Sykes.Regression.pdf*

[9] Wikipedia. "Regression Analysis." Retrieved June 1, 2009, from *http://en.wikipedia.org/wiki/Regression_analysis*

[10] Fox, J., & Fox, J. (2008). *Applied Regression Analysis and Generalized Linear Models* (2nd ed.). Los Angeles: Sage.

[11] Cousins, M., & Stark, J. W. C. (2003). "A Predictive Modeling Primer." Paper presented at the Annual Meeting, Orlando.

[12] Cumming, B., et al. (2002). "Predictive Modeling." Paper presented at the Health Spring Meeting, San Francisco.

[13] Senensky, B. (2008). "Predictive Modeling." *CompAct* (SOA Technology Section newsletter), July 2008.

[14] Armstrong, J. S. (2001). *Principles of Forecasting: A Handbook for Researchers and Practitioners* (Section 8: "Neural Networks for Time-Series Forecasting"). Boston, MA: Kluwer Academic.

[15] Shapiro, A. F., Pflumm, J. S., & DeFilippo, T. A. (1999). "The Inner Workings of Neural Networks and Genetic Algorithms." *Actuarial Research Clearing House,* 1, 415-426.

[16] Wikipedia. "Artificial Neural Network." Retrieved June 1, 2009, from *http://en.wikipedia.org/wiki/Artificial_neural_network*

[17] Armstrong, J. S. (2001). *Principles of Forecasting: A Handbook for Researchers and Practitioners* (Section 11: "Econometric Forecasting"). Boston, MA: Kluwer Academic.

[18] Wikipedia. "Econometrics." Retrieved June 1, 2009, from *http://en.wikipedia.org/wiki/Econometrics*

[19] Spanos, A. (1986). *Statistical Foundations of Econometric Modelling.* Cambridge; New York: Cambridge University Press.

[20] Anderson, J. M. (2000). "Computer Models for Retirement Policy." Paper presented at the Spring Retirement Meeting, Las Vegas.

[21] Wikipedia. "System Dynamics." Retrieved June 1, 2009, from *http://en.wikipedia.org/wiki/System_dynamics*

[22] Sterman, J. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Boston: Irwin/McGraw-Hill.

[23] Epstein, J. M., Axtell, R., & 2050 Project. (1996). *Growing Artificial Societies: Social Science from the Bottom Up.* Washington, D.C.: Brookings Institution Press.

[24] Gilbert, G. N. (2008). "Agent-Based Models." Los Angeles: Sage Publications.

[25] Wikipedia. "Agent-Based Model." Retrieved June 1, 2009, from *http://en.wikipedia.org/wiki/Agent-based_model*

[26] Miller, J. H., & Page, S. E. (2007). *Complex Adaptive Systems: An Introduction to Computational Models of Social Life.* Princeton, N.J.: Princeton University Press.

[27] North, M. J., & Macal, C. M. (2007). *Managing Business Complexity: Discovering Strategic Solutions with Agent-Based Modeling and Simulation.* Oxford; New York: Oxford University Press.

[28] Adler, M., & Ziglio, E. (1996). *Gazing Into the Oracle: the Delphi Method and Its Application to Social Policy and Public Health.* London: Jessica Kingsley Publishers.

[29] Lawrence, M., Goodwin, P., O'Connor, M., & Onkal, D. (2006). "Judgemental Forecasting: A Review of Progress Over the Last 25 Years." *International Journal of Forecasting*, 22, 493-518.

[30] Surowiecki, J. (2004). *The Wisdom of Crowds: Why the Many are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies, and Nations* (1st ed.). New York: Doubleday.

[31] Geweke, J., & Whiteman, C. (2004). "Bayesian Forecasting" in *The Handbook of Economics Forecasting*. Retrieved June 1, 2009, from *http://www.biz.uiowa.edu/faculty/cwhiteman/bayesianforecasting.pdf*

[32] West, M., & Harrison, J. (1997). *Bayesian Forecasting and Dynamic Models* (2nd ed.). New York: Springer.

[33] Armstrong, J. S. (2001). *Principles of Forecasting: A Handbook for Researchers and Practitioners* (Section 13: "Combining Forecasts"). Boston, MA: Kluwer Academic.

[34] Lapide, L. (2008, June 1, 2009). "Thinking About Composite Forecasting." *The Journal of Business Forecasting.* Retrieved Summer 2008, from *http://ctl.mit.edu/public/jbf_summer_2008.pdf*