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Forecasting by Exponential Smoothing

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FORECASTING BY EXPONENTIAL SMOOTHING

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FORECASTING BY EXPONENTIAL SMOOTHING

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T.P.C.

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Chapter 1

INTRODUCTION

Forecasting is attempting to predict the future. It is an estimate of what the future demands. There are many ways to predict the future or to forecast. The purpose of this paper is to present various forecasting techniques, concentrating on exponential smoothing. Exponential smoothing is a method of forecasting that uses the least possible amount of past data, reflecting those past movements in the data. This paper will concentrate on the various types of exponential smoothing adapted to particular and unique data. The paper will point out the effects of external information on forecasts and how exponential smoothing is used in forecasting. It will attempt to show some of the more important applications of forecasting. An important part of this paper is a program to forecast by exponential smoothing. This program will provide a user with a means of forecasting based on the information he provides. The technique is capable of simple forecasting using the least possible information or it can accommodate a user who does not know any information about his data. The program will analyze the data, present pertinent information for future forecasts, and provide a forecast. In addition, the program can update information for the user's forecasts by utilizing recent effects on data.

A discussion on control systems in general and a control system of the program is provided.

The main purpose of the program is to select, if the user desires, the best smoothing constants. There are many theories concerning the selection of smoothing constants, but the user typically ends up guessing on some value between 0 and 1.0. Generally, a value closer to 0 will cause certain effects on forecasts as will values closer to 1.0. A user has no way of knowing the smoothing constant(s) that is best for his data unless he tries all possible values and tests for that value that best describes his data. The program will accommodate the user by finding the smoothing constant(s) that best describes his data by attempting many combinations of constants in addition to finding the smoothing routine that best describes the data. If the user desires, the program provides a comparison of the users' given constants and what the program computes as optimal.

This information, in addition to a forecast, will enable the user to obtain more important information on his data. The forecast will then be the best, since the program has found the best smoothing constants and provided the best fit on past data. The past data is usually not needed in forecasts by exponential smoothing. In the program, past data is recommended periodically to update the smoothing constants and factors. This paper then provides a user manual to accommodate any user. It describes the requirements, uses, and results of the program. The paper provides understanding of smoothing techniques and a program with which to forecast or predict the future. By use of the program, a user can obtain a 'best' estimate of what the future demands.

Chapter 2

MAJOR FORECASTING APPROACHES

METHODOLOGY OF FORECASTING

Some consideration must be given to the current thinking on forecasting. Barry Shore categorizes forecasting into three techniques: (1) Judgemental analysis, (2) Econometric forecasting, and (3) Time Series analysis. Judgemental analysis relies on the art of human judgement. This category may rely heavily upon consumer opinions, surveys, marketing trials and salesmen's estimates. Econometric forecasting relies on the field of statistics. In this category the analyst attempts to uncover the cause-and-effect relationship between sales and some other forces that are related to sales. This process utilizes regression and correlation techniques. Time Series analysis attempts to indentify the historical pattern of demand for the product and extrapolates this into the future.[1]

John E. Biegel feels that, "...a forecast is basically a guess, but by the use of certain techniques it can be more than just a guess". To make a forecast meaningful, it should be in terms of the units to be planned or scheduled, and should cover a time period at least as long as the period of

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[1] Barry Shore, Operations Management (New York: McGraw-Hill Book Company, 1959), pp. 271-274.

time required to make a decision and to put that decision into effect. There is little or no value in making a forecast for such a short time interval that effective action cannot be taken. Any time a decision is made about the future, there is at least an implied forecast underlying that decision. He emphasizes that planned forecasts are much more valuable and accurate than intuitive forecasts.[2]

William Voris gives steps in preparing a sales forecast: (1) To prepare company records or develop historical data, (2) Attempt to relate company sales of the industry of which the company is a part, (3) Relate this industry to some national data which reflect the influence of the national economy on future sales of the industry, and (4) Analyze the interrelationships of the statistics gathered.[3]

There are many different forecasting techniques at the disposal of a user. John F. Magee maintains that:

> Techniques are highly diverse and depend strongly on the nature of the company, the data-handling facilities and analysis skills available, and particularly on the types of customer and industry information which may exist.

Approaches to forecasting vary widely among companies, because satisfactory general methods of forecasting are rare, because

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[2] John E. Biegel, Production Control: A Quantitative Approach (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963), p. 16.

[3] William Voris, Production Control, Text and Cases (Homewood, Illinois: Richard D. Irwin, 1961), pp. 133-135.

expediency and available data have strong influence, and because many companies fail to realize how many forecasts they actually make. There are general classes of approaches used for making different general types of forecasts. Some of the general classifications are business planning, intermediate operation planning, short run production control, and forecasts of item requirements.[4] Biegel, like Magee, suggests that forecast approaches should be classified according to use. He suggests another; the classification of time span covered. Still another method suggested is by method of generation.[5]

Thus, there are various opinions on how a forecast should be made and on what that forecast should concentrate. The opinions are all correct yet they all differ in method to some extent. A company or individual must weigh its particular situation and make a forecast based on requirements particular to itself. However, it must relate to other companies and to the industry as a whole to determine its position. Many, if not all, agree that forecasts are either by opinion of some sort or by some statistical analysis of the requirements, and above all, the forecasts must be based on the past, whether a time series or guesswork.

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[4]John F. Magee, Production Planning and Inventory Control (New York: McGraw-Hill Book Company, Inc., 1958), pp. 118-119.

[5]Biegel, op. cit., p. 18.

COMMON FORECASTING TECHNIQUES

One common method of forecasting is by use of averages. According to the American Institute of Certified Public Accountants, the most obvious and simple way of using past data as a guide to predicting for the next period is to average all available data or the data for a definite number of past periods. The great drawback of this method is that the most recent figure is given no more emphasis than data several periods back.[6]

One of the techniques developed to overcome the weakness of the simple average as a basis for forecasting is the moving average. In this method, the influence of past data is minimized by considering only the figures for the most recent periods. Moving averages are extremely easy to compute, but records must be kept and earlier data is not considered.[7] The problem seems to lie in how many past figures to consider or the length of the interval. Robert G. Brown maintains that the moving average is an attempt at compromise. The objective is to take a long enough base period to allow random fluctuations in demand to cancel each other out, but

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[6]American Institute of Certified Public Accountants, Techniques for Forecasting Product Demand, A Management Services Technical Study (New York: American Institute of Certified Public Accountants, Inc., 1968), pp. 2-3

[7]Ibid., pp. 3-7

a short enough period to discard information that is no longer relevant.[8]

Thomas E. Vollman says that as the number of observations to be included in the moving average grows larger, the forecasting model will tend to do a better job of smoothing or damping out the noise; but as the number of observations grows larger, the older data are included and the forecasting model becomes less responsive to changes in demand patterns.[9]

A moving average is simply the sum of the demands for the desired number of past periods divided by the number of demands included in the sum. For each period, the new moving average is computed by dropping the demand for the most prior period and adding the demand for the most recent period. Some of the problems of moving averages are: (1) they lag a trend, (2) they are out of phase when data is cyclic, and (3) the maximum forecast by a moving average will be less than maximum demand in a cyclic pattern, whereas the minimum forecast will exceed the minimum actual demand of a cyclic pattern.[10]

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[8]Robert G. Brown, Smoothing, Forecasting, and Prediction of Discrete Time Series (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963), pp. 98-99.

[9]Thomas E. Vollman, Operations Management: A System Model-Building Approach (Reading, Massachusetts: Addison-Wesley Publishing Company, 1973), pp. 487-489.

[10]Biegel, op. cit., pp. 34-35.

Shore describes an advanced method of averages or the weighted average as weighing the data in such a way that the most recent data have the heaviest weight. In a weighted average, a forecasting scheme can respond more effectively to recent changes in the level of the series.[11] Biegel points out that it is difficult to obtain an estimate of the error in a forecast made by the weighted average.[12]

According to Shore, another common and widely used method of forecasting is by regression analysis or econometric forecasting. Regression analysis attempts to explain the reasons behind changes in the behavior of a series, rather than just focusing on time as the only explanatory variable. The essence of econometric forecasting is, "the identification of those causative factors which can best explain changes in the variable in which we are interested, and their use for predictive purposes". Regression analysis differs from exponential smoothing in that the former seeks cause and effect while the latter accounts for the time series by breaking it down into its basic components; trend, irregular, seasonal, etc. Shore defines simple regression analysis with the following relationship: y is a function of x.[13]

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[11] Shore, op. cit., pp. 274-275.

[12] Biegel, loc. cit.

[13] Shore, op. cit., pp. 301-302.

Another common technique of forecasting is by exponential smoothing. This technique will be discussed in detail in Chapter 5.

OTHER FORECASTING TECHNIQUES

There are a wide variety of forecasting techniques which have been developed for specific applications. A few of these techniques will be presented in the following.

Brown suggests that in inventory control, a second-order system could be developed to track trend in demand. The calculation of trend by use of a kind of second-order on any system is the best in inventory control.[14] Another method suggested by Brown is the use of a known autocorrelation function.[15]

In considering a technique, one could seek several alternatives: (1) maximize the probability of being exactly right, without regard to how large the error is when wrong, (2) maximize the probability that the errors do not exceed some threshold value and (3) minimize the average absolute value of the error, rather than the average square value.

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[14]Robert G. Brown, Statistical Forecasting for Inventory Control (New York: McGraw-Hill Book Company, 1959), pp. 65-70.

[15]Ibid., pp. 70-72.

In this approach, Brown carries out a formal differentiation to find the weights that minimize the mean square error.[16]

Magee suggests a combination of methods to forecast demand. Some companies rely on economic forecasts for a period one to five years ahead for policy and capital, then on field opinion, forecast for near term estimates. Statistical techniques are used to break down field forecasts into detail.[17] Thus it can be logically understood that not one method but a combination may be useful.

Magee points out other statistical techniques among which are correlation and correlation with lags. A number of methods exist for developing seasonal indices of demand based on past experience, such as the extrapolation method using autocorrelation and others.[18] Biegel gives an approach called curvilinear regression for forecasting. In this statistical approach, the data is assumed to have a curvilinear form.[19] Holt, Modigliani, Muth, and Simon suggest other statistical forecasting methods. They suggest linear

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[16]Ibid.

[17]Magee, op. cit., pp. 122-123.

[18]Ibid., pp. 123-129.

[19]Biegel, op. cit., pp. 38-39.

extrapolation applied to non-stationary processes. Another method suggested is analysis of variance and covariance.[20]

[20] Charles C. Holt, Franco Modigliani, John F. Muth, and Herbert A. Simon, Planning Production, Inventories, and Work Force (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1960), p. 152.

Chapter 3

EXTERNAL INFORMATION

External information is information other than direct data which could possibly add to an explanation or contribute to the understanding of the data. This is the type of information that cannot be measured, but indeed must be included in any study of data. This chapter will attempt to point out some of the common external information and show its importance in analyzing data.

Albert A. Hirsch, using the Bureau of Economic Analysis as a forecasting instrument, gives some judgemental elements in forecasting. He says, "a model can be a powerful aid to forecasting, but it should not be a straightjacket." Most forecasters exercise control on models by departing from mechanical procedures. Departures are based on internal information (part equation residuals), external information (economy emphasis), or judgemental restrictions. Judgemental elements are used by constant adjustment not in the formula already. Hirsch gives reasons on why adjustments are made:

> First, the recent pattern of residuals may not suggest 'decay' process given in the formula...Second, there may be special factors which explain the most recent residuals but which are not relevant in a special way. Third, the forecaster may know about an impending circumstances, either as a certainty or as a substantial possibility, which calls for special adjustments; or he may regard certain factors that are not incorporated into the model structure as relevant during the period of forecast.

After a run is made, some adjustments must be made if the outputs conflict with what is indicated by partial data. In addition, some outputs can be considered as unreasonable, so adjustment must be made.[1] Even though the BEA Quarterly Model is an econometric routine, it can be concluded that certain elements of judgement and other external information must be used for all models.

Thomas E. Vollman says that models are either extrinsic or intrinsic. The concern here is on extrinsic models and their effects. Extrinsic forecasts have an outside or external orientation and are formulated upon associations such as sales of appliances and disposable personal income. Extrinsic forecasts are usually based on regression analyses. Extreme care must be taken in the interpretation of statistical associations to infer that cause-effect relationships exist.[2]

The American Institute of Certified Public Accountants feel that some sort of causal relationship exists which could be referred to as correlation analysis where a factor is found that seems to correlate with demand. Even though some analysis shows a relationship, there is no real evidence that

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[1]Albert A. Hirsch, "The BEA Quarterly Model as a Forecasting Instrument," Survey of Current Business, 53, No. 8, (August, 1973), pp. 30-32.

[2]Thomas E. Vollman, Operations Management: A System Model-Building Approach (Reading, Massachusetts: Addison-Wesley Publishing Company, 1973), pp. 483-484.

a relationship exists. And so, if such a relationship exists, with little changed will the same relationship exist? In most cases the relationship is not simple and linear, but curvilinear and may involve simultaneous equations.[3]

In forecasting, only several items are consistently used which are; demand, levels of trend, seasonal factors, and deviations. Another external element that businesses and forecasters must consider is the market. The market is that element that does affect demand. Robert Brown says that marketing intelligence can be developed in three different ways:

> (a) Long-term outlook for the industry and for the firm's share of the market;
> (b) Information from the field, through salesmen's reports and market research, on customer's intentions and the plans of the competition;
> (c) Plans for new products and special promotions aimed at maintaining or increasing the share of the market.[4]

One can obtain these plans by industry forecasts and promotion plans to gauge the future of an industry or product.

Most models work well for the generalized industry. Every industry is different in some way or another. Special conditions exist for each and every industry to make it the independent industry it is. Vollman gives some problems or

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[3]American Institute of Certified Public Accountants, Techniques for Forecasting Product Demand, A Management Services Technical Study (New York: American Institute of Certified Public Accountants, Inc., 1968), pp. 36-40.

[4]Robert G. Brown, Management Decisions for Production Operations (Hinsdale, Illinois: The Dryden Press, Inc., 1971), p. 68.

situations that will call for modifications to the regular models. It is a bad assumption that demand patterns will not change. He corrects the problem by making the smoothing constant in a smoothing routine closer to one. A better proposal may well be to reevaluate the situation and possibly develop a new constant based on the latest effects of the data, and thus no radical impact will take place. Another problem is promotions, since forecasts cannot possibly be accurate when promotional activities are used, but promotions are necessary. Just as an industry seasonalizes its data with seasonal factors, possibly it can promotionalize its data to produce promotional indices. Another problem is that industries must adjust for lumpy demand, where demand in intervals is zero or very low. Lump demand also exists when forecasts are based on internal considerations rather than external considerations. To solve the problem, Vollman suggests a technique called probability forecasting, where the demand of these items in a period is an independent random event where sales should resemble past history.[5]

The common and accepted approach to forecasting sales, for example, is to study past sales. This should provide the best information. Holt, Modigliani, Muth, and Simon say that this approach is not always the best and that improved forecasts could be obtained on the basis of indicators other than

[5]Vollman, op. cit., pp. 508-511.

past sales. The company should study those indicators of general business activity whose movements are expected to parallel closely with the industry's item. In the case of paint sales, for example, the company should consider instead:

> (1) GNP in constant dollars; (2) Disposable Personal Income delfated by an implicit delfator of the consumption component of GNP; (3) the new construction component of GNP in constant dollars, (4) the Gross Private Investment component of GNP in constant dollars minus changes in inventories; (5) the Federal Reserve Board Index of Industrial Production.[6]

Thus, a few ideas on external information and its effect on forecasts have been provided. It can be generalized that models must consider external information that applies to its product and other activities relating to its product. Judgemental analysis is necessary at certain levels to add the human element. Even the BEA forecasting model makes use of judgemental analysis and makes certain adjustments based on external information.

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[6]Charles C. Holt, Franco Modigliani, John F. Muth, and Herbet A. Simon, Planning Production, Inventories, and Work Force (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1960), pp. 145-146.

Chapter 4

APPLICATIONS IN FORECASTING

It is now apparent that man is able to forecast the future using many different methods. These methods combined with human elements enable man to project to the future and give the consumer what is demanded. This chapter will attempt to point out some of the more generalized uses of forecasts in an attempt to show that forecasts can be used in just about anything. Common uses of forecasts are in inventory control, production planning, and sales. Forecasts can also be used for such things as anticipating student enrollment in universities, or the effects one chemical may have on another substance. Some may think that this is just a dream! If it is possible to forecast sales and production, certainly it is possible to forecast chemical effects.

Thomas E. Vollman indicates that in forecasting many attempt to identify past basic demand levels generated by a complex set of known and unknown factors. In doing so, efforts are divided into two categories of models; one for estimating future demand level and another concerned with assessments of the influence of additional or new causal factors on a given level of demand.[1]

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[1]Thomas E. Vollman, Operations Management; A System Model-Building Approach (Reading, Massachusetts: Addison-Wesley Publishing Company, 1973), pp. 479-480.

Forecasts, regardless of the application, are an extreme necessity in many businesses. The basic reason a company forecasts is to be prepared for the future. Thus, one must attempt to observe the market place a few periods ahead. The lag time is necessary for a business to examine its inventories and production capabilities and estimate its capability to meet future demand. It can then reorder if necessary. Another use of the lag is to accommodate those vendors that also need time to produce the raw material. Industries need to project for the future and adjust as necessary:

> 1. To determine the necessity for and the size of plant expansions. 2. To determine the intermediate planning for existing products to be manufactured with existing facilities. 3. To determine the short range scheduling of existing products to be manufactured on existing equipment.[2]

INVENTORIES

One of the more common uses of forecasts by businesses is inventory control. Inventory theory is defined as finding input (replenishment) and output (demand) functions for an inventory (defined as an ideal resource of any kind) that maximize a given measure of effectiveness subject to certain

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[2]John E. Biegel, Production Control: A Quantitative Approach (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963), p. 17.

restrictions.[3] Robert G. Brown suggests that techniques for application to inventory control problems are methods of adaptive forecasting and statistical determination of safety stock.[4]

A.H. Packer attempts to illustrate adaptive forecasting in inventory control. The procedures he followed in reaching objectives were:

> 1. Build a model of the particular inventory studied through formulation of a nd expression... 2. Manipulate the model through a period of time simulating the present inventory decision rules... 3. Manipulate the model through the same period of time simulating the proposed decision rules or control variables (a number of simulations are required to establish the optimum exponential smoothing parameter values)... 4. Compare (statistically) the results of the simulations and raw conclusions as to the magnitude of the improvement.[5]

Packer uses the exponential smoothing technique to forecast and points out several davantages of this technique:

> 1. Only records of the last estimate of the average and a smoothing factor need to be retained. 2. The impact of recent experience on the next estimate of demand can be easily adjusted. 3. The average can account for a trend or cyclical demand situation. 4. The impact of any single month's experience decreases exponentially with time, if

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[3]A.H. Packer, "Simulation and Adaptive Forecasting As Applied to Inventory Control," Operations Research, 15, No. 4, (July 1967), p. 660.

[4]Ibid., p. 661.

[5]Ibid., p. 662-663.

> the model of the demand curve is a straight line, then exponential smoothing fits a model that minimizes the weighted sum of the squares of the errors.[6]

The problem in Packer's model is the choice of a proper smoothing constant. He suggests trying out a few values and finding the best fit.[7] Thus it can be realized that in this problem as well as any, the best smoothing constant is essential.

The importance of inventories must not be underestimated. Production could stop as well as goods and services not provided for customers because of poor inventory control. Elwood S. Buffa insists that demand forecast is critical for some of the most important decisions in production and operations management, particularly those related to inventories, etc. Forecasts are a critical input to the design of a system because they are a direct factor in the determination of the most economical production design of products.[8]

There are various kinds of inventories that are used for analytical purposes. These are pipeline, lot size or cycle, buffer, decoupling, and seasonal. Pipeline inventories are those at hand used to meet every lag during the transit time or to fill the pipeline. Lot size inventories are the

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[6]Ibid., p. 665.

[7]Ibid., p. 665-666.

[8]Elwood S. Buffa, Modern Production Management, 4th Edition (New York: John Wiley and Sons, 1973), pp. 474-476.

amount present for specified periods. This should be as much as possible to minimize storage costs. Buffer stock is used to protect against unpredictable variation in demand and supply time. Decoupling inventories are the amount in stock that will make the required operations independent enough of each other so that low cost operation can be carried out. Inventories in warehousing can proceed independent of manufacturing. Seasonal inventories attempt to follow demand on a seasonal basis.[9]

It can be realized that inventory control systems are varied and complex. The generalized applications and methods were introduced. Forecasting is truly essential in inventory control, for without forecasts there would be no control.

PRODUCTION PLANNING

Another common use of forecasts is in production planning. Todays industries must plan for very important elements of production such as payrolls, hiring, layoffs, inventories, and machine costs. These and many other items compose the cost of production. The forecasts are necessary because of the tremendous costs incurred by any one of the production elements. An accurate forecast is essential to the planning of production.

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[9]Ibid., p. 476-479.

Production planning is actually deciding how many of each product to manufacture. Industry is lashed with the responsibility of making products before they are sold and before they know to whom the product is to be sold or the quantity. As is evident, bad forecasts cost money. If an industry underestimates, the product runs out and sales are lost. If an industry overestimates, the industry must then incur the cost of inventories and products must be marked down. Because of raw materials, inventory control, and equipment, forecasts must be made far in advance. Forecasts aid in determining factory schedules which are the heart of any production department. Forecasts are objectives and can be generalized as sales programs and goals. It is an attempt to develop competition. Forecasts of production develop budgets by generating plans for income and profit. Production planning is a basis for inventory control.[10]

Franklin G. Moore says that production control does not forecast sales. Its function is to analyze tentative forecasts made by others into factory capacity requirements and help in developing forecasts and production needs. Moore adds that most industries have the production control department do the forecasting, because the sales department is likely to be optimistic at times. This should avoid irregular production.[11]

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[10]Franklin G. Moore, Production Control (New York: McGraw-Hill Book Company, Inc., 1959), pp. 111-113.

[11]Ibid., pp. 123-124.

John Magee says that production planning is concerned with the future, with layout of production operations to meet future anticipated sales with facilities that may not even exist. Production planning must fix some or all the characteristics of manufacturing and distribution operations. Thus, the objective is to arrive at statements about general characteristics of manufacturing during the period planned. He says that production planning methods have two important uses. One is direct planning used to draw up production plans, subject to costs, policies, finances, customer service, and labor stability. The other function is to give management guides for use in setting the basic policies.[12]

Just as in inventory control, forecasts are a necessary and an important part of production planning. An accurate forecast can be very important to an industry's production planning in the form of schedules. Costs are minimized with a good and accurate forecast.

SALES

Any industry must depend on forecasts for sales. Sales forecasts give the industry that basic element used to determine the amount of product that must be produced and in turn a production plan which results in optimum inventory

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[12]John F. Magee, Production Planning and Inventory Control (New York: McGraw-Hill Book Company, Inc., 1958), p. 133.

control. Sales forecasts measure consumer demand in the form of tastes, seasons, styles, and many other unmeasurable items of utility.

William Voris attempts to define the sales forecasts as:

> an attempt to determine objectively the volume of sales which can reasonably be expected by the subject company at some future date.

The type and quantity of manufacturing exerts a big influence on the importance of a sales forecast. The sales forecast is used primarily to evaluate over-all economic conditions and serves as a general guide. Voris suggests several uses of sales forecasts as:

> 1. The sales forecast is of value in making policy decisions that involve budgeting...
> 2. In controlling inventories...
> 3. In improving production control through a more accurate picture of the future...
> 4. In setting up an accurate yardstick for evaluating territories and salesmen...
> 5. In planning expansion realistically...
> 6. In allocating wisely the money to be spent in sales promotion and advertising.
> 7. In eliminating or replacing unprofitable products.
> 8. In developing effective financial controls...
> 9. In establishing personnel policies more effectively.[13]

Samuel Eilon says that market research is an indispensable part of the planning function of an industry. The study

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[13]William Voris, Production Control, Text and Cases (Homewood, Illinois: Richard D. Irwin, 1961), pp.131-133.

of those factors in the market that contribute to a final sales forecast is closely associated with activities included as one of the functions of the sales department. In making a sales forecast, several considerations must be included. These are consumption and its restrictions, the product and its limitations, consumers and buying power, competition, saturation, replacement, distribution, advertising, terms of sale, pricing, business cycles, and general satisfying of consumer demand.[14]

OTHER APPLICATIONS

Forecasts have a variety of uses as were discussed above. Some of the other applications may be new product demand, forecasting aggregate orders, and forecasting the economy.

Hamburg and Atkins have a computer model for forecasting new product demand. The model was used to guide marketing decisions during the life of the new product. It uses past data and includes a feedback system providing for reforecasts as new data is available. Traditional methods of time series analysis were not used because there was no history of past data. The model utilized the amount of

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[14]Samuel Eilon, Elements of Production Planning and Control (New York: The Macmillan Company, 1962), pp. 100-114.

awareness and information as it came in to develop a forecast. It can reforecast as data enters the system.[15]

The forecast of aggregate orders is an attempt for an industry to project on forecast sales of another company to determine its sales. The process works because one company's output is another company's input. This type of forecast is closely related to sales forecasts.

The BEA Quarterly Model was used as a forecasting instrument. The Bureau of Economic Analysis Quarterly model belongs to the large model class in forecasting. It is also used to analyze the impact of government policies. Thus, the economy in general is forecast. In this particular case, forecasting refers to the estimation of probable values of economic variables. This model is an econometric forecast of the economy. The validity of this forecast is based on past performance and prediction errors.[16]

Psychologists who have studied the learning process have developed a model. They say that one's level of understanding at any time is equal to his previous level of

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[15] Hamburg, M. and R. J. Atkins, "Computer Model for New Product Demand," Harvard Business Review, 45 March, 1967, pp. 109-113.

[16] Albert A. Hirsch, "The BEA Quarterly Model as a Forecasting Instrument," Survey of Current Business, 53, No. 8, (August, 1973), pp. 24-25.

understanding plus some fraction of the difference between a new experience and his previous understanding.[17]

As has been demonstrated in this chapter there are many uses of forecast. A good forecast can be applied to almost anything. One can even use good forecasts in budget planning for the family. For any problem man can develop for himself, a forecast can be used in solving it.

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[17]Robert G. Brown, Smoothing, Forecasting and Prediction of Discrete Time Series (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963), p. 104.

Chapter 5

EXPONENTIAL SMOOTHING

GENERAL

Exponential smoothing is a forecasting technique based upon the moving averages method. Unlike the moving averages method, exponential smoothing does not weigh the effects of past data equally. Exponential smoothing can allow the user to apply weight to the latest data and then affect the forecast. Similarly, with this technique, industry can adjust the routine to react to particular situations if necessary. Exponential smoothing can be simple or it can allow for trend in the data. It can also adjust for seasonal effects or allow for all effects at one time-trend, seasonal, and irregular patterns. A distinct advantage of exponential smoothing is that unlike moving averages and other methods, this technique does not require past data to forecast.

SIMPLE EXPONENTIAL SMOOTHING

Barry Shore points out that the simplest kind of time series is one with only irregular movement. If the data is weighted in such a way that the most recent data had the heaviest weight, the forecasting scheme could respond more effectively to recent changes in the series. In general notation, the weighted average in five terms is:

$$F = W_n d_n + W_{n-1} d_{n-1} + W_{n-2} d_{n-2} + W_{n-3} d_{n-3} + W_{n-4} d_{n-4}$$

where:

F = new average to be used as a forecast

W_n = weight in month n

d_n = actual demand in month n

The restriction is:

$$\sum_{i=1}^{n} W_i = 1$$

The above example of a weighted average is similar to exponential smoothing. Exponential smoothing, however, continues indefintely into the past.

$$F = W_n d_n + W_{n-1} d_{n-1} + W_{n-2} d_{n-2} + \ldots$$

and

$$\sum_{i=1}^{n} W_i = 1$$

The weights sum to 1. Exponential smoothing allows the weights to be chosen in a special way. The weights are powers of a smoothing constant A:

$$D_n = Ad_n + A(1-A)d_{n-1} + A(1-A)^2 d_{n-2} + A(1-A)^3 d_{n-3} + \ldots$$

D_n is used to represent the smoothed average computed in period n. The value of A is restricted between 0 and 1. For example, if A = .1, the exponentially smoothed function would be:

$$D_n = .1d_n + .09d_{n-1} + .081d_{n-2} + \ldots$$

Another way to specify the exponentially smoothed function is:

$$D_n = D_{n-1} + A(d_n - D_{n-1})$$

where:

D_{n-1} = exponentially smoothed average determined last month, or this month's forecast

d_n = this month's actual demand

Thus, the new average is equal to the old average plus some part of the error in estimating this month's demand. A more shortened form of the function, which is most useful is:

$$D_n = Ad_n + (1-A)D_{n-1}$$

Thus, it can be noted that the preceeding shortened form will solve the data storage problem.[1] Example: The smoothing constant A is equal to .1. Last month's forecast for the month (D_{n-1}) is equal to 14. The actual demand this month (d_n) is equal to 12. Next month's demand (D_n) would be calculated as follows:

$$D_n = .1(12) + (1-.1)14$$

$$D_n = 1.2 + .9(14)$$

$$D_n = 1.2 + 12.6$$

$$D_n = 13.8$$

Next month's demand would be forecast as 13.8. In using exponential smoothing only the last forecast must be retained.

Thomas Vollman points out that the effect of each demand observation is retained forever. The weight associated

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[1]Barry Shore, Operations Management (New York: McGraw-Hill Book Company, 1959), pp. 274-277.

with the demand estimate is subject to exponential decay. As any actual demand always has an impact on the forecasted demand, it will retain some influence on estimates of future demand.[2]

Robert G. Brown gives three advantages of exponential smoothing. He says that smoothing is accurate and proves that this function minimizes the weighted sum of squared residuals. The computations are simple and require less arithmetic than a moving average. The file of historical information is shortened from n-1 observations to D_{t-1}. And finally as mentioned above, exponential smoothing is flexible; capable of adjusting to any type of data.[3]

TREND AND IRREGULAR

Some data clearly contain a trend with some irregular noise factors. When the simple exponential model is used on this type of data, the smoothed series lags behind the actual series, assuming an upward trend. Barry Shore corrects for the lag by the following:

$\bar{D}_n = D_n$ + correction for lag due to trend

$\bar{D}_n$ becomes the new trend corrected forecast. He

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[2]Thomas E. Vollman, Operations Management: A System Model-Building Approach (Reading, Massachusetts: Addison-Wesley Publishing Company, 1973), pp. 491-492.

[3]Robert G. Brown, Smoothing, Forecasting and Prediction of Discrete Time Series (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963), p. 102.

determines the trend corrected average as:

$$\bar{D}_n = D_n + \frac{1-A}{A} T_n$$

T_n = exponentially smoothed trend

T_n is computed in the following manner:

$$T_n = T_{n-1} + A(t_n - T_{n-1})$$

where:

$$t_n = D_n - D_{n-1}$$

A more versatile model, which can be used for irregular and trend components is:

$$D_n = (D_{n-1} + T_{n-1}) + A\left[d_n - (D_{n-1} + T_{n-1})\right]$$

$$T_n = T_{n-1} + B\left[(D_n - D_{n-1}) - T_{n-1})\right]$$

and:

$$\bar{D}_n = D_n + T_n$$

where:

D_n = is the smoothed average

D_{n-1} = smoothed average determined last period

d_n = this month's actual demand

T_n = exponentially smoothed trend

T_{n-1} = smoothed trend determined last month

$\bar{D}_n$ = the smoothed average corrected for trend

When the trend factor (T_{n-1}) is unknown, the trend can be assumed as zero, therefore $T_{n-1} = 0$. The remaining values of the trend factor can then be computed.[4]

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[4]Shore, op. cit., pp. 280-283.

Example:

$$\text{Assume } A = .1$$
$$B = .1$$
$$D_1 = 12$$
$$T_1 = 4$$
$$d_2 = 14$$

$$D_2 = (12 + 4) + .1[14 - (12 + 4)]$$
$$D_2 = (16) + .1\ (-2)$$
$$D_2 = 16 + (-.2)$$
$$D_2 = 15.8$$
$$T_2 = 4 + .1[(15.8 - 12) - 4]$$
$$T_2 = 4 + .1\ (-.2)$$
$$T_2 = 3.98$$
$$\bar{D}_2 = 15.8 + 3.98$$
$$\bar{D}_2 = 19.78$$

It is cautioned that the above function for exponential smoothing for trend and irregular components assumes that the trend factor may be described by the difference between the old and new averages. Both averages in the function could possibly have been unduly influenced by random factors in recent demand.[5]

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[5] American Institute of Certified Public Accountants, Techniques for Forecasting Product Demand, A Management Services Technical Study (New York: American Institute of Certified Public Accountants, Inc., 1968), p. 18.

SEASONAL AND IRREGULAR

Some data contain seasonal factors that influence the level of demand and seasonal adjustments must be made to the forecast. If seasonal factors are present, the data must be deseasonalized. The seasonal factor is F_{n-L} where L is the number of periods in the cycle and n is the period to be forecast. The smoothed deseasonalized average is:

$$D_n = D_{n-1} + A \left[\frac{d_n}{F_{n-L}} - D_{n-1} \right]$$

where:

D_n = deseasonalized computed forecast

D_{n-1} = deseasonalized average computed last period

$\frac{d_n}{F_{n-L}}$ = this period's deseasonalized actual demand

A = smoothing constant

The seasonal factor F_{n-L} is based on the pattern of seasonal variation that occurred L periods ago, 2L periods and on. An efficient way of computing and updating a weighted average with a seasonal factor would be exponential smoothing. A function for updating seasonal factors is:

$$F_n = F_{n-L} + C \left[\frac{d_n}{D_n} - F_{n-L} \right]$$

where:

F_n = new exponentially smoothed seasonal factor

F_{n-L} = seasonal factor computed during the corresponding season last year.

and used to deseasonalize demand in the
ore explains the function; the new updated
s equal to the old seasonal estimate F_{n-L}
.ct. 1 C of the difference between the actual
is period and the old estimate. To fore-
period n + 1:

F_{n-L+1}

ecast for the next period
easonalized smoothed demand for period n.
onal factor applying to next period's fore-
cast and computed n-L+1 periods ago.

$\bar{D}_{n,1}$ would then be the forecast with the seasonal factors considered.[6]

Example:

Assume $A = .1$

$C = .2$

$d_1 = 51.0$

$D_1 = 51.0$

$F_{1-4} = 1.0$

$F_{2-4} = 1.2$

$L = 4$

$$D_1 = 51.0 + .1 \left[\frac{(51.0)}{(1.0)} - 51.0 \right]$$

[6]Shore, op. cit., pp.284-286.

F_n will be stored and used to deseasonalize demand in the next year. As Shore explains the function; the new updated seasonal factor is equal to the old seasonal estimate F_{n-L} plus some fraction C of the difference between the actual seasonal factor this period and the old estimate. To forecast for the next period n + 1:

$$\bar{D}_{n,1} = D_n \cdot F_{n-L+1}$$

where:

$\bar{D}_{n,1}$ = forecast for the next period

D_n = deseasonalized smoothed demand for period n.

F_{n-L+1} = seasonal factor applying to next period's forecast and computed n-L+1 periods ago.

$\bar{D}_{n,1}$ would then be the forecast with the seasonal factors considered.[6]

Example:

Assume $A = .1$

$C = .2$

$d_1 = 51.0$

$D_1 = 51.0$

$F_{1-4} = 1.0$

$F_{2-4} = 1.2$

$L = 4$

$$D_1 = 51.0 + .1 \left[\frac{(51.0)}{(1.0)} - 51.0 \right]$$

[6]Shore, op. cit., pp.284-286.

$D_1 = 51.0 + .1\ (51.0 - 51.0)$

$D_1 = 51.0 + 0$

$D_1 = 51.0$

$F_1 = 1.0 + .2 \left[\frac{(51.0)}{(51.0)} - 1.0\right]$

$F_1 = 1.0 + .2\ (1 - 1.0)$

$F_1 = 1.0 + 0$

$F_1 = 1.0$

$\bar{D}_{1,2} = D_1\ F_{2-4}$

$\bar{D}_{1,2} = 51.0\ (1.2)$

$\bar{D}_{1,2} = 61.2$

To illustrate the above example, the following table (Table 1) may be appropriate:

Table 1

n	d_n	D_n	F_n	$\bar{D}_{n,1}$
			1.0	
			1.2	
			1.0	
		51.0	.8	
1	51.0	51.0	1.0	61.2
2	61.0			

Brown gives principles to follow for deciding to use a seasonal method of forecasting. There must be a definite, dependable reason that creates demand at one period during a year and diminishes it at another. In addition, the seasonal variation in demand should be larger than the random variations or noise. Failure to observe the principle could lead to inventory problems and much extra work.[7]

TREND, SEASONAL, AND IRREGULAR

It is possible for data to contain a trend factor in addition to irregular and seasonal components. The function for data with trend irregular, and seasonal components is:

$$D_n = (D_{n-1} + T_{n-1}) + A \left[\frac{(d_n)}{(F_{n-L})} - (D_{n-1} + T_{n-1}) \right]$$

where:

T_{n-1} = smoothed trend factor computed last period. The last deseasonalized average is added to trend. It is then deseasonalized and trend corrected for the present period. The trend factor is computed as:

$$T_n = T_{n-1} + B \left[(D_n - D_{n-1}) - T_{n-1} \right]$$

The seasonal factor is computed as before:

$$F_n = F_{n-L} + C \left[\frac{(d_n)}{(D_n)} - F_{n-L} \right]$$

The forecast for the next period would then be:

$$\overline{D}_{n,1} = (D_n + T_n) F_{n-L+1}$$

where:

T_n = trend factor

F_{n-L} = seasonal factor (n-L) periods ago

d_n = actual demand this period

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[7]Robert G. Brown, Statistical Forecasting for Inventory Control (New York: McGraw-Hill Book Company, 1959), p. 129.

D_n = forecast average computed this period

D_{n-1} = forecast average computed last period for the period.

Thus, the average is deseasonalized trend corrected for the next period, then multiplied by the seasonal factor to give a seasonalized demand estimate.[8]

Example: Using the following table (Table 2), demand for period 2 will be computed.

Table 2

n	d_n	D_n	F_n	T_n	$\bar{D}_{n,1}$
			1.0		
			1.2		
			1.0		
		91	0.8	10	
1	101	101	1.0	10	133.2
2	128				

A = .2

B = .3

C = .1

$$D_1 = (91 + 10) + .2\left[\frac{(101)}{(1.0)} - (91 + 10)\right]$$

$$D_1 = 101 + .2\ (101 - 101)$$

$$D_1 = 101$$

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[8]Shore, op. cit., p. 287-288.

$$F_1 = 1.0 + .1 \left[\frac{(101)}{(101)} - 1.0\right]$$

$$F_1 = 1.0$$

$$T_1 = 10 + .3 \left[(101-91) - 10\right]$$

$$T_1 = 10 + .3\ (10-10)$$

$$T_1 = 10$$

$$\overline{D}_{1,1} = (101 + 10)\ 1.2$$

$$\overline{D}_{1,1} = 133.2$$

The forecast for period two would be 133.2. Note the use of the seasonal factor n-L periods ago to calculate the forecast for period two. The seasonal factor computed above will be used n + 3 periods from now to calculate a forecast.

Shore says that by the progression in models, a model with trend is more general than the simple model, or especially that a model with seasonal, irregular, and trend factors is more general than a model with trend. It is incorrect to assume that if the builder of a model is uncertain as to the presence of trend or seasonal factors, that he should use the model containing seasonal, trend, and irregular components. If this mistake were made, the model will react to certain sequences of noise and interpret them as seasonal or trend factors.[9]

Brown attempts to prove the theorem of exponential smoothing in Smoothing, Forecasting, and Prediction of Discrete Time Series. He then develops models for smoothing

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[9]Ibid., pp. 290-291.

higher-order polynomials. Some of these models are double exponential smoothing, based on the double moving average, triple exponential smoothing, and multiple smoothing in general.[10]

SELECTION OF THE SMOOTHING CONSTANT

The exponential smoothing functions for simple, trend and irregular, seasonal and irregular, and trend, seasonal, and irregular components have been presented. It can be realized that all functions have a smoothing constant or constants. It is apparent that the values assigned to these constants, A,B, and C, play an important part in the function. In general cases, the recommended value is .1, but this may not be the best value. These constants can be any value between zero and one. The better choice of a smoothing constant will yield better forecasts.

Shore explains the problem as choosing a value that will respond to bona fide changes in level but not to random unexplainable changes called noise. If A is set 1.0, the new forecast will be equal to this period's actual demand. This puts weight on this period but not on previous periods. As A is shifted toward zero, emphasis shifts from recent data more evenly over all the periods. As he points out, for low

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[10] Brown, <u>Smoothing, Forecasting, and Prediction of Discrete Time Series</u>, op. cit., pp. 123-143.

values of A, the response to sudden changes becomes sluggish, regardless of whether the change is bona fide or noise. He says that there is no way to determine beforehand which value of A will perform the best. "Several values must be tried." Testing must be accomplished to compare the forecast ability of different values. Shore suggests one method of testing that is used in the program EXPO. A value of .1 is given to A. Using past data, a forecast is made for the second period by computing a smoothed average from data in period 1. Then, the values are plotted on a graph (actual and smoothed averages). The process continues until all values are computed and plotted. Then, a new and different value of A is used to determine new forecasted values. Several values of A are attempted. It follows that one can determine which value of A tracks the actual demand best.[11]

The objectives of a model are to minimize forecast errors. Some combinations of A,B, and C have different errors than other combinations. As a result, many combinations should be tried before choosing a set.[12] Winters used a technique in determining values for A,B, and C in a model. He tried all combinations of weights, 0 to 1.0 for each of the three factors. For each combination used in the calculation, a standard deviation of forecast errors was computed. The

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[11] Shore, op. cit., pp. 277-278.

[12] Ibid., p. 290.

values with the least standard deviation gave access to a finer grid of values.[13] This method is somewhat used in the forecasting model EXPO.

Vollman maintains that the choice of the smoothing constant is situation dependent and should be based on the costs of forecast errors and one's model of behavior which generates the demand. It has been shown that for fairly stable forecasting situations, smoothing constants in the neighborhood of .1 tend to yield low forecast errors.[14]

Rao and Shapiro say that if a time series satisfies a value of A between .1 and .2, the forecasts are stable. When a change occurs in the series, such a value of A will cause the smoothed series to lag behind the actual series for some period of time. A high value of A at the point where the change occurred makes the smoothed series catch up rapidly. As the smoothed series catches up, a small value of A is then used. They, therefore, recommend a procedure based on the Fourier transform of the autocovariance function of the series that will automatically increase the value of A when a change occurs and reduce it to about .1 when the series

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[13] Ibid.

[14] Vollman, op. cit., p. 495.

stabilizes. This process is called adaptive smoothing using evolutionary spectra, the power spectrum.[15]

Brown suggests that the smoothing constant is generally between .1 and .3. He attempts to define an exponential smoothing system as equivalent to an n-period moving average, that is to say the smoothing constant is elected to give the same average age of the data. This would be $\frac{1-A}{A} = \frac{n-1}{2}$ or $A = \frac{2}{n+1}$. Brown has a table of smoothing constants arranged according to the number of observations. Brown says that generally forecasts are less stable for larger values of the constant, but the speed of response to a step input increases.[16] He also says that if there is reason to feel that a conventional average over the past n observations would be satisfactory between smoothing the random fluctuations and response to real changes in demand, then the equivalent value is:

$$A = \frac{(n-1)}{(n+1)}$$ [17]

Thus, several means at arriving at some values for A, B, and C have been presented. The values are certainly

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[15]Ambar G. Rao and Arthur Shapiro, "Adaptive Smoothing Using Evolutionary Sectra," Management Science, 17, No.3, (November, 1970), p. 209.

[16]Brown, Smoothing, Forecasting, and Prediction of Discrete Time Series, op. cit., p. 107.

[17]Robert G. Brown, Management Decisions for Production Operations (Hinsdale, Illinois: The Dryden Press, Inc., 1971), p. 60.

situation dependent and must be taken from the data. There is no formula for computing a basic value of A, B, and C. The values A, B, and C that fit the data the best should be used. A best fit could be accomplished by a least variance approach. Many feel that the choice of the values assigned to A, B, and C are of little importance; however, it can be realized that this could be the key to a good or bad forecast. The main emphasis of any forecast should be on the choice of the smoothing constant. The 'best' exponential smoothing constant will yield the 'best' forecast.

Chapter 6

CONTROL SYSTEMS AND VALIDITY OF FORECAST

Once the data is present and values have been selected to be assigned to the smoothing constants, the next objective is to monitor the model. At some point in time, the forecast model may need some adjustment. There are many ways to monitor a model and recognize a model out of control. If a model is out of control or values are improperly selected, the forecast cannot be valid. A suggested approach to controlling a model is to monitor the variance. One could recognize simply when the forecast is getting further and further away from actual demand. At this point, the model could be analyzed and adjusted. The smoothing constants could be recalculated. In any case, the model is simply not working and something must be done to put it back on track.

Barry Shore develops a control system to monitor the magnitude of the difference between the actual and forecast values. If a model is correct, the forecast error, difference in actual and forecast values, should average out to zero. A cumulative sum of errors could be maintained and when the sum is too large, the system is out of control.[1]

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[1]Barry Shore, Operations Mangement (New York: McGraw-Hill Book Company, 1959), p. 291.

Robert Brown suggests a smoothed error estimate Zn.

$$Zn = Z_{n-1} + E(e_n - Z_{n-1})$$

where:

e_n = is the actual error in period n

$e_n = d_n - D_{n-1}$

E = smoothing constant

He then develops an estimation of the system variability called the mean absolute deviation, MAD:

$$MAD_n = MAD_{n-1} + E(|en| - MAD_{n-1})$$

MAD_{n-1} = smoothed values last period

E = same constant used in computing the error

$|en|$ = absolute value of actual forecast error.[2]

There should be control over the quality of forecasts for four reasons. Knowledge of the reliability of forecasts is basic to fixing inventory reserves needed to maintain service in the presence of error. Secondly, knowledge of the range of error and cost of maintaining inventory to absorb error gives a basis for projecting effort to improve forecasts. Also, a record of errors and causes of errors gives the forecaster raw material to study in improving forecasting techniques and reliability. Fourth, a record aids in determining any systematic bias in the forecast. Such charts give important records for determining the limits of forecasts,

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[2]Ibid., pp. 291-293.

unexpectedly large forecast errors, and developing trends and biases in errors.[3]

Many models have been used for the sole purpose of controlling the forecast and recognizing forecast errors. Some suggested models are a pattern recognition model developed by Russell Fogler,[4] control systems using spectra analysis by Rao and Shapiro,[5] forecast evaluation in choosing a forecasting method,[6] and even a technique used to control the BEA model.[7] Some method of control must be applied to a model even if it is simply monitoring the forecasts for any unusual predictions. However complicated the system, human intervention is necessary. That form of intervention, after an error signal is detected, is to readjust A, B, and C accordingly and again monitor the system. Also, a re-examination of the time series may be warranted in an effort to determine whether another model might be more appropriate.

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[3]John F. Magee, Production Planning and Inventory Control (New York: McGraw-Hill Book Company, Inc., 1958), p. 130.

[4]Russell Fogler, "A Pattern Recognition Model for Forecasting," Management Science, 20, No. 3, (April 1974), pp. 1178-1189.

[5]Ambar G. Rao and Arthur Shapiro, "Adaptive Smoothing Using Evolutionary Spectra," Management Science, 17, No. 3, (November, 1970), pp. 209-210.

[6]Joel S. Demski and Gerald A. Feltham, "Forecast Evaluation," Accounting Review, 47, (July, 1974), pp. 533-548.

[7]Albert A. Hirsch, "The BEA Quarterly Model as a Forecasting Instrument," Survey of Current Business, 53, No. 8, (August, 1973), pp. 25-38.

According to Magee, the question of forecast reliability is one of the greatest sources of misunderstanding and frustration in the construction of forecasts. One reason may be the belief that the forecast is or should be fixed. He points out that a forecast is an evaluation of incomplete evidence indicating what the future may look like. A forecast is not expected to be accurate. A forecast should be appreciated as a guide or estimate, realizing that it will be in error to some degree and that plans must be made to account for some error. A forecast made without an estimate of error is incomplete.[8]

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[8]Magee, op. cit., pp. 115-116.

Chapter 7

EXPO- A MODEL FOR EXPONENTIAL SMOOTHING

THE MODEL

The model EXPO, Appendix 1, is a FORTRAN program used to forecast by exponential smoothing. The model is designed to allow a user to forecast any type of data; simple, trend, seasonal, and a combination of trend, seasonal, and irregular. The model can forecast based on information provided for the next period or can create its own forecasting information. A comparison can be generated between the users values of smoothing constants and the constants provided by the model. If the user desires, values of smoothing constants, trend factors, or seasonal factors can be calculated. Finally, a user may simply submit his data and the model will compute all possible sub-models, trend, simple, seasonal, or combination, and provide the best sub-model as well as the best smoothing constants.

FORECASTING USING EXPO

This section attempts to give a detailed explanation of the program EXPO. Reference to Appendix 1 is necessary. The program uses a FORTRAN IV compiler and occupies 46,704 bytes of information. The linkages necessary will depend on system design; and the use of EXPO is explained in Appendix

2. Several areas are dimensioned to provide for the input past data (BATA), calculated forecasts (ADEM), calculated trend factors (ATREN), calculated seasonal factors (ASEAF), dummy storage areas (ADAM and ERR2), and error or variance storage areas for comparison of least variance (ERR1). In most cases, name (n,11) will be used as an area in which the user provided values of constants, are stored as they are computed. After the values with the least variance or best fit is determined, name (n,1) is used to store values as computed.

The program begins by writing headings and then reading in parameters for execution. These parameters are explained in Appendix 2. Initial values are set and the program proceeds to that point directed by the user: simple, trend and irregular, seasonal and irregular, trend, seasonal, and irregular, or undetermined by the user.

When the smoothing technique is directed, the program determines what the user needs for computation. He can direct a forecast based on inputed values, direct the program to compute smoothing values, compare the values, or have the program compute a plot of the data based on his smoothing values and based on the computed or best values for comparison. With all techniques, the program determines whether past data is provided. If it is provided, the past data is read into the system. If no data is present, the system reads in some values provided by the user for computation.

The values are then computed depending on type and written out. When data is provided, the program determines if some values are provided for comparison. If so, it reads the data into the system for future use and calculation as necessary. The user then may specify a plot of the forecast using his smoothing constant(s) and may not want a new computed constant(s). However, if a new constant(s) is desired, the constant values are initialized. In simple smoothing A = 0 and is incremented by .1 for each iteration. The same occurs for B and C, accordingly.

Examining each type of computation, simple smoothing attempts all values of A from .1 to 1.0. The first past forecast is set to equal the actual demand. Then, for each value of A, the forecast is computed for each period read in based on the formula provided in Chapter 5. A computation of the difference between the forecast and actual demand is accumulated for a variance of the forecasts using each value of A. Thus, one variance is computed for each of the ten values of A. Now, the program compares the variances and finds the least variance by brute force, retaining values indicating computation of that variance. Then, the program has the best value for A and its plot. It then writes out the plot if directed by the user. If the user provided his constant and desired a plot, the program computes a plot using the same initial values, but uses the smoothing constants provided. It also computes a variance. The final steps are to write out the plots (provided or computed) or the desired information.

Trend and irregular smoothing attempts all values of A and B from .1 to 1.0. The first past forecast is set to equal the actual demand. The trend factor begins at zero. Then for each value of A and B, the forecast is computed for each period read in based on the formula provided in Chapter 5. A computation of the difference between the forecast and actual demand is accumulated for a variance of the forecasts using each value of A and B, between .1 and 1.0. One variance is computed for each of ten values of A and ten values of B. The program compares the one hundred variances, finding the least variance. Accordingly, the best value of A and B is used to calculate the plot for print out if desired. If a plot is desired, using the user's input values of A and B, it is computed and printed out. A variance is also computed.

Seasonal and irregular smoothing attempts all values of A and C from .1 to 1.0 as in trend and irregular. The execution is the same as trend and irregular, except for the formula used. The first values are the same, but the seasonal factors for the number of periods is computed by the average percentage method. The data is computed for quarterly data and for monthly data as directed by the user. Thus, one hundred variances are computed for every value of A and

C between .1 and 1.0 and computed quarterly or on a monthly basis. A plot is calculated and printed out as before.

The smoothing function providing for trend, seasonal, and irregular components combine the efforts of the above two routines. Values are computed using A, B, and C between .1 and 1.0 for quarterly data or monthly. Thus, here one thousand variances are computed. Values are computed for a plot and printed if desired as before.

Finally, there is a routine for the user not knowing about his data. This routine must have the data from past periods. It allows computation in all the above mentioned functions saving the least variance of each and the critical values. All routines are attempted. Then, the routine calculates a plot to be printed out for each method attempted. Finally, the five least variances are then printed out for examination.

The last part of the program is the list of format statements used in input and output. This provides for any input/output routine desired.

CHOICE OF SMOOTHING CONSTANT

As was pointed out, the single most important element of the exponential smoothing forecasting function is the smoothing constant. The program does not use a set formula to compute a smoothing constant. The best constant(s) provides the best fit for the data it is smoothing. The program finds the best fit on the data by finding the values that generate the least variance. The variance is computed by:

$$S^2 = \sum_{i=1}^{n} \frac{(d_i - D_i)^2}{n-1}$$

S^2 = the variance

d_i = actual demand period i

D_i = forecast in period i

n = number of observations

Once the least variance or best fit is determined, the values associated are used to forecast. This is a trial and error method, but every set of data is different, thus they each have special smoothing constant values. EXPO provides the best constants to be used with this particular data.

These constants can then be used to forecast demand for its specific purpose. The user may want to check some other values used as smoothing constants. EXPO will use his values and compare his results with the results calculated. This allows the user to examine the effects on his data. He may be willing to sacrifice least variance for some other characteristics. It is recommended that the calculated values of the smoothing constants be recomputed at certain intervals. When the forecast errors begin to enlarge out of a predetermined range, new values of the constants should be computed based on the data. As a result, past data need be used only when new values are calculated. All other times in forecasting, the user need only retain the constants and previous forecasts.

CONTROL AND VALIDITY OF FORECAST IN EXPO

EXPO monitors the forecast errors in computing new smoothing constants as any model should. For the user that provides past data for computations of new values, EXPO monitors forecast errors while computing the variance of each iteration. This control system is used by EXPO so that the variance does not go completely out of control. The sum of forecast errors is not allowed to get above a maximum value. Another type of control system is suggested to the user. The exact method will be the decision of the user. Variances are provided, if desired by the user to keep records. Also, the user can use any of the methods listed in Chapter 6. A control system to detect out of tolerance forecasts does not exist in EXPO, because human intervention is necessary in controlling a forecast. The user should monitor the variance and forecast errors. He should recompute the smoothing constants, based upon the last batch of data. The optimum system would be to compute a new value to be assigned to constants, for each forecast accomplished. Thus, control, as well as accuracy is present in such a system.

Chapter 8

CONCLUSION

Forecasting attempts to predict the future and is only an estimate. Several techniques have been presented concentrating on exponential smoothing. Exponential smoothing may not be the best method of forecasting but it does have many advantages as pointed out. A forecasting technique has been presented that uses the least amount of data while relfecting past movement in the data. Applications of exponential smoothing as well as its function in forecasting were presented. A program was written that gives the user the ability to forecast by exponential smoothing in many ways. This program could simply forecast a simple exponential smoothing forecast or could analyze the data and develop the best smoothing constants as well as the best smoothed forecast. The user is no longer put in a position of guessing or approximating the smoothing constants. The best constants are those constants that generate the best fit on the data. EXPO gives this unique commodity to the user. A user manuel is provided so that EXPO can be easily used. Thus, a forecast can be provided with little effort.

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APPENDIXES

APPENDIX 1

```
      DIMENSION DATA(100),ADEM(100,11),ATDEM(100,11),ASEAE(100,11),
     1ERR1(10,10,10),ERR2(100,12),ADAM(100,12)
      WRITE(6,1)
      READ(5,2)IA,INUM,IMETH,IPLOT,IDATA,INEW,ITHINK
      ICODE=0
      DEMN=0.0
      I=0
      IF(IMETH.EQ.0)GO TO 10
      IF(IMETH.EQ.1)GO TO 20
      IF(IMETH.EQ.2)GO TO 30
      IF(IMETH.EQ.3)GO TO 40
      IF(IMETH.EQ.4)GO TO 50
   20 IF(IDATA)60,70,60
   70 IF(IA)80,90,80
   80 READ(5,3)ACT,DEM,A
      DEMN=0.0
      DEMN=A*ACT+(1.-A)*DEM
      IF(I.EQ.1) GO TO 100
      WRITE(6,4)A,ACT,DEM,DEMN
      GO TO 99
   60 READ(5,5)(DATA(J),J=1,INUM)
      I=1
      IF(IA)80,100,80
  100 IF(INEW)101,105,101
  101 ATRY=0.0
      DO 103 ITRY=1,10
      ER=0.0
      ATRY=ATRY+.1
      ADEM(1,ITRY)=DATA(1)
      IN=0
      INUMM=INUM-1
      DO 102 ID=1,INUMM
      IDD=ID+1
      ADEM(IDD,ITRY)=ATRY*(DATA(IDD))+(1.-ATRY)*ADEM(ID,ITRY)
      IN=IDD+1
      IF(IN.GT.INUM)GO TO 102
      ER=(DATA(IN)-ADEM(IDD,ITRY))**2+ER
  102 CONTINUE
      ERR1(ITRY,1,1)=ER/(INUM-1)
  103 CONTINUE
      ER=0.0
      ADEM(1,11)=DATA(1)
      ESM=ERR1(1,1,1)
      DO 104 II=1,10
      IF(ESM.LT.ERR1(II,1,1))GO TO 104
      ESM=ERR1(II,1,1)
      ISAV=II
  104 CONTINUE
      ATRY=0.0
      DO 105 II=1,ISAV
```

```
105 ATRY=ATRY+.1
106 IF(IPLOT)109,107,109
107 IF(DEMN.NE.0.0)GO TO 108
    WRITE(6,6)ATRY,BATA(INUM),ADEM(INUM,ISAV),ESM
    GO TO 99
108 WRITE(6,7)A,ACT,DEM,DEMN,ATRY,ADEM(INUM,11),ESM
    GO TO 99
109 IF(DEMN.NE.0.0)GO TO 111
    WRITE(6,601)
    DO 110 ID=1,INUM
110 WRITE(6,8)BATA(ID),ADEM(ID,ISAV)
    WRITE(6,9)ATRY,ESM
    GO TO 99
111 INUMM=INUM-1
    DO 112 ID=1,INUMM
    IDD=ID+1
    ADEM(IDD,11)=A*(BATA(IDD))+(1.-A)*ADEM(ID,11)
    IM=IDD+1
    IF(IM.GT.INUM)GO TO 112
    ER=ER+(BATA(IM)-ADEM(IDD,11))**2
112 CONTINUE
    EER=ER/(INUM-1)
    WRITE(6,602)
    DO 113 ID=1,INUM
113 WRITE(6,11)BATA(ID),ADEM(ID,11),ADEM(ID,ISAV)
    WRITE(6,12)A,EER,ADEM(INUM,ISAV),ATRY,ESM,ADEM(INUM,11)
    GO TO 99
 30 IF(IDATA)61,71,61
 71 IF(IA)81,90,81
 81 READ(5,13)ACT,TREN,DEM,A,B
    DEMN=0.0
    TRENN=0.0
    DEMN=(DEM+TREN)+A*(ACT-(DEM+TREN))
    TRENN=TREN+B*((DEMN-DEM)-TREN)
    DEMN=DEMN+TRENN
    IF(I.EQ.1)GO TO 200
    WRITE(6,14)A,B,ACT,DEM,TREN,DEMN,TRENN
    GO TO 99
 61 READ(5,5)(BATA(J),J=1,INUM)
    I=1
    IF(IA)81,200,81
200 IF(INEW)201,206,201
201 ATRY=0.0
    BTRY=0.0
    DO 203 ITRY=1,10
    ER=0.0
    BTRY=BTRY+.1
    ATRY=0.0
    DO 214 JTRY=1,10
    ER=0.0
```

```
      ATRY=ATRY+.1
      ADAM(1,JTRY)=DATA(1)
      ATREN(1,JTRY)=0.0
      INUMM=INUM-1
      IM=0
      DO 202 ID=1,INUM
      IDD=ID+1
      ADAM(IDD,JTRY)=(ADAM(ID,JTRY)+ATREN(ID,JTRY))+ATRY*(DATA(ID)-
     1(ADAM(ID,JTRY)+ATREN(ID,JTRY)))
      ATREN(IDD,JTRY)=ATREN(ID,JTRY)+BTRY*((ADAM(IDD,JTRY)-
     1ADAM(ID,JTRY))-ATREN(ID,JTRY))
      ADEM(IDD,JTRY)=ADAM(IDD,JTRY)+ATREN(IDD,JTRY)
      IF(IDD.GT.INUM)GO TO 202
      IF(ER.GE.10.E+20)GO TO 202
      ER=(DATA(IDD)-ADEM(IDD,JTRY))**2+ER
  202 CONTINUE
      ERR1(ITRY,JTRY,1)=ER/(INUM-1)
  214 CONTINUE
  203 CONTINUE
      ER=0.0
      ATREN(1,11)=0.0
      ADAM(1,11)=DATA(1)
      ESM=ERR1(1,1,1)
      DO 204 II=1,10
      DO 215 IJ=1,10
      IF(ESM.LT.ERR1(II,IJ,1))GO TO 215
      ESM=ERR1(II,IJ,1)
      ISAV1=II
      ISAV2=IJ
  215 CONTINUE
  204 CONTINUE
  530 ATRY=0.0
      BTRY=0.0
      DO 205 II=1,ISAV2
  205 ATRY=ATRY+.1
      DO 216 II=1,ISAV1
  216 BTRY=BTRY+.1
      INUMM=INUM-1
      DO 217 ID=1,INUM
      IDD=ID+1
      ADAM(IDD,1)=(ADAM(ID,1)+ATREN(ID,1))+ATRY*(DATA(ID)-(ADAM(ID,1)
     1+ATREN(ID,1)))
      ATREN(IDD,1)=ATREN(ID,1)+BTRY*((ADAM(IDD,1)-ADAM(ID,1))-
     1ATREN(ID,1))
      ADEM(IDD,1)=ADAM(IDD,1)+ATREN(IDD,1)
  217 CONTINUE
  206 INAM=INUM+1
      IF(IPLOT)209,207,209
  207 IF(DEMN.NE.0.0)GO TO 208
      WRITE(6,15)ATRY,BTRY,DATA(INUM),ADEM(INAM,1),ATREN(INUM,1),ESM
```

```
      GO TO 99
  208 WRITE(6,16)A,B,ACT,TREN,DEM,TRENN,DEMN,ATRY,BTRY,ATREN(INAM,1),
     1ADEM(INAM,1),ESM
      GO TO 99
  209 IF(DEMN.NE.0.0)GO TO 211
      WRITE(6,603)
      DO 210 IDD=2,INAM
      ID=IDD-1
  210 WRITE(6,17)DATA(ID),ADEM(IDD,1),ATREN(ID,1)
      WRITE(6,18)ATRY,BTRY,ESM
      GO TO 99
  211 INUM=INUM-1
      DO 212 ID=1,INUM
      IDD=ID+1
      ADAM(IDD,11)=(ADAM(ID,11)+ATREN(ID,11))+A*(DATA(ID)-
     1(ADAM(ID,11)+ATREN(ID,11)))
      ATREN(IDD,11)=ATREN(ID,11)+B*((ADAM(IDD,11)-ADAM(ID,11))-
     1ATREN(ID,11))
      ADEM(IDD,11)=ADAM(IDD,11)+ATREN(IDD,11)
      IF(IDD.GT.INUM)GO TO 212
      ER=ER+(DATA(IDD)-ADEM(IDD,11))**2
  212 CONTINUE
      EER=ER/(INUM-1)
      WRITE(6,604)
      DO 213 IDD=2,INAM
      ID=IDD-1
  213 WRITE(6,19)DATA(ID),ADEM(IDD,11),ATREN(ID,11),ADEM(IDD,1),
     1ATREN(ID,1)
      WRITE(6,21)A,B,EER,ADEM(INAM,11),ATREN(INUM,11),ATRY,BTRY,ESM,
     1ADEM(INAM,1),ATREN(INUM,1)
      GO TO 99
   40 IF(IDATA)62,72,62
   72 IF(IA)82,90,82
   82 READ(5,22)ACT,DEM,A,C,SEAF,L,ASEAF1
      DEMN=0.0
      SEAFM=0.0
      SEAFM=SEAF+C*(ACT/DEM-SEAF)
      DEMN=DEM+A*(ACT/SEAF-DEM)
      DEMN=DEMN*ASEAF1
      IF(L.EQ.1)GO TO 300
      WRITE(6,23)A,C,ACT,DEM,SEAF,ASEAF1,L,SEAFM,DEMN
      GO TO 99
   62 READ(5,5)(DATA(J),J=1,INUM)
      I=1
      IF(IA)82,300,82
  300 IF(INEW)301,306,301
  301 COMP=0.0
      J=0
      K=0
      J1=0
```

```
700 DO 705 III=1,ITHINK
    J=J+1
    IF(J.GT.INUM)GO TO 702
    COMP=COMP+DATA(J)
705 CONTINUE
    COMP1=COMP/ITHINK
    K=K+1
    DO 701 II=1,ITHINK
    J1=J1+1
    ERR2(K,II)=DATA(J1)/COMP1
701 CONTINUE
    COMP=0.0
    COMP1=0.0
    GO TO 700
702 COMP=0.0
    DO 703 II=1,ITHINK
    DO 704 III=1,K
    COMP=COMP+ERR2(III,II)
704 CONTINUE
    ERR2(II,1)=COMP/K
    COMP=0.0
703 CONTINUE
    L1=ITHINK
305 ATRY=0.0
    CTRY=0.0
    DO 303 ITRY=1,10
    ER=0.0
    CTRY=CTRY+.1
    ATRY=0.0
    DO 314 JTRY=1,10
    ER=0.0
    ATRY=ATRY+.1
    ATREN(1,JTRY)=DATA(1)
    DO 318 III=1,L1
318 ASEAE(III,JTRY)=ERR2(III,1)
    INUMM=INUM-1
    IN=0
    DO 302 ID=1,INUM
    IDD=ID+1
    IDS=ID-L1
    IF(IDS.LE.0)IDS=ID
    IDST=IDS+1
    IF(IDS.EQ.L1)IDST=1
    ATREN(IDD,JTRY)=ATREN(ID,JTRY)+ATRY*(DATA(ID)/ASEAE(IDS,JTRY)-
   1ATREN(ID,JTRY))
    ASEAE(ID,JTRY)=ASEAE(IDS,JTRY)+CTRY*(DATA(ID)/ATREN(IDD,JTRY)-
   1ASEAE(IDS,JTRY))
    ADEN(IDD,JTRY)=ATREN(IDD,JTRY)*ASEAE(IDST,JTRY)
    IF(IDD.GT.INUM)GO TO 302
    IF(ER.GE.10.E+20)GO TO 302
```

```
      EP=(DATA(IDP)-ADEM(IDP,JTRY))**2+EP
  302 CONTINUE
      ASEAE(IDP,JTRY)=ASEAE(IDST,JTRY)+CTRY*
     1(DATA(IDP)/ATREM(IDP,JTRY)-ASEAE(IDST,JTRY))
      EPR1(ITRY,JTRY,1)=EP/(INUM-1)
  314 CONTINUE
  303 CONTINUE
  319 ER=0.0
      ESM=EPR1(1,1,1)
      DO 304 IJ=1,10
      DO 315 II=1,10
      IF(ESM.LT.EPR1(II,IJ,1))GO TO 315
      ESM=EPR1(II,IJ,1)
      ISAV1=II
      ISAV2=IJ
  315 CONTINUE
  304 CONTINUE
  540 ATRY=0.0
      CTRY=0.0
      ISAV3=11
      ATREM(1,11)=DATA(1)
      ATREM(1,1)=DATA(1)
      DO 398 III=1,11
  398 ASEAE(III,1)=EPR2(III,1)
      DO 305 II=1,ISAV2
  305 ATRY=ATRY+.1
      DO 316 II=1,ISAV1
  316 CTRY=CTRY+.1
      INUMM=INUM-1
      DO 317 ID=1,INUMM
      IDP=ID+1
      IDS=ID-ISAV3
      IF(IDS.LE.0)IDS=ID
      IDST=IDS+1
      IF(IDS.EQ.ISAV3)IDST=1
      ATREM(IDP,1)=ATREM(ID,1)+ATRY*(DATA(ID)/ASEAE(IDS,1)-ATREM(ID,1))
      ASEAE(ID,1)=ASEAE(IDS,1)+CTRY*(DATA(ID)/ATREM(IDP,1)-
     1ASEAE(IDS,1))
      ADEM(IDP,1)=ATREM(IDP,1)*ASEAE(IDST,1)
  317 CONTINUE
      ASEAE(IDP,1)=ASEAE(IDST,1)+CTRY*(DATA(IDP)/
     1ATREM(IDP,1)-ASEAE(IDST,1))
  306 INAM=INUM+1
      IF(IPLOT)309,307,309
  307 IF(DEMM.NE.0.0)GO TO 308
      WRITE(6,24)ATRY,CTRY,DATA(INUM),ADEM(INAM,1),ASEAE(INAM,1),ESM,
     1ISAV3
      GO TO 99
  308 WRITE(6,25)A,C,ACT,SEAE,DEM,SEAEM,DEMM,ATRY,CTRY,ASEAE(INAM,1),
     1ADEM(INAM,1),ESM,ISAV3
```

```
      GO TO 99
  309 IF(DEMN.NE.0.0)GO TO 311
      WRITE(6,605)
      DO 310 IDD=2,INAM
      ID=IDD-1
  310 WRITE(6,26)DATA(ID),ADEM(IDD,1),ASEAE(ID,1)
      WRITE(6,27)ATRY,CTRY,ESM,ISAV3
      GO TO 99
  311 INUM=INUM-1
      DO 306 II=1,L
  306 ASEAE(II,11)=ERR2(II,1)
      DO 312 ID=1,INUM
      IDD=ID+1
      IDS=ID-L
      IF(IDS.LE.0)IDS=ID
      IDST=IDS+1
      IF(IDS.EQ.L)IDST=1
      ATREM(IDD,11)=ATREM(ID,11)+A*(DATA(ID)/ASEAE(IDS,11)-ATREM(ID,11))
      ASEAE(ID,11)=ASEAE(IDS,11)+C*(DATA(ID)/ATREM(IDD,11)-
     1ASEAE(IDS,11))
      ADEM(IDD,11)=ATREM(IDD,11)*ASEAE(IDST,11)
      IF(IDD.GT.INUM)GO TO 312
      ER=ER+(DATA(IDD)-ADEM(IDD,11))**2
  312 CONTINUE
      ASEAE(IDD,11)=ASEAE(IDST,11)+C*(DATA(IDD)/
     1ATREM(IDD,11)-ASEAE(IDST,11))
      SER=ER/(INUM-1)
      WRITE(6,606)
      DO 313 IDD=2,INAM
      ID=IDD-1
  313 WRITE(6,28)DATA(ID),ADEM(IDD,11),ASEAE(ID,11),ADEM(IDD,1),
     1ASEAE(IDD,1)
      WRITE(6,29)A,C,SER,ADEM(INAM,11),ASEAE(INAM,11),L,ATRY,CTRY,ESM,
     1ADEM(INAM,1),ASEAE(INAM,1),ISAV3
      GO TO 99
   59 IF(IDATA)63,73,63
   73 IF(IA)83,90,83
   83 READ(5,49)ACT,TREM,DEM,A,B,C,SEAE,L,ASEAE1
      DEMN=0.0
      TREMN=0.0
      SEAEM=0.0
      SEAEM=SEAE+C*(ACT/DEM-SEAE)
      DEMN=(DEM+TREM)+A*(ACT/SEAE-(DEM+TREM))
      TREMN=TREM+B*((DEMN-DEM)-TREM)
      DEMN=(DEMN+TREMN)*ASEAE1
      IF(L.EQ.1)GO TO 400
      WRITE(6,31)A,B,C,ACT,DEM,TREM,SEAE,ASEAE1,L,TREMN,SEAEM,DEMN
      GO TO 99
   63 READ(5,5)(DATA(J),J=1,INUM)
      L=1
```

```
      IF(IA)83,400,83
  400 IF(INEW)401,406,401
  401 COMP=0.0
      J=0
      K=0
      J1=0
  800 DO 805 III=1,ITHINK
      J=J+1
      IF(J.GT.INUM)GO TO 802
      COMP=COMP+DATA(J)
  805 CONTINUE
      COMP1=COMP/ITHINK
      K=K+1
      DO 801 II=1,ITHINK
      J1=J1+1
      ERR2(K,II)=DATA(J1)/COMP1
  801 CONTINUE
      COMP=0.0
      COMP1=0.0
      GO TO 800
  802 COMP=0.0
      DO 803 II=1,ITHINK
      DO 804 III=1,K
      COMP=COMP+ERR2(III,II)
  804 CONTINUE
      ERR2(II,1)=COMP/K
      COMP=0.0
  803 CONTINUE
      L1=ITHINK
  495 ATRY=0.0
      BTRY=0.0
      CTRY=0.0
      DO 403 ITRY=1,10
      ER=0.0
      CTRY=CTRY+.1
      BTRY=0.0
      DO 414 JTRY=1,10
      ER=0.0
      BTRY=BTRY+.1
      ATRY=0.0
      DO 499 LTRY=1,10
      ER=0.0
      ATRY=ATRY+.1
      ADAM(1,LTRY)=DATA(1)
      DO 418 III=1,L1
  418 ASEAE(III,LTRY)=ERR2(III,1)
      ATREM(1,LTRY)=0.0
      INUMM=INUM-1
      IN=0
      DO 402 ID=1,INUM
```

```
      IPP=IP+1
      IPS=IP-11
      IF(IPS.LE.0)IPS=IP
      IPST=IPS+1
      IF(IPS.EQ.11)IPST=1
      ADAM(IPP,LTRY)=(ADAM(IP,LTRY)+ATREN(IP,LTRY))+ATRY*(BATA(IP)
     1/ASEAF(IPS,LTRY)-(ADAM(IP,LTRY)+ATREN(IP,LTRY)))
      ATREN(IPP,LTRY)=ATREN(IP,LTRY)+BTRY*((ADAM(IPP,LTRY)-
     1ADAM(IP,LTRY))-ATREN(IP,LTRY))
      ASEAF(IP,LTRY)=ASEAF(IPS,LTRY)+CTRY*(BATA(IP)/ADAM(IPP,LTRY)
     1-ASEAF(IPS,LTRY))
      ADEM(IPP,LTRY)=(ADAM(IPP,LTRY)+ATREN(IPP,LTRY))*ASEAF(IPST,LTRY)
      IF(IPP.GT.IMMM)GO TO 402
      IF(ER.GE.10.E+20)GO TO 402
      ER=(BATA(IPP)-ADEM(IPP,LTRY))**2+ER
  402 CONTINUE
      ASEAF(IPP,LTRY)=ASEAF(IPST,LTRY)+CTRY*
     1(BATA(IPP)/ADAM(IPP,LTRY)-ASEAF(IPST,LTRY))
  488 ERR1(LTRY,JTRY,ITRY)=ER/(IMMM-1)
  499 CONTINUE
  414 CONTINUE
  403 CONTINUE
  419 ER=0.0
      ESM=ERR1(1,1,1)
      DO 498 I2=1,10
      DO 404 IJ=1,10
      DO 415 II=1,10
      IF(ESM.LT.ERR1(II,IJ,I2))GO TO 415
      ESM=ERR1(II,IJ,I2)
      ISAV1=II
      ISAV2=IJ
      ISAV3=I2
  415 CONTINUE
  404 CONTINUE
  498 CONTINUE
      ISAV4=ITHINK
  550 ATRY=0.0
      BTRY=0.0
      CTRY=0.0
      ADAM(1,11)=BATA(1)
      ADAM(1,1)=BATA(1)
      ATREN(1,11)=0.0
      DO 497 I3=1,ISAV4
  497 ASEAF(I3,1)=ERR2(I3,1)
      DO 495 II=1,ISAV1
  495 CTRY=CTRY+.1
      DO 416    =1,ISAV2
  416 BTRY=BTRY+.1
      DO 496 II=1,ISAV3
  496 ATRY=ATRY+.1
```

```
      INUMM=INUM-1
      DO 417 ID=1,INUM
      IDD=ID+1
      IDS=ID-ISAV4
      IF(IDS.LE.0)IDS=ID
      IDST=IDS+1
      IF(IDS.EQ.ISAV4)IDST=1
      ADAM(IDD,1)=(ADAM(ID,1)+ATREN(ID,1))+ATRY*(DATA(ID)/ASEAF(IDS,1)
     1-(ADAM(ID,1)+ATREN(ID,1)))
      ATREN(IDD,1)=ATREN(ID,1)+BTRY*((ADAM(IDD,1)-ADAM(ID,1))
     1-ATREN(ID,1))
      ASEAF(ID,1)=ASEAF(IDS,1)+CTRY*(DATA(ID)/ADAM(IDD,1)-ASEAF(IDS,1))
      ADEM(IDD,1)=(ADAM(IDD,1)+ATREN(IDD,1))*ASEAF(IDST,1)
  417 CONTINUE
      ASEAF(IDD,1)=ASEAF(IDST,1)+CTRY*(DATA(IDD)/
     1ADAM(IDD,1)-ASEAF(IDST,1))
  406 INAM=INUM+1
      IF(IPLOT)409,407,409
  407 IF(DEMN.NE.0.0)GO TO 408
      WRITE(6,32)ATRY,BTRY,CTRY,DATA(INUM),ADEM(INAM,1),ATREN(INAM,1),
     1ASEAF(INAM,1),ESM
      GO TO 99
  408 WRITE(6,33)A,B,C,ACT,TREN,SEAF,DEM,TDEMN,SEAFN,DEMN,ATRY,BTRY,
     1CTRY,ATREN(INAM,1),ASEAF(INAM,1),ADEM(INAM,1),ESM,ISAV4
      GO TO 99
  409 IF(DEMN.NE.0.0)GO TO 411
      WRITE(6,607)
      DO 410 IDD=2,INAM
      ID=IDD-1
  410 WRITE(6,34)DATA(ID),ADEM(IDD,1),ATREN(ID,1),ASEAF(ID,1)
      WRITE(6,35)ATRY,BTRY,CTRY,ESM,ISAV4
      GO TO 99
  411 INUMM=INUM-1
      DO 494 II=1,L
  494 ASEAF(II,11)=EPR2(II,1)
      DO 412 ID=1,INUM
      IDD=ID+1
      IDS=ID-L
      IF(IDS.LE.0)IDS=ID
      IDST=IDS+1
      IF(IDS.EQ.L)IDST=1
      ADAM(IDD,11)=(ADAM(ID,11)+ATREN(ID,11))+A*(DATA(ID)/
     1ASEAF(IDS,11)-(ADAM(ID,11)+ATREN(ID,11)))
      ATREN(IDD,11)=ATREN(ID,11)+B*((ADAM(IDD,11)-ADAM(ID,11))-
     1ATREN(ID,11))
      ASEAF(ID,11)=ASEAF(IDS,11)+C*(DATA(ID)/ADAM(IDD,11)-ASEAF(IDS,11))
      ADEM(IDD,11)=(ADAM(IDD,11)+ATREN(IDD,11))*ASEAF(IDST,11)
      IF(IDD.GT.INUMM)GO TO 412
      ER=ER+(DATA(IDD)-ADEM(IDD,11))**2
  412 CONTINUE
```

```
      ASEAF(IDD,11)=ASEAF(IDST,11)+C*(DATA(IDD)/
     1ADAM(IDD,11)-ASEAF(IDST,11))
      EER=ER/(INUM-1)
      WRITE(6,608)
      DO 413 IDD=2,INAM
      ID=IDD-1
  413 WRITE(6,36)DATA(ID),ADEM(IDD,11),ATREN(ID,11),ASEAF(ID,11),
     1ADEM(ID,1),ATREN(ID,1),ASEAF(ID,1)
      WRITE(6,37)A,B,C,EER,ADEM(INAM,11),ATREN(INAM,11),ASEAF(INAM,11),I
     1,ATRY,BTRY,CTRY,ESM,ADEM(INAM,1),ATREN(INAM,1),ASEAF(INAM,1),ISAV4
      GO TO 99
   10 IF(IDATA)64,90,64
   64 ICODE=1
      DEMM=0.0
      READ(5,5)(DATA(J),J=1,INUM)
      GO TO 101
   99 IF(IMETH.NE.0)GO TO 9999
      ICODE=ICODE+1
      IF(ICODE.EQ.2)GO TO 201
      IF(ICODE.EQ.3)GO TO 301
      IF(ICODE.EQ.4)GO TO 495
 9999 STOP
   90 WRITE(6,39)
      GO TO 9999
    1 FORMAT(10X,'MINUTEMAN EDUCATIONAL PROGRAM'//10X,'SOUTH DAKOTA ',
     1'STATE UNIVERSITY'//3X,'FORECASTING BY EXPONENTIAL SMOOTHING')
    2 FORMAT(I1,I3,4I1,I2)
    3 FORMAT(2F7.2,F4.2)
    4 FORMAT(3X,'GIVEN VALUES'/4X,'A',5X,'ACT DEM',3X,'LAST FORECAST',
     12X,'NEW FORECAST'/2X,F4.2,4X,F7.2,6X,F7.2,7X,F7.2)
    5 FORMAT(F7.2)
    6 FORMAT(3X,'COMPUTED VALUES'/4X,'A',5X,'ACT DEM',3X,'NEW FORECAST'
     1,3X,'VARIANCE'/2X,F4.2,4X,F7.2,6X,F7.2,7X,F8.1)
    7 FORMAT(3X,'GIVEN VALUES'/4X,'A',5X,'ACT DEM',3X,'LAST FORECAST',
     12X,'NEW FORECAST'/2X,F4.2,4X,F7.2,6X,F7.2,7X,F7.2/3X,
     1'COMPUTED VALUES'/4X,'A',5X,'VARIANCE',3X,'NEW FORECAST'/2X,
     1F4.2,4X,F8.1,5X,F7.2)
  601 FORMAT(3X,'ACTUAL DATA',4X,'COMPUTED FORECAST')
    8 FORMAT(6X,F7.2,11X,F7.2)
    9 FORMAT(3X,'COMPUTED VALUES'/4X,'A',4X,'VARIANCE'/2X,F4.2,5X,F8.1)
  602 FORMAT(3X,'ACTUAL DATA',3X,'FORECAST GIVEN',3X,'NEW FORECAST')
   11 FORMAT(6X,F7.2,8X,F7.2,8X,F7.2)
   12 FORMAT(3X,'GIVEN VALUES'/4X,'A',5X,'VARIANCE',6X,'NEW FORECAST'
     1/2X,F4.2,4X,F8.1,8X,F7.2/3X,'COMPUTED VALUES'/4X,'A',5X,'VARIANCE'
     1,6X,'NEW FORECAST'/2X,F4.2,4X,F8.1,8X,F7.2)
   13 FORMAT(F7.2,F6.2,F7.2,F4.2,F4.2)
   14 FORMAT(3X,'GIVEN VALUES'/4X,'A',4X,'B',4X,'ACT DEM',3X,
     1'LAST FORECAST',3X,'LAST TREND',3X,'NEW FORECAST',3X,'NEW TREND'
     1/2X,F4.2,1X,F4.2,3X,F7.2,5X,F7.2,10X,F6.2,7X,F7.2,9X,F6.2)
   15 FORMAT(3X,'COMPUTED VALUES'/4X,'A',4X,'B',4X,'ACT DEM',2X,
```

```
      1'NEW FORECAST',2X,'NEW TREND',2X,'VARIANCE'/2X,F4.2,1X,F4.2,3X,
      1F7.2,4X,F7.2,7X,F6.2,3X,F8.1)
   16 FORMAT(3X,'GIVEN VALUES'/4X,'A',4X,'B',4X,'ACT DEM',2X,
      1'LAST TREND',2X,'LAST FORECAST',2X,'NEW TREND',2X,'NEW FORECAST'
      1/2X,F4.2,1X,F4.2,3X,F7.2,4X,F6.2,7X,F7.2,8X,F6.2,6X,F7.2/3X,
      1'COMPUTED VALUES'/4X,'A',4X,'B',4X,'NEW TREND',2X,'NEW FORECAST'
      1,3X,'VARIANCE'/2X,F4.2,1X,F4.2,5X,F6.2,6X,F7.2,6X,F8.1)
  603 FORMAT(3X,'ACTUAL DATA',3X,'COMPUTED FORECAST',3X,
      1'COMPUTED TREND')
   17 FORMAT(5X,F7.2,10X,F7.2,13X,F6.2)
   18 FORMAT(3X,'COMPUTED VALUES'/4X,'A',4X,'B',4X,'VARIANCE'/2X,
      1F4.2,1X,F4.2,3X,F8.1)
  604 FORMAT(3X,'ACTUAL DATA',2X,'FORECAST GIVEN',3X,'TREND GIVEN',3X,
      1'NEW FORECAST',3X,'NEW TREND')
   19 FORMAT(6X,F7.2,6X,F7.2,10X,F6.2,8X,F7.2,8X,F6.2)
   21 FORMAT(3X,'GIVEN VALUES'/4X,'A',4X,'B',3X,'VARIANCE',3X,
      1'NEW FORECAST',3X,'NEW TREND'/2X,F4.2,1X,F4.2,1X,F8.1,6X,F7.2,
      18X,F6.2/3X,'COMPUTED VALUES'/4X,'A',4X,'B',3X,'VARIANCE',3X,
      1'NEW FORECAST',3X,'NEW TREND'/2X,F4.2,1X,F4.2,1X,F8.1,6X,F7.2,8X,
      1F6.2)
   22 FORMAT(2F7.2,2F4.2,F6.2,I2,F6.2)
   23 FORMAT(3X,'GIVEN VALUES'/4X,'A',4X,'C',3X,'ACT DEM',3X,
      1'LAST FORECAST',3X,'LAST SEASONAL',3X,'PREV LAST SEAS',3X,'PERIOD'
      1/2X,F4.2,1X,F4.2,2X,F7.2,5X,F7.2,10X,F6.2,12X,F6.2,10X,I2/3X,
      1'NEW SEASONAL',3X,'NEW FORECAST'/6X,F6.2,9X,F7.2)
   24 FORMAT(3X,'COMPUTED VALUES'/4X,'A',4X,'C',3X,'ACT DEM',3X,
      1'NEW FORECAST',3X,'NEW SEASONAL',3X,'VARIANCE',4X,'PERIOD'/2X,
      1F4.2,1X,F4.2,2X,F7.2,5X,F7.2,9X,F6.2,7X,F8.1,6X,I2)
   25 FORMAT(3X,'GIVEN VALUES'/4X,'A',4X,'C',3X,'ACT DEM',3X,
      1'LAST SEASONAL',3X,'LAST FORECAST',3X,'NEW SEASONAL',3X,
      1'NEW FORECAST'/2X,F4.2,1X,F4.2,2X,F7.2,6X,F6.2,10X,F7.2,10X,F6.2,
      19X,F7.2/3X,'COMPUTED VALUES'/4X,'A',4X,'C',3X,'NEW SEASONAL',3X,
      1'NEW FORECAST',3X,'VARIANCE',3X,'PERIOD'/2X,F4.2,1X,F4.2,4X,F6.2,
      110X,F7.2,5X,F8.1,7X,I2)
  605 FORMAT(3X,'ACTUAL DATA',3X,'COMPUTED FORECAST',3X,
      1'COMPUTED SEASONAL')
   26 FORMAT(5X,F7.2,10X,F7.2,13X,F6.2)
   27 FORMAT(3X,'COMPUTED VALUES'/4X,'A',4X,'C',3X,'VARIANCE',3X,
      1'PERIOD'/2X,F4.2,1X,F4.2,2X,F8.1,6X,I2)
  606 FORMAT(3X,'ACTUAL DATA',2X,'FORECAST GIVEN',2X,'SEASONAL GIVEN',
      12X,'NEW FORECAST',2X,'NEW SEASONAL')
   28 FORMAT(5X,F7.2,6X,F7.2,10X,F6.2,10X,F7.2,8X,F6.2)
   29 FORMAT(3X,'GIVEN VALUES'/4X,'A',4X,'C',3X,'VARIANCE',2X,
      1'NEW FORECAST',2X,'NEW SEASONAL',2X,'PERIODS'/2X,F4.2,1X,F4.2,1X,
      1F8.1,6X,F7.2,8X,F7.2,9X,I2/3X,'COMPUTED VALUES'/4X,'A',4X,'C',
      13X,'VARIANCE',2X,'NEW FORECAST',2X,'NEW SEASONAL',2X,'PERIOD'/2X
      1,F4.2,1X,F4.2,1X,F8.1,5X,F7.2,8X,F7.2,9X,I2)
   49 FORMAT(F7.2,F6.2,F7.2,3F4.2,F6.2,I2,F6.2)
   31 FORMAT(3X,'GIVEN VALUES'/4X,'A',4X,'B',4X,'C',3X,'ACT DEM',3X,
      1'LAST FORECAST',3X,'LAST TREND',3X,'LAST SEASONAL'/2X,3(F4.2,1X),
```

```
   11X,2(F7.2,5X),3X,F6.2,9X,F6.2/3X,'PREV LAST SEASONAL',3X,'PERIOD'
   1,3X,'NEW TREND',3X,'NEW SEASONAL',3X,'NEW FORECAST'/8X,F6.2,13X,
   1I2,7X,F6.2,8X,F6.2,9X,F7.2)
 32 FORMAT(3X,'COMPUTED VALUES'/4X,'A',4X,'B',4X,'C',3X,'ACT DEM',2X,
   1'NEW FORECAST',2X,'NEW TREND',2X,'NEW SEASONAL',2X,'VARIANCE'/2X,
   13(F4.2,1X),1X,F7.2,4X,F7.2,7X,F6.2,6X,F6.2,7X,F8.1/3X,'PERIOD'/
   15X,I2)
 33 FORMAT(3X,'GIVEN VALUES'/4X,'A',4X,'B',4X,'C',3X,'ACT DEM',3X,
   1'LAST TREND',3X,'LAST SEASONAL',3X,'LAST FORECAST'/2X,3(F4.2,1X),
   11X,F7.2,5X,F6.2,9X,F6.2,10X,F7.2/3X,'NEW TREND',3X,'NEW SEASONAL'
   1,3X,'NEW FORECAST'/5X,F6.2,8X,F6.2,9X,F7.2/3X,'COMPUTED VALUES'/
   14X,'A',4X,'B',4X,'C',3X,'NEW TREND',3X,'NEW SEASONAL',3X,
   1'NEW FORECAST',3X,'VARIANCE',3X,'PERIOD'/2X,3(F4.2,1X),3X,F6.2,8X
   1,F6.2,9X,F7.2,6X,F8.1,6X,I2)
607 FORMAT(3X,'ACTUAL DATA',3X,'COMPUTED FORECAST',3X,'COMPUTED TREND'
   1,3X,'COMPUTED SEASONAL')
 34 FORMAT(5X,F7.2,10X,F7.2,13X,F6.2,12X,F6.2)
 35 FORMAT(3X,'COMPUTED VALUES'/4X,'A',4X,'B',4X,'C',3X,'VARIANCE',
   13X,'PERIOD'/2X,3(F4.2,1X),1X,F8.1,6X,I2)
608 FORMAT(1X,'ACTUAL DATA',2X,'FORECAST GIVEN',2X,'TREND GIVEN',2X,
   1'SEASONAL GIVEN',2X,'NEW FORECAST',2X,'NEW TREND',2X,
   1'NEW SEASONAL')
 36 FORMAT(3X,F7.2,7X,F7.2,9X,F6.2,8X,F6.2,10X,F7.2,7X,F6.2,6X,F6.2)
 37 FORMAT(3X,'GIVEN VALUES'/4X,'A',4X,'B',4X,'C',3X,'VARIANCE',2X,
   1'NEW FORECAST',2X,'NEW TREND',2X,'NEW SEASONAL',2X,'PERIOD'/2X,
   13(F4.2,1X),1X,F8.1,4X,F7.2,7X,F6.2,7X,F6.2,9X,I2/3X,
   1'COMPUTED VALUES'/4X,'A',4X,'B',4X,'C',3X,'VARIANCE',2X
   1,'NEW FORECAST',2X,'NEW TREND',2X,'NEW SEASONAL',2X,'PERIOD'/2X,
   13(F5.3),1X,F8.1,4X,F7.2,7X,F6.2,7X,F6.2,9X,I2)
 38 FORMAT(3X,'VARIANCES'/5X,'SIMPLE',3X,'TREND',3X,'SEASONAL',3X,
   1'COMBINATION',3X,'MINIMUM'/5X,F6.2,4X,F6.2,5X,F6.2,7X,F6.2,7X,
   1F6.2)
 39 FORMAT(1X,'***ERROR*** NO DATA GIVEN AND NO VALUES PROVIDED')
    END
```

APPENDIX 2

THE USAGE MANUAL

This manual is designed to explain the capabilities and proper use of the program EXPO. The program has the following capabilities:

(1) To provide an exponentially smoothed forecast for:

(a) simple

(b) trend and irregular

(c) seasonal and irregular

(d) trend, seasonal, and irregular

with factors, constants, and the last forecast provided.

(2) To compute an exponentially smoothed forecast for:

(a) simple

(b) trend and irregular

(c) seasonal and irregular

(d) trend, seasonal, and irregular,

the best smoothing constant(s), factors, and a new forecast.

(3) To compute (1) above as well as (2) for comparison. This option also allows for plotting of both (1) and (2).

(4) To compute the best fit in all functions for the purpose of determining the best smoothing constants as well as the function.

As mentioned previously, the control cards for program execution will depend on the system used. The first card read into the program EXPO is the parameter card. This card dictates execution of the program. The card layout is as follows:

Column 1: 0 - Smoothing constants, and values not provided.

1 - Smoothing constants, and values provided.

Column 2-4: Number of past data to input - n

Column 5: Method of computation;

0 - Computed constants as well as the best function.

1 - Simple exponential smoothing

2 - Trend and irregular

3 - Seasonal and irregular

4 - Trend, seasonal, and irregular

Column 6: 0 - Do not plot out forecast data

1 - Compute data and plot out

Column 7: 0 - Past forecast not provided

1 - Past forecast provided

Column 8: 0 - Do not compute new smoothing constants

1 - Compute new smoothing constants. (A, B, or C)

Column 9-10: Used for seasonal data only

04 - Quarterly data

12 - Monthly data

The first card will contain values as outlined above. The data, if it is provided, should be in the following format:

Column 1-7: - the value with a decimal point.

The remainder of the input stream depends upon the user's needs. If the user intends to provide the past data, the past data stream will come before the provided input values; smoothing constants, last forecast, and factors. With no data, the input values will follow the parameter card. Example:

	With Data	Without Data
Card #1	000911.1	- 10001000
#2	2.1	- 6.0 8.0 .1
#3	2.2	- EOF
#4	3.0	
#10	2.5	
#11	EOF	

The input value and forecast will depend on the function to be used: (all require decimal points except *)

(1) simple - Column 1-7: actual demand
8-14: last forecast
15-18: value of A

(2) trend and irregular
Column 1-7: actual demand
8-12: trend factor
13-19: last forecast

Column 20-23: value of A

24-27: value of B

(3) seasonal and irregular

Column 1-7: actual demand

8-14: last forecast

15-18: value of A

19-22: value of C

23-27: seasonal factor

28-29: period -04 or 12*

30-34: seasonal factor n-L periods ago

(4) trend, seasonal, and irregular

Column 1-7: actual demand

8-12: trend factor

13-19: last forecast

20-23: value of A

24-27: value of B

28-31: value of C

32-36: seasonal factor

37-38: period -04 or 12*

39-43: seasonal factor n-L

Example 1 of input file: A simple exponential smoothing function is desired for the following information. Actual demand was 10.0, the last forecast was 9.5, the smoothing constant is .1. The input stream would be:

10001000 Δ indicates spaces

10.0ΔΔΔ 9.5ΔΔΔΔ.1

EOF

Example 2 of input file: Data is provided for a seasonal exponential forecasting function. A plot is desired to compare the old smoothing constants results to the new. Actual demand is 10.0, the last forecast is 9.5, the seasonal factor is .9, the last seasonal factor n-L is 1.1, A is 1, and C is .2. There is quarterly data provided. The input stream would be:

1005.311104

9.0

10.0

9.0

10.0

9.5

10.0ΔΔΔ9.5ΔΔΔΔ.1ΔΔ.2ΔΔ.9ΔΔΔ041.1

EOF

Output depends on the type of function used. A plot will be provided if a 1 is put as column 6 of the control card. One example of output would be:

A	C	VARIANCE	NEW FORECAST	NEW SEASONAL	PERIOD
.1	.1	54.22	51.00	.99	4

Another example of output would be:

ACTUAL DATA	FORECAST GIVEN	NEW FORECAST
8.00	8.00	8.00

6.00	7.80	7.80
9.00	7.92	7.92
8.00	7.93	7.93
7.00	7.84	7.84
8.00	7.85	7.85
6.00	7.67	7.67

GIVEN VALUES

A	VARIANCE	NEW FORECAST
.1	.96	7.67

COMPUTED VALUES

A	VARIANCE	NEW FORECAST
.1	.96	7.67

To execute EXPO on the present system, the control cards are stored already. Simply create a data file as explained previously with a /* as an end of file. Upon completion, insert: SUBMIT JCL13, EXPO, LINK1,* and end the file. Upon completion of execution to obtain output insert: OUTPUT MMEP1013.