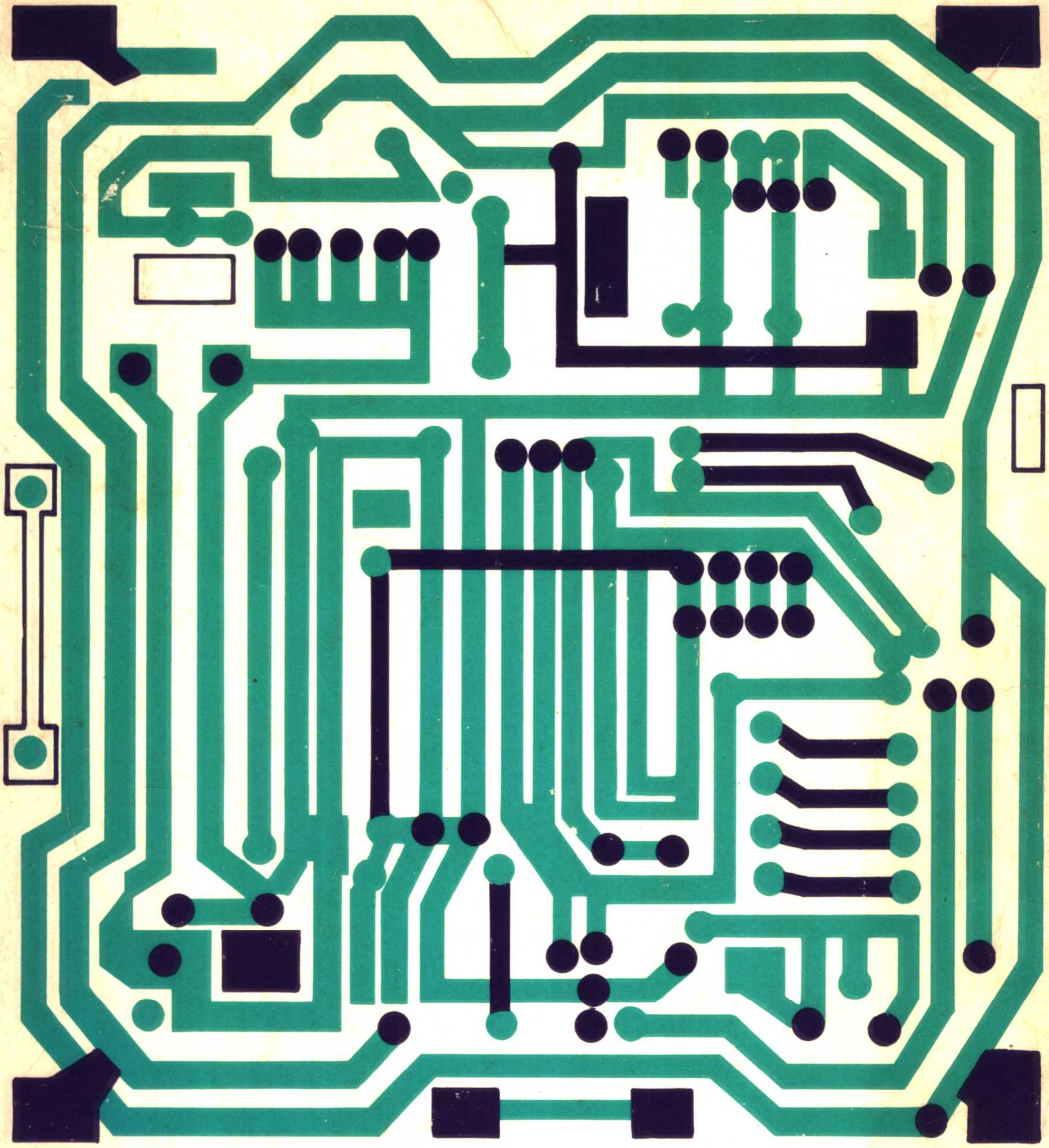
SECOND EDITION



COMPUTER MODELS IN OPERATIONS MANAGEMENT

A COMPUTER-AUGMENTED SYSTEM

ROY D. HARRIS
MICHAEL J. MAGGARD

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A Computer-Augmented System

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Preface to the Revised Edition

This revised edition contains twelve computer models for use in management analysis and decision making. The purpose of these models remains the same: to teach the use of the computer as a tool of the manager.

This revision includes the addition of two models. LINPRO will solve linear programming problems via the simplex algorithm. MRP will explode a bill of material, compute net requirements, and compute order quantities with lead time offsetting. MRP is intended to illustrate some basic concepts which have been integrated under the heading of Materials Requirements Planning.

This revision also includes some changes in the input data structure. Those changes are intended to facilitate the use of the programs by the beginning students. Other changes, particularly in MAINSIM, increase the variety of alternatives which can be analyzed by the user. All the input data now includes a final STOP card to bring each program to a "neat" termination. Also in the spirit of the times, we have been less free with the use of printout paper.

We have found that the use of the computer exercises can bring a lot of spice and power to the analysis of the appropriate types of management problems. We appreciate the many kind comments from the users of the first edition who have shared this experience.

We renew the debt of appreciation to those who helped with the first edition. To that original debt we must now add Bill Lesso for his work on Program LINPRO and Joe Orlikcy for his assistance with Program MRP. The College of Business Administration at the University of Texas at Austin and the School of Management at Boston University have provided the hours of computer time which we continue to consume.

Most of all, to Cathy and Pat we say THANKS.

Roy D. Harris

Michael J. Maggard

Preface to the First Edition

This book contains ten computer models for use in management analysis and decision making. The purpose of these models is to teach the use of the computer as a tool of the manager.

Each of the ten exercises is designed to be used in a similar manner as the traditional case. That is, the user is presented with a problem or problem situation. The user can use the computer model to help analyze and solve part or all of the management problem. Finally, the user must write up his problem analysis and solution much in the same manner as the usual case write-up. This manual provides the user with the computer model and the supporting information on how and when it is appropriate to use the model. The instructor must assign problem situations or cases for the user to solve.

All of the exercises have been used in introductory level courses at the undergraduate and graduate level. There is no computer programming required. However, the user should be able to keypunch data decks, submit decks to the computer center, and retrieve the output. The emphasis in the exercises is on the formulation of appropriate data inputs and the interpretation of the outputs.

Each exercise is organized in a similar manner. The first section of each presents an introduction to the theory and concepts used in the computer model. This is followed by a simple, hand-computed example problem. Next shown is the correct input and the resulting output when the computer model is used to solve the simple problem. Then, more complex problems are solved to illustrate additional uses of the computer model as a management analysis tool. Finally, the last section of each exercise contains a program listing so that those who are interested may see the internal workings of the model.

The use of the computer models in this book requires the availability of a small to medium-sized computer with a card reader and a line printer. Each of the ten exercises has associated with it a computer program and data cards. The computer programs are written in the FORTRAN IV computer language.

The models in this text are based upon operations management methods developed by a number of contributors and widely discussed in the literature. We have tried to give references that include or lead to the original contributors and that include the discussion in the literature. We hope we have made no major omissions. Our contribution has been to provide integrated text, problems, and computer models.

The authors received some support from the University Research Institute and the Management Department at the University of Texas at Austin. Dean George Kozmetsky provided encouragement and the hours of computer time we consumed. Frederick W. Martin of the MHMR Computation Center assisted with the IBM 360 program codes.

Several people helped in the preparation of this book. Jim Dyer assisted with SQC, Roy Pursley with BALANCE and QUESIM, Chalmer Wren with CRIT, Caroline Smith with DECIDE and Tom Rimkus with a number of coding problems. Our colleague, Howard Johnson provided an early version of UNISIM. Other students and collegues too numerous to mention used, critiqued, and helped revise early versions. To all of them, our thanks.

Austin, Texas

Michael J. Maggard

Roy D. Harris

Computer Models in Operations Management

Contents

EXERCISE

1 FUTURE

a statistical forecasting model

computes forecasts by the statistical methods of mean, regression line, seasonal averages, seasonal regression line, moving average, and exponential smoothing

What is past is prologue.
What will be, will be.

These two statements give widely divergent views of the future. The first considers the future as a natural extension of the past. The second considers the future as unknown or, at least, beyond control.

If your view of the future is that "what is past is prologue," then this exercise may be useful to you, for we present here some statistical methods for translating quantitative facts about the past into a forecast for the future. Basic to the use of forecasting techniques is the premise that past history is a representation of the effects of the factors, forces, fates, and relationships which were at work in the past, and that these same forces will be at work in shaping the future. If the premise is correct, a knowledge of the past, coupled with the right model for interpretation, should yield an accurate forecast of the future.

The managerial ethic encompasses the idea of planning and controlling the use of resources to produce desired outputs. It is a natural part of this ethic to attempt to prepare for the future. Better still, if the manager can influence or change the forces which cause a specific outcome then he may go so far as to create the desired future. The manager, however, cannot always control all the forces which determine the future. For example, he cannot control his customers. The next best thing to control of the future is an accurate forecast of the future so that appropriate preparation may be made. The last thing a manager wants to do is back into the future with an attitude of "what will be, will be."

Forecasting then, is a natural tool of the manager. It is another way to gain control, to be prepared, to manage. The statistical forecasting techniques presented in this exercise are useful to the manager insofar as he believes that the same forces at work in the past will continue to operate in the future. If he believes that different forces will be at work in the future, that the quantitative data of the past will prove an imprecise basis for a forecast of the future, then he must discard the forecast or modify it by the use of subjective judgment based upon his past experience. The reader should note well that this program is designed only as an aid in statistically translating the quantitative facts of the past into a forecast for the future. Any qualitative factors that may have an effect on the accuracy of the forecast should be considered in evaluating the forecasts provided by program FUTURE.

Six different statistical forecasting techniques and the computer program to do their respective computations are presented in this exercise. Section 1.1 presents the arithmetic average and Section 1.2 illustrates linear regression. Section 1.3 presents the concept of a "season" and two seasonal average forecasting techniques. The forecasting techniques known as moving averages and exponential smoothing are illustrated in Sections 1.4 and 1.5, respectively. The forecast produced by each of these methods on the same set of historical data will be illustrated in each section by the use of the computer model FUTURE.

1.1 ARITHMETIC AVERAGE

This section introduces the use of the simple average as a forecasting method. The complete computer input required by program FUTURE to perform the required computations and the resulting output are also presented.

The Arithmetic Average Forecast

A simple view of the future, from a computational standpoint, is that the future will tend toward the average of past occurrences. The not-so-simple assumption underlying this method of forecasting is the concept of the "average" level. The average is an approximation of the naturally occurring level of activity based on the available historical data. According to this concept, if the activity strays from this average value then those same forces which helped determine the average of the past will soon return the activity to this preferred or naturally occurring level of activity. A good forecast for the future, if this is true, would be the average of all past occurrences.

The statistical method is quite simple. One merely computes the average or, more correctly, the statistical mean, as follows:

$$\overline{Y}=\frac{Y_1+Y_2+\ .\ .\ .\ +Y_n}{n}$$

where $\overline{Y}$ = mean
Y_n = individual historical value
n = number of individual values

Suppose, for example, that there are six periods of history data for sales of Quasar Widgets:

PERIOD	SALES
1	1447.
2	1384.
3	1219.
4	1047.
5	887.
6	759.

The mean is computed by the formula

$$\overline{Y} = \frac{1447. + 1384. + 1219. + 1047. + 887. + 759.}{6}$$

$$\overline{Y} = \frac{6743}{6} = 1123.83$$

From these data, the forecast for as many future periods as one cares to estimate is the same. Thus

PERIOD	FORECAST SALES (Y)
7	1123.83
8	1123.83
9	1123.83

As additional periods of actual sales occur these will be added to the computation so that an updated forecast can be obtained.

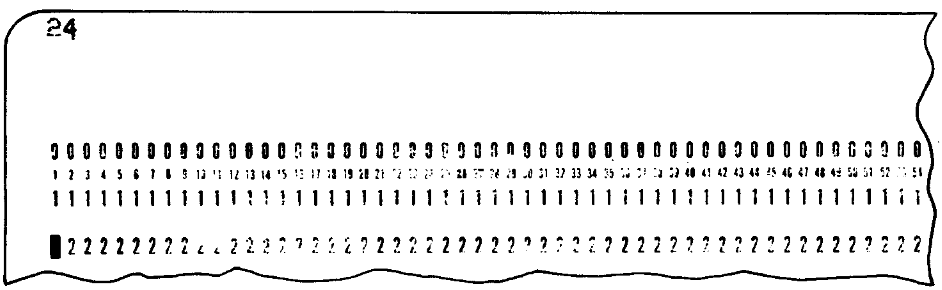
It should be noted that a prediction based on the statistical mean of a set of historical occurrences does not take into account the order in time in which each point was observed. Each activity level is weighted equally by this method and no sense of a direction over time is conveyed in the prediction. The following section on regression analysis demonstrates how the order of occurrence in time can be included in the determination of a predictive model.

Computer Input —Arithmetic Average

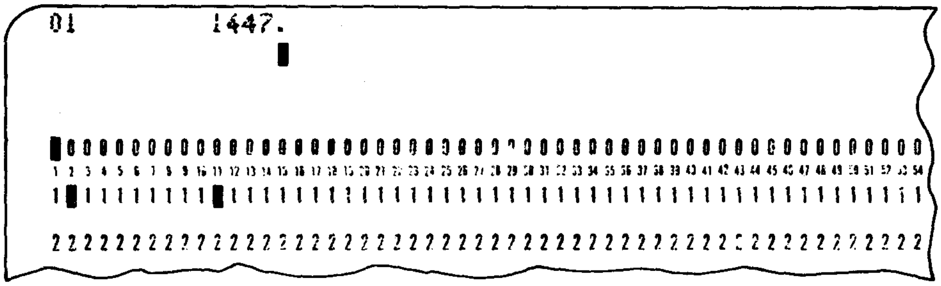
This section presents the data deck required as input to the computer program FUTURE.

User name card is the first card in the data deck. It is used to identify who is making the analysis and any other identification desired. This card is *free field,* in that any information may be keypunched in columns 1 to 40.

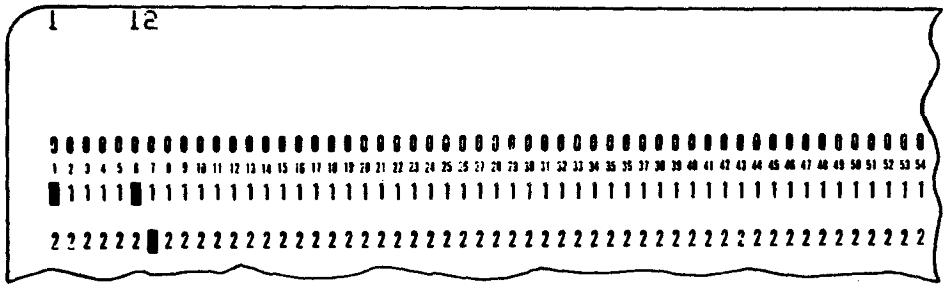
History control card is the second card in the data deck. This card contains the number of history periods (N) to be analyzed. The number is keypunched in columns 1 and 2.



History data cards are the next N cards in the data deck. Each card contains the period number in columns 1 and 2 and the history data keypunched starting in column 11. The decimal point must be punched. The first history data card contains period 01 history and the last history data card contains period N history.

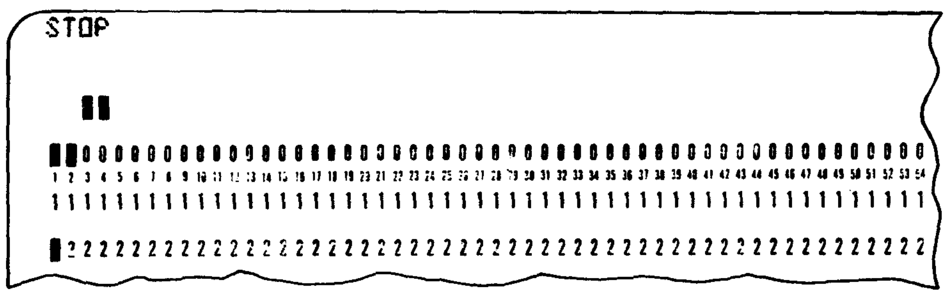


Analysis control card is the next card in the data deck. This card contains a code for the type of analysis to be done, keypunched in column 1, and the number of periods (M) to be forecast in columns 11 and 12. For the sample problem this card is



Code 1 in column 1 requests the computation of the forecast based upon the arithmetic mean. Codes 2, 3, 4, and 5 are used for requesting other forecasting techniques which are discussed in the following sections. A 99 punched in columns 1 and 2 signals the computer program FUTURE that the input data is complete, that is, all history data and analysis control cards have been read in for this problem. It is also a signal to check for additional data decks.

Termination card is the last card in the data deck and must contain STOP in the columns 1–4.



The complete data deck for the mean forecast is shown in Figure 1-1 for twenty-four periods of history data. Each line corresponds to one keypunched card.

FIGURE 1.1 Computer input—arithmetic average.

```
YOUR NAME FUTURE DATA
24
01          1447.
02          1384.
03          1219.
04          1047.
05           887.
06           759.
07           814.
08           834.
09          1009.
10          1133.
11          1146.
12          1401.
13          1421.
14          1328.
15          1350.
16          1022.
17          1105.
18           877.
19           913.
20           926.
21          1104.
22          1234.
23          1329.
24          1609.
1    12
9
STOP
```

Computer Output —Arithmetic Average

For the input data given in Figure 1-1 program FUTURE prints out the forecast as shown in Figure 1-2. The top part of the computer output is simply a printout of the input data to serve as a check and reminder. The lower portion contains the results of the analysis requested on the analysis control card. Three lines of identifying information are printed out followed by the forecast for the number of periods requested on the analysis control card. In this example the last history data period was 24 and the forecast begins in period 25 continuing for the requested twelve periods through period 36.

The reader should note that the average forecast based upon twenty-four periods of data is different from the sample computations which only consider the first six periods.

In program FUTURE no attempt is made to specify "correct" or "good" forecasts. The user must determine which forecast is "best" based upon one's beliefs about the nature of the system from which the data was drawn and what forces will be influential in the future. Several statistical procedures are also available for this determination (see references).

1.2 REGRESSION ANALYSIS

In this section the least squares regression equation is presented as a forecasting method. The required computer input and the resulting computer output are also discussed.

The Regression Forecast

A casual inspection of the first six periods of sales of Quasar Widgets refutes the notion that natural forces are present that would keep the sales at a constant level. The sales, during the first six periods at least, are successively

FIGURE 1-2
Computer output—arithmetic average.

```
PROGRAM FUTURE FOR YOUR NAME FUTURE DATA
HISTORY DATA FOR 24 PERIODS
 1             1447.0
 2             1384.0
 3             1219.0
 4             1047.0
 5              887.0
 6              759.0
 7              814.0
 8              834.0
 9             1009.0
10             1133.0
11             1146.0
12             1401.0
13             1421.0
14             1328.0
15             1350.0
16             1022.0
17             1105.0
18              877.0
19              913.0
20              926.0
21             1104.0
22             1234.0
23             1329.0
24             1609.0


FUTURE RESULTS FOR YOUR NAME FUTURE DATA
ANALYSIS CONTROL CARD REQUESTS
CODE  PER  ONE  TWO  MOVE  ALPHA
 1    12    0    0    0        0

MEAN FORECAST RESULTS
FORECAST BASED ON 24 PERIODS OF HISTORY
FORECAST 12 PERIODS INTO FUTURE
PERIOD    FORECAST
  25        1137.4
  26        1137.4
  27        1137.4
  28        1137.4
  29        1137.4
  30        1137.4
  31        1137.4
  32        1137.4
  33        1137.4
  34        1137.4
  35        1137.4
  36        1137.4


FUTURE RESULTS FOR YOUR NAME FUTURE DATA
ANALYSIS CONTROL CARD REQUESTS
CODE  PER  ONE  TWO  MOVE  ALPHA
 9     0    0    0    0        0
```

down. That is, they decrease in each successive period and there is no evidence so far that the sales trend will reverse and move back up toward the average.

A possible modification of the forecast assumption is to take into account any upward, downward, or cyclical trend. This "corrected mean" (a re-

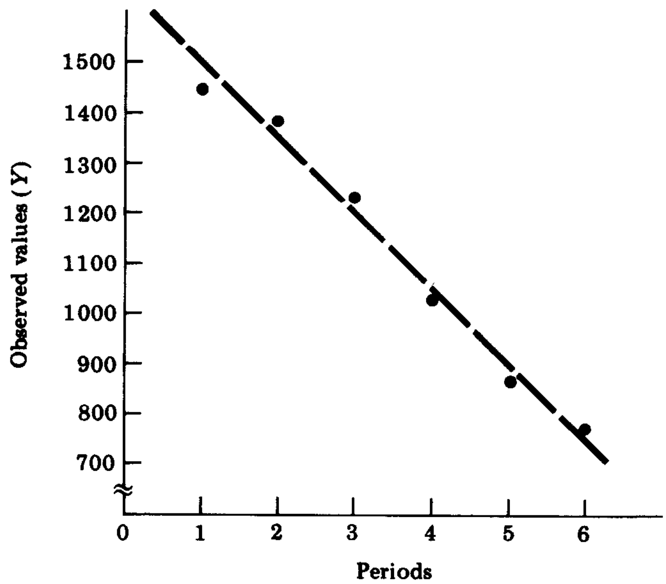


FIGURE 1-3 Regression line for periods 1 through 6.

gression line) can be plotted as a straight line over time. The regression line defines where the history data and forecast should be at any point in time. The slope of the line defines the change in the mean over time.

The mathematical implementation of this forecast assumption is the least-squares regression equation. The "best-fit" regression equation on the history data yields the values for the forecast periods for as many periods into the future as desired. As before, as more history becomes available it is added so that a better forecast can be obtained. Of course, the regression method also assumes the continuance of past conditions.

The equation for a straight line is:

$Y' = a + bX'$ where Y' = computed value of Y for a given value of X'
a = value of Y' at X equal to zero (Y intercept)
b = slope of the line

The nomenclature X' and Y' is used to distinguish the computed values (X' and Y') from their observed values (X and Y). The values for a and b are determined under the least-squares procedures using the following computational equations:

$$a = \frac{\Sigma X^2 \Sigma Y - \Sigma X \Sigma XY}{n\Sigma X^2 - (\Sigma X)^2}$$

$$b = \frac{n\Sigma XY - \Sigma X \Sigma Y}{n\Sigma X^2 - (\Sigma X)^2}$$

It is understood that the summations cover all the observed values of X and Y and that n is the total number of observed values. A sample computation is shown in Figure 1-4.

The regression equation $Y' = 1634.13 - 145.90X'$ may be used to forecast as many periods ahead as desired. The forecast for periods 7 through 12 is

FIGURE 1-4 Computation of the regression equation for periods 1 through 6.

X	Y	X^2	XY
1	1447	1	1447
2	1384	4	2768
3	1219	9	3657
4	1047	16	4188
5	887	25	4435
6	759	36	4554
$\Sigma X=21$	$\Sigma Y=6743$	$\Sigma X^2=91$	$\Sigma XY=21049$

$$a=\frac{\Sigma X^2\Sigma Y-\Sigma X\Sigma XY}{n\Sigma X^2-(\Sigma X)^2} \qquad b=\frac{n\Sigma XY-\Sigma X\Sigma Y}{n\Sigma X^2-(\Sigma X)^2}$$

$$a=\frac{(91)(6743)-(21)(21049)}{(6)(91)-(21)^2} \qquad b=\frac{(6)(21049)-(21)(6743)}{(6)(91)-(21)^2}$$

$$a=1634.13 \qquad b=-145.80$$

$$Y'=1634.13-145.80X'$$

shown below. The forecast for period 7 is the quantity obtained for Y' when X' is equal to 7.

PERIOD (X')	FORECAST (Y')
7	613.53
8	467.73
9	321.93
10	176.13
11	30.33
12	−115.47 or 0

While noting that this is a much more pessimistic forecast than the prior forecast based on the mean of 1,123.8 unit sales per period, the reader should remember that this forecast is based on only the first six periods and that the natural level of activity is in a downtrend. It also assumes that the order of occurrence over time is meaningful in defining the natural level. The sample computations presented above are for only the first six periods of past demand data in order to simplify the computations. Of course one could derive the regression equation based upon all twenty-four periods of past demand data. If you do you'll find the equation to be:

$$Y'=1076.1+4.91X'$$

This equation produces a forecast not of zero, but of increasing sales of five units (4.91) each period. This is explained simply by the fact that Quasar Widget sales turned upward in period 7 after a steady decrease for the first six periods. Over the twenty-four periods, sales went up and down but the underlying trend averages out to be up five units per time period. You've probably noticed that the calculation of the regression equation is quite tedious. Fortunately, tedious calculations are the special forte of the electronic computer. The next section contains instructions on how to use the computer program FUTURE to do the necessary calculations and print out the results.

Computer Input—Regression Analysis

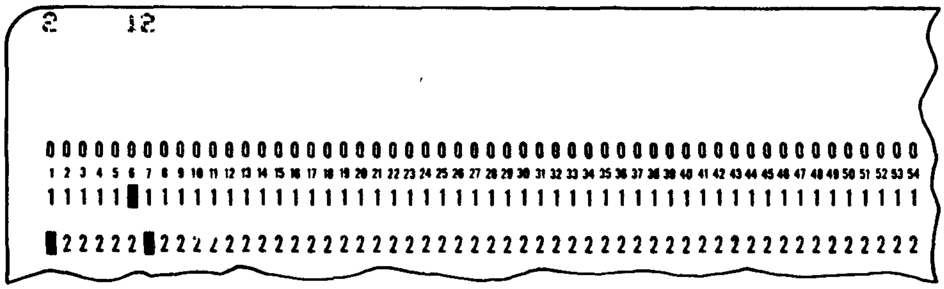
This section describes the computer input deck required to perform the computations required for regression analysis. The emphasis will be upon the changes required in the computer input presented in Section 1.1 in order to do regression analysis as opposed to the arithmetic average.

The *user name card*, first in the deck, may be keypunched to note that a different problem is being run.

The *history control card* is the same as before, second in the deck, with the number of history periods keypunched in columns 1 and 2.

The *history data cards* are the same as before. Twenty-four cards are required with the period number keypunched in columns 1 and 2 and the history data keypunched in columns 11–20.

The *analysis control card* must be modified to indicate that regression analysis is required. *Code* 2 in column 1 requests regression analysis.



The *termination card* is the last card in the data deck and STOP must be keypunched in columns 1–4.

The complete data deck is shown in Figure 1.5. Note that all cards are the same except the analysis control card. This card has been changed to reflect the request for the regression analysis forecasting technique.

FIGURE 1-5
Computer input—regression analysis.

```
YOUR NAME FUTURE DATA
24
01        1447.
02        1384.
03        1219.
04        1047.
05         887.
06         759.
07         814.
08         834.
09        1009.
10        1133.
11        1146.
12        1401.
13        1421.
14        1328.
15        1350.
16        1022.
17        1105.
18         877.
19         913.
20         926.
21        1104.
22        1234.
23        1329.
24        1609.
2    12
9
STOP
```