THE SPREADSHEET OPERATIONS MANAGER

EVERETTE S. GARDNER, JR.

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Center for Global Manufacturing
University of Houston

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ABOUT THE AUTHOR

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PREFACE

The Spreadsheet Operations Manager (SOM) is a collection of 35 professional templates for use with Lotus 1-2-3, Version 2.01 or higher, and compatible programs. In particular, the templates work with the Student Edition of Lotus 1-2-3 as well as with Quattro Pro. Each template is a comprehensive model of an operations problem, including sample data, preset graphs, and step-by-step instructions for analysis.

The target user is the student in an undergraduate or MBA course in Production and Operations Management. The aim is to make these courses more practical and entertaining by automating most of the quantitative analysis. SOM allows the professor and student to focus on applications, problem formulation, and "what-if" analysis rather than computation and algorithms.

Each template in SOM is thorough. There is no need to refer to tables of probabilities, learning curve parameters, control limits, sample sizes, or similar details. All such information is built into the templates, through numeric approximations or internal tables. Furthermore, the templates are large enough to handle realistic problems. There is no need to insert rows or modify the spreadsheets in any way to handle different amounts of data.

What spreadsheet skills do you need? SOM is aimed at the novice. All you need to know is how to retrieve files, move the cursor, and enter numbers in cells. The first chapter of the tutorial that accompanies Lotus 1-2-3 is adequate background. However, students who have a working knowledge of Lotus 1-2-3 can go much farther with the templates by studying the modeling techniques, macros, and cell formulas.

A work of this magnitude could not be created alone. Two of my doctoral students at the University of Houston, Conor O'Muirgheasa and Ray Forsthoffer, improved the design of the models and managed the testing. Cynthia Gardner, of EDS, Inc., read the manuscript and made many helpful suggestions. Basheer Khumawala, my colleague in the Center for Global Manufacturing at the University of Houston, helped design a powerful group of MRP and production planning models. Special thanks go to Frank Burrows, my editor at McGraw-Hill, for his ideas and encouragement.

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CONTENTS

Chapter 1 Getting Started

This chapter explains how to install the models, manage data files, and label graphs. For users new to spreadsheets, several tips are given for entering data in different formats.

1.1 Worksheet instructions

The Spreadsheet Operations Manager (SOM) is a collection of 35 professional templates for use with Lotus 1-2-3, Version 2.01 or higher, and compatible programs. In particular, the templates work with the Student Edition of Lotus 1-2-3 as well as with Quattro Pro (using its 1-2-3 menu option). Each template is a comprehensive model of an operations problem, including sample data, preset graphs, and step-by-step instructions for analysis.

SOM is delivered on two 5 1/4-inch, 360K diskettes or one 3 1/2-inch diskette. The worksheets total about 690K bytes. If you have a hard disk, copy these files to any subdirectory and then retrieve them as you would any other worksheet files. There are 36 worksheets, including 35 models plus a file named INDEX.WK1, shown in Figure 1-1, which helps retrieve files. Simply place your cursor on a file name and press the Enter key. INDEX is not designed for use with 360K diskettes because it assumes that all SOM files are stored together on one diskette or in the same subdirectory on a hard disk.

If a model contains macros, they are always named with the letters A - Z and listed at the top of the worksheet. All macros are executed by holding down the Alt key and pressing the letter indicated. When a model requires substantial data entry, three macros are always available: Alt R, Alt L, and Alt E. Alt R resets the worksheet by clearing old data, initializing certain control cells, and making other preparations to solve a new problem. Alt L performs a reset like Alt R and then prompts you for the name of a data file to load into the current worksheet. Alt E extracts input data and stores it in a separate worksheet file under a name of your choosing. Thus you can save your input data using Alt E and retrieve it later using Alt L. If a model does not require substantial data entry, no macros are used to manage data. All you have to do is enter new values in the input cells.

If graphs are attached to a worksheet, input cells for graph titles are found in the top left corner. The cells are labeled "Title1", "Title2", "X-axis", and "Y-axis." Entries in these cells automatically appear on graphs. If one of the graph labels is not displayed, the corresponding title is reserved for internal model use. Instructions to view the graphs are also listed at the top of the worksheet. The instructions are simple: you either execute a macro or press the F10 key, depending on the model.

In testing SOM, we found that spreadsheet novices sometimes become confused when entering numbers in cells that display dollar signs or percentages. Even though a cell displays a dollar sign, most spreadsheet programs will not accept a dollar sign in data entry. You must enter the number without a dollar sign. When a cell displays a percent sign, you must enter the number as a fraction. For example, 20% is entered as .2.

Figure 1-1

	A	B	C	D	E
1	INDEX		To retrieve a file, place cursor on file name and press enter.		
2					
3	#	Ch.	File name	Topic	Function
4	--	----	---------	--------------	-----------------------------------
5	1	2	SIMPLE	Forecasting	Simple exponential smoothing
6	2	2	TREND1	Forecasting	Smoothing linear, exp., & damped trends
7	3	2	TREND2	Forecasting	Smoothing a linear trend only
8	4	2	REG	Forecasting	Forecasting with linear regression
9	5	2	REGSEAS	Forecasting	Seas. adj. via linear regression
10	6	2	DESMON	Forecasting	Ratio-to-moving avg. seas. adj. - monthly
11	7	2	DESQTR	Forecasting	Ratio-to-moving avg. seas. adj. - qtrly.
12	8	3	EOQ	Inventory mgmt.	Economic order quantity
13	9	3	EOQBACK	Inventory mgmt.	EOQ with backorders
14	10	3	EOQDISC	Inventory mgmt.	EOQ with quantity discounts
15	11	3	EOQPROD	Inventory mgmt.	EOQ for production lot sizes
16	12	3	ROP	Inventory mgmt.	Reorder points and safety stocks
17	13	4	BOM	MRP	Bill of materials model
18	14	4	MRP1	MRP	MRP inventory record
19	15	4	MRP2	MRP	Simplified MRP inventory record
20	16	4	POQ	MRP	Period order quantity vs. EOQ
21	17	4	LTC	MRP	Least-total-cost lot sizing
22	18	5	APP	Prod. planning	Aggregate production planning
23	19	5	RUNOUT	Prod. planning	Run-out time production planning
24	20	5	LEARN	Prod. planning	Learning curves
25	21	6	LINEBAL	Layout,location	Assembly-line balancing
26	22	6	CENTER	Layout,location	Center-of-gravity method
27	23	7	SKED1	Scheduling	Job sequencing (1 work station)
28	24	7	SKED2	Scheduling	Job sequencing (2 work stations)
29	25	7	SKED3	Scheduling	Job sequencing (3 work stations)
30	26	7	CPM	Scheduling	Critical-path scheduling
31	27	8	ACCEPTSA	Quality	Acceptance sampling
32	28	8	PROBDIST	Quality	Probability distributions
33	29	8	LIMIT	Quality	Control limit calculator
34	30	8	MEANRANGE	Quality	Preparation of data files for MRCHART
35	31	8	MRCHART	Quality	Control chart (mean and range)
36	32	8	PCHART	Quality	Control chart (percent defective)
37	33	8	CCHART	Quality	Control chart (nbr. defects per unit)
38	34	9	SINGLEQ	Waiting lines	Single-server queuing models
39	35	9	MULTIQ	Waiting lines	Multiple-server queuing model

Novices may also be confused by cells that display a series of asterisks (*******). The asterisks indicate that the column width is too small to display the number in that cell. To fix this problem, the first step is to press the slash key (/). On the menu displayed at the top of the screen, select Worksheet Column Set-Width. At this point, the prompt at the top of the screen will say: "Enter column width (1..240):" followed by the current width of the column in characters. Type in a larger number than the one displayed and press the Enter key. This is a trial-and-error process so you may have to repeat the operation until the asterisks disappear.

Modify SOM models at your own risk. We do not recommend modifications because you may destroy named ranges, hidden cells, and macros that depend on a fixed location for input data and control parameters.

1.2 References

The models in SOM automate most of the quantitative analysis in four textbooks:

Aquilano, N. J., and Chase, R. B., *Fundamentals of Operations Management.* Homewood, Illinois: Irwin, 1991.

Chase, R. B., and Aquilano, N. J., *Production and Operations Management* (Third Edition), Homewood, Illinois: Irwin, 1989.

Dilworth, J. B., *Operations Management: Design, Planning, and Control for Manufacturing and Services*, New York: McGraw-Hill, 1992.

Stevenson, W. J., *Production/Operations Management* (Third Edition), Homewood, Illinois: Irwin, 1990.

The forecasting models go beyond most production and operations texts and are based on the following reference:

Levin, R. I., Rubin, D. S., Stinson, J. P., and Gardner, E. S., Jr., *Quantitative Approaches to Management* (Eighth Edition), New York: McGraw-Hill, 1992.

These references often present different models for solving the same problem. Thus SOM contains alternative models. For example, there are two worksheets for smoothing a trend, three worksheets for seasonal adjustment, and two worksheets for MRP inventory plans. For many other problems, alternative models are available within the same worksheet.

The references use a variety of conflicting mathematical notation. To prevent confusion, mathematical notation has been avoided throughout SOM.

Chapter 2 Forecasting

Four demand forecasting models are available in Sections 2.1 - 2.4. The exponential smoothing models extrapolate historical data patterns. Simple exponential smoothing is a short-range forecasting tool that assumes a reasonably stable mean in the data with no trend (consistent growth or decline). To deal with a trend, try one of the trend-adjusted smoothing models (TREND1 or TREND2). TREND1 lets you compare several different types of trend before committing to a forecast, while TREND2 forecasts a straight-line or linear trend only. To forecast with the regression model in REG, you must identify one or more causal variables to explain the variable you are trying to forecast.

The exponential smoothing worksheets accept either nonseasonal data or data which has been seasonally-adjusted using of the models in Sections 2.5 - 2.7. If your data contain a seasonal pattern, perform a seasonal adjustment before you apply exponential smoothing. Seasonal adjustment removes the seasonal pattern so that you can concentrate on forecasting the mean or trend. REGSEAS is the easiest adjustment procedure. DESMON or DESQTR give more accurate results at the cost of some added complexity.

2.1 Simple exponential smoothing (SIMPLE)

More than 25% of U.S. corporations use some form of exponential smoothing as a forecasting model. Smoothing models are relatively simple, easy to understand, and easy to implement, especially in spreadsheet form. Smoothing models also compare quite favorably in accuracy to complex forecasting models. One of the surprising things scientists have learned about forecasting in recent years is that complex models are not necessarily more accurate than simple models.

The simplest form of exponential smoothing is called, appropriately enough, simple smoothing. Simple smoothing is used for short-range forecasting, usually just one time period into the future. The model assumes that the data fluctuate around a reasonably stable mean (no trend or consistent pattern of growth). If the data contain a trend, try one of the trend-adjusted smoothing models (TREND1 or TREND2).

Figures 2-1 and 2-2 illustrate an application of simple exponential smoothing at the International Airport in Victoria, Texas. The airport has been open for a year and the data in column D of Figure 2-1 are the monthly numbers of passengers embarked. The terminal manager feels that he has enough data to develop a forecast of passengers one month in advance in order to schedule part-time employment for airport parking, baggage handling, and security.

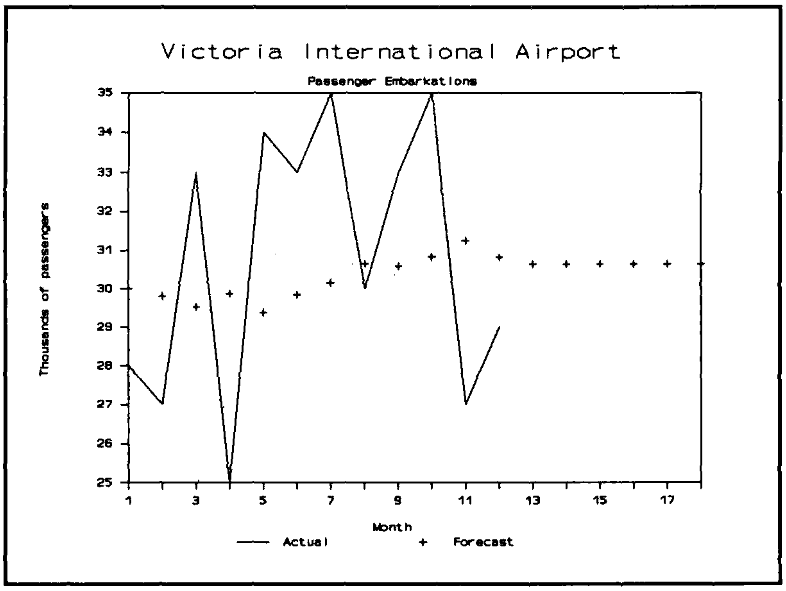
To get the forecasting process started, SIMPLE automatically sets the first forecast (E19) equal to the average of the number of warm-up data specified in cell E12. The number of warm-up data is 6, so the first forecast of 30.0 is the average of the data for months 1-6. If you don't like the first forecast, replace the formula in E19 with a value. Thereafter the forecasts are updated as follows: In column F, each forecast error is equal to actual data minus the forecast for that period. In column E, each forecast is equal to the previous forecast plus a fraction of the previous error. This fraction is found in cell E11 and is called the smoothing weight. The model works much like an automatic pilot, a cruise control on an automobile, or a thermostat. If a given forecast is too low, the forecast error is positive, and the next forecast is increased by a fraction of the error. If a given forecast is too high, the forecast error is negative, and the next forecast is reduced by a fraction of the error. If we get lucky and a forecast is perfect, the error is zero and there is no change in the next forecast.

A total of 12 data observations are entered in Figure 2-1. The model automatically makes forecasts through month 48, regardless of the number of data entered. For months 13-48, the forecasts are constant. Why? Remember that the model assumes no trend, so the only option is to project the last forecast for every period in the future.

Figure 2-1

	A	B	C	D	E	F	G	H	I
1	SIMPLE	SIMPLE EXPONENTIAL SMOOTHING					Alt R	Reset worksheet	
2	Title1:	Victoria International Airport					Alt L	Load data file	
3	Title2:	Passenger Embarkations					Alt E	Extract data file	
4	X-axis:	Month							
5	Y-axis:	Thousands of passengers					Alt G	Graph forecasts	
6							Alt T	Run MSE table	
7							Alt V	View error summary	
8									
9									
10	INPUT:						OUTPUT:		
11	Smoothing weight:				0.10		Nbr. of data:		12
12	Nbr. of warm-up data:				6		Warm-up MSE:		13.2
13							Forecasting MSE:		11.4
14							Warm-up MAD:		3.5
15							Forecasting MAD:		3.0
16									
17							Seas.	Final	
18	Year	Mon.	t	Data	Fcst.	Error	index	fcst.	
19	1991	1	1	28	30.0	-2.0			
20		2	2	27	29.8	-2.8			
21		3	3	33	29.5	3.5			
22		4	4	25	29.9	-4.9			
23		5	5	34	29.4	4.6			
24		6	6	33	29.8	3.2			
25		7	7	35	30.2	4.8			
26		8	8	30	30.6	-0.6			
27		9	9	33	30.6	2.4			
28		10	10	35	30.8	4.2			
29		11	11	27	31.2	-4.2			
30		12	12	29	30.8	-1.8			
31	1992	1	13		30.6	NA			
32		2	14		30.6	NA			
33		3	15		30.6	NA			

Figure 2-2



To graph the data and forecasts, as shown in Figure 2-2, use the Alt G macro. This macro automatically displays forecasts for 6 time periods beyond the end of the data entered.

In the output section, I11..I15, the model counts the number of data entered and computes mean forecast error measures. The MSE is the mean-squared-error and the MAD is the mean of the absolute errors or the mean-absolute-deviation. Both the MSE and MAD are computed for two samples of the data. The first sample (periods 1-6) is called the warm-up sample. This sample is used to "fit" the forecasting model; that is, to run the model through the first part of the data to get "warmed up." The second part of the data (periods 7-12) is used to test the model and is called the forecasting sample. Accuracy in the warm-up sample is really irrelevant. Accuracy in the forecasting sample is more important because the pattern of the data often changes over time. The forecasting sample is used to evaluate how well the model tracks such changes. There are no statistical rules on where to divide the data into warm-up and forecasting samples. There may not be enough data to have two samples. A good rule of thumb is to put at least six nonseasonal data points or two complete seasons of seasonal data in the warm-up. If there is less data than this, there is no need to bother with two samples. In a long time series, it is common in practice to simply divide the data in half. If you don't want to bother with a warm-up sample, set the number of warm-up data equal to the total number of data. The forecasting MSE and MAD will then be set to zero.

Press Alt V to see a detailed table of error information (Figure 2-3). Column L is the average of the data through each observation. Since we specified 6 periods to warm up, the average at the end of period 6, 30.0, was used as the first forecast. Columns M-Q show various error measures as of the end of each time period. The error summary extends for 48 periods.

Figure 2-3

	K	L	M	N	O	P	Q
13	ERROR	SUMMARY					
14							
15							
16		(1)	(2)	(3)	(4)	(5)	(6)
17		Avg.	Sum of	Sum of	Abs.	Sum of	
18	t	data	errors	error^2	error	abs. err	MAD
19	1	28.0	-2.0	4.0	2.0	2.0	2.0
20	2	27.5	-4.8	11.8	2.8	4.8	2.4
21	3	29.3	-1.3	24.0	3.5	8.3	2.8
22	4	28.3	-6.2	47.6	4.9	13.1	3.3
23	5	29.4	-1.6	69.0	4.6	17.8	3.6
24	6	30.0	1.6	78.9	3.2	20.9	3.5
25	7	30.7	6.4	102.4	4.8	25.8	3.7
26	8	30.6	5.8	102.8	0.6	26.4	3.3
27	9	30.9	8.2	108.7	2.4	28.8	3.2
28	10	31.3	12.4	126.1	4.2	33.0	3.3
29	11	30.9	8.1	144.1	4.2	37.2	3.4
30	12	30.8	6.3	147.4	1.8	39.1	3.3

How do you choose the weight in cell E11? A range of trial values must be tested. The best-fitting weight is the one that gives the minimum MSE in the warm-up sample. There are two factors which interact to determine the best-fitting weight. One is the amount of noise or randomness in the series. The greater the noise, the smaller the weight must be to avoid overreaction to purely random fluctuations in the time series. The second factor is the stability of the mean. If the mean is relatively constant, the weight must be small. If the mean is changing, the weight must be large to keep up with the changes. Weights can be selected from the range 0 - 1 although we recommend a minimum weight of 0.1 in practice. Smaller values result in a very sluggish response to changes in the mean of the time series.

Use the Alt T macro to test alternative weights. When this macro is executed, the trial weights in range W3..W12 are automatically substituted, one-at-a-time, into cell E11. The warm-up MSE for each weight is recorded and the screen displays a table of the results. You can change the trial weights in cells W3..W12 and run the Alt T macro as many times as you like. Because the mean of the Victoria data is constant, the minimum MSE is found using the smallest weight, 0.10.

The forecasting model in SIMPLE is based on two equations that are updated at the end of each time period:

Forecast error	=	actual data - current forecast
Next forecast	=	current forecast + (weight x error)

A little algebra shows that this model is equivalent to another model found in many textbooks and in practice:

Next forecast	=	(weight x actual data) + [(1 - weight) x current forecast]

The model in SIMPLE is much easier to understand and requires less arithmetic. It is true that the model requires computation of the error before the forecast can be computed. However, the error must always be computed to evaluate the accuracy of the model.

Before entering your own data in SIMPLE, use Alt R to reset the worksheet. Change the year and months in columns A and B starting at row 19. Enter data in column D starting at row 19. The Alt E macro extracts a column of data observations from range D19..D66. When you select Alt E, you are prompted for the name of a worksheet file to save the data. The Alt L macro loads a worksheet data file that can be nonseasonal or seasonal. If the data are nonseasonal, the input file has 1 column of data which is automatically loaded into the range D19..D66. If the data are seasonal, the input file is produced by one of the seasonal adjustment worksheets (in sections 2.5 - 2.7) and has 2 columns. The first column consists of seasonally-adjusted data and is automatically loaded by Alt L into D19..D66. The second column contains seasonal indices which are automatically loaded into the range I19..I66. Column J multiplies the forecasts of seasonally-adjusted data in column E times the seasonal indices in column I to produce final seasonalized forecasts. The Alt L macro works the same way in the TREND1 and TREND2 models. The seasonal adjustment procedure is explained in detail in section 2.5.

2.2 Smoothing linear, exponential, and damped trends (TREND1)

Exponential smoothing with a trend works much like simple smoothing except that two components must be updated each period: level and trend. The level is a smoothed estimate of the value of the data at the end of each period. The trend is a smoothed estimate of average growth at the end of each period.

To explain this type of forecasting, let's review an application at Alief Precision Arms, a company that manufactures high-quality replicas of the Colt Single-Action Army revolver and other revolvers from the nineteenth century. Alief was founded in 1980 and, as shown in Figure 2-5, experienced rapid growth through 1987. Since 1987, growth has slowed and Alief is uncertain about the growth that should be projected in the future.

The worksheet shown in Figure 2-4 was developed to help Alief compare several different types of trend forecasts. Let's start with the simplest case, the linear or straight-line trend, which predicts that growth will be a constant amount each period in the future. To get started, initial values for level and trend are computed in cells G18 and H18. The level is a smoothed estimate of the current value of the data. Trend is the amount of growth each period. Level and trend are updated as follows:

Forecast error	=	Actual data - current forecast
Current level	=	Current forecast + (level weight x error)
Current trend	=	Previous trend + (trend weight x error)
Next forecast	=	Current level + current trend

For example, the forecast error in 1991 is data minus forecast or 44.5 - 45.4 = -0.9. The current level is the forecast for 1991 plus the level weight times the error, or 45.4 + 0.9 x -0.9 = 44.6. The current trend is the previous trend plus the trend weight times the error, or 1.5 + 0.3 x -0.9 = 1.2. The forecast is the current level plus trend or 44.6 + 1.2 = 45.8. Beyond the end of the data, the forecasts increase by the amount of the last computed trend. In the Alief data, the last trend was 1.2 so the forecasts increase by 1.2 each year in the future.