SAS: A DECISION SUPPORT SYSTEM FOR MANAGEMENT

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"Our progress depends to a considerable extent on seeing to it that the simplifying processes move forward in approximate balance with the complicating processes."

Ralph J. Cordiner
New Frontiers for Professional Managers

ABSTRACT

In the past few years, there has been a growing controversy in the literature over the utility of many Operations Research publications. Some readers argue, and rightfully so, that most of the articles are authored by researchers, statisticians, and mathematicians who have little knowledge of or regard for the true fabric of management. As such, mathematical rigor and abstract thought are often emphasized to the exclusion of real world practicality. Consequently, the gap continues to widen between the academic theoretician who structures the methodology and the working manager who has to live with the daily problems.

To help bridge the gap, this paper focuses on SAS as a practical decision support system. At the outset, the authors would like to make it clear that there will be no appeal to rigor, elegance, or mathematical gymnastics. The principal thrust of this paper will be on conventional managerial problems of productivity, absenteeism, forecasting, compensation and equipment procurement. The authors will demonstrate that in the absence of staff, time, and other resources, SAS is a powerful methodology to employ to generate quick and dirty solutions to practical problems. The paper is action or results oriented with particular emphasis placed on queueing models, ANOVA, Box-Jenkins, X-11, Monte Carlo methods, regression, and cluster analysis.

INTRODUCTION

In the practical eight-to-five world of middle management, one simply can't afford the luxury of academic theory and sophisticated methodology in the problem solving process. All too often, the manager is limited by available data, prevailing software, existing staff, budget size, and time contraints. Two crucial skills that are necessary in this particular setting are the ability to simplify and the ability to communicate. Anything, therefore, that contributes to clarity of presentation, simplification, reliability, timely solutions, and minimal staffing is a welcome addition to a manager's decision support system.

It has only been in the last two years that the authors have become familiar with the Statistical Analysis System (SAS). They hope to demonstrate in this paper that SAS is a practical methodology to use in the problem solving process. More specifically, they will concentrate on the use of graphics as a tool of analysis to emphasize informational concepts. The examples will be drawn from the areas of forecasting, compensation, and other managerial problems. To maintain propriety, all of the data and operating divisions of the company are disguised.

FORECASTING

Box-Jenkins Method

The first case study deals with the short term forecasting of revenue, expense, and net income for the ABC division. In particular, the authors were given a monthly data base of 41 observations dealing with the period of January 1978 through May 1981. The task at hand was to use a naive extrapolation technique to forecast monthly components for the remaining seven months of 1981 as well as total net income for the entire fiscal year. To keep the exercise simple, seasonality was not considered.

To accomplish the task, the authors turned their attention to the statistical methodology of Box-Jenkins [1-5]. More specifically, a total of 96 different ARIMA models were entertained with the number of autoregressive or moving average terms not exceeding 3. To identify the most promising models, the authors reviewed the sample autocorrelation function, the partial autocorrelation function, stationarity, and the significance of the parameter estimates. In addition, the residuals were examined and relatively simple models with a minimum standard error of the estimate were entertained. In the final analysis, the authors settled on ARIMA (2,1,0) models for revenue and expense and used the following functional relationship to determine net income:

$$\text{Net Income} = \text{Revenue} - \text{Expense} \qquad (1)$$

Historical revenue data and forecast, with upper and lower 95% confidence limits, are shown in Figure 1. The overall results suggested that if conditions continued in the future as they had in the past, then net income for fiscal year 1981 could have approached $2.47 million.

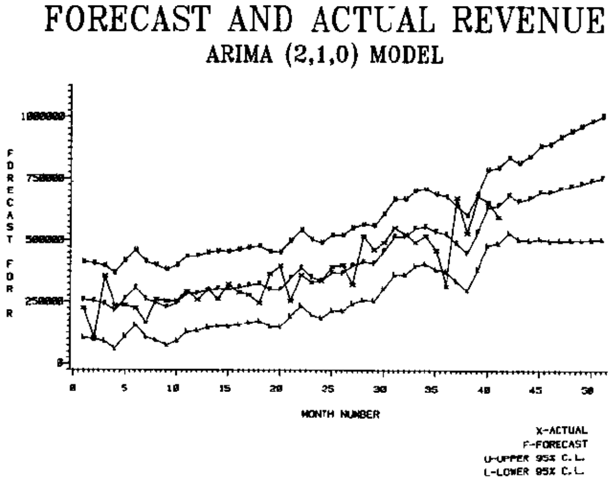


FIGURE 1

X-11 Model

As a second example of statistical forecasting, consider the case of the XYZ division that wanted to forecast direct manhours (MH) expended by the division in November, 1980. The data base to be employed consisted of 120 monthly observations captured for the period 1970 to 1979. To bring the problem into clearer relief, a multiplicative type of time series analysis (TSA) model was assumed that employed PROC X11[6,7]. The general components of this chronological series are shown in Table 1.

TABLE 1
X-11 TSA COMPONENTS
NOVEMBER, 1980 FORECAST

TSA COMPONENT		PERCENT
Trading Day	(TD)	92.0
Seasonal	(S)	95.6
Irregular	(I)	N(100,1.3)
Trend	(T)	129,201*
Cyclical	(C)	69.7

*In manhours

In reviewing the above results, it should be noted that stable seasonality was present at the 1% level of significance and the irregular component passed a Kolmogorov-Smirnov test for normality (PROC KSLTEST). To isolate the secular trend component, PROC NLIN was employed with a Gompertz function using the principal of non-linear least squares. The cyclical component is only approximate and a further detailed analysis using a Fourier series could have been employed[8]. Finally, the trading day component was derived by properly weighting the data to reflect calendar composition.

Assuming a general multiplicative TSA model of the following functional form,

$$MH = TD \times S \times I \times T \times C \qquad (2)$$

a 99.7% confidence interval estimate for November direct manhours in thousands would be (76.1, 82.3). This interval estimate was considered precise enough for manpower planning in the XYZ division.

Monte Carlo Analysis

Another demonstration of forecasting methods involves the projection of XYZ division manpower requirements for the next four quarters as well as the following year. In particular, in June of 1982, the authors were asked to perform this analysis for each job class within the XYZ division, in addition to the division as a whole. The inputs to this study included the following data for each of 84 potential projects: number of manhours required, beginning date, length, type, and both optimistic and pessimistic probability estimates of being awarded the proposal. The authors were also given the percentage of work done by each job class for four project types.

In order to develop a solution, the authors utilized the tools of Monte Carlo Simulation [9]. This approach simulated 1000 possible project award combinations for both the optimistic and pessimistic probabilities for each job class. It should be noted that all projects assumed a level manpower distribution for the duration of the job. The results produced probability distributions of manhour requirements, an example of which is depicted in Figure 2. This optimistic probability distribution for job class 15 in the first quarter of 1983 is typical of those generated for each job class. Most distributions were unimodal, right skewed, and had a high degree of variability.

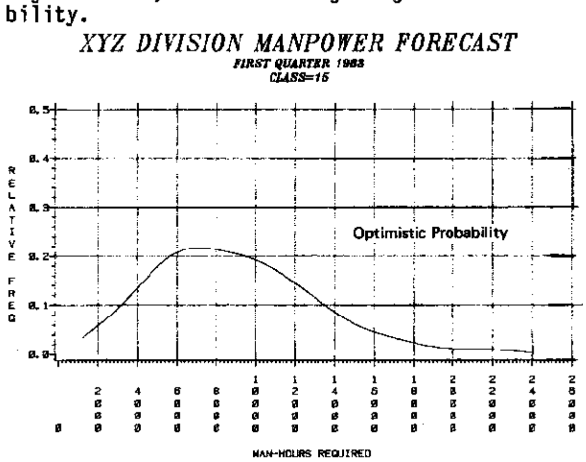


FIGURE 2

Because of the variability, the medians of the manhour probability distributions were chosen as the best projections. These results were then converted from manhours to personnel required using a conversion factor of 160 manhours per man-month. The final forecast thus consisted of an optimistic and pessimistic prediction for each job class-time period combination as well as for all of Division XYZ.

COMPENSATION

Some Simple Models

In the field of data processing, Source EDP is a respected source of data on salary information[10]. Each year, this firm publishes by position and level of experience salary data for the 15, 50, and 85th percentiles. To facilitate extrapolation and quick comparisons, normal probability models were developed from the published data for each of 48 different data processing positions. Some typical results are shown in Figure 3 for a Data Base Specialist (DBS) with over 4 years of experience. From this graph it can be seen that a professional DBS with 15 years of experience and a monthly salary of $3,400 would fall in the 63rd percentile. Quick checks such as this allow the manager to monitor competitive salary levels on an on-going basis.

SOURCE EDP 1982 NATIONAL SALARY SURVEY

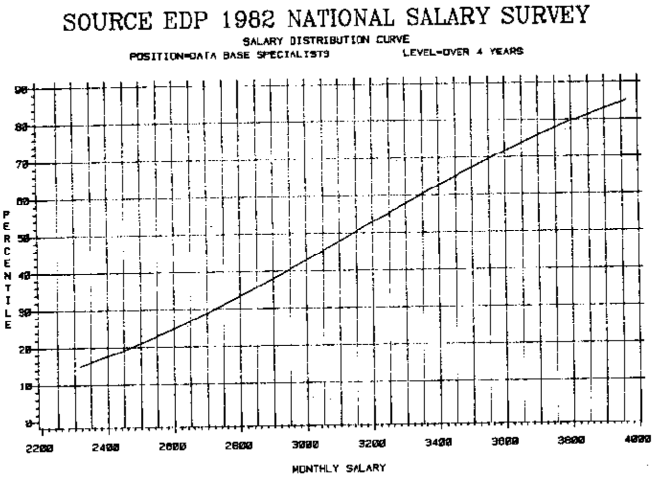


FIGURE 3

Another tool of analysis used in salary administration is the Salary Maturity Curve. In this graph, monthly salary is normally plotted against experience in classification for various job positions. Traditionally, second degree polynomials have been fit to this data to make some average comparisons or to construct prediction limits. It has been our experience that this curve fitting procedure generally leads to poor results. As an alternative to this method, Figure 4 shows a typical maturity curve fit by PROC NLIN. The basic function employed is the Logistic function which has desirable asymptotic properties. In future studies of industry data, we hope to employ this method of non-linear analysis.

SALARY MATURITY CURVE

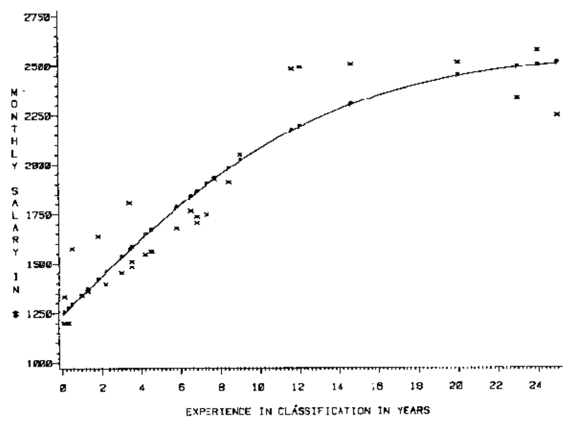


FIGURE 4

A Comprehensive Approach

As a continuing effort on salary administration, one of the authors (RAG) is a participating member of the company's Compensation Advisory Group (CAG). One of the responsiblities of this task force is to systematically evaluate the existing pay structure[11]. Since much of this effort depends on written job descriptions, we will demonstrate the method by drawing on a particular example from the ABC division.

In this specific instance, 18 bench mark positions were numerically evaluated by 8 members of the CAG. Evaluation points were developed for six factors relating to knowledge, problem solving, physical-mechanical-and mental skills, interpersonal skills, impact, and authority. The maximum number of evaluation points possible for all 6 factors on a particular bench mark position was 1,000. As a preliminary analysis in grouping these jobs into seven different pay grades (Q,...,W), the authors employed PROC CLUSTER to sort and position the data into a cluster map[12]. The results of this analysis are shown in Table 2.

TABLE 2
CLUSTER MAP
COMPENSATION ANALYSIS

PAY GRADE	JOB CODE
Q	C01, T01
R	C02, T02
S	LTO, PR1, EP1
T	DES, PR2, EP2
U	COA, PA1, TA1
V	PA2, TA2
W	MCO, TA3, PRL

In reviewing this data, it is important to keep in mind that these positions have been grouped from the least important grade Q to the most important grade W.

To take the preliminary analysis one step further, the authors sought to correlate evaluation points (pay grade) with existing market data on salary. The results of this analysis using PROC GLM are shown in Figure 5. The correlation coefficient (+0.98) for this simple linear regression is statistically significant at the 1% level[13]. The results tend to confirm the overall consistency of the internal evaluation system with existing market pay structure.

ABC DIVISION EVALUATION SYSTEM
ACTUAL MONTHLY SALARY VS. EVALUATION POINTS

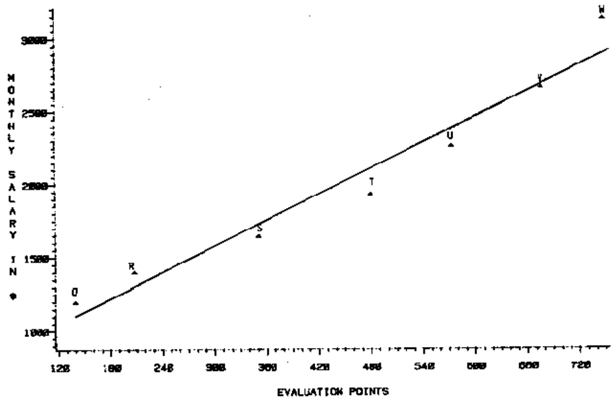


FIGURE 5

MISCELLANEOUS

Queueing Models

As Gjertsen[14] and Dickerson and Young[15] point out, the field of computer science offers a wide variety of applications for conventional queueing models. The specific application the authors will address here deals with the number of tape drives needed in a computing center to meet a desired threshold of service.

To accomplish the analysis, the authors have assumed the M/M/S model described by Wagner[16] and have used SMF data on arrival and service time patterns. The multi-channel queueing model was originally written in BASIC on an Apple II plus minicomputer and then integrated with SAS on the mainframe at Stearns-Roger. For a given arrival and service time pattern, the program evaluates the probability of a busy period, the average line length, the expected number of jobs in service, the average number of jobs in the system, the expected time in the system, and the probability distribution for the number of jobs in the system.

Figure 6 summarizes the average number of minutes in the system as a function of the number of tape drives employed. In this particular analysis, the decision was made to increase from four to five tape drives and then adopt a wait and see attitude. The authors anticipate that any future analysis will focus on sensitivity considerations as well as on the nature of the assumed probability distributions.

TAPE DRIVE ANALYSIS
(M/M/S MODEL -- OCTOBER 1981)

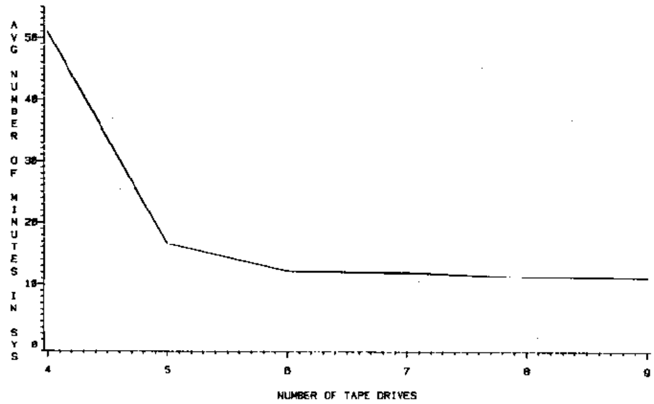


FIGURE 6

Absentee Analysis

It is not uncommon in an employee performance evaluation to focus on excessive absenteeism as a criterion variable. Figure 7 describes a simple analysis on manhours of sick leave done on an employee of the ABC Division. The study covers the period from 1979 through 1981 and reflects observed holiday schedules, vacations, and weekends. The null hypothesis that sick leave is uniformly distributed across days of the week is summarily rejected using the chi-square statistic[17]. The pattern of variation indicates that absenteeism is more likely to occur on a Monday or a Wednesday than any other day of the week. As a consequence of this analysis, an action report was written by the Manager, and employee absenteeism has improved considerably ever since.

ABSENTEE ANALYSIS
TOTAL MANHOURS OF SICK LEAVE
1979 THROUGH 1981

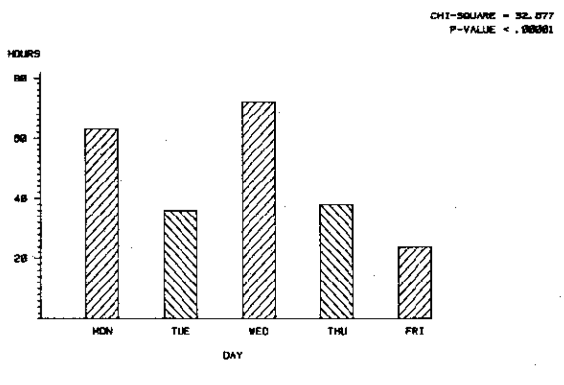


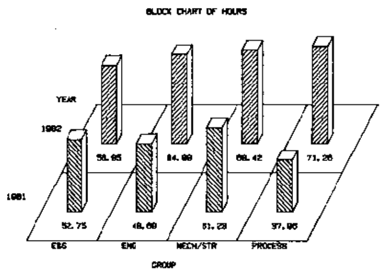
FIGURE 7

Productivity

As a final example of the use of SAS as a decision support system, the authors will turn their attention to the measurement of productivity in the ABC Division. For the particular department in question (ENG), there are three operating groups: Electrical and Support (E&S), Mechanical and Structural (MECH/STR), and the Process group.

In the last few years, this department has experienced considerable turnover of personnel so that it is more than of passing interest to measure improvement in productivity as new people adapt to a learning curve situation. To facilitate the analysis, Figure 8 summarizes performance by year and by group for the criterion variable labor hours billed. A closer examination of the results using a two way ANOVA[13] indicates a 31% increase in department productivity with the most substantial increase taking place in the Process group. By comparison, group differences were not significant at the 10% level. Although not shown, the authors have taken the analysis one step further by developing learning curves for each of the new people on staff. These learning curves serve as guidelines for rewarding individual performance.

AVERAGE LABOR HOURS BILLED
1981-1982



ANOVA RESULTS
YEARLY DIFFERENCES SIGNIFICANT AT 0.10 LEVEL
GROUP DIFFERENCES NOT SIGNIFICANT AT 0.10 LEVEL
FIGURE 8

CONCLUSION

In closing, the authors would like to point out that one of the roles of management is to measure what it most affects[18]. The old axiom that if you can't measure it, you can't manage it is certainly intuitively clear today. Hopefully this paper demonstrates that SAS contributes significantly to the measurement process. The authors could have made their point just as easily by using alternative examples employing PROC CORR, PRINCOMP, RANK, FORECAST, SPECTRA, STEPWISE, or UNIVARIATE. In the final analysis, it should be clear that SAS serves as a simple but powerful decision support system in the problem solving process.

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