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ABSTRACT

There are increasing numbers of commercially available computer graphics packages, both in terms of hardware and software, that can be utilized by instructors, practitioners, and students of education. With the proliferation of low-cost graphic terminals, time-sharing capabilities, and recent advances in mini- and microcomputers, computer graphics and associated applications have been practical, reliable, cost-effective, and available at a host of working, user-oriented levels. Working databases used for instructional purposes in undergraduate and graduate marketing courses, especially in physical-distribution related subjects, illustrate the potential capabilities of appropriate computer software packages such as SYMAP, SYMVU, PLOTALL, QUSMO, and QUTAB. Applications and examples derived from these packages can be represented from existing output facilities, such as the line-printer terminal, incremental drum-plotter, flatbed plotter, and electrostatic plotter. Computer graphics can be an essential tool in helping consumers of information to conceptualize and ultimately visualize raw data files. In addition, the basic skills that students learn in applying computer graphics to business decision-making situations enhance their preparation for the world of work. Seven tables and eight references are provided as well as seven samples of computer-generated graphic displays. (Author/MES)

EDUCATIONAL CONCEPTS OF COMPUTER GRAPHICS IN THE CLASSROOM

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ABSTRACT

There are increasing numbers of commercially available computer-graphic packages, both in terms of hardware and software that can be utilized by instructors, practitioners, and students of education. With the proliferation of low-cost graphic terminals, time-sharing capabilities, and recent advances in mini- and microcomputers, computer graphics and associated applications have been practical, reliable, cost-effective, and available at a host of working, user-oriented levels. Working data bases used for instructional purposes in undergraduate and graduate marketing courses, especially in physical-distribution related sbujects, illustrated the potential capabilities of appropriate computer-software packages such as: SYMAP, SYMVU, PLOTALL, QUSMO, and QUTAB Applications and examples derived from these packages are represented from existing output facilities, such as the line-printer terminal, incremental drum-plotter, flatbed plotter, and electrostatic plotter. Computer graphics can be an essential tool in helping consumers of information to conceptualize and ultimately visualize raw data files. In addition, the basic skills that students learn in applying computer graphics to business decision-making situations enhances their preparation in the world of work.

INTRODUCTION

Since its introduction in industry and academic centers in the 1960s, the field of computer graphics has captured the technical, ascetic, and artistic interests, from rapidly increasing numbers of users from a vast variety of disciplines. No longer must the potential user be proficient in the complexities of mathematical elements and computer graphics. As suggested by Rogers and Adams (1976), Scott (1982), and Maft (1983), almost everyone will be affected by this rapidly expanding technology, which combines the age-old art of graphical communication with recent advances in digital computers. Now, relatively low-cost terminals, time sharing options, and advances in mini- and microcomputers have made computer graphics practical, reliable, cost effective, and readily available to the potential user. In fact, the last few years has seen a tremendous influx of research on business applications of the computer, especially the mini- and microcomputers. However, there does not appear to be as great a volume of literature on the business and educational applications of these recent advances on the use of the computer in the classroom, especially concerning computer graphics.

Hence, the thrust of this paper is to discuss the basic types of computer-generated display devices, and to illustrate the combined use of line-printer maps, digital storage, and transfer of information into projected three-dimensional surfaces for viewing as instructional aids to geographic and business education. Although beginning business and geographic graduates, managers, and other business-related personnel have many applications of such output to illustrate basic concepts of marketing and physical distribution phenomena and its spatial interpretation, applications of computer graphics and basic principles are not limited to a single discipline of study. In fact, with the widespread use of microcomputers in the classroom for computer-assisted instructional purposes, the expanding use of computer graphics in all disciplines and its application to communicate often difficult-to-interpret data bases and concepts is rapidly becoming an essential tool for use in the classroom by educational practitioners. The usefulness of computer-graphical systems must, however, be based on their ability to communicate the results of data manipulation and ease of access. An understanding of the basic computer graphics in the classroom. Not all possible computer hardware and software types are discussed in this paper, since a magnitude of such devices and packages with length lists of menus exist (Smith, Timmerman and Seymour, 1984). However, the basic display devices that are commonly available (including raster refresh, directed beam refresh, storage tube, and plasma panel) coupled with the basic output devices (such as mechanical plotters, electrostatic plotters, hardcopy devices, and color plotters) will be briefly discussed. However, the bulk of the paper will concentrate on marketing/business education examples to illustrate the process of converting complex information and models to easily communicated computer-graphical displays in the classroom.

COMPUTER INPUT DEVICES

Input devices can be grouped into two basic formats, including the batch mode (reading one job or program in one-at-a-time) and the interacting mode (which includes the ability of the user to communicate with the program while it is running). Batch jobs usually can be initiated by reading in cards, tape, and CRT (cathode-ray tube) via some type of terminal capability of reading information in these particular modes. The interactive mode requires the user to interrupt the computer programs so that new or revised information can be entered before the final execution of the program. Although there exists a large number of devices to accomplish this task, the simplest and most common is the alphanumeric keyboard. More sophisticated input devices include light pens, joy sticks, track balls, mouse, function switches, control dials, and analog tablets. These other input devices usually constitute greater flexibility and faster speeds of interaction than the alphanumeric keyboard, which frequently becomes a test of your typing skills.

COMPUTER OUTPUT DEVICES

There are a variety of output devices in use in computer graphics, but most of them fall into a few basic categories. Graphic display devices are usually divided between CRT, pen and ink plotter, dot matrix plotter, and the plasma panel. The three basic types of CRT devices for computer graphics include the direct view storage tube (sometimes referred to as the visible tube display), refresh, and raster scan. The direct view storage tube is probably most common to the public and is similar to an oscilloscope with a relative long-life phosphor or image phosphor. Storage tubes have the advantages of being flicker free, good resolution, low cost, relatively easy to obtain an acceptable hard copy of the frame or screen image, and more suited to time-sharing applications. Unfortunately, the screen cannot be selectively erased in order to change any element of the graphic display, thus the whole picture must be redrawn and hence, no dynamic motions are possible. The refresh CRT is based on a television-like tube of short-lived phosphor persistence, thus causing flicker. However, the refresh can be used to show dynamic motion and allow selective elements of the display to be created, changed, or removed. Disadvantages of the refresh system include higher cost and greater difficulty in obtaining a good quality hard copy of the image. Lastly, the raster scan CRT, which uses a standard television monitor for the display console, makes use of a series of dots. In the consideration of a raster-scan CRT graphic display system, color is possible, but cost is a function of the resolution needed. In addition, the selective erase feature is more difficult to use, and obtaining quality hard copies are problems.

Traditional hard copy graphical devices generally involve the digital incremental pen and ink plotters, flat pen plotter is generally limited to 8 directions of pen movement, thus a curved line appears to be made up of a series of small steps. The incremental drum plotter, which was the major device used to create the three-dimensional computer graphics found in the paper, refers to a type of plotter on which the paper is help by two rolls--a supply roll and a take-up roll--separated by a drum. Although incremental plotters can provide high-quality hard copy of graphical output, they are generally slower than CRT graphics and, hence, are not used for most real-time interactive graphics. The electrostatic dot matrix printer/plotter operates quite differently by depositing particles of toner onto small electrostatically charged areas of special paper. The electrostatic plotter was the device used to generate the bar, pie, and line plots found in the study (Rogers and Adams, 1976; Maft, 1983). Lastly the plasma panel, which was initially developed a few years ago and recently staging a comeback, is essentially a gas-filled matrix or panel that usually can be viewed from both sides. However, although good resolution is possible, it is cost prohibitive and not popularly accepted. Tables 1 and 2 present a summary of the financial and physical parameters that should be considered in the final selection of computer-graphical devices (both input and output) and the proper software package to enhance geographic/business education activities.

APPLICATIONS OF SELECTED COMPUTER GRAPHICS TO SPATIAL AND SURVEY RESEARCH

Introduction to Classroom Examples

Examples of primary and secondary databases researched and collected by the author for use in undergraduate/graduate marketing/physical distribution management and related courses at Eastern Kentucky University's Department of Business Administration. Portions of the courses emphasize the spatial variability of transportation costs and the need to communicate this information to prospective clients and consumers. Generally, most theoretists of physical distribution expect the distance factor in predicting transportation costs to reflect the "tapering" principle--transportation rates initially increases significantly with distance, then increase at diminishing rate. This relationship has been studied for years as a basic principle in business logistics, and the function is expected to be relatively smooth in nature and predictable in form. However, especially through three-dimensional displays of spatially-oriented transportation costs, this relationship is more complex and difficult to interpret. Probably, many economic and physical characteristics influence transportation rates, thus each area must be analyzed in relation to the environmental constraints that exists, both the economic and physical aspects. In addition, information dealing with the frequency counts, summaries of statstics, and other data dealing with survey-research problems are more effectively communicated in a graphical form. Hence, to illustrate the use of computer graphics in the classroom, several databases were established for students to access for report-writing purposes. The databases include marketing-research survey results, geographically oriented-transportation costs from a variety of origin and destination points, and revenue/expense data for departments within unnamed companies.

In addition, various options exist to allow users to mathematically model selected variables based on geographic coordinates (spatial variability).

Computer-Generated Output

Figures 1 through 3 illustrate representative information from the databases in pie-chart, line-graph, bar-graph form via the electrostatic output device, respectively. The user input, via the computer-software PLOTALL (Klein, 1976), for example, to arrive at Figure 1 was simply the following instructions that the student/practitioner typed in at a terminal:

```
THE VARIABLE IS SATISFACTION
THERE ARE 4 CASES
READ THE DATA
-104, -48, -31, -89, -190
THE TYPE OF PLOT IS PIE PLOT
START SHADING
PLOT SATISFACTION
STOP
END
```

As shown in Figure 1, the negative sign associated with the data values results in each pie slice being separated from the center of the pie shape. The other basic graphical forms of frequency distributions are portrayed in Figures 2 and 3, and use similar options to generate them. Hence, the statements required are English-like and require virtually no prior programming experience to write them and execute the computer graphics.

The graphic displays of the three-dimensional plots were generated through the use of QUSMO (Sawan and Nash, 1974) and SYMAP, SYMVU (Dougenik and Sheehan, 1979). The basic line-printer map was also generated by SYMAP, a software package that has been commercially available for a number of years and is well-documented (Fig. 4). The simple use of the program's electives allows students/users to create 89 by 98 data matrix on tape/disk storage. This data matrix can be read from storage to a user-oriented plotting software, namely QUSMO. Table 3 illustrates the basic specifications of the stored datamatrix, as well as basic descriptive statistics. Table 4 presents a partial listing of the data matrix by rows and columns. The following list of commands, for example, is required to retrieve the stored matrix and execute three-dimensional plotting software:

```
a //FT08F001 DD DSN=USER.  ADS 19, DISP-SHR
b COSTS FOR TRANSPORTATION PER CLASS DIFFERENCES BETWEEN
c COST IN DOLLARS
d YES  NO
e NORTHEAST                 0.7
```

The computer-generated, three-dimensional plots of this digitized surface of spatially oriented transportation costs can be found in Figures 5 and 6. Figure 5 is the surface as viewed from the southeast direction and Figure 6 is the surface as viewed from the northeast direction.

Model comparisons and hypothesis testing of best fit surfaces can also be performed (Smith 1983). Table 5 lists the basic electives in SYMAP to generate a third-degree, best-fitted polynomial-trend surface. Table 6 summarizes the error measures and coefficients of the third-degree surface. Table 7 contains a listing of the actual predicted, residual transportation costs, as well as the location coordinates of each of the 79 destination points to Kentucky from Chicago, Illinois that was utilized to create the database. Figure 7 graphical portrays the error surface as a function of distance and magnitude of error derived from use of the third-degree surface. In addition, uses of the databases can generate other graphically-portrayed models in forecasting and report writing. The examples in the various Figures and Tables are but a few of the many survey and spatial analyses available to consumers of information.

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[a] This entry is JCL (job control language) showing where the tape/disk file is located, and will change somewhat depending on the computer installation.

[b] User entered title.

[c] User-entered legend.

[d] Statistics and time-series options.

[e] Direction of viewing and final plot-size factor for output.

CONCLUSION

As evident from the figures generated from applying only a few aspects of established databases for instructional purposes, a large range of computer graphics can be utilized for students and practitioners to conceptualize and visual complex interactions of survey-research data and transportation costs as a function of distance. Students/practitioners should be in better positions to grasp more components of a research problem to make more effective decisions and better communication of their analyses. With the increasing use and availability of appropriate software and hardware, computer modeling should be used in conjunction with statistical models to better portray and communicate the complex interactions found dealing with "real-world" problems. With the advent of increased computer technology and associated applications that graduate business personnel will rapidly find themselves confronted with, we as instructors in the various disciplines should take steps to help our students make that transition with a minimum of stress.

TABLE 1. Computer system checklist comparing resolution, accuracy, repeatability, color, and speed with types of input and output devices and software needed.

Characteristics	Input	Output	Display	Software	Tape	Disk	Printer	Overall
Resolution	X	X	X	X				X
Accuracy	X	X	X					X
Repeatability	X	X						
Color	X	X	X					
Speed	X	X	X	X	X	X	X	X

Source: Control Data Corporation, 8100 34th Ave., Minneapolis, Minnesota 55440.

TABLE 2. - Financial and physical considerations of selecting the proper computer graphics system for use in educational applications.

Financial and Physical Attributes/Factors	Overall Considerations/Concerns
Interface	Other systems, software, devices
Software	General graphics, applications, languages
Hardware functions	All devices (specific requirements)
Vector/Rastor/Both	Each device and overall system
Throughout	Overall system, units of work vs. units of time
Hard copy output	Your needs
Input	Range of data sources
Physical environment	Temperature, humidity, lighting, static, dirt, noise
Delivery time	Hardware, software (when must system be operational?)
Personnel constraints	How many operators? With what skills?
System and device Reliability	Maximum down time per week/month
Costs	Standard, custom services (software). Include taxes, delivery, installation, training, site preparation, maintenance, software
Financing	Rental; Purchase; Leasing
Vendor stability	Check Dunn & Bradstreet, Better Business Bureau Banks, references

Source: Control Data Corporation, 8100 34th Ave., Minneapolis, Minnesota 55440.

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CAPTIONS OF SELECTED TABLES

TABLES

QUICK SMOOTH

COSTS FOR TRANSPORTATION PER CLASS DIFFERENCES BETWEEN 100 AND 77.5 KENTUCKY

LEGEND SPECIFIED FOR THE PLOTTED SCALE IS : COST IN DOLLARS

SIZE FACTOR SET TO 0.7000

VERTICAL SCALE FACTOR SET TO 2.0000

SYMAP INPUT HAS BEEN SPECIFIED

THE UNIT NUMBER = 8 - THE DATA WILL BE READ FROM THERE

NOTE* ADDITIONAL JCL (IE. NEW DD CARD) IS REQUIRED FOR THIS UNIT NUMBER

THE NUMBER OF ROWS ON THE SYMAP FILE EXCEEDS 98 -
ONLY 98 WILL BE READ

THE NUMBER OF ROWS READ FROM THE SYMAP FILE WILL BE 89

HE NUMBER OF COLUMNS READ FROM THE SYMAP FILE WILL BE 98

SURFACE WILL BE VIEWED FROM THE SOUTHEAST

NUMBER OF ROWS IN DATA MATRIX 89

NUMBER OF COLUMNS IN DATA MATRIX 98

DATA EXTREMES ARE 2.85000 , 3.32171

MEAN = 2.92404

STANDARD ERROR OF THE MEAN = 0.00248

STANDARD DEVIATION = 0.14614

SKEWNESS = -175.37541

STANDARD ERROR FOR SKEWNESS = 0.04153

KURTOSIS = 2974.84180 3

COSTS FOR TRANSPORTATION PER CLASS DIFFERENCES BETWEEN 100 AND 77.5 KENTUCKY

ROW # INPUT MATRIX

	2.95	2.94	2.92	2.91	2.93	2.95	2.97	2.97							
66	-2.00 -2.00 2.00 2.06 2.05 3.00 3.00	-2.00 -2.00 2.00 2.00 2.05 3.06 2.99	-2.00 -2.00 2.00 2.00 2.05 3.00 2.90	-2.00 -2.00 2.00 2.06 2.00 3.00 2.97	-2.00 -2.00 2.00 2.00 2.00 3.00 2.90	-2.00 -2.00 2.00 2.00 2.07 3.07 2.99	-2.00 -2.00 2.00 2.00 2.90 3.07 3.00	-2.00 -2.00 2.00 2.06 2.90 3.06 3.00	-2.00 -2.00 2.00 2.00 2.92 3.00	-2.00 -2.00 2.00 2.05 2.94 3.05	-2.90 2.07 2.00 2.05 4.96 3.05	-2.00 2.07 2.00 2.05 2.99 3.04	-2.00 2.07 2.00 2.05 3.01 3.03	-2.90 2.00 2.00 2.05 3.03 3.02	-2.00 2.00 2.00 2.05 3.00 3.01
67	-2.00 -2.00 2.00 2.06 2.05 3.13 3.05	-2.00 -2.00 2.00 2.06 2.05 3.13 3.00	-2.00 -2.00 2.06 2.06 2.00 3.13 3.00	-2.00 -2.00 2.00 2.00 2.06 3.13 3.04	-2.00 -2.00 2.00 2.00 2.07 3.13 3.00	-2.00 -2.00 2.00 2.00 2.00 3.12 3.00	-2.00 -2.00 2.06 2.06 2.09 3.12 3.04	-2.00 -2.00 2.00 2.06 2.91 3.11 3.03	-2.00 -2.00 2.06 2.00 2.93 3.10	-2.00 -2.00 2.00 2.05 2.00 3.09	-2.00 2.07 2.00 2.05 2.09 3.09	2.09 2.07 2.30 2.05 3.02 3.00	2.00 2.07 2.06 2.05 3.05 3.07	2.00 2.00 2.00 2.05 3.00 3.00	-2.00 2.00 2.90 2.05 3.10 3.05
68	-2.00 2.09 2.06 2.07 2.05 3.10 3.10	-2.00 2.09 2.06 2.07 2.05 3.10 3.10	-2.00 -2.00 2.06 2.06 2.06 3.17 3.10	-2.00 -2.00 2.06 2.00 2.00 3.17 3.10	-2.00 -2.00 2.06 2.00 2.07 3.17 3.00	-2.00 -2.00 2.06 2.06 2.09 3.12 3.00	-2.00 -2.00 2.06 2.00 2.90 3.16 3.00	-2.00 -2.00 2.06 2.00 2.93 3.15 3.06	-2.00 -2.00 2.00 2.00 2.95 3.15	-2.00 -2.00 2.00 2.0C 2.90 3.14	2.09 2.07 2.00 2.05 3.01 3.13	2.09 2.07 2.07 2.05 3.05 3.12	2.00 2.00 2.07 2.05 3.00 3.12	2.00 2.0C 2.07 2.95 3.11 3.11	2.09 2.06 2.07 2.05 3.13 3.11
69	-2.00 2.09 2.06 2.07 2.05 3.10 3.16	-2.00 2.09 2.00 2.07 2.06 3.26 3.16	-2.00 2.09 2.00 2.07 2.06 3.21 3.10	-2.00 2.09 2.06 2.07 2.07 3.22 3.10	-2.00 -2.00 2.06 2.07 1.00 3.21 3.14	-2.00 -2.00 2.00 2.00 2.99 3.21 3.13	-2.00 -2.00 2.06 2.00 2.91 3.20 3.11	-2.00 -2.00 2.00 2.06 2.94 3.20 3.09	-2.00 -2.00 2.07 2.06 2.97 3.10	2.00 -2.00 2.07 2.00 3.00 3.14	2.00 -2.00 2.07 2.05 3.00 3.17	2.09 2.07 2.07 2.05 3.07 3.17	2.09 2.04 7.07 2.05 3.11 3.16	2.09 2.06 2.07 2.05 3.14 3.16	2.09 2.06 2.07 2.05 3.17 3.16
70	-2.00 2.09 2.06 2.67 2.08 3.22 3.21	-2.00 2.00 2.00 2.07 2.06 3.23 3.21	-2.00 2.09 2.06 2.07 2.06 3.20 3.22	-2.00 2.09 2.00 2.07 2.07 3.25 3.22	-2.00 2.09 2.06 2.07 2.09 3.24 3.22	-2.00 2.09 2.00 2.07 2.00 3.24 3.17	-2.00 -2.00 2.27 2.07 2.92 3.23 3.14	-2.00 -2.09 2.07 2.06 2.75 3.22 3.12	2.09 -2.00 2.07 2.00 2.90 3.22	2.09 -2.00 2.07 2.00 3.01 3.21	2.00 2.07 2.07 2.00 3.05 3.20	[illegible] [illegible] 2.07 2.06 3.09 3.20	2.00 2.07 2.07 2.05 3.13 3.14	2.00 2.00 2.07 2.05 3.12 3.20	2.00 2.00 2.07 2.05 3.19 3.20
71	-2.00 0.09 2.00 2.07 2.05 3.20 3.20	-2.00 2.00 2.06 2.07 2.00 3.25 3.27	-2.00 2.09 2.06 2.07 2.07 3.26 3.20	-2.00 2.09 2.04 2.07 2.07 3.20 3.29	-2.00 2.00 2.07 2.07 2.00 3.27 3.25	-2.00 2.09 2.07 2.07 2.91 3.20 3.21	-2.00 2.09 2.07 2.07 2.03 3.26 3.17	2.09 2.09 2.07 2.07 2.00 3.25 3.14	2.00 -2.00 2.07 2.06 2.99 3.24	2.09 2.06 2.07 2.06 3.03 3.20	2.09 2.07 2.07 2.00 3.07 3.23	2.09 2.07 2.07 2.06 3.11 3.23	2.00 2.07 2.07 2.06 3.15 3.23	2.09 2.00 2.07 2.05 3.10 3.24	2.09 2.00 2.07 2.05 3.21 3.25
72	-2.00 2.09 2.06 2.00 2.00 3.25 3.27	-2.00 2.09 2.06 2.00 2.00 3.27 3.20	-2.00 2.00 2.07 2.00 2.07 3.20 3.29	-2.00 2.09 2.07 2.00 2.67 3.20 3.20	-2.00 2.00 2.07 2.07 2.00 3.20 3.20	-2.00 2.09 2.07 2.07 2.91 3.20 3.22	2.09 2.09 2.07 2.07 2.93 3.27 3.10	2.09 2.09 2.07 2.07 2.94 3.27 3.14	2.09 2.05 2.07 2.07 3.00 3.20	2.00 2.05 2.07 2.07 3.03 3.25	2.09 2.07 2.00 2.00 3.07 3.25	2.00 2.07 2.00 2.06 3.11 3.25	7.09 2.07 7.00 2.00 3.16 3.75	2.09 2.07 2.00 2.2C 3.19 3.25	2.09 2.06 2.00 2.00 3.22 3.26
73	-2.00 2.09 2.07 2.00 2.00 3.27 3.29	-2.00 2.00 2.07 2.00 2.06 3.20 3.30	-2.00 2.09 2.97 2.00 2.07 3.29 3.30	-2.09 2.00 2.07 2.00 2.07 3.20 3.30	-2.00 2.00 2.07 2.00 2.00 3.30 3.26	-2.00 2.00 2.07 2.00 2.91 3.29 3.22	2.09 2.09 2.07 2.00 2.93 3.29 3.10	2.09 2.00 2.00 2.07 2.96 3.20 3.13	2.09 2.00 2.00 2.07 3.00 3.20	2.00 2.00 2.00 2.97 3.03 3.27	2.00 2.00 2.00 2.07 3.06 3.27	2.90 2.07 2.09 2.06 3.12 3.27	2.C0 2.07 2.00 2.06 3.10 3.27	2.09 2.07 2.0C 2.00 3.20 3.27	2.09 2.07 2.00 2.00 3.23 3.20
74	-2.00 2.09 2.07 2.00 2.06 3.26 3.29	-2.00 2.09 2.07 2.00 2.00 3.20 3.29	-2.00 2.09 2.07 2.00 2.07 3.29 3.20	-2.00 2.00 2.07 2.00 2.07 3.30 3.20	-2.00 2.00 2.07 2.00 2.00 3.30 3.24	-2.00 2.09 2.00 2.00 2.90 3.30 3.20	-2.00 2.09 2.00 2.00 2.92 3.29 3.16	2.00 2.00 2.00 2.00 2.95 3.29 3.13	2.09 2.00 2.00 2.00 2.99 3.29	2.09 2.00 2.00 2.07 3.02 3.20	2.09 2.00 2.00 2.07 3.07 3.20	2.09 2.00 2.00 2.07 3.12 3.20	2.09 2.07 2.90 2.06 3.10 3.27	2.00 2.07 2.00 2.00 3.20 3.20	2.00 2.07 2.00 2.00 2.23 3.20
75	-2.00 2.09 2.07 2.09 2.06 3.26 3.20	-2.00 2.09 2.07 2.09 2.06 3.20 3.27	-2.00 2.09 2.07 2.09 2.07 3.29 3.20	-2.00 2.09 2.00 2.09 2.07 3.30 3.20	-2.00 2.00 2.00 2.00 2.00 3.30 3.22	-2.00 2.09 2.00 2.00 2.09 3.30 3.10	-2.00 2.09 2.00 2.00 2.90 3.30 3.15	-2.00 2.00 2.00 2.00 2.94 3.30 3.11	2.09 2.00 2.00 2.00 2.90 3.29	2.00 2.00 2.0A 2.00 3.01 3.20	2.00 2.00 2.00 2.07 3.04 3.29	2.90 2.00 2.09 2.07 3.11 3.20	2.09 2.00 2.09 2.C7 3.10 3.20	2.09 2.07 2.09 2.06 3.10 3.20	2.00 2.07 2.09 2.06 3.23 3.20
76	-2.00 2.09 2.00 2.09 2.06 3.20 3.27	-2.00 2.00 2.00 2.09 2.07 3.27 3.05	-2.00 2.09 2.00 2.09 2.07 3.20 2.24	-2.00 2.09 2.00 2.09 2.07 3.30 3.20	-2.00 2.09 2.00 2.09 2.07 3.30 3.19	-2.00 2.09 2.00 2.00 2.00 3.30 3.18	-2.00 2.09 2.00 2.09 2.09 3.30 3.11	-2.00 2.09 2.00 2.09 2.93 3.30 3.00	2.09 2.00 2.00 2.00 2.96 3.30	2.07 2.0A 2.09 2.00 3.00 3.30	2.09 2.00 2.09 2.00 3.05 3.29	2.09 2.00 2.09 2.07 3.11 3.29	2.09 2.00 2.09 2.07 3.16 3.20	2.00 2.00 2.00 2.07 3.10 3.20	2.00 2.00 2.09 2.07 3.22 3.20

F-MAP

DISTRIBUTION COTS FOR DIFFERENCES BETWEEN CLASSES 77.5 AND 100
STATE OF KENTUCKY

ALAN D. SMITH EASTERN KENTUCKY UNIVERSITY
ELECTIVE

```
 1 MAP DIMENSIONS ARE    9.00 INCHES LONG BY    0.00 INCHES WIDE
 8 SUPPRESSION OF CONTOUR LINES OR BOUNDARIES
15 NUMBER OF CHARACTERS PER INCH IS 10.0 DOWN AND 10.0 ACROSS
21 SYMVU TAPE CREATED AND PRINTED
24 SUPPRESSION OF NUMERIC INFORMATION
38 TREND SURFACE ANALYSIS. ORDER        3.00
```

0.000000 MINUTES FOR INPUT 5

COEFFICIENTS OF THE TREND SURFACE (ORDER 3), SYMAP AXIS SYSTEM

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THE VALUE OF THE FUNCTION AT COORDINATES X AND Y IS

Z = + 0.53764160172D+01          - 0.40624614518D+00 X      - 0.58931266603D+00 Y
    + 0.40084452568D-01 Y2       - 0.20337755771D-03 X3     - 0.16742968670D-02 X2Y
    + 0.19743721504D-01 X2       + 0.58751160760D-01 XY
    - 0.12683058020D-02 XY2      - 0.68289588992D-03 Y3
```

ERROR MEASURES

STANDARD DEVIATION	0.11
VARIATION EXPLAINED BY SURFACE	0.27707443E+01
VARIATION NOT EXPLAINED BY SURFACE	0.91382563E+00
TOTAL VARIATION	0.36845703E+01
COEFFICIENT OF DETERMINATION	0.75198573
COEFFICIENT OF CORRELATION	0.86717111

6

NATES. SURFACE VALUES (3. ORDER) AND RESIDUALS

E N T I O N : COORDINATES GIVEN IN SYMAP AXIS SYSTEM (ORIGIN IN NW CORNER

X-COORD	Y-COORD	Z-VALUE	VALUE	RESIDUAL
13.200	0.800	2.860	2.917	-0.057
13.200	1.500	2.860	2.878	-0.018
11.700	2.300	2.860	2.824	0.036
12.600	2.500	2.860	2.838	0.022
13.400	2.400	2.860	2.866	-0.006
14.000	2.100	2.860	2.893	-0.033
15.400	2.200	2.860	2.972	-0.112
11.800	3.000	2.860	2.818	0.042
14.100	3.000	2.890	2.903	-0.013
16.800	2.200	3.220	3.079	0.141
17.600	1.700	3.250	3.156	0.094
10.100	3.700	2.860	2.800	0.060
11.700	3.500	2.860	2.821	0.039
12.600	3.600	2.890	2.852	0.038
13.400	3.500	2.890	2.883	0.007
14.200	3.500	2.890	2.923	-0.033
13.600	4.100	2.890	2.919	-0.029
14.500	4.300	2.890	2.979	-0.089
15.100	4.000	2.890	2.999	-0.109
16.400	3.600	2.890	3.071	-0.181
17.700	2.900	3.220	3.161	0.059
18.400	2.500	3.220	3.225	-0.005
18.600	3.500	3.220	3.250	-0.030
10.400	4.500	2.860	2.823	0.037
11.500	4.700	2.860	2.864	-0.004
14.200	5.200	3.150	3.026	0.124
15.200	5.200	2.890	3.083	-0.193
17.000	4.400	3.250	3.150	0.100
17.500	5.000	3.250	3.216	0.034
18.400	5.000	3.250	3.277	-0.027
19.600	5.100	3.220	3.360	-0.140
5.200	5.200	2.860	2.868	-0.008
4.200	5.500	2.860	2.895	-0.035
6.500	5.300	2.850	2.833	0.017
8.200	5.300	2.850	2.826	0.024
9.800	5.500	2.890	2.864	0.026
11.700	5.800	2.860	2.956	-0.096
13.000	5.500	3.150	2.988	0.162
13.600	5.600	3.150	3.028	0.122
14.400	5.700	3.150	3.080	0.070
16.300	6.200	3.150	3.229	-0.079
16.700	5.600	3.250	3.203	0.047
17.300	6.400	3.350	3.295	0.055
19.100	5.800	3.350	3.351	-0.001
3.900	6.800	2.860	2.868	-0.008
5.500	6.800	2.860	2.867	-0.007
7.100	6.400	2.850	2.866	-0.016
8.200	6.400	2.890	2.889	0.001
8.700	6.200	2.890	2.886	0.004
9.800	6.900	2.890	2.989	-0.099
11.600	6.700	2.890	3.045	-0.155
1.200	8.200	2.890	2.859	0.031
2.400	7.600	2.890	2.872	0.018
2.400	8.800	2.890	2.885	0.005
3.300	9.200	2.890	2.944	-0.054
4.300	8.600	2.890	2.944	-0.054
3.400	7.500	2.860	2.873	-0.013
5.600	8.400	2.890	2.980	-0.090
7.200	8.400	2.890	3.052	-0.162
6.300	7.300	2.850	2.909	-0.059
7.900	8.800	3.300	3.141	0.159
8.300	7.900	3.300	3.042	0.258
9.100	8.600	3.300	3.175	0.125
9.800	7.800	3.300	3.099	0.201
10.500	8.700	2.890	3.262	-0.372
11.700	7.400	2.890	3.136	-0.246
12.300	7.500	3.220	3.177	0.043
12.200	8.600	3.720	3.328	0.392
13.500	7.300	3.220	3.208	0.012
15.000	7.100	3.250	3.254	-0.004
16.000	7.000	3.350	3.288	0.062
17.000	6.900	3.350	3.321	0.029
18.800	6.700	3.500	3.377	0.123
15.100	7.800	3.250	3.339	-0.089
14.800	8.400	3.350	3.402	-0.052
16.100	8.200	3.350	3.416	-0.066

FIGURE CAPTIONS

FIGURE

1. Distribution of questionnaire respondents according to product satisfaction and performance.

2. Line graph of sales, in millions of dollars, as a function of time of sales.

3. Bar plot of expenses by department in an unnamed company.

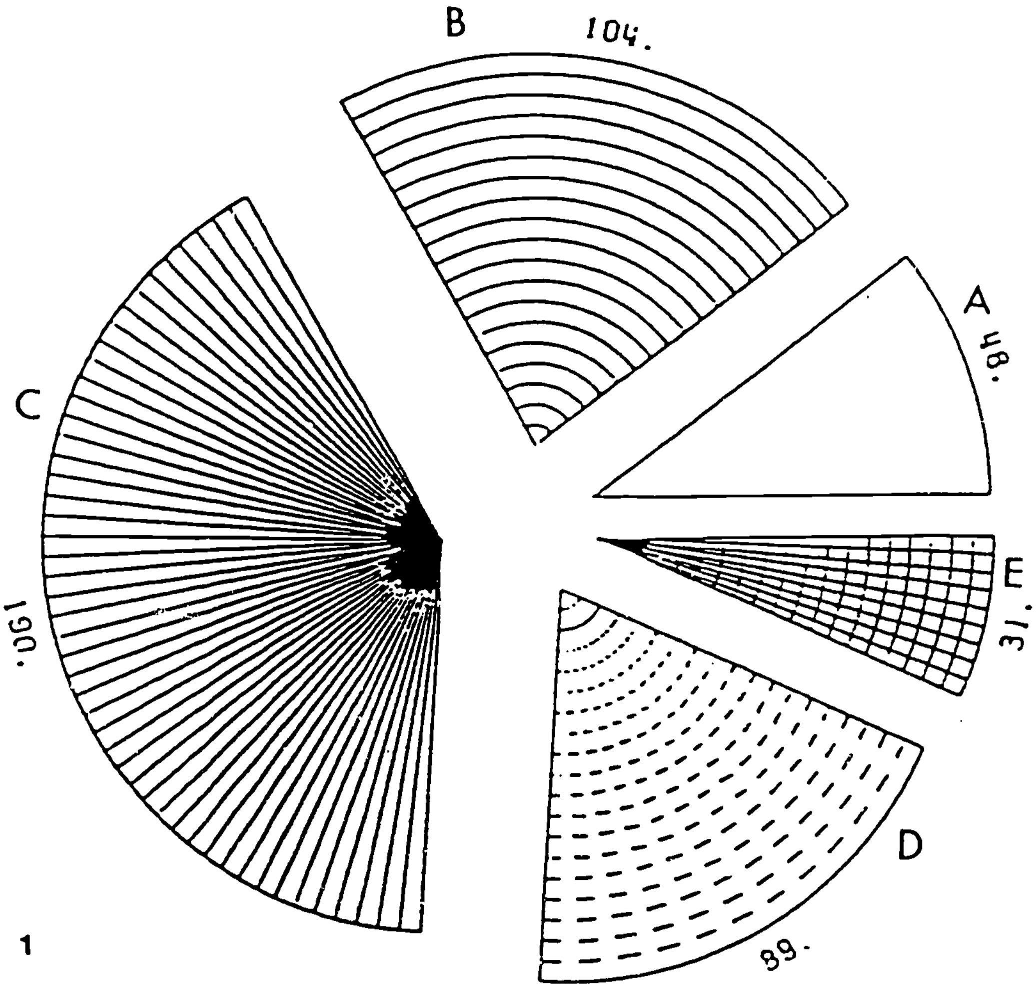
4. Line-printer map of transportation costs as generated from SYMAP and eventually di digitized.

5. Three-dimensional surface displaying transportation costs to Kentucky from Chicago, Illinois as viewed from the southeast direction, 30° degrees from the datum plane.

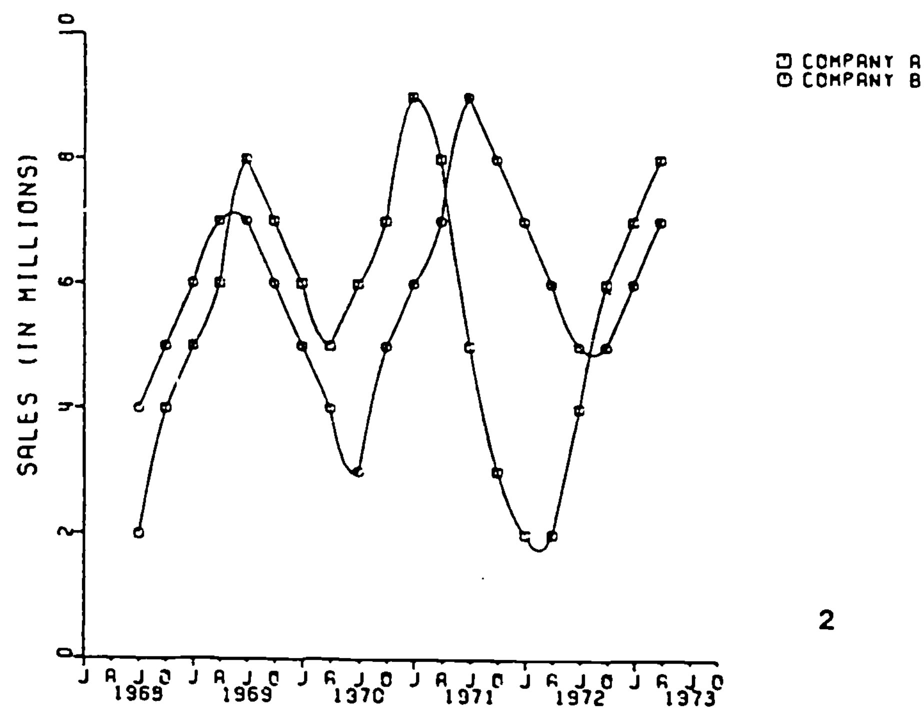
6. Three-dimensional surface displaying transportation costs to Kentucky from Chicago, Illinois as viewed from the northeast direction, 30° degrees from the datum plane.

7. Error surface (actual minus predicted transportation costs) as a function of distance and magnitude associated with the third-order, polynomial, best-fitted trend equation.

A denotes no satisfaction
B denotes little satisfaction
C denotes moderate satisfaction
D denotes much satisfaction
E denotes factor does not apply



QUARTERLY SALES



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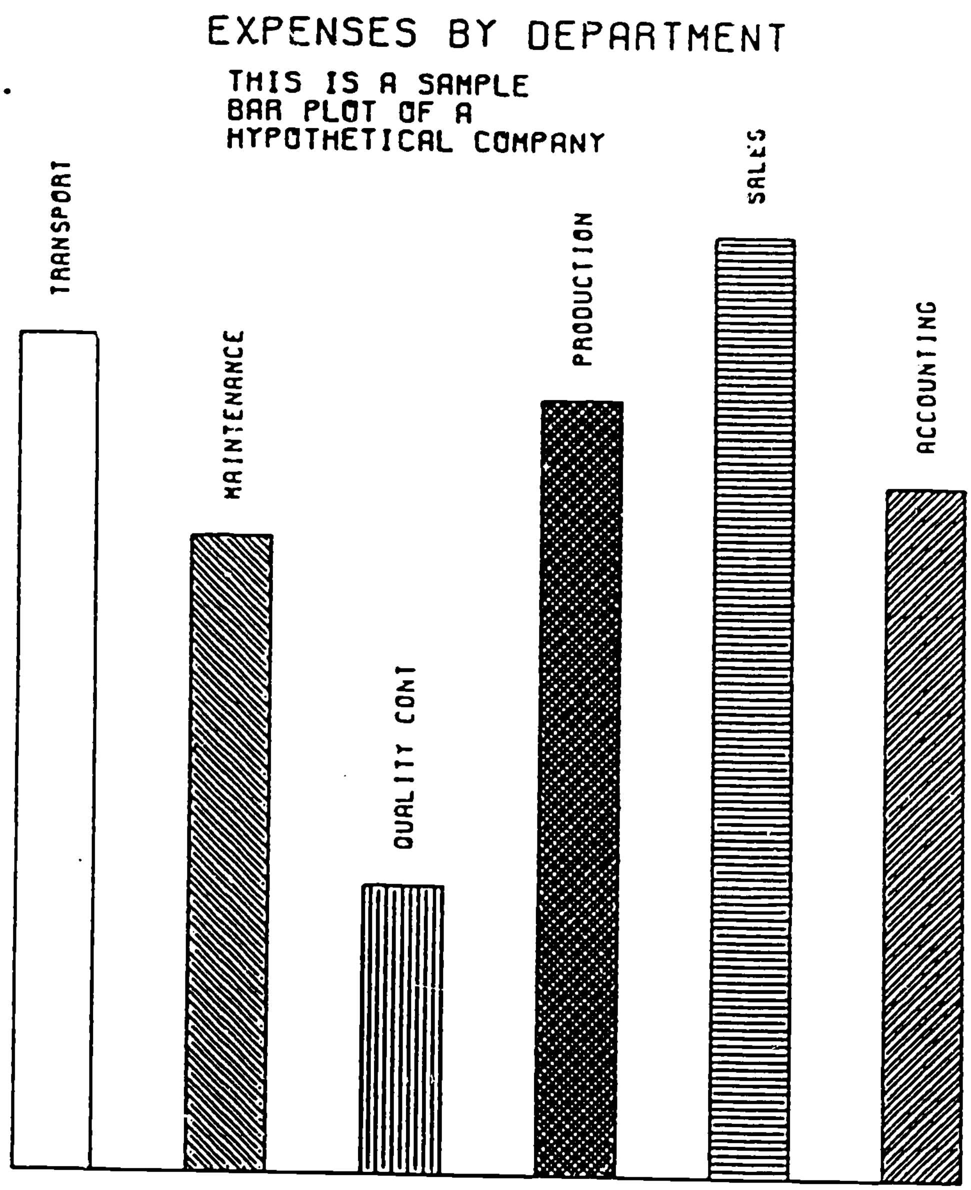
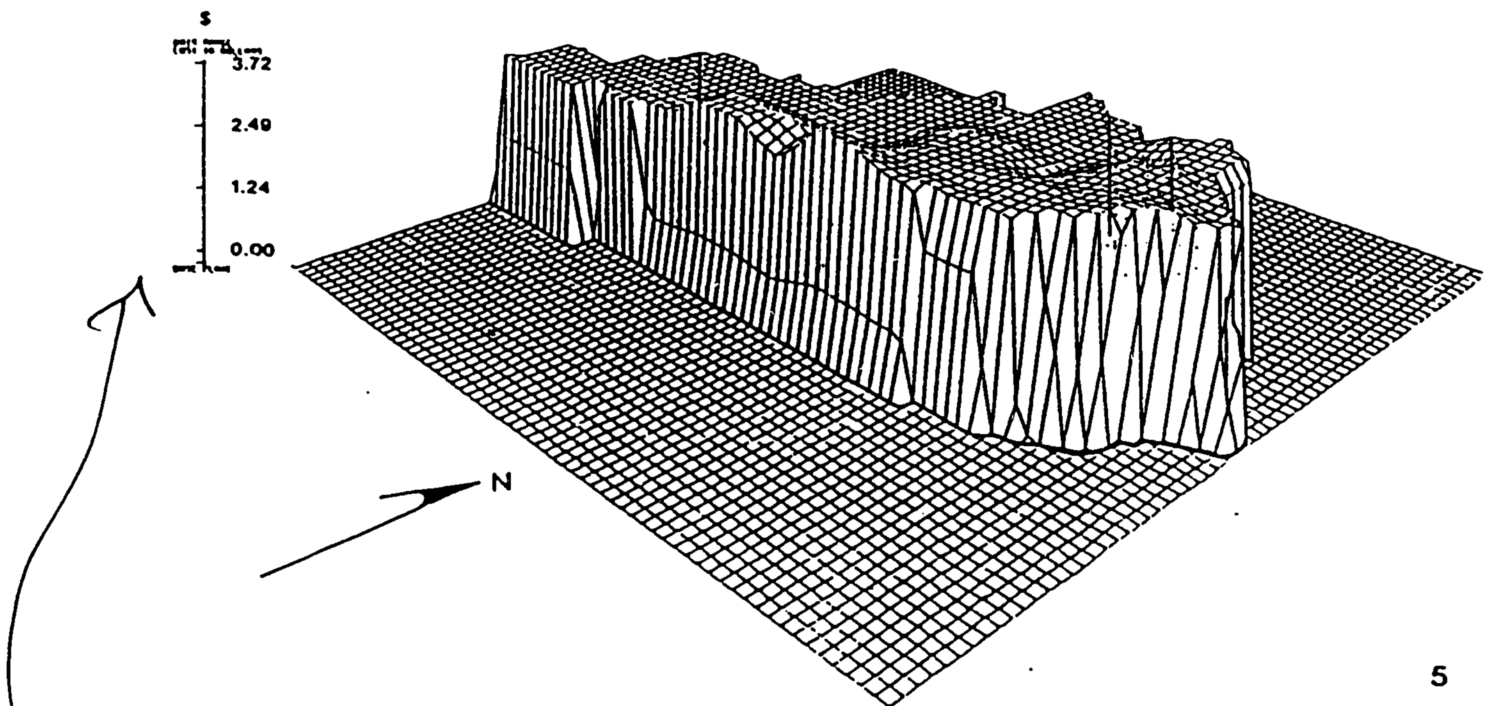
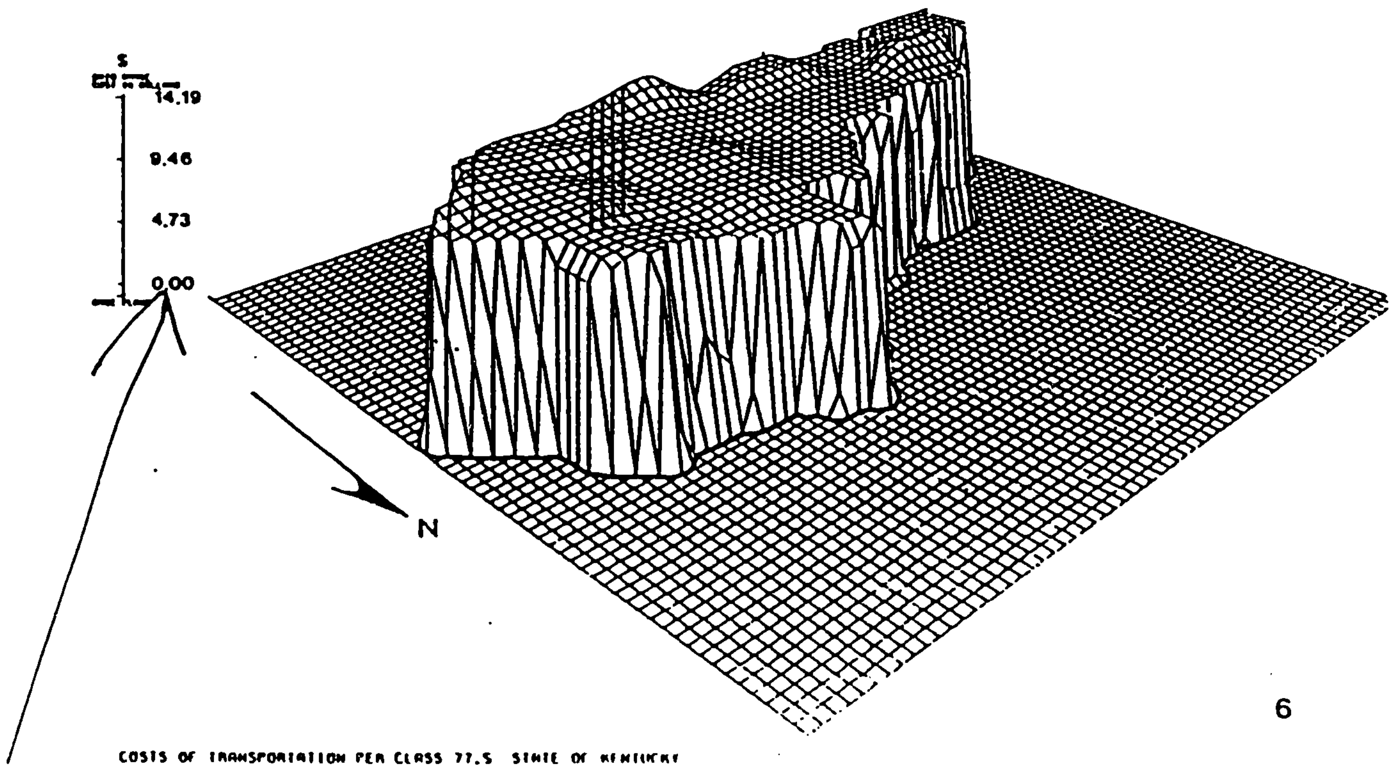

EXPENSES BY DEPARTMENT
THIS IS A SAMPLE
BAR PLOT OF A
HYPOTHETICAL COMPANY
TRANSPORT
MAINTENANCE
QUALITY CONT
PRODUCTION
SALES
ACCOUNTING

3



COSTS FOR TRANSPORTATION PER CLASS DIFFERENCES BETWEEN 100 AND 77.5 KENTUCKY



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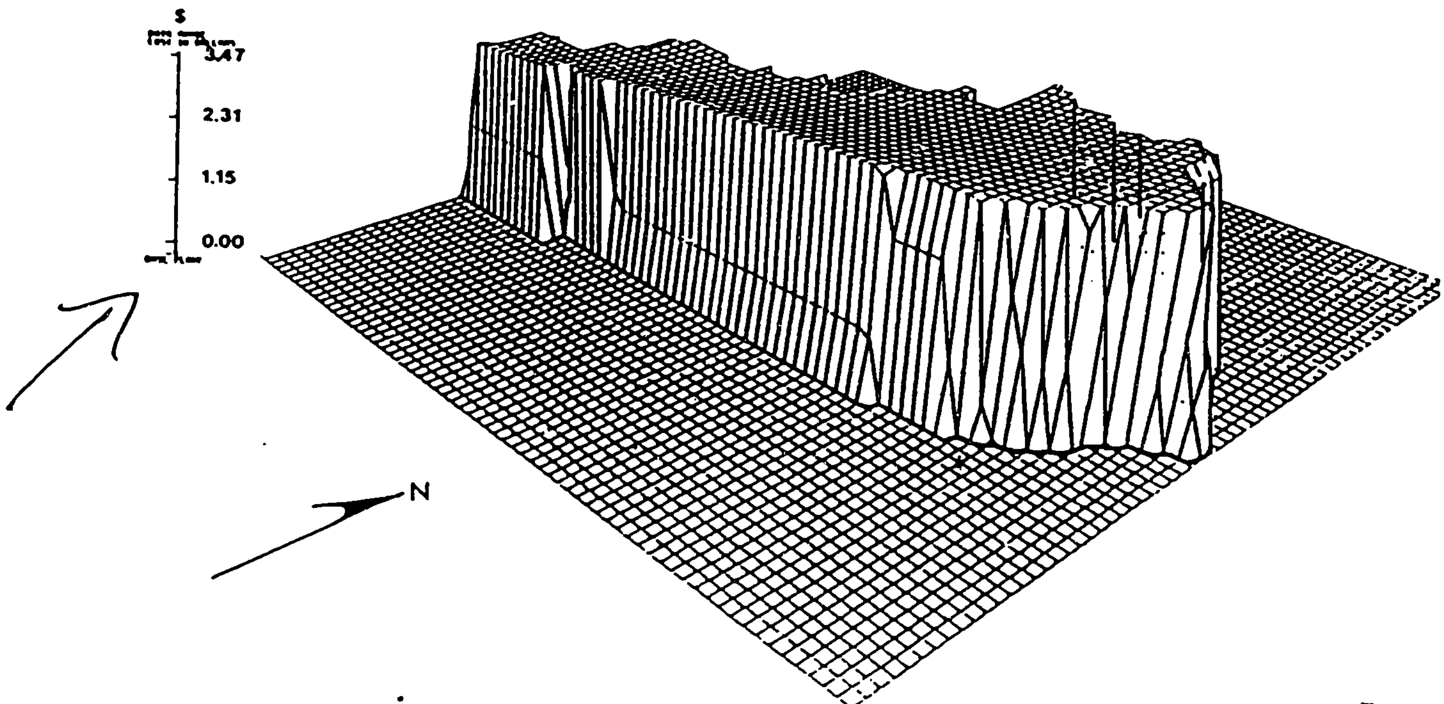
COSTS OF TRANSPORTATION PER CLASS 77.5 STATE OF KENTUCKY



COSTS OF TRANSPORTATION BETWEEN CLASSES FOR KENTUCKY THIRD DEGREE TREND 7