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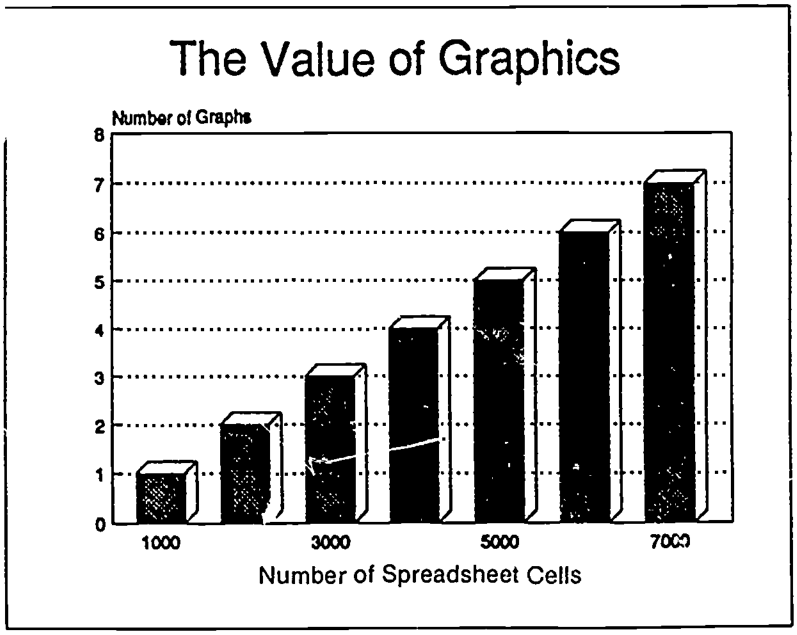
ABSTRACT

This guide to the discovery, analysis, production, communication, and use of statistical information through graphic forms produced by a computer is designed to enable researchers to conduct their analyses and report research results more effectively. It is designed both for individuals with little knowledge about the use of statistical graphs or with using a computer to create graphs, and for those who have reached a plateau in using such graphics. Topics covered in the first three major sections include: (1) Getting Started with Graphics (an approach for individuals, an overview, the anatomy of a graph, and characteristics of graphic quality and effectiveness); (2) Choice, Design, and Production of Statistical Graphics (process of graphic design and production and standards, principles, and guidelines for graphic design); and (3) Implementation and Use of Statistical Graphics (a strategy for extending the use of graphics in the office, and approaches for hardware and software selection). The fourth major section provides annotated bibliographies of books and periodicals ranging from the introductory and general levels through technical and system-specific publications, and briefly describes five graphics organizations, associations, and conferences. Nineteen references are listed. (RP)

The Design, Production and Use of Computer Graphics:

A Tutorial and Resource Guide



Association for Institutional Research

AIR
for Management Research, Policy Analysis, and Planning

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University of Michigan
Spring 1987

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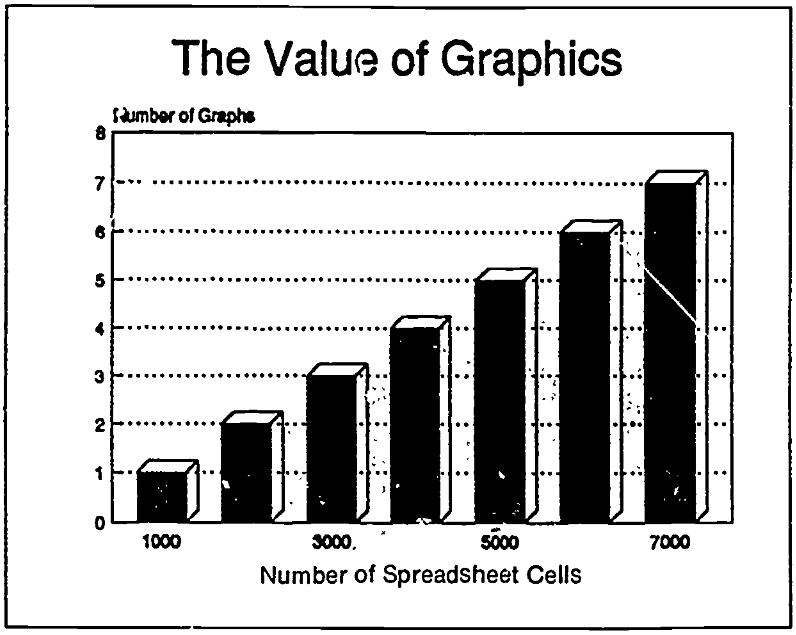

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PREFACE

This monograph is about the discovery, analysis, production, communication and use of statistical information through graphic forms produced by a computer. The basic premise is that extending knowledge and skills about statistical graphics through this tutorial and resource guide will enable us to conduct our analyses and report research results more effectively.

Expanding graphic awareness, and increasing knowledge and use are worthy objectives of professional development for individuals, and for our field. Use of statistical graphs has not penetrated far into professional practice, in part, because previously graphic construction was time consuming if done by oneself and costly if done by graphic artists. Also, the use of graphics has been degraded by some believing that statistical analyses and tables of numbers are better because they are "serious" while graphs are inferior because they are "superficial" or "simplistic."

Literacy, numeracy, and articulacy are recognized as basic intellectual skills. Recently a fourth primary area has been asserted: **graphicacy**-the ability to analyze and communicate visually or graphically (Balchin and Coleman). These four basic skills are not substitutes for each other, but rather are complimentary areas. One skill is not inherently superior nor inferior to another. They are only more or less effective for particular purposes, conditions, and personal styles (Schmid, p. 11).

Why Should We Make Greater Use of Statistical Graphics?

Displayed below are four data sets (Anscombe, p. 17-21). Analysis by traditional statistical techniques reveals that each set has the same linear model, that is, each set has the same mean, regression line, correlation coefficient, and so forth.

Set I x	Set I y	Set II x	Set II y	Set III x	Set III y	Set IV x	Set IV y
10.1	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

Set Statistics: N=11; Mean of X's = 9.0; Mean of Y's = 7.5; Equation of regression line Y=3+0.5X; Correlation coefficient = .82.

Most exploration and analysis would start and stop with these kinds of analytic techniques and measures but is this adequate and most effective? When these data sets are shown through graphics (see Figure 1, page iv), quite different structures and shapes emerge. From this example the power and potential of graphics should be self-evident.

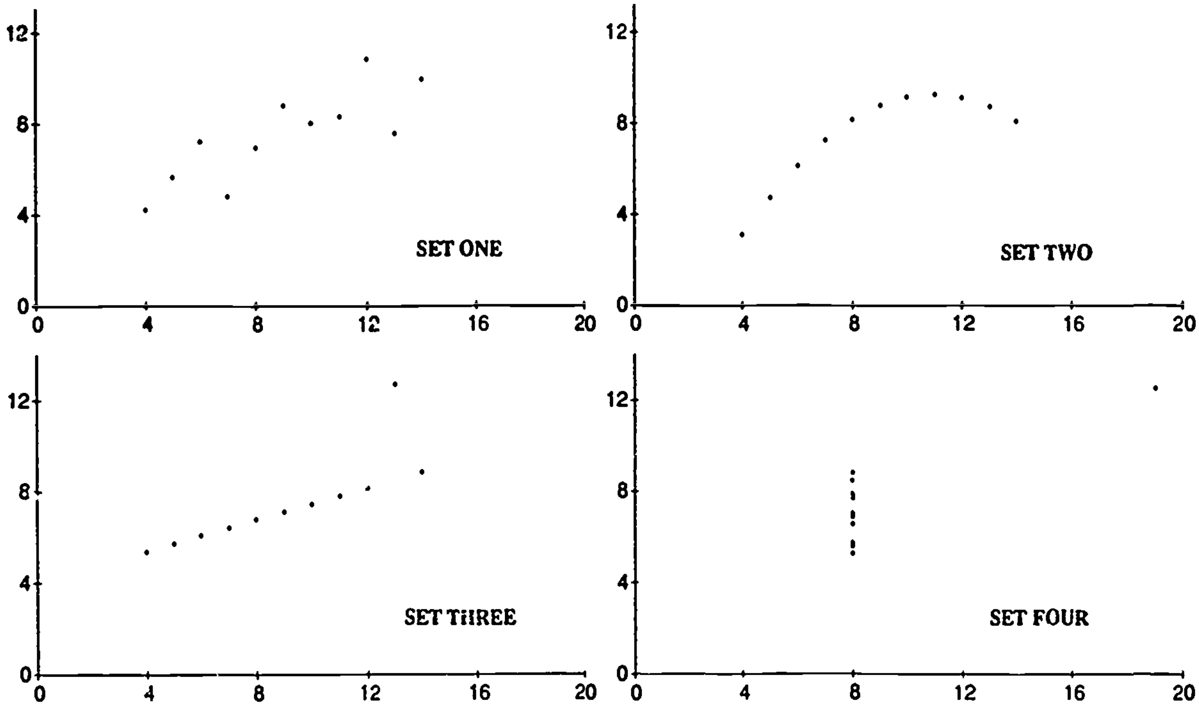


Figure 1-What a Difference a Graph Makes

Note: Produced with Chart software and printed on an Apple LaserWriter.

To be designed well and used effectively, graphics draw upon knowledge in a variety of disciplines: from statistics regarding the handling of data; from various sciences regarding the physical aspects of visual perception; from the arts in matters of graphic design; from technical areas regarding production; from many fields for methods of interpretation and analysis; and from the social sciences and management about effective communication and use. Crosscutting areas like graphics seldom fare well in discipline based education and specialized work settings. We lack graphic knowledge.

Statistical graphics have much potential but their design and use present many challenges. On the one hand, recent research indicates that use of graphs can improve the effectiveness of analysis and the impact of reports and presentations significantly (ISSCO, 1982). However, research also shows that graphics are used infrequently in most professional areas and, even when employed, they often contain significant flaws in design and production (Sabban). Finally, new research indicates that even experienced people often err in extracting information and drawing conclusions from graphs (DeSanctis, Cleveland).

The arrival of the microcomputer and a growing array of software on the desktop of professionals now make the use of graphic forms possible for all of us by bringing the cost, the time, and the technical production of charts and graphs to a practical level. Also, the extension of computer networks make powerful mainframe graphic resources more readily available and attractive when used in conjunction with local capabilities.

Executives and researchers, swamped with lengthy and complex reports, tables, and print outs, are developing an appetite for alternative forms of acquiring and interpreting information. The conditions are right for a "great leap forward" in the use of graphics in our professional work.

Access to technology has stimulated a renewed interest in the use of graphs. However, mere access has not ensured the production of quality graphics nor secured their use with validity and integrity. Contrary to the rhetoric of many software vendors, it is not possible for untrained, inexperienced operators to produce quality graphs with regularity.

We do not usually persist in using bad grammar or incorrect techniques of analysis, but most of us are unaware of or content to live with gaps in our graphic education. This leads us to miss occasions to use graphics, to make foolish choices in graphic design, to produce inferior results, and to misuse graphics--even if equipped with state of the art technology.

This monograph is about the design, production, and use of statistical charts and graphs made with a computer. The aim is to assist in filling some of the void in our graphics education about standards of design and techniques of production, and to help in making better choices about and better use of the technology.

To the extent that this publication deals with computers, it focuses on microcomputers. This is not because they are clearly the best choice in the long run for computer graphics. Rather it reflects the fact that most of us in research already have access to microcomputers, and some have graphics software. Thus, it seems like the logical place to begin. But at most institutions, if graphics are to be linked to institutional data bases, if the use of graphics is to extend into the organization, and if graphic production for ongoing applications is to be optimized, then mainframe or minicomputer resources must be a part of an overall strategy.

To the extent that information is provided about specific manufacturers, the primary coverage is about IBM and Apple products, and compatibles. This focus is not out of the conviction that these are the best products for computer graphics and analysis; it should not be construed as a blanket recommendation. Those contemplating acquisitions should be aware of and investigate other very attractive and powerful tools for graphics and analysis such as those made by Hewlett-Packard and others.

Space limitations do not permit dealing with more vendors. These focal points were chosen because presently there is a larger installed base of hardware from these focal companies than any others and a greater range of graphics software to choose from for this equipment than for others.

This tutorial is of broad use and value, even with these foci, because it is not a "how-to-do-it" book for specific products. Central topics such as standards, guidelines, and effective use transcend technology.

Newcomers to the field and topic of graphics may want to use this as an instructional primer and read it from beginning to end. More experienced researchers and planners, and those more knowledgeable about graphics may want to approach it more selectively as a reference.

Note well that computer graphics is a field undergoing rapid expansion and change. Some citations and information will become dated in a few years; thus resources for keeping up to date have been outlined. However, the core sections on principles and guidelines will serve well as a basic reference for some time to come.

THE DESIGN, PRODUCTION, AND USE OF COMPUTER GRAPHICS:
A TUTORIAL AND RESOURCE GUIDE

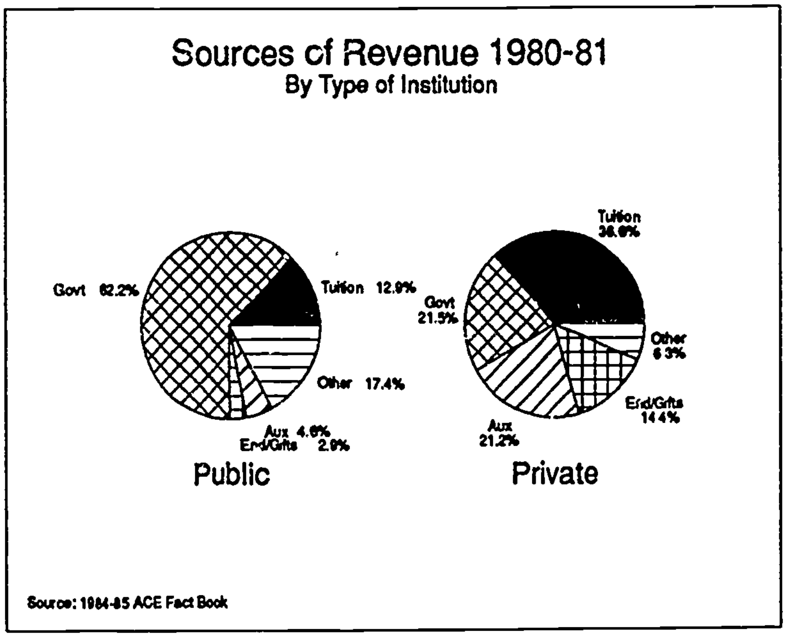
SECTION I: GETTING STARTED WITH GRAPHICS

A: Getting Started with Graphics--An Approach for Individuals

B: How to Think About Graphics--An Overview

C: The Anatomy of a Graph

D: Characteristics of Graphic Quality and Effectiveness



Produced with Harvard Presentation Graphics software and printed on an Apple LaserWriter printer.

A: GETTING STARTED WITH GRAPHICS--AN APPROACH FOR INDIVIDUALS

Those with little knowledge about the use of statistical graphs or with little experience using computers may feel uncertain about the ways to get started in computer graphics. Others who have made an initial foray into using graphics, perhaps through microcomputer spreadsheet software, may have reached a plateau of use and could benefit from suggestions about how to advance without breaking the office or personal budget.

Steps that an individual might take to get started and to advance are outlined below. Many actions can be taken at minimal expense and without prior agreement from others. This section is intended to stimulate ideas, and to provide suggestions from which to choose rather than to prescribe a sequence and content for the best way or only way to proceed.

1. **COMMITMENT: GOALS: PLANS**-Make a commitment to graphics; establish some personal objectives and an overall plan for the year.

   A. First: do something; try to do it well; try to do it better.

   B. Second: develop concrete objectives and a coherent plan for involvement in graphics that are related to your work setting.

2. **INFORMATION:EDUCATION:TRAINING**-Obtain initial information, education, and training on graphics and computing.

   A. Read and acquire selected publications for an overview.

   Information to be considered might cover: graphic design and production; theory and applications for use of graphics in statistical analysis; guides to selecting and operating computer hardware and software; information and reviews about specific products and many more topics.

   Much material is available free of charge at libraries, at computing centers, on computer bulletin boards, from retail stores or from vendors--including demonstration software. Many publications are also available on the newsstand, and from major chain bookstores and campus bookstores. However, as many have or will soon find out, impulse buying without prior critical review of magazines and books can lead to a significant cash outlay with little of lasting value to show for it. See Section IV for further information.

   B. Raise your awareness about uses of statistical graphics.

   1) Note and critique the use of statistical graphs in publications and presentations:

   --<u>at meetings</u> of deans, executive officers and boards of trustees, at budget and legislative hearings, at consultants presentations and news conferences, at meetings of professional associations and local community organizations and so forth.

Look for and critique the use of graphics:

--in your office analyses and reports, in other publications at your institution; in the Chronicle, New Directions, and other professional publications; in the Wall Street Journal, the Sunday New York Times, USA Today, Time, Business Week, and other common publications; and even on the nightly news.

--but observe with a very critical eye the quality, style, and applications which vary greatly in these and other publications. As a consumer, sharpen you vision and standards for what makes an effective graphic display of statistical information.

2) Look for opportunities for the use of graphics in your work.

--In analysis: How did you conduct your most recent research? Did you first run statistical analyses such as correlations, and draw conclusions about the structure of the data and the relationships among variables, then draft a table and write up results, and--only then, maybe, draw a graph to show the results?

--Could your analysis have been more efficient and effective if you had used graphical methods early in the analysis and not merely at the end?

--In presentations and publications; in areas of management: At meetings and about regular reports of your organization, ask: how might graphics have been used? Everywhere data are presented, ask: could graphics have been used as well or better?

C. Seek out or create beginning professional development and training opportunities for yourself.

1) Take a workshop or seminar conducted by your institution's computing center or microcomputer education center; get them to initiate a course if one is not available. Attend an AIR Forum workshop or professional development opportunity or one done by an external group.

2) Get on mailing lists; attend product briefings by vendors.

3) Attend computer and software expositions and fairs.

4) Seek out other resources such as local microcomputer user groups, and computer bulletin boards.

5) Join new professional organizations with a focus on graphics and attend their conferences and seminars (see Section IV, K).

6) Invite someone to the office for an in-service training presentation and tutorial or try some beginning instruction yourself to find out what you do and do not know and what you need to know!

3. ACCESS TO GRAPHICS TECHNOLOGY-Gain or increase ongoing access to hardware and software capabilities for the design and production of computer graphics.

A. Identify and explore existing institutional graphics resources in the academic and administrative computing centers, the audio-visual center, the publications department, and other departments.

B. Develop coalitions with other offices; look for opportunities for shared use of resources, particularly for more expensive, limited use equipment.

C. Develop a graphics prospectus and long term acquisition plan for the office, including cost-benefit analyses and implementation plans.

D. Conduct an educational briefing and demonstration for the persons who will make decisions about expenditures for graphics and for those who are potential users.

E. Persuade the administrative and/or academic computing center to acquire graphics software and hardware.

F. Acquire for the office initial graphics production capabilities.

4. IMPLEMENTATION:EXPERIMENTATION:-Experiment broadly with the use of statistical graphics and seek critical feedback.

A. Test out the use of graphics in the early analytical stages of research, not merely after statistical analyses have been completed.

B. For existing reports and publications, try to use graphics as alternatives to tabular and written portions, not only as additions to the data overload problem; integrate graphics as new projects evolve.

C. Develop and use graphic displays for oral presentations.

D. Actively seek critical reactions to your graphics.

5. EXPANDED AWARENESS AND USE-Extend the awareness and use of computer graphics to others inside and outside your office.

A. Help implement an overall, ongoing strategy for acquisition, operation, and use within the office (See Section III).

B. Hold briefings or demonstrations inside or outside the office.

C. Initiate a graphics production service for your area.

D. Teach others to design and produce computer graphics; instruct others about principles and standards of design and use.

E. Share equipment and software (legally!) with others.

6. GROWTH AND DEVELOPMENT:KEEPING UP WITH THE FIELD-Recognize the emerging nature of the field of computer graphics and make provisions for ongoing professional development, and for acquiring additions to and upgrades of hardware and software.

A. Subscribe to or obtain free publications about new products, about graphic design and production tips, and about new applications; test out demonstration software.

B. Join and become active in graphics oriented organizations.

C. Seek additional training in graphics, computing, and graphical analysis; learn by teaching others.

D. Read the growing body of research regarding the effectiveness of: graphs versus other forms such as tables; different kinds of graphs for different purposes and levels of task complexity; the use of different aspects such as color; and the use of graphs for improving the speed and quality of decision making.

E. Make contributions to your professional organizations; conduct demonstrations; give tutorials and workshops on the use of graphics.

Again the steps outlined above are intended to stimulate other ideas and to provide guidance for getting started; the items taken together are not conceived as a recipe for "gourmet graphics".

MOVING ON...WHAT TO READ NEXT?

Part B of this section provides an overview and framework for thinking about graphics from a broad perspective; that is, how to conceptualize the use of statistical graphics in an organizational context and not merely as discrete artistic and analytic products.

Those in need of basic orientation and instruction about graphs, per se, are provided with an explication of the anatomy of a graph in Part C. Elements of statistical graphs are outlined, defined, and illustrated. Characteristics of high quality, effective graphics are discussed in Part D. These divisions provide a common language and framework for understanding the later sections on graphic design and production.

Section II outlines a process and considerations for selecting the right type of graph to use (Part E), and sets forth standards, guidelines, tips, and principles for graphic design (Part F).

These first two sections are meant to assist individuals in getting started with statistical graphics; in Section III, Part G provides a companion set of steps and suggestions for extending the use of statistical graphics through the development and implementation of an overall office strategy and plan. Part H is designed to aid in the selection of software and hardware.

Finally, in Section IV bibliographic and organizational resources are presented and discussed including: an annotated bibliography; graphics and computing publications; and graphics organizations and associations.

B: HOW TO THINK ABOUT GRAPHICS--AN OVERVIEW

A conceptual framework for thinking about graphics is presented below to provide guidance for understanding the design, production, and use of statistical graphics in an organizational context.

GRAPHIC FORMS AND AREAS OF APPLICATION

The world of graphics is broad and diverse, and undergoing rapid development and change. General areas of work making extensive use of graphics, specially computer graphics, include:

***Art and Design *Games and Entertainment *Training and Education *Research and Science *Business and Management**

One basic way of thinking graphics is to distinguish between graphic forms that are primarily pictorial in content from those that are statistical or numerical in nature. At the pictorial end of the spectrum there are uses such as animation and illustration. On the numerical side, there are familiar analytic uses such as the analysis and display of research or business data in a time series, a scatter plot, or other graphic form.

There are a number of interesting applications and useful computer graphics software programs in the pictorial area, e.g., "paint", "draw", and "desktop publishing" programs. However, given the primary work of researchers and planners, this tutorial will only deal with statistical graphics applications drawn from research, business, and management.

Statistical graphics should not be viewed as ends in themselves and can most profitably be weighed in an organizational context. Graphics can serve various roles in problem solving and de sion making including to assist in: 1) the identification and conceptualization of problems and issues; 2) information processing and analysis; and 3) the interpretation, decision making, and communication of information (Bertin).

Much of what is written in the popular and technical press is still narrowly depicted under a few headings: "business and analytic graphics" or "presentation graphics" -- but these terms are not used consistently. However, new applications and new terminology for statistical graphics are emerging, facilitated by expanding software and computing capabilities, and by a more sophisticated and comprehensive vision of the role of graphics in an organization. Functional uses of statistical graphics for research and management purposes have been further outlined (DeSanctis):

1. Scheduling and Project Management Graphics
2. Analytical Graphics
3. Reporting and Monitoring Graphics
4. Decision Support Graphics
5. Presentation Graphics

In leading business firms and other settings, support for these kinds of functional uses are being incorporated into "visual information systems" which are integrated with institutional data bases and more traditional management information systems. These applications and the expanded notion of information systems, herald a new level of penetration and integration of graphics into the organization.

A SYSTEMS VIEW OF GRAPHIC ANALYSIS AND COMMUNICATION

In learning about and producing graphs it is easy to focus too narrowly on graphs as ends in themselves, while ignoring the context and the factors that affect their design, production, and use. A broader view is to think of a graph as part of a system or process of analysis, communication, or management. System elements include (Schmid):

1. The Purpose and Use of the Graph.
2. The Graphic Language: Symbols and Rules.
3. The Graph or Graphic Series.
4. The Information in the Graph and the Data Behind It.
5. The Production Technology.
6. The Communication and Viewing Medium.
7. The Organizational Environment for Production and Use.
8. The People: Their Graphic Skills and Decision Styles.
9. The People: the Roles They Play.

Each one of these elements affects the production and use of graphics. From the point of view of the researcher, some of these aspects are within his or her control but many important ingredients can, at best, be only influenced but not controlled. What seems at first to be a straightforward design and production process turns out to be amazingly complex. If these diverse elements and complexity of relationships are ignored, then the probability of effective design and use is decreased.

THE PEOPLE: ROLES IN THE STATISTICAL GRAPHICS SYSTEM

Among the most significant elements in the process are the people and the roles that they play. If our point of view is the whole process from design through production to usage, then there are a number of different key roles can be identified. In many instances a single person will fill more than one role, and several persons may fill a role simultaneously. These roles and how they interact with each other and other elements of the system are shown on Figure 2 and discussed below.

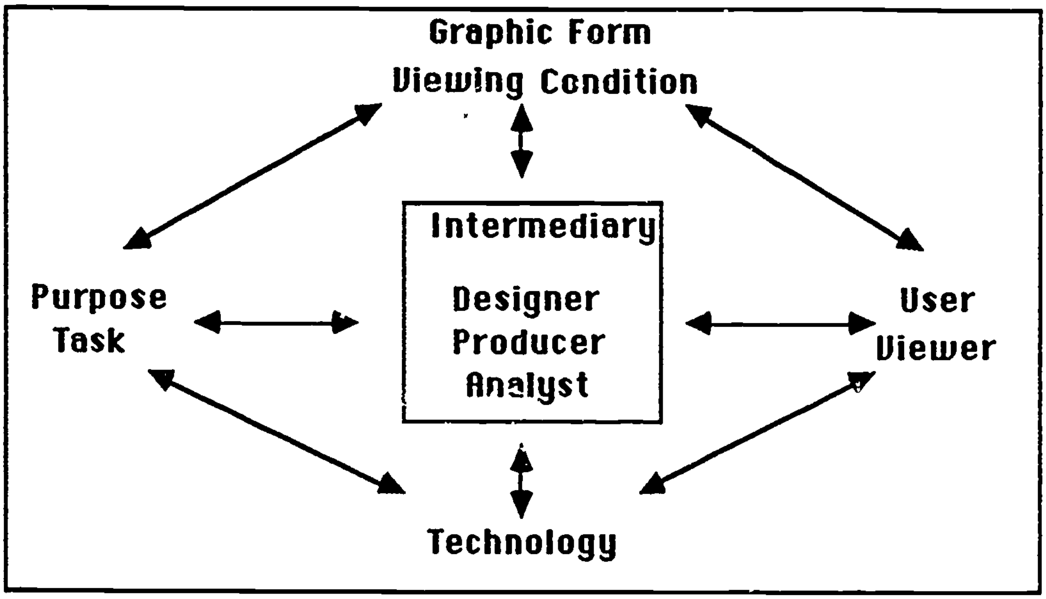


Figure 2-Roles and Relationships

NOTE: Produced with MacDraw software and printed on an Apple LaserWriter.

1. **The End Users: Researcher; Decision Maker; Manager; Audience**
   The end user may be actively involved by requesting and producing graphics or may be a more passive target of graphic communication initiated by someone else.

   Educating the user in selecting the most appropriate type of graphic for the purposes intended, and teaching users to extract information from graphs are important activities.

2. **The Intermediary**
   On many occasions persons play what might be called an intermediary role. This may be to transmit a request for a graphic from a user to an analyst or designer or to pass on completed work to the user.

   This role is a key one and a vulnerable point in the design process, particularly if, as it often seems, the intermediary knows little about the purpose of the graph and the data to be depicted, and little about graphic principles and standards. Educating intermediaries as well as end users is required if use of graphics is to be successful.

3. **The Analyst/Researcher/Information Specialist**
   The person who assembles the data to be graphed is obviously pivotal in the process. This tutorial is, by and large, written from the perspective of researchers and information specialists, and intended to facilitate their assuming expanded roles in the graphics arena.

4. **The Graphic Designer**
   Another role is that of translating the purpose to be served and the data itself into technical specifications for a graph. At least superficially, the end user may often be the initial designer, having ideas about and preferences for the type of graph to be produced as well as for points to be made and data to be graphed. This is the case particularly for management applications.

   However, graphic design in research and analysis is often very much more of an emergent process. With the researcher personally at the helm of the graphics software, the design of graphs in analysis is often experimental and interactive. When using graphs more for discovery and understanding, results of the first graphs suggest others to be produced in order to reveal data structures and relationships. Often this entails testing out different types of graphs as well as recalculating data, and including and excluding data in order to "see what there is to see". This mode of design is in sharp contrast with that where the point to be made by the graph is known in advance; both have their place.

5. **The Graph Maker/Computer Operator**
   The person who translates graphic design specifications into the actual product plays an important role, because there are still a number of important decisions made at this stage. With access to graphics software on a microcomputer, the researcher or manager now often assumes the roles of graphic designer and producer that were once performed by specialists. To put this capacity directly in the hands of the user can be efficient and effective if there is adequate knowledge about design.

6. **The Graphics Programmer**
   With the availability of preprogrammed mainframe subroutines that researchers can call into their analytic programs and with the advent of microcomputer graphics programs, the role of graphics programmers has changed and will continue to change.

   In the future the focus will probably shift to the programming necessary for operation of a distributed "visual information system" that will link graphics capabilities directly to unit and institutional data bases, and decision support systems, and to statistical analysis software; and to programming that supports a graphics system capable of functioning in a complex, networked environment of micros, minis, and mainframe computers.

7. **The Graphics System Designer and Manager**
   When initial concepts for a graphics or visual information system are translated into reality as a part of decision support systems, several other roles will likely emerge, namely those of designing and managing "the system" as distinct from the roles of designing and producing actual graphics.

IMPLICATIONS FOR PRACTITIONERS

The roles outlined above also reflect different stages of the process of analysis, communication, or decision making and come into play at different points in time. Phases of the processes of decision and analysis have been conceptualized as including (Sprague and Carlson):

1) INTELLIGENCE-definition or discovery of questions or problems.

2) DESIGN AND ANALYSIS-discovery of alternatives or structures; confirmation or refutation of questions.

3) REFLECTION AND CHOICE-presentation, interpretation, and decision.

4) IMPLEMENTATION-communication and implementation of decisions; management of plans and monitoring results.

Graphics can be employed effectively at each stage as will be illustrated in later sections.

As depicted in Figure 2, the roles interact with each other and with other elements of the system such as the purpose and uses of the graphic or the viewing conditions. With the increased penetration and use of computers and graphics in an organization, and with continued rapid changes in technology, the roles and relationships are likely to undergo further strain and change. As the technology puts more capability directly in the hands of end users, roles of others may be changed significantly, if not diminished. This environment presents both threats to and opportunities for researchers and other professionals.

This part has provided a framework for thinking about graphics in terms of roles, functions, and processes in an organization. From this global view, we turn next to a more detailed look at statistical graphs to provide common language and reference for considering standards and guidelines for the design and production.

C. THE ANATOMY OF A GRAPH

This section concerns understanding the elements and language of statistical graphs. There are a myriad of decisions to be made in the design, production, and use of statistical graphs. The section aims to provide a common language and framework in order to understand and to apply guidelines and standards such as those discussed in Section II, F.

Since the terminology of graphs is not fully developed and designations are not consistent across disciplines, areas of application, or across computer programs, it is important to give attention to learning the parts and the language of graphs in order to achieve best results. Most common terms and alternatives are defined below and illustrated in Figure 3.

Graph, chart, and diagram are all terms used to refer to graphic displays. They denote a group of related facts organized in the form of a figure, drawing, or table. In current usage, chart is the most generic term, referring to the pictorial display of words in an organized fashion (e.g., an organization chart), or to an organized, symbolic representation of data (e.g., a bar chart and a map), or to text and symbols that depict or explain an object, concept, or process (e.g., a flow chart and Figure 2). In common usage, a diagram is synonymous with the third meaning of chart, a figure that explains or illustrates something. A graph, generally given a more restricted meaning, is a statistical chart.

In this document the term, graph, will be used throughout--referring to a figure of numbers and other symbols representing logical numerical sequences or relationships that are displayed in accordance with mathematical rules.

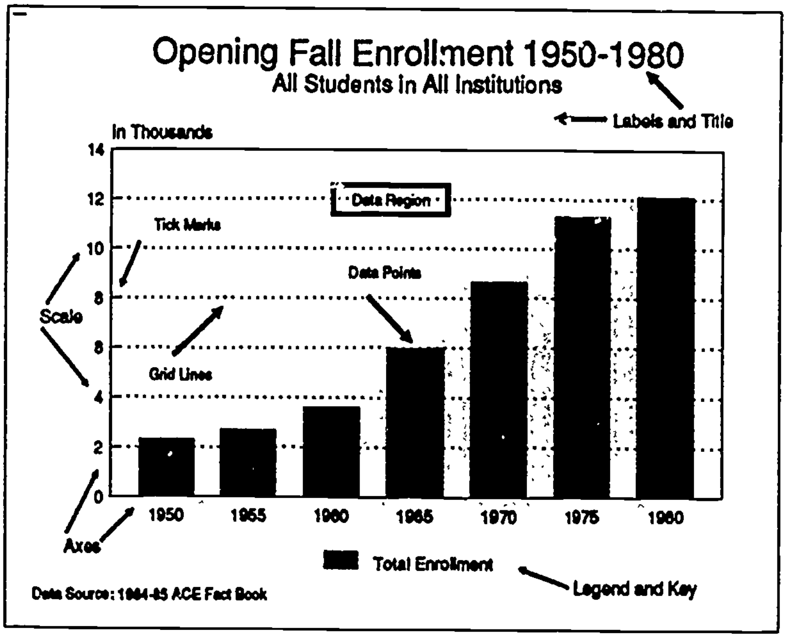


Figure 3-The Anatomy of a Graph

Note: Produced with Harvard Presentation Graphics and printed on an Apple LaserWriter printer.

ELEMENTS AND ASPECTS OF A GRAPH--A GLOSSARY

1. <u>**Axes: X and Y; Height, Width, and Depth**</u>

In a two-dimensional graphic system, axes are the horizontal (x) and vertical (y) "rulers" along which variables and values are depicted. Axes are also known as: horizontal and vertical scales, and category (X-axis) and value (Y-axis) scales. By convention categorical, time and independent variables are generally shown on the X-axis; while response variables and dependent variables are usually shown along the Y-axis. A third (z) axis is also used on occasion to show "depth" as well as "height" and "width."

2. <u>**Data Components**</u>

A. Data Region; Plot

The data region or plot is the area of the graph within which data points and data series are plotted. It is the rectangular area within the bounds of the axes or, in the case of pie charts and maps, the area within the circle and boundary, respectively.

B. Data Point; Data Series; Data Shape

Together a numerical value, depicted by a plotting symbol, and its axis designation (e.g., Fiscal Year) are a data point. A data series is a set of related data points. The "shape" of the data is shown in two or three dimensions of space.

C. Data Marker and Pattern

A marker is the symbol used to show the location of a data point or data series, and a pattern is the design used to distinguish parts and areas of a graph from each other (see Symbolic Components below).

D. Data Label

A data label is the text that names data points and series. The text may consist of numbers as well as words. Numbers, in a label, are not treated as values but as words (see Text Components below).

3. <u>**Symbolic Components**</u>

A. Tick Marks

Tick marks are short lines, perpendicular to the axes, that are used to indicate regular intervals of the scale and categories. Marks may be totally inside or outside the data region, or may cross the axes.

B. Grid or Reference Lines; Annotations

Grid or reference lines are lines perpendicular to one or both axes, generally extensions of tick marks, that extend across the data region. Annotations are symbols such as arrows, numbers, or text used to call attention to a particular point or area.

3. C. Marker, Pattern, Tone, and Color

A marker is a symbol used to show the location of a data point or a set of symbols used to depict a data series. A pattern is the design used to distinguish parts of a graph. Patterns include lines, bars, or areas of different size, thickness, or style such as crosshatching. Colors and tones of different intensities and hues are also used to differentiate data and other elements.

D. Frame or Box

The frame or box is the linear border around the data region (the axis frame), and the legend, title, and labels; and the border around an individual graph or of a series of graphs. The axis frame may include lines on two or four sides. Frames around other elements are optional.

4. <u>Text Components</u>

A. Title and Footnotes

The title is the text label that specifies the name of a individual graph and/or the name of a series of graphs. Titles are most often shown above the data region. A footnote is text, usually shown below the data region, that gives an explanation for an aspect of the graph or for the graph as a whole such as the source of the data. In some scientific and publishing areas, a title is called a legend and is placed below the graph; it may include explanatory information that might be in a footnote, and may also summarize points in the graph.

B. Legend and Key

A legend is an area of a graph that holds one or more sets of labels and symbols (keys) that together represent the names of variables or series. The legend, often enclosed in a box, may be placed outside the data region--to the side, or below or above the graph--or it may be within the data region. A key is a marker or other symbol such as a colored or patterned box or line that is identical to the marker of the variable to which it refers.

C. Labels for: Data; Axes; Tick Marks

A label is the text that refers to discrete graphic elements including data points and series, the respective axes, and tick marks. The text may consist of numbers as well as words; in a label, numbers are not treated as values but as words.

D. Font

A font is the style of print characters used for text such as titles.

5. <u>Scale</u>

Scale is used to refer both to values and names along the axes and to the measurement units or distances between points along the axes.

6. Other Elements

Depending upon the type of graphic and the production capabilities, other elements may be manipulated. These include:

A. Size and Shape of the Graph

The size of the graph is its overall external dimensions, including title, labels, legend, and footnotes and not just the dimensions of the data region. Two-dimensional graphs are most often rectangular in shape, by convention generally wider than high; but they may also be square, circular, or irregular in shape as in the case of maps.

B. Page and Graph Orientation

Two aspects of orientation come into play, that of the page itself and of the graph on the page. The page or output medium such as a slide may either be shown in "portrait" mode (the top of the page along its short dimension) or in "landscape" mode (the top of the page along its long dimension). Also, the graph itself can either be shown in portrait or landscape mode with either page orientation.

C. Projection and Perspective

Shape is rendered by projection techniques, the process of forming an image by rays of sight taken to a particular direction from an object to a plane. Projection methods vary depending upon the direction in which the line of sight is taken relative to the plane. A perspective projection shows an image as it would appear to the eye (French, et al, p. 82). Projection and perspective are usually of greater concern for CAD applications and for maps than for statistical graphs.

D. Panel or Multiple; Series or Chartbook

A panel or multiple is a set of related graphs shown on one page. A graph series or chartbook is a group of related graphs, one to a page or pages of multiples, that are presented as a collection.

E. Movement; Dynamic or Interactive Graphs

Change or movement of variables may be depicted in a series of graphs on hard copy. On other output media, such as a a monitor or video tape, dynamic change can be represented by having one graph or a series of graphs "unfold" before the viewer. As an example, a dynamic graph, directly connected to an empirical model on a spreadsheet, could show visually the results of "What if..." changes.

Standards, principles, and guidelines for making choices about each element are discussed in Section II, F. As will be apparent, on many occasions these recommendations conflict; the designer is called upon to consider trade-offs. What may be less apparent to the naive computer graphics user, is the extent to which default and fixed decisions about these design elements have been made by the software designer. Designers must make active use of the options for manipulating graphic components in order to produce effective graphs.

D: CHARACTERISTICS OF GRAPHIC QUALITY AND EFFECTIVENESS: TWENTY STANDARDS

Over the years conventions, rules of thumb, standards, and principles have emerged regarding the design and use of graphic materials. Touchstones come from the art of practice as well as from the findings of science. In spite of that, professionals in diverse fields have achieved general agreement as to what constitutes excellence in statistical graphics.

Characteristics of effective graphics and standards of quality put forward by leading practitioners and theorists can be grouped within four broad areas (Tufte, Schmid, White, Cleveland):

Visual Clarity and Excellence

Accuracy, Integrity, and Understanding

Fit Between Purpose, Data, Conditions of Use, and Users

General Strategy for the Use of Statistical Graphics

General characteristics and standards are outlined and discussed under each area. This provides a framework for the discussion of more specific, detailed guidelines and principles presented in Part E.

VISUAL CLARITY AND EXCELLENCE

Visual clarity and excellence are central to the processes of graphic analysis and communication. At the most basic level, the viewer--whether a manager, researcher, or a general audience--must be able to see the information depicted in the graph. The process is enhanced if information can be discerned efficiently. Other things being equal, it is desirable for graphics to achieve aesthetic excellence and elegance as well.

Graphs of high quality and effectiveness should:

1. Attract and keep attention, but not detract from the data.

2. Make information readily accessible and easy to view.

3. Show the major points clearly and do not make the viewer guess about facts.

4. Convey information with clarity, conciseness, and coherence.

5. Eliminate unnecessary graphic elements and data, and reduce the empty space.

6. Stimulate the viewers to compare and contrast information.

Attention is affected both by content and graphic style. The viewer must be interested in the content and feel that the information can be readily discerned from the graph. This can be facilitated by clear titles, labels, and legends that provide necessary and desirable information; and by the reduction or elimination of distracting or unnecessary data and graphic elements such as numerous grid lines.

These standards of visual clarity and excellence are also more likely to be achieved if graphs:

7. Serve clear purposes and objectives.

8. Serve a limited set of objectives.

9. Serve important and meaningful objectives.

For graphic analysis to be effective, the purpose should be clear to the researcher, and for the intended communication to take place, the purpose should also be clear to the viewer. These standards are more likely to be achieved if limited set of purposes is set forth for each graph.

For example, it may be more effective to show data trends on one graph and the composition of those changes on another in order to ensure that both kinds of information gain attention. However, too many graphs serving unimportant purposes or providing little information will likely diminish the viewer's receptivity to the important ones. A graph may serve a single or limited purpose, but still be quite complex and contain much data.

ACCURACY, INTEGRITY, AND UNDERSTANDING

Perceiving data within a statistical graph is only the first requirement. For a graph to be successful, the analysis and communication must occur with a precision that facilitates the interpretation of significance and that promotes understanding.

Graphs of high quality and effectiveness should:

10. Depict data with accuracy, validity, and integrity; without distortion and manipulation.

11. Lead the viewer to focus on the content rather than the design, analytic methodology, or production technology.

In order to achieve accuracy and integrity, we must pay attention both to aspects of data measurement and to elements of perception. Accuracy implies that the visual depiction of the data must be consistent with the numerical representation (Tufte). Different graphic forms affect the accuracy of perceptions. For example, differences in magnitude can be estimated more accurately on bar charts than on pie charts. At a minimum we need to learn and to apply graphics standards that are analogous to those we apply in statistical analysis and in grammar and writing.

FIT BETWEEN DATA, PURPOSES, CONDITIONS OF USE, AND USERS

A statistical graph is a tool, the means to an end rather than an isolated object. Thus, to be effective graphs must be created with a larger context and other elements of the analysis and communication process in mind. The context in which they will ultimately be used is of particular importance; questions of "fit" and appropriateness come into play. Given the goals and constraints under which statistical graphics are produced and used, and given many data and design decisions to be made, often it is necessary to make trade-offs between competing standards and objectives.

Graphs of high quality and effectiveness should:

12. Be appropriate for the data used and points to be made.

13. Be appropriate for the knowledge and skills of the users.

14. Be appropriate for the medium and conditions of use.

15. Achieve elegance through simple and fitting solutions.

GENERAL STRATEGY FOR THE USE OF STATISTICAL GRAPHS

Much of what is set forth about standards for statistical graphs is oriented to the single graph, including very detailed recommendations about how to handle discrete elements such as labels, tick marks, grid lines and so forth. Specific principles pertaining to these matters are discussed in Part E.

Beyond the characteristics of good individual graphs, and beyond rules and tips about components, there is the need for guidelines that consider: the role of a graph as a whole; an individual graph in relation of other graphs and as a part of a graphic series; statistical graphics in relation to other means of analysis and communication employed; and the process of designing and producing statistical graphs. These concerns have been termed aspects of overall strategy for statistical graphs (Cleveland).

Graphs of high quality and effectiveness should:

16. Present data in a coherent structure and consistent style.

17. Be well integrated with other graphs and with information presented in other forms.

Graphics are more likely to be effective when:

18. Developed initially in an iterative, experimental manner.

19. Used with regularity for important, ongoing functions.

Within a single report or presentation, comprehension and communication are facilitated if the same style and conventions are used for titles, legends, labels, scales and the like from graph to graph. Often it is effective to use graphs in regular, important reports that typically contain much tabular data (e.g., monthly finance or admissions reports). For such uses, the same graph style and type of content should be used over time so that the regular viewer can focus on the information, rather than on learning new formats.

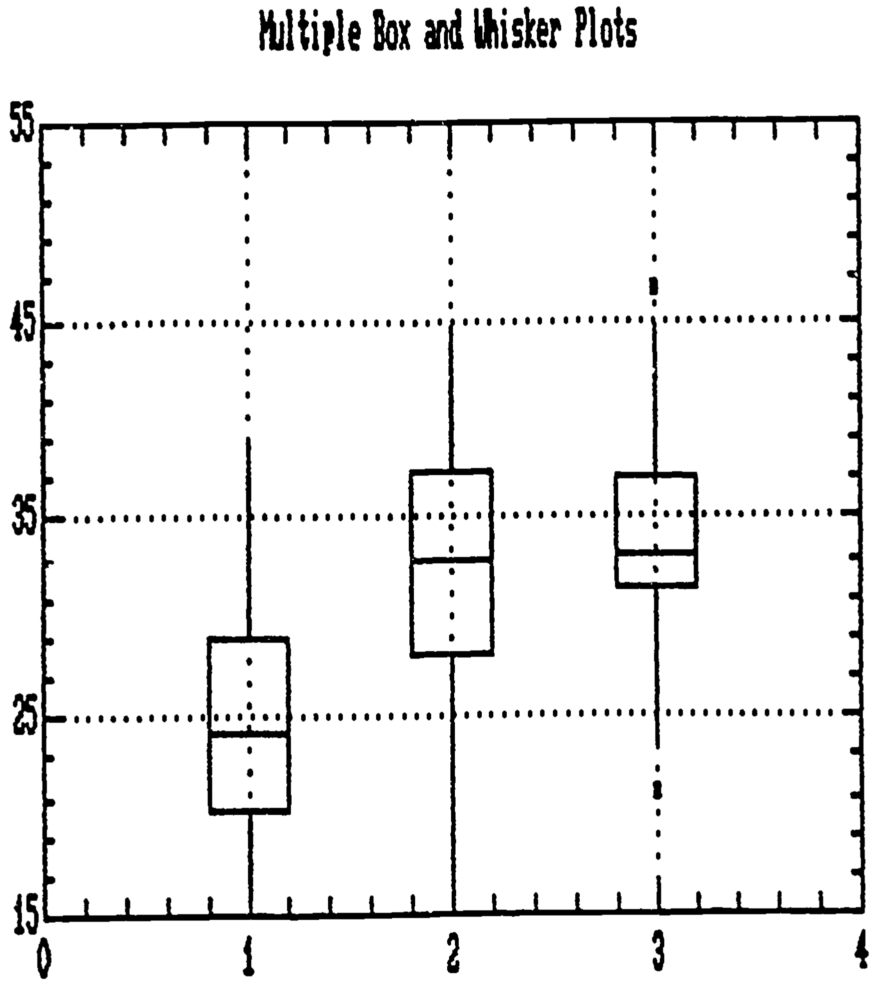
Finally, excellence in research and communication implies that:

20. Statistical graphics should not be used in analysis and presentations if some other technique or methodology is more effective.

To summarize:"Excellence in statistical graphics consists of complex ideas communicated with clarity, precision, and efficiency (Tufte,p.13)."

E: The Process of Graphic Design and Production

F: Standards, Principles, and Guidelines for Graphic Design



Produced with Statgraphics software and printed on an Epson FX 80 dot matrix printer.

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E: THE PROCESS OF GRAPHIC DESIGN AND PRODUCTION

Give a kid a hammer and he or she will discover that everything needs pounding. Give staff members a new computer graphics program and they may find everything needs charting. Are graphics another "solution in search of a problem"?

One fundamental problem is that many people do not know "when to stop" the production of graphics. Often we do not think explicitly and carefully about practical limits in the use of graphics or data. Used judiciously and wisely, charts and graphs can be an effective alternative to formidable piles of computer printouts and to crowded data tables. However, evidence suggests that some of us are prone to adding a graphic to every table or printout, compounding the problem of information overload and reducing the probability of effective communication.

Whether graphics are used as part of a published report or as an adjunct to an oral presentation, the advice of professionals is the same. In order to be effective, choose and use visuals with discrimination because "when you pick your exhibits carefully and present them strategically, you more clearly explain and more convincingly persuade (Humes, p. 37)."

A second basic question is "when to start"; that is, when to use graphic forms rather than some other means of presenting information. A sage observation is that "Knowing when not to start at all is as important as knowing when to stop (White, 1984, p. 10)."

In the preface we noted that the basic intellectual skills, including graphic skills, are not inherently better or worse, only more or less appropriate and effective depending on the purpose and conditions. On most occasions we have the choice of presenting statistical information in textual, tabular, or graphic forms, or in some combination of these forms. Experienced researchers and users of graphics note that:

> **"Before a decision is made to present data in graphic forms there should be good and sufficient reasons for such a choice. The advantages should unmistakably outweigh any disadvantages in comparison to textual or tabular presentation. Charts are not merely cosmetic appendages; they must serve a useful purpose based on careful insight and judgment (Schmid and Schmid, p. 7)."**

Effective use of text allows the author to guide readers toward intended conclusions or to spare them from misinterpretation. But poor text can also mislead and obfuscate. Tables can facilitate precise comparisons and provide supporting information for other forms of display, but important information may be lost in the forest of data. Graphs can communicate much information quickly with power and appeal and can reveal information not readily apparent in other forms, but graphs are also subject to distortion and manipulation (Schmid and Schmid, p. 7). Thoughtful choice is required in "starting and stopping" the use of graphics.

We must always weigh the advantages and disadvantages of graphics in relation to other forms of analysis and communication. The wisdom and discipline with which we do so will help determine whether or not graphics become an useful aspect in our array of tools and techniques.

TEN STEPS IN THE CHOICE AND DESIGN OF GRAPHS

After deciding that the use of a graph is appropriate, the designer is then faced with a myriad of choices in actual design and production. In the absence of an explicit and systematic process to follow, the results may be of lower quality and less effective than they can or should be. The discipline of following steps such as those outlined below is a good habit to follow, even if the work is only for yourself.

1. Identify the broad purpose of the work and of the graphics within it. Is it primarily for analysis, management, or presentation?

2. Identify the environment and constraints under which graphs will be produced and used: the audience (and their knowledge and skills); the viewing medium (screen, hard copy, slides); the setting (in person, in a report or published document); the available time; the capacities of the hardware and software; the number of copies; and the cost.

3. Outline the purpose of each graph and for the series. Do you want to: examine the structure of the data, see the relationship between two or more variables, see trends over time, compare two or more data series, show the magnitude or proportion of elements, or serve other purposes?

4. Identify the point to be made by the graph, or, within analysis, the type of information to be discovered or the question to be answered.

5. Obtain and scan the data for problems, limitations, and opportunities.

6. Select the most appropriate type of graph in light of points above.

7. Design the graph in light of recommended standards and guidelines.

8. Produce the initial graph; review it for accuracy and for other effective display options; study the graph for insights and conclusions; design and experiment with other graphic analyses and displays suggested by results of initial efforts.

9. Combine graphs with other work; present or distribute; and revise--in all probability!

10. Document sources, definitions, and design specifications; and file for future reference.

As discussed in Part B, there are a number of steps and roles in the design, production, and use of graphs. The process can go astray at many points. Special efforts need to be made to prevent or overcome problems. Two means that graphic designers and analysts have found to facilitate communication between different participants are: 1) to create a graphics request form patterned after the menu choices of the graphics software, and 2) to create a chartbook or view book, a library of a actual and hypothetical examples from which the user may choose the desired type and style. These tools should increase the utility of the results for the user and the efficiency of the process for the designer.

HOW TO CHOOSE THE RIGHT GRAPH--MATCHING PURPOSES AND TYPES
Two important steps in graphic design are: 1) specification of the purpose of the graph and 2) selection of the most appropriate type of graph to accomplish that purpose. This matching process is complicated by the fact that most types of graphs serve multiple purposes and a single objective can be met by several different choices. Nonetheless, some forms of graphs are better suited for some purposes than others.

Several uses for statistical graphs include: 1) presentation, 2) analysis, and 3) management. Often there is not a sharp distinction to be made between these uses. However, choices and applications will be discussed separately in order to broaden and sharpen thinking, and in order to highlight new uses and new graphic forms that are emerging.

Graphs for Presentation and Basic Analysis-Historically the most extensive uses of statistical graphs have been for presentation and for relatively simple analyses. Figure 4 depicts some of these common purposes in relation to basic types of graphs. In the design process the creator should first identify the purpose to be served by the graph (depicted down the first column), and then consider the types of graphs available (shown in the other columns), in order to select the most appropriate option.

Several points are in order about the information in Figure 4. First, while the list of basic purposes is fairly complete, there are many more types and variations of graphs than can readily be shown. The figure is intended to illustrate most likely generic choices, rather than to provide a definitive guide. Second, highly stylized examples are shown only in the cells having the strongest fit between purpose and type; others graphs are possible, but are considered inferior to those shown. Third, the figure is meant to stimulate explicit thinking that ought to occur during design.

What happens more typically is that the designer begins by picking the type of graph, and then proceeds immediately to depict the data. Basic purposes seldom get considered the first time around, if ever. Often the result is an inappropriate or ineffective graph that does not meet standards of visual clarity and excellence.

A common problem with such a random approach is that the designer attempts to accomplish too many things with a single graph and ends up with an inferior product. For example, trying to show both the magnitude of trends and the composition of those changes on the same graph may create confusion; better to make one or two good graphs than one poor one.

An often stated design axiom is to reduce the amount of data shown; better advice would be to constrain the number of purposes but show lots of data for that clear but limited purpose. More detailed discussions of the interaction between type and purpose can be found in other works (MacGregor, Schmid and Schmid, Schmid, White, Tufte, ISSCO [1981]).

For choice and design with microcomputer graphics software, a "gallery of graphs" is often shown in visual menu form. Five or more basic graph types are generally available, along with five to seven variations within each type. Again the computer-assisted design process, like the manual style, leads the designer to emphasize the graph type and to ignore or play down the purpose of the graph. Self discipline is required to make it work.

Presentation and Basic Analysis: A Matrix of Graph Types and Purposes

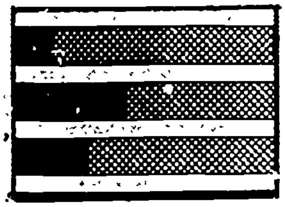
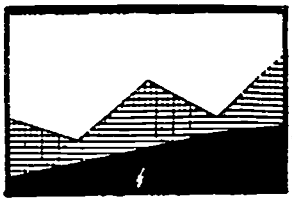
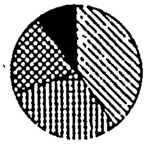
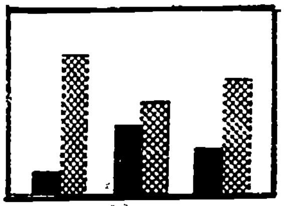
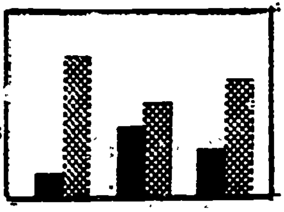
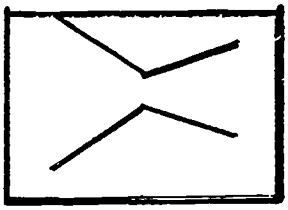
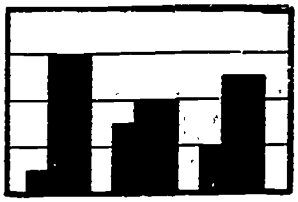
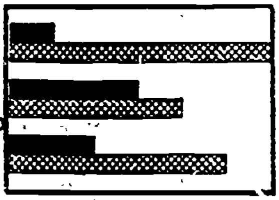
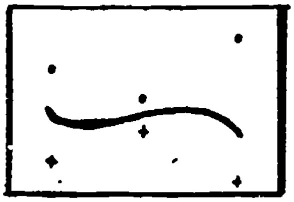
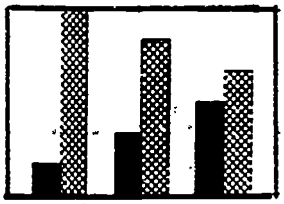
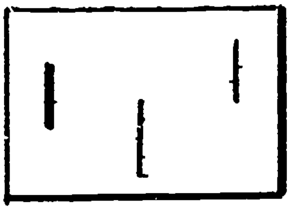
Purposes	Types of Graphs			
Do you want to...?	Bars and Columns	Line	Area	Pie and Other
Show the Composition, Parts of the Whole.				
Compare Magnitudes or Items.				
Show Trends and Change; Time series				
Compare the Relationship Between Variables				
Compare Differences and Ranges.				

Figure 4

Bar and Column charts are among the most versatile and prevalent types of statistical graphics. They are most useful to compare the magnitude of items--to show the difference between a number of items at one point in time or a few items across a limited time period--and to compare the composition of items and parts of the whole. Bars and columns serve less effectively to show trends of a number of items over a broad span of time.

Lines and Curves are often the first choice to use in showing the nature and direction of trends or change over time. They are less well suited to show the amount of change or to compare the relative size between items or variables. Semi-log charts would better depict rates of change.

Pie Charts are best used to show composition or component parts of the whole--for a single item at one point in time. They are not well suited for comparing two different items or of one item at two points in time. Stacked bar or stacked column charts are better for that purpose because differences in magnitude can be judged better with parts of bars and columns having straight lines, rather than by parts of circles.

Pie charts are among the most common types of graphics--and among the most misused and misinterpreted. A proliferation of pie charts is often tantamount to talking down to the viewing audience.

Area, Surface, or Band charts can be used to show the composition of a whole, or to show the trend of a whole and its component parts over time. However, this type of chart should not be used if one or more of the items are highly variable over time; this makes it difficult, if not impossible, to discern the trend of each individual component.

Other Types of graphs and chart also merit consideration. Semi-logarithmic charts are useful in showing percentage and proportional relationships, rates of change rather than amounts of change. Audiences may need to be educated to use this type to its best advantage.

Statistical maps also have potential for conveying information. However, designers should note that the size of the state may carry a subliminal impression about the magnitude of the item depicted that is different from the actual magnitude.

Mixed Types of graphs--for example, showing both columns and a line on one graph--can be very effective. Scatter plots with fitted curves or trend lines are a classic and potentially effective means of depicting the relationship between variables.

Multiples or Panels--showing several related graphs (either of the same type or different types) on the same page or a matrix of graphs showing pairwise comparisons of variables can be a very effective alternative to showing a number of data series on a single graph.

Designers using computer software should be aware that many programs are capable of producing graphic forms that are not recommended for critical purposes, i.e., using two pie charts to compare components of two items or to compare trends over time. Do not accept a program's default "solution" without critical review.

__Data Exploration and Complex Analysis__- Even when claimed as analytic graphs, graphics are generally used to __illustrate__ relationships and results discerned through prior statistical analysis, rather than being employed earlier and more centrally in the analytic process to __discover__ relationships and structures. A premise of this monograph is that graphics ought to play a more central role, at an earlier stage of analysis than is typically the case now.

Most of the graphs discussed above can be used, alone or in combination, for more complex analysis as well as for presentation of results. In part, the use of graphics in analysis is a question of timing and point of view as much as the type of graph itself--one graph employed "up front" in an early stage of analysis to explore the nature and structure of the data might be thought of as "analytic" while the same graph used only after statistical analyses have been done to depict results might be termed a "presentation" graph.

This section has been set forth separately in order to inform researchers and planners about new modes of true graphical analysis that are emerging, and in order to encourage greater use of graphical analysis techniques earlier in the research process.

The depth and complexity of analytic uses are beyond full explication here and, unfortunately, there is still only a limited amount of microcomputer graphics and statistical software that permits the full range of graphic analysis that would be desirable. See Part I for references about the use of these newer analytical techniques such as Exploratory Data Analysis using graphics, and for information about statistical packages for microcomputers that incorporate graphics.

Analytic purposes, types of data, and types of graphs that are appropriate for data exploration and more complex analyses are depicted on Figure 5. These approaches to graphical analysis have been suggested by Chambers __et al__, Cleveland, and Tukey.

Most analysis, whether statistical or with graphics, consists of operating on the raw data or upon derived information. Sections A and B on Figure 5 outline graphic forms for looking at the raw data, first one data set and then a comparison of distributions. One of the positive aspects of graphic analysis is that the graphic form is not dependent upon nor limited by the desired approach to statistical analysis.

Desired analyses of multiple variables usually consist of exploring dependencies or causality among variables, or patterns and relationships among variables; these spheres of analysis are shown in Sections C and D, along with graphic forms.

Finally, most statistical analysis is carried out with assumptions made about the data such as the assumption that data are distributed along a normal curve. Section E on Figure 5 outlines graphic procedures for assessing data assumptions. This discussion should reinforce the sense that graphical and statistical analysis are powerful allies rather than one being better than the other or a replacement for the other. Used together, analysis is enhanced beyond what it could be using either approach alone.

Data Exploration and Complex Analysis: Matrix of Types and Purposes

Analytic Purposes; Nature of the Data	Types of Graphs				
A. Explore Distributions- One Data Set	Quartile Plot	Scatter Plot; Symmetry	Box Plot;	Histogram; Density Trace	Stem and Leaf
B. Compare Distributions- Two or More Sets	All from Section A. above plus: Collections of Single Data Set Displays; Ratio and Difference Plots				
C. Analyze Two Variables- Dependencies and Relationships	Individual variable analysis (A); then compare (B); Scatter Plots; Strip Medians and Box Plots; Smoothing and Transformations; Two-D Local Densities;				
D. Analyze Multiple Variables- Dependencies and Relationships	Strategies above plus Draftsman's Display; Symbolic Scatter Plots; Casement Display; Partitioning and Multiwindow Displays; Residual Plots; Hybrids				
E. Assess Distributional Assumptions	Quartile Plots; Straight-Line Deviations; Probability Plots				

Figure 5

Adapted from Chambers _et al_, Cleveland, and Tukey

The general mode of analysis may be to confirm or to explore and discover. Regardless of the analytic method, Chambers _et al_ note the importance of developing an overall strategy and framework that are characterized by: 1) matching graphics with analytic goals; 2) an iterative approach to the work; 3) care in sorting out true messages from artifacts; 4) flexibility in graphic applications; and 5) concern for interpretability--relating the structure of findings back to the initial data (pp. 316-319).

Management Applications of Graphics-The serious use of graphs for management purposes is growing. Certainly presentation and analytic graphs are often used by management--the question how can graphs be used for management in ways beyond the traditional uses in annual reports and in speeches to illustrate points. Given the emergent and idiosyncratic nature of management uses, the framework below is highly preliminary and only suggestive of possibilities and of new things to come.

In the Figure 6 the attention shifts from individual graphs to broader areas of application. The orientation moves from the use of single graphs in an ad hoc manner to the ongoing production of graphics chartbooks, collections of institutional data depicted in statistical graphs, and to on-line visual information systems or graphic support systems linked to institutional data bases. Many of these uses are characterized by needs for high quality, high volume, and fast output; mainframe capabilities and network linkages are probably required for a fully functional system.

Why are graphics useful for management purposes--because statistical graphics can assist in reducing the organization's "information float" by making more information more readily accessible than it otherwise could be in other forms such as computer print outs.

Management: A Matrix of Graphic Applications and Purposes

Management Functions/ Purposes	Examples of Graphic Applications in Management		
Reference	Pocket Chartbook		
Reporting		Organizational Chartbook	
Monitoring, Early Warning System			On-Line Graphics in DSS
Quality Control		Performance Chartbook	
Project Management	Gantt Charts PERT Charts		
Strategic Planning			Visual Info. System

Figure 6

F: STANDARDS, PRINCIPLES, AND GUIDELINES FOR GRAPHIC DESIGN

The anatomy of a graph and the elements to be decided upon in design were outlined in Part C. In Part D the characteristics of graphs of high quality were identified and discussed. In Part E types and purposes of graphs were set forth and discussed in the context of functional uses.

Good graphics do not "just happen" any more than an excellent analysis or piece of writing happens by chance. In this section standards, guidelines, and principles for the design and use of statistical graphics--which are analogous to rules of grammar, punctuation, and computation--are outlined and illustrated.

These guidelines deal in more detail with the interactions among: graphic elements; the standards of quality, the types and purposes of graphs, and the uses to be served. Fundamentals are drawn from diverse origins. Most of the sources are reviewed in Part I (Cleveland, Tufte, Schmid, White, MacGregor, ISSCO [1981], and Harvard Presentation Graphics).

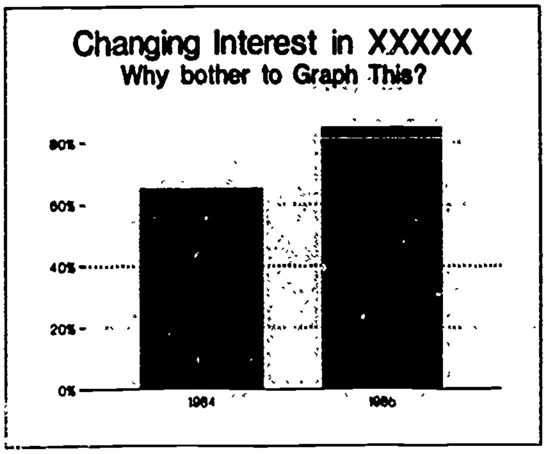
Most standards and principles outlined apply to graphs used in analysis and management as well as to those for presentation purposes, and most apply to all output media. However, designers need to be alert to contrary situations where principles should not be applied unilaterally. For example, an analytic graph to be viewed on paper at the user's leisure has a greater "carrying capacity" of data than would a graph prepared as an adjunct to a speech. Since most standards are set forth with presentations in mind, those designing graphs for other purposes should consider and apply specific standards with discretion rather than following them to the letter. As analytic and management uses expand, new conventions and guidelines more directly applicable to these areas will emerge.

In the process of design and production there are many trade-offs to be made among standards, and between standards and other considerations such as the viewing conditions, the graphic knowledge and skills of the viewers, or the need to have a consistent series of graphs over time rather than merely the best individual graph at one point in time.

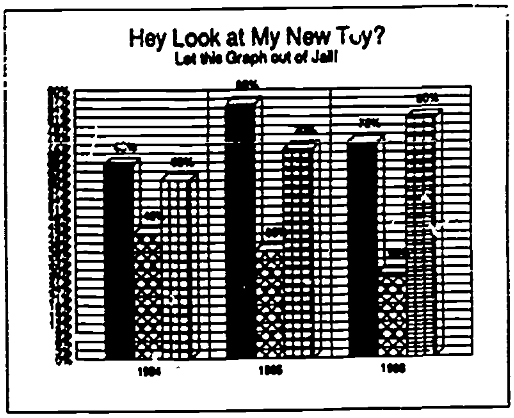
The points set forth and illustrated below are guidelines and suggestions, not rules to be followed dogmatically in all circumstances; discretion must be used in applying the principles. This does not mean that the recommended standards are arbitrary--to the contrary, many are grounded in research and most devolve from long practical experience (See Cleveland, DeSanctis for a discussion of research findings).

Standards for graphic achievement are concerned with: visual clarity and excellence; accuracy, integrity, and understanding; the fit between the purpose, the data, the conditions of use, and the users; and an overall strategy for the use of statistical graphs. As will be apparent, some principles apply to the graph as a whole, while others pertain to discrete elements, and still others apply to a series of graphs.

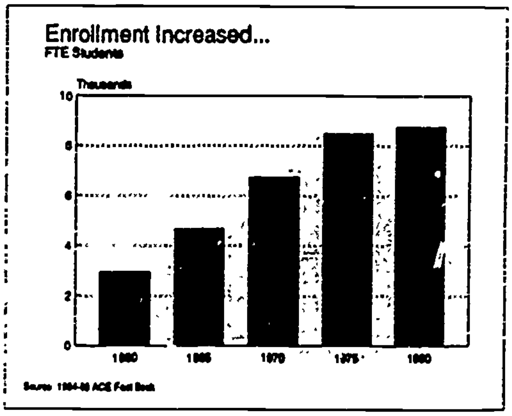
Above all, the standards are set forth and are intended to be applied so that improved solutions can be found to new and old problems of the discovery of information; of communication with clarity, efficiency, and integrity; and so that improved understanding and decision making occur.

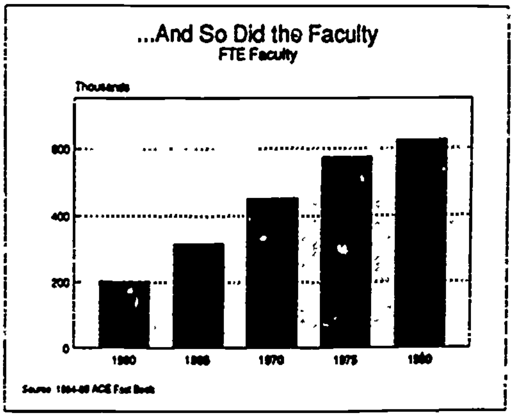


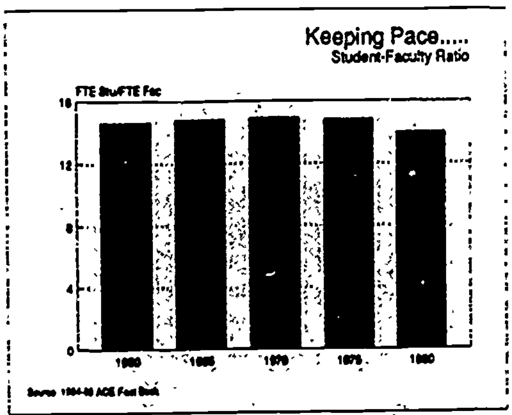
The graph should serve an important purpose.



Remove the "chartjunk," show the data.







Use a series of small multiples as an alternative to a single graph.

Use series to build up a point.

The Graph As a Whole

Point 1. The graph should serve an important purpose; it should add or reveal information and not merely serve as a redundant source. Know when "not to start" a graph. In oral presentations, fewer graphs with more viewing time are preferable to graphic "overkill" and split second views.

Point 2. The graph should serve a clear purpose and present a limited number of central points, but it should show much rather than little data.

Point 3. When using a graph in an oral presentation, limit the amount and the complexity of the information to what can be readily perceived by the audience; under other conditions (e.g., in reports) take the opportunity to show more complex ideas and relationships, and include more data.

Multiple Graphs and Graphic Series

Point 4. Use small multiple graphs, a number of related graphs on the same page, or a graphic series as an alternative to one large graph with many confusing lines or bars (see Figure 1, page iv).

Point 5. When using multiples, a series, or a number of graphs in the same report or presentation, establish a consistent and coherent structure and style. For related graphs, in so far as possible, use the same scale from graph to graph in order to present information with integrity. Also, use the same conventions for titles, labels, definitions, and the like. When purposes permit, use the same type of graph or a limited number of types so that the audience can focus on the content rather than the form. Orient the graphs in the same direction on the page.

The Users; The Viewing Audience

Point 6. Match the graph with the graphic and analytic knowledge and skills of the audience and with their content knowledge, but do not "talk down" to them with a graph. Do not limit graphs to simple pie charts when much more powerful and effective graphic forms are available.

Integration of Forms

Point 7. Consider combining a statistical graph and a small data table in an integrated chart in order to convey information at a glance and to be able to refer to specific points with greater precision.

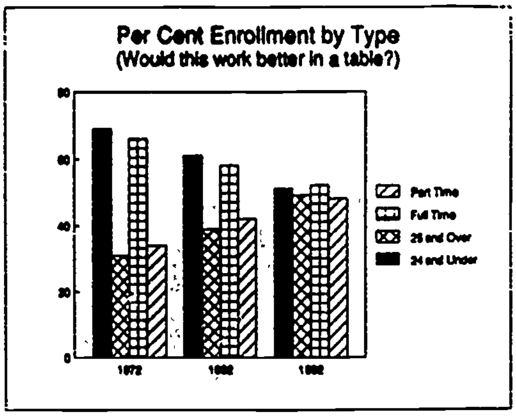
The Graphic Signature

Point 8. For an office, establish a "graphic signature"--a style and set of conventions for titles, labels, legends, footnotes, and fonts just as you would establish standard formats for data tables, and for memos.

Standards for Reproduction and for Viewing Conditions

Point 9. Match the size, content, and quality of reproduction with the uses and viewing conditions. Make sure that the graphs will be legible under the final conditions of reproduction and use.

When overhead transparencies or slides are used, be sure that the symbols and text are large enough and distinct enough to be read by everyone in the room. When graphs are reduced or enlarged, and when reproductions are made on the copier, make sure that the text and symbols are still legible. Generally, simply copying a graph drawn for a published report onto a transparency will not result in a figure of appropriate size or content.

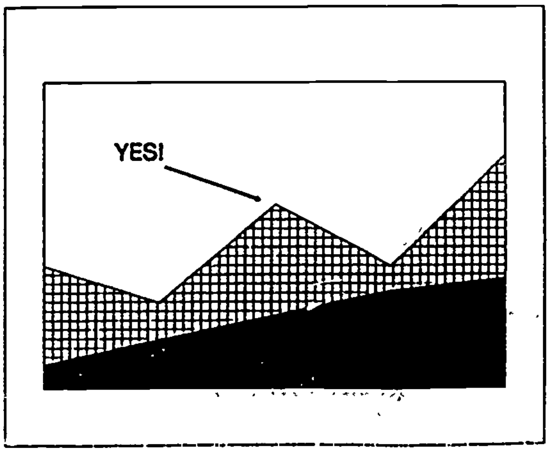


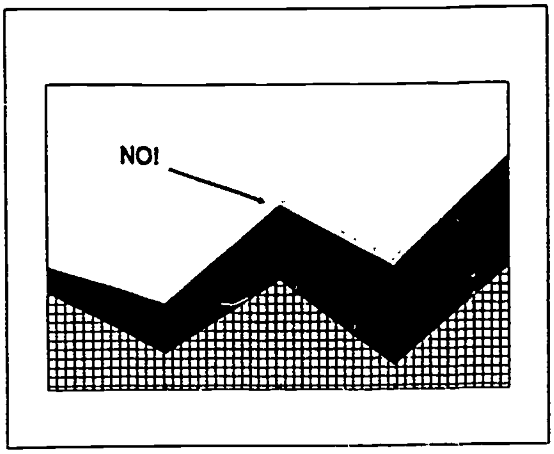
Know when to graph,
"when to start"

Per Cent Enrollment by Type
(How does this compare with a graph?)

Enrollment Category	1972 %	1982 %	1992est %
24 and Under	69	61	51
25 and Over	31	39	49
Full-Time	66	58	52
Part-Time	34	42	48

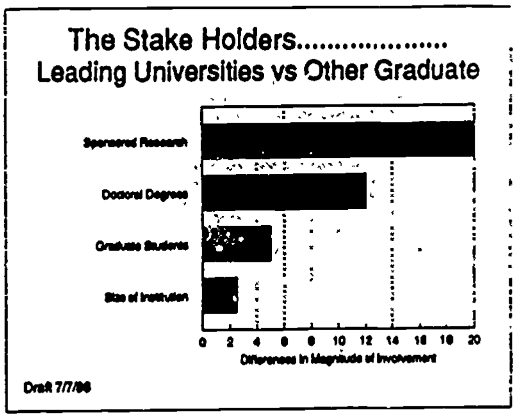
and when to use table.



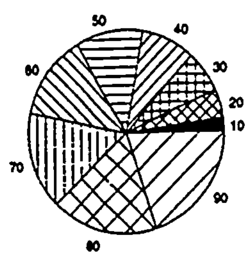


put the variable that varies the least
on the bottom; ut the darkest color
next to the axis.

Sort the data.



Use few variables.



combine small slices

The Data; The Points

Point 10. Above all else, show the data (Tufte). Remove extraneous elements such as unnecessary grid lines, excessive tick mark values and labels, particularly unnecessary elements in the data region.

Point 11. Reduce the amount of open space in the data region, provided relationships are not distorted, by filling the region with data.

Point 12. Show main points and conclusions in the graph; consider stating the point in the title. In an oral presentation, consider presenting a group of graphs to "build up" the findings and conclusions in a series of more simple graphs rather than showing a single, more data intensive graph that is more appropriate for hard copy viewing conditions.

Data Management

Point 13. For financial data, show constant and current dollar values.

Point 14. For insight and impact consider graphing percentages, ratios, or index numbers rather than raw numbers.

Point 15. Consider sorting and presenting variables by size or some other organizing principle rather than in random order or alphabet order.

Point 16. On stacked bar or column charts and on pie charts, sort the values in order of magnitude. Show the largest value next to the axis.

Point 17. Limit the number of components shown on a pie, stacked bar, or column charts to five to seven; combine variables with small values.

Lines; Markers; Symbols

Point 18. Make the data lines in a line graph more distinct than the grid--thicker, more intense, or with a more striking pattern.

Point 19. Make symbols obvious enough to show data points clearly. Use distinct symbols such as solid lines and ones of greater thickness to show actual data; use less striking symbols such as dots for estimated data.

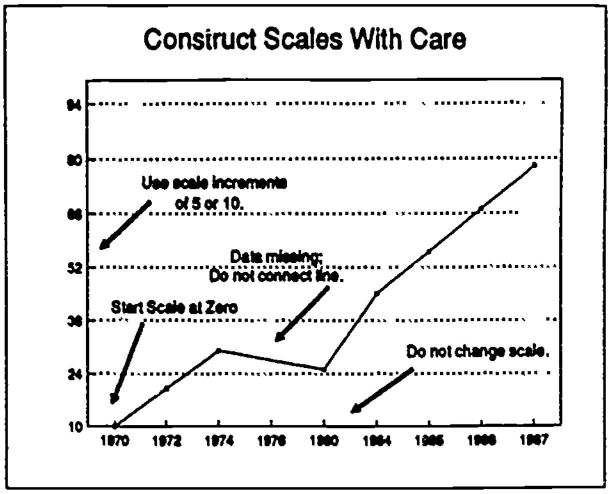
Scales

Point 20. Generally start the value scale at zero when comparing totals and magnitudes. If the scale must start other than at zero, clearly point out the alternative origin with a label.

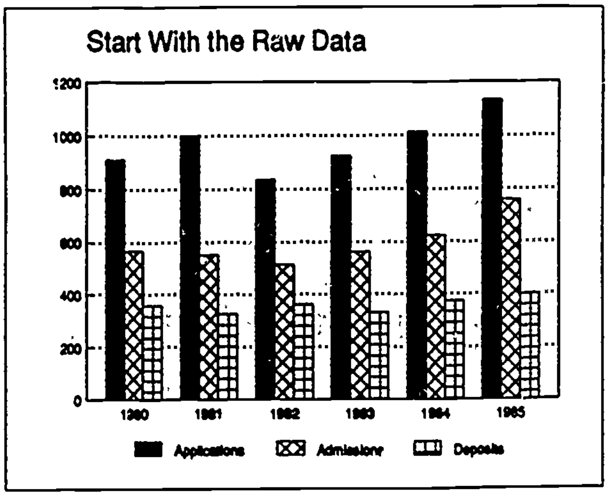
Point 21. Make the scales of the two axes compatible and in proportion with each other in order not to distort the data; when using computer graphics software, question the default values established for the scale.

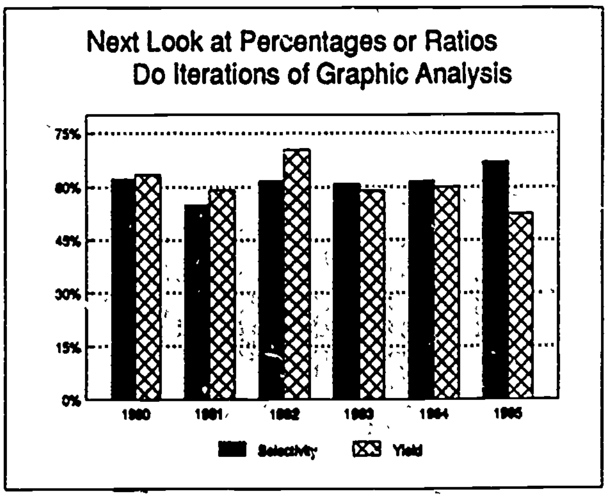
Point 22. Along the respective axes, retain the same scale intervals and markers throughout. If data are missing, consider showing several panels covering the actual ranges, rather than using a single graph that suggests a continuous data series. This solution is preferable to showing a "scale break" with a zig zag line across the axis.

Point 23. When data are missing in a line graph, do not connect the extant points; this could lead to a possible distortion of information.



Develop an analytic strategy.





Point 24. Use scale values, tick marks, and tick mark labels that make comparisons and interpretations easy, i.e., use values such as 5's and 10's to facilitate reading the data.

Point 25. When using multiple graphs or a related graphic series, use common or compatible scales in so far as possible.

Point 26. Scale labels are generally shown on the left side and at the bottom; consider showing the y-axis labels on the right side for some uses, particularly if it is important to gauge the values on the right side more precisely than those on the left. Some experts suggest showing scale values on all four sides. Showing the y-axis label horizontally at the top may be preferable to a vertical placement because of legibility.

Point 27. When showing two different variables or data series on a single graph, each with a different scale (one shown on the left side and one on the right), choose the scales and labels with great care; consider two smaller multiples as an alternative.

Enhancements; Patterns
Point 28. Use enhancements such as colors or "canned images" sparingly.

Point 29. When using patterns and colors, choose those adjacent to each other with care in order to differentiate, and to avoid optical illusions or displeasing combinations. Use the darkest color or the most striking pattern to show the point or series to be emphasized.

Labels, Titles, Legends, Keys, and Footnotes
Point 30. Title and annotate the graph clearly and completely.

Tick Marks and Grid Lines
Point 31. Limit use of grid lines and tick marks--enough to gauge the value of the variables, but not many that detract from the data itself.

Point 32. Use horizontal grid lines with column charts and vertical grid lines for bar charts.

Perspective, Orientation, and Perception
Point 33. Use three dimensional displays and unusual perspectives with care because it is easy to distort relationships; avoid them if there is the need to judge differences in magnitude or trends with precision.

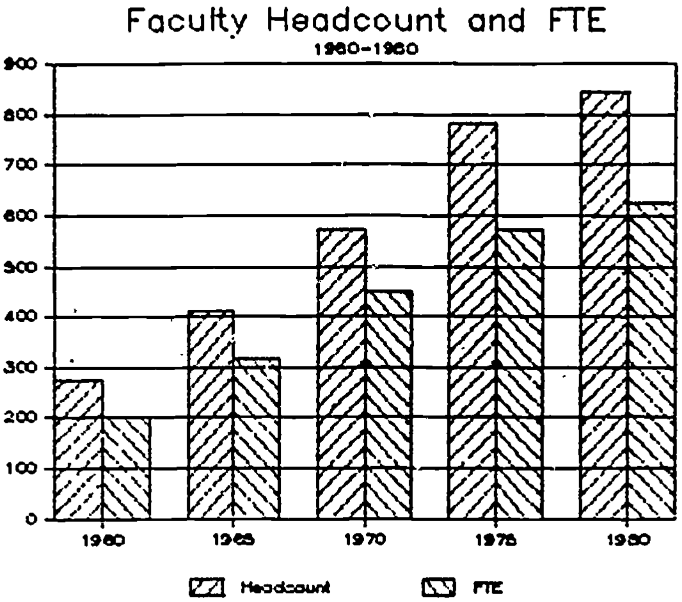
Point 34. If comparing proportions or magnitudes, it is possible to do so with greater accuracy using heights than circles. Therefore, tend to use bar or column charts rather than pie charts for these purposes.

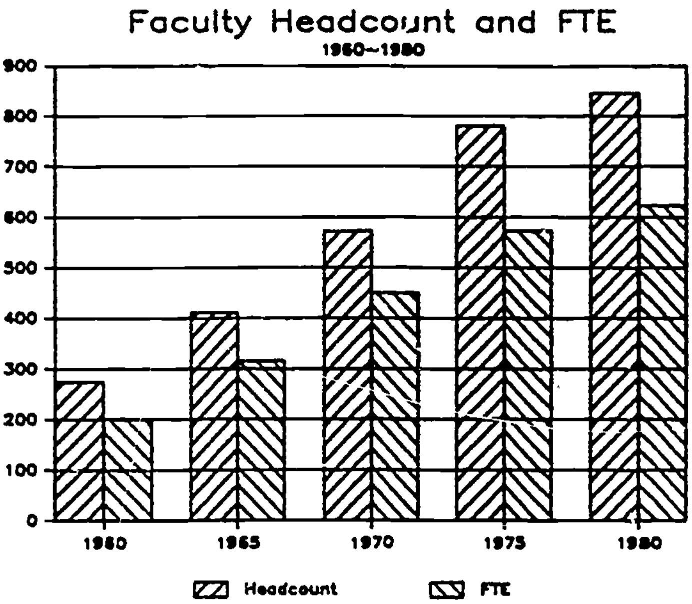
Point 35. Graphs should tend toward the horizontal, greater in length than height, but shown in portrait rather than landscape mode on the page. What is most pleasing aesthetically may conflict with what is practical given the nature of the data.

The points outlined above are intended as guidelines for consideration, and not laws to be followed slavishly. Still, in order to achieve high quality graphics, it is important for the graph creator to make explicit, well-considered choices about them rather than leaving the decisions to the computer program.

G: Extending the Use of Graphics--An Office Strategy

H: Approaches for Hardware and Software Selection





The top graph was produced with Lotus 123 and printed on an Epson FX80 dot matrix printer; the lower graph was produced with Lotus 123 and plotted on a Hewlett-Packard 7470A plotter.

G: EXTENDING THE USE OF GRAPHICS--AN OFFICE STRATEGY

Section A provided guidance for getting individuals started with computer graphics. The focus of this section moves beyond the capabilities and needs of an individual to the office as a whole.

Strategy--Chains of Ends and Means

Most of us have proceeded or will proceed to acquire graphics software and hardware --the means-- with little or no regard for the ends. And then use often develops in a random fashion, sometimes languishing and sometimes mushrooming out of control.

The development of an overall office strategy for graphics--one that is explicitly related to the office mission--is more likely to lead to graphics becoming a pervasive and effective force than is an approach of simply extending access to computer graphics to all staff members and offering a graphics production service to the institution as a whole.

A plan should entail both a concern for ends -- what do we want to achieve? -- and for means or tactics -- what are our options and preferences for achieving ends? Strategy also concerns of questions of "fit"--the integration of graphics into various functions and activities within the office, and the meshing of the office graphic capabilities with the larger environment.

There is no single, best strategy for the role and use statistical graphics within a planning and research office or in other professional settings, nor is there "one best way" to implement graphics. Thus, it would serve no useful purpose to spin out a prescriptive strategy or set of office objectives for the introduction and use of graphics without regard for an existing office situation.

To focus on graphics while ignoring the office context and external environment would make it all to easy to view the use of graphics as an end in itself and not for what it is -- merely a tool to be used judiciously with other tools. Also, creating objectives for tools such as graphics in isolation can lead to the kind of thinking that suggests graphics is the <u>best</u> solution or the only solution to "the problem." Sometimes it is; more often than not graphics can be an effective <u>component</u>, but seldom the total or best overall solution.

For an office, many aspects of a graphics strategy and plan for implementation that need to be addressed are analogous to those outlined for individuals in Part A. Major areas outlined earlier included:

1. Commitment; Goals; Plans
2. Information; Education; Training
3. Access to Graphics Technology
4. Implementation and Experimentation
5. Expanded Awareness and Use; Evaluation

However, the design for an office must be more than a plan for individuals "writ large"; dimensions need to be added to address greater complexity, different needs, and broader capacities and resources.

With respect to goals the first question is: what are the strategic directions and priorities of the office or organization, and within that context, what could or should be the role of computer graphics?

Are your initial objectives modest? Is your office priority to improve analysis and communication? Is expanded use of graphics an important way to assist in accomplishing these ends? If so, then your next step would probably be to assess opportunities for incorporating graphics into your existing work and make graphics a more central aspect of new work as it emerges. For example, you might start by introducing or improving graphics in you institutional Fact Book and in your annual enrollment projections and reports.

At this point other important questions emerge. Will all staff members be expected to achieve some basic level of competency in graphical analysis and presentation graphics, or will the design and production of graphics be viewed as an areas of specialization?

For some organizations the primary competitive question may be one of expanding or improving service, and you might see computer graphics as having a role to play in this area. A companion office objective might be to increase the visibility of the office and to use graphics and a primary means for achieving those ends. In this scenario you might start a graphics production service, develop and introduce a pocket chartbook for institutional executives, furnish a statistical graph each week to the institution's newspaper, and provide in-service training for others.

Many have found this to be a successful strategy. Nonetheless there are risks associated with it. The demand for production graphics may boom--and boomerang--competing with or taking over from other office work, or demanding resources beyond the means of the office. To see a graph that you spent several hours in producing and perfecting used in a meeting of the board of trustees in rewarding. However, the thrill goes out of graphics the first time you have to spend the weekend running the plotter to produce twenty original copies of four-color charts! The PC and dot matrix printer or plotter were not designed for high volume jobs.

For some offices the directions may be more ambitious such as to assist in improving the environment for graphics on campus. Such a role might include participation in the selection of graphics hardware and software, involvement in the development of "production graphics" capabilities on the mainframe linked to the institutional data bases, and providing leadership in the development of graphics components for executive decision support systems.

Whatever level you decide upon, there are common concerns and questions. Who are the likely users of graphics? Does your equipment and software fit those needs or, if not, are resources available to do so? What are the cost-benefits of choosing graphics over some other area of practice?

Rather than "making work" one should look for important, high payoff areas as sights for graphics applications. For example, an office might develop an on-line graphics systems for showing admissions and enrollment data, for showing monthly revenue and expense information, or for monitoring energy consumption. Get on with graphics.

H: APPROACHES FOR HARDWARE AND SOFTWARE SELECTION

Excellent graphics capabilities are available for all sizes and types of computers--micro, mini, and mainframe but given the focus of this guide, most attention will be given to microcomputer options and considerations. Still, readers are encouraged to examine other possibilities, either as a piece of the solution or as the primary vehicle for graphics. Cost constraints may suggest or dictate the stand-alone microcomputer route initially. However, eventually mini or mainframe computing solutions will need to be included if use of graphics is to pervade the institution.

There were at least two hundred microcomputer programs with graphics capabilities and more than two hundred vendors selling graphics software and hardware for the microcomputer; continued expansion is expected. Under these conditions, the odds of making a successful match between your needs on the one hand, and what is available in hardware and software on the other hand, are likely to increase if the selection is done carefully.

ELEMENTS OF HARDWARE FOR A GRAPHICS SYSTEM

In theory the choice of software should precede that of hardware, but in reality the reverse is usually true. Most likely readers already have some microcomputing capacity and are seeking new graphics options. The aim here is to provide the reader with an overview of major hardware components required or available to support graphics, to point out some other sources of information, and to identify some common problems and objectives.

Hardware elements of a microcomputer graphics system may include:

1. The "System"-The Central Processing Unit (CPU)
2. Monitor
3. Graphics Adapter Board; Graphics Chips (may be required)
4. Input Devices (most devices are optional)
5. Printers and Plotters (plotter optional)
6. Other Output Media and Devices (optional)
7. Mass Storage Devices (optional)
8. Network and Communication Links (optional)

Even if starting with an existing microcomputer, additional devices may be required to get a functioning and effective graphics system. A graphics adapter board often will be required to run graphics software, although graphics capabilities may already be built into the system. New graphics standards for boards are emerging so careful investigation is required. Recently the IBM EGA board has emerged as a defacto standard; whether this will be supplanted by the newer IBM VGA equipment remains to be seen.

A new monitor may be required since not all older monitors will support graphics. Choices about monochrome or color, and about the degree of screen resolution are also factors to be decided. Also, the monitor and the graphics adapter card will need to be compatible; high resolution of a monitor will not be available unless supported by the adapter card.

The size of the memory of the central processing unit may need to be expanded in order the run the desired software at all, or in order to run it quickly and efficiently. New input devices will probably not be required, though many options beyond the keyboard, such as the light pen, mouse, digitizing pad, and so forth, are available.

However, if the objective is to achieve high quality output, then other peripherals such as high quality printers, plotters, and photographic capabilities will need to be considered. Decision factors for hard copy output devices include: 1) image quality; 2) resolution; 3) speed; 4) equipment cost; and 5) cost per copy of output (Laroff). Given the cost of the equipment, trade-offs will probably need to be considered. Since much peripheral equipment is specialized and not likely to be used intensively by a single office, opportunities for shared equipment are important.

Other possible options include hard disks or other mass storage devices and the means for linking the microcomputer to a network or mainframe computer. This equipment is not required to produce graphics, but may be desirable if graphics are to be used broadly and effectively. For example, communications links would be important for access to institutional data bases, access to shared equipment, and for making completed graphs available to others. Buyer's guides for monitors, boards, plotters, and printers are available in a number of publications (see Section IV, J).

Above all, the hardware and graphics software must be compatible with each other and with the operating system software. There must be: sufficient main memory to run the chosen software, the required number of drives, a match between the version of the operating system software and the version of the graphics software, and compatibility between the graphics software and the printer (a software driver to link the software to the printer). The safest route is to see the desired configuration actually running, before purchase, rather than merely relying upon assertions of manufacturers and sales persons.

TYPES OF MICROCOMPUTER GRAPHICS SOFTWARE

The routes available to acquire microcomputer graphics capabilities are so numerous as to present a "blooming, buzzing confusion." Before choosing a specific product, a decision must be made about the type of graphics software. Major alternatives are described and discussed below.

1. **Multipurpose or Integrated Programs with Graphics**

   Most people have probably been introduced to computer graphics via the graphics capabilities in spreadsheet or multipurpose programs such as Lotus 123, Excel, or Reflex. This graphics capacity represented a significant advancement in access, cost, and timeliness over prior alternatives such as graphs produced by artists, or those drawn by hand by untrained persons--and certainly better than none at all.

   Spreadsheet programs have clearly contributed to a renewed interest in graphics, but with experience and growth in sophistication most users find these programs inadequate for serious graphics. Currently the graphic forms in these programs are limited and the quality of output is not outstanding.

   Related enhancement packages are also available for these programs: to improve the graphics quality and power of spreadsheets, to import of graphics into word processing documents, and to add graphics capacity to statistics programs. A modular approach to integrating graphics is emerging; vendors of word processing and statistics programs now are beginning to offer graphics modules that can be run in a stand-alone mode or in conjunction with the companion program.

2. Stand-alone, Dedicated Graphics Programs

A. Graphics Programs for Depicting and Manipulating Data
Those interested in producing graphs of greater sophistication and quality than those possible with multipurpose programs should next consider the offerings of dedicated, stand-alone graphics programs. For professionals in research and planning, the data input and manipulation qualities of programs are of central importance in addition to the scope, power, and artistic quality of graphics.

In current usage, programs that produce statistical graphs of high artistic quality, suitable for publishing (e.g., graphs produced by plotters) and/or that produce graphics in various media used for oral presentations (e.g., slides, overhead transparencies) are typically called "presentation graphics" programs.

By default or deduction, then, programs deemed as not producing "presentation quality" graphics are generally termed "business" or "analytic" graphics. However, these designations have little to say about the suitability of the program for analysis. Most of the writing about graphics in the popular computing press is either biased toward presentations over analysis or reviewers do not have the knowledge to judge the graphical analysis and data handling potencies of graphics programs. What a program is called is not an infallible guide to its capabilities.

Rather than classifying graphics programs as being for "business" or "presentation", it is more informative to judge them along dimensions suggested in Part E: 1) Presentation graphics and basic analysis capacities; 2) Data exploration and complex analysis qualifications; and 3) Management applications and systems linking capabilities.

If multipurpose or integrated programs and stand-alone graphics programs were assessed along these three dimensions, current quality ratings would fall roughly as shown below. Mainframe or minicomputer configurations would probably be required, in the short run, to achieve strong ratings for management systems.

Graphics Assessment for Types of Microcomputer Software Programs

Dimensions/Uses	Multipurpose with Graphics	Stand-alone Graphics
* Presentation Quality and Simple Analysis Capabilities	Low	Medium to High
* Data Exploration and Complex Analysis Capabilities	Low to Medium	Low to Medium
* Management Applications and Systems Capabilities	Low	Low

The advantages of multipurpose programs include: compatibility (of data and file formats, of equipment), potential for integration (of basic functions such as analysis and graphics, word processing and graphics), and, probably, reduced costs for software and reduced time for learning

The disadvantages of graphics in multipurpose programs compared with dedicated graphics programs are, generally, the following: fewer types of graphs available, less power and flexibility for changing images and data, lower quality of output, fewer alternatives for high quality, high volume input and output media and devices.

2. B. Statistical Programs with Graphics
Programs that warrant the serious attention of researchers are those that successfully combine more traditional statistical analyses and graphics in microcomputer programs (e.g., microcomputer versions of SAS, BMD, and SPSS) or those that include newer approaches to graphics and statistics (e.g., Statgraphics, Sygraph).

2. C. Other Graphics Programs or Features
In addition to programs that produce statistical graphs, there are programs with other graphical or visual features that may be of interest and use for different purposes. Some types now available include:

1) Paint, draw, freehand graphics, and design programs.
2) Computer aided design (CAD) programs.
3) Word and organization chart programs.
4) Font enhancers and desktop publishing programs.
5) Project management programs with Gantt and PERT charts.
6) Map and atlas programs.
7) Graphical outliners and "idea processor" programs.

Map programs with data base connections are arriving on the market; the potential for use in enrollment and admissions research, and in development and alumni relations looks promising. Newer "idea processors" have the capacity to link ideas or concepts with icons or graphs. Also, there is at least one memory resident graphics program that can be invoked while in another program (e.g., Graph-in-a-Box).

Steps for Software Selection
Possible steps to be followed in the selection of graphics software are outlined below. Similar steps could be followed for hardware too.

1. Develop an overall office strategy and plan for computational, analytic, and graphic support.

2. For each type of hardware and software, outline purposes to be served, the needs and characteristics to be met, users (of products, of results), the environment for running and use, and the constraints. Ask users about information needs and decisions to be made.

3. Translate strategy and needs into selection criteria.

4. Get general product information (from vendors, reviews, buyers' guides, users groups).

5. Get demonstration copies or have a demonstration from a dealer or vendor, or try o t products from user groups or colleagues.

6. Test and evaluate products (using your own real data, with your current or planned equipment set up) for: ease of learning, ease of use, for speed, for all phases of operation (data entry, graphic production, graphic and data manipulation, file import, file and data management), and for output quality and diversity.

7. Have potential users (of software, of results) test and evaluate both the operation of the software and the final results.

8. Evaluate the software against criteria (e.g., ease of learning) and select the most appropriate software.

Evaluative Criteria for Graphics Software

Outlined below are criterion categories that might be applied for the evaluation and selection of graphics software. Many of the factors are applicable to other software and to hardware.

1. **Vendor Characteristics and Performance**
   - A. Prominence and Stability.
   - B. Product Market Share and Installed Base.
   - C. Technical Product Support (kind, extent, cost).
   - D. Product Development and Upgrade Policies.
   - E. Product Reliability Record.

2. **Product Documentation and Training: Scope and Quality**
   - A. From the Vendor:
     - 1) Printed manual (comprehensiveness, quality, readability).
     - 2) Tutorial (printed or computerized).
     - 3) On-line help.
     - 4) Seminars, workshops, and training programs.
     - 5) User groups and newsletters.
   - B. From Other Sources:
     - 1) How-to-do-it books and applications manuals.
     - 2) Video and audio cassettes.
     - 3) Training seminars and workshops.

3. **Product Characteristics, Specifications and Performance**
   - A. General Technical Considerations:
     - 1) Operating systems and hardware supported.
     - 2) Memory requirements.
     - 3) Other hardware required and supported: graphics adapter boards, monitors, printers, plotters, input and output devices, disk drives and hard disks.
     - 4) Compatibility with other software and equipment:
       - a) File structure compatibility for import and export to other microcomputer programs (spreadsheets, data base, statistics) and mainframe data bases.
       - b) Multiuser and network compatibility.
     - 5) Copy protection (yes/no) and back ups.

B. Implementation and Operating Considerations:
1) Ease of installation and set up.
2) User interface (menu, commands).
3) Learning time and retention of proficiency.
4) Ease of use.
5) Error handling capabilities.
6) Data manipulation (selection, sort, recalculation) and management (entry, import, export).
7) Graphic design and manipulation.
8) Connectivity; networking potential and performance.
9) Cost/speed/performance/power trade-offs; life cycle costs.

C. Program Characteristics and Capabilities:
1) Number, style and features of graphics supported:
Basic forms only or advanced; structured graphs only or custom and free hand as well; special capabilities (built in analysis and calculations, maps, text handling, "slide shows").

2) Presentation graphics features:
Number and style of fonts; size of data range; multiple graphs on a page or singles only; graphs only or combinations of graphs, text, and tabular data; number of colors supported; other special features such as picture libraries and slide shows; and free positioning of charts, free positioning of labels.

3) Design and default standards:
Appropriate choices for scales; effective use of color; appropriate choice of patterns for defaults.

4) Analytical and computational capabilities:
No internal computational capabilities, simple calculations, or complex manipulation; number of variables, periods or series depicted for analysis and for presentation; dynamic links between graphic image and data bases.

5) Management applications and graphics system capabilities:
Links to networks and data bases; support for high quality, high volume, and high speed output; support for production of linked tables without rekeying.

6) Flexibility and power:
Capacity to: add and move labels; move images; add arrows and other annotations; superimpose; window; highlight and explode; and change background and foreground; support for multiple graphs on a page, mixed types on a single graph, and mixed types and sizes on a page.

No products satisfy all important criteria. As with other decisions, purchasers will be faced with trade-offs: typically power, flexibility, and scope versus cost, ease of learning, and ease of use.

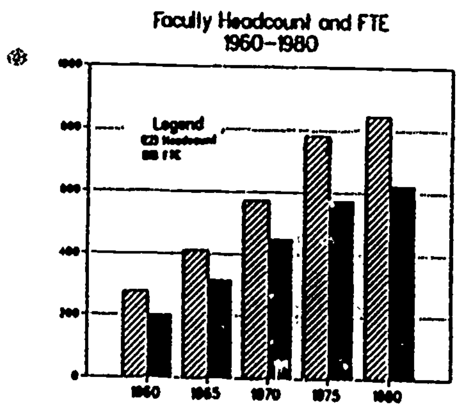
If you are reading this after 1987, there is a high probability that new types of products and new characteristics have become available; you would be advised to seek other works such as those outlined in Section J.

FROM STANDARDS TO PRACTICE

Translating recommended standards into a good design, a good design into a quality graph is still a challenge, even with computerized tools. Currently the most widely used technology for producing graphics in research offices is a microcomputer using graphics routines within spreadsheet software, and printed on a dot matrix printer. The visual quality of the graphs from this combination receives mixed reviews.

For offices and clients accustomed to using no graphs or to using a few rare graphics produced by hand, the results of spreadsheet/dot matrix graphics are often viewed as being of good visual and analytic quality--<u>initially</u>. Very quickly it becomes apparent that this spreadsheet/dot matrix combination is not capable of producing graphs of acceptable quality for many purposes. Even though the results may be technically correct and deemed suitable for simple analyses, the needed power for more complex analyses and the desired quality for presentations (transparencies, overheads, and the like), for publications cannot be achieved over time with this "introductory" combination.

Increased visual and technical quality in graphics can be achieved, for a price, with stand-alone graphics programs, plotters, laser printers, graphics terminals, mainframe graphics programs and so forth. Contrasts in the visual quality of graphic output are demonstrated below, and on the Section III header page. The chart below was produced with TELL-A-GRAPH, a mainframe graphics program that is widely available, and rendered with a plotter. The other two were produced with Lotus 123; one was printed on an Epson FX80 dot matrix printer while the other was plotted on a Hewlett-Packard plotter. All have been reduced on a copier.



The production of graphs of excellence and integrity is not an end in itself but a means to achieving objectives for discovery, analysis, interpretation, reporting, and communication of statistical information in an effective manner. No doubt most offices will be faced with making trade-offs between cost and quality. But the sobering fact is that the availability of state of the are equipment and programs cannot ensure the production of graphs that have integrity and visual excellence--human factors still prevail.

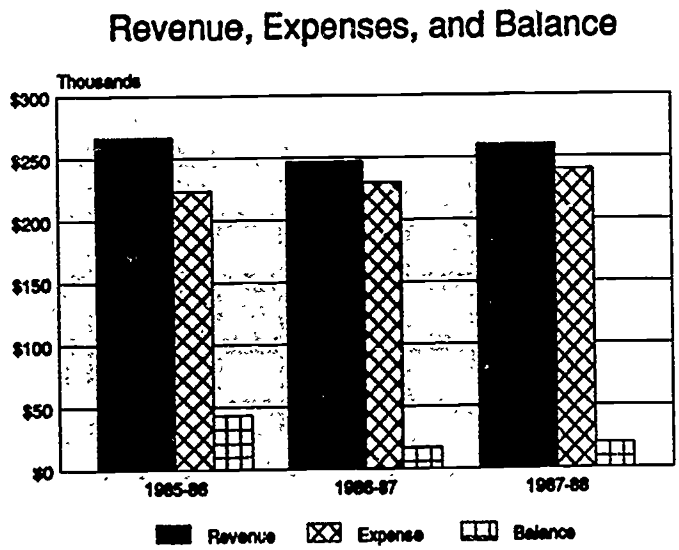
SECTION IV: BIBLIOGRAPHIC AND ORGANIZATIONAL RESOURCES

I: Building a Graphics Library--An Annotated Bibliography

J: Graphics and Computing Publications

K: Graphics Organizations, Associations, and Conferences

L: Coda



Produced with Harvard Presentation Graphics software and printed on a Hewlett-Packard Laserjet printer.

AN INTRODUCTION TO BIBLIOGRAPHIC AND ORGANIZATIONAL RESOURCES

The initial sections of this monograph have provided an introduction to the design, construction, and use of statistical graphics with a computer; and guidance for getting started with graphics. Given the complexity of the subject and the rapid growth and change of the technology, this document has limitations. Researchers need to know about other resources in order to gain greater depth and breadth, and need means for obtaining ongoing information about new products and new applications.

To these ends Part I provides an annotated bibliography of books and articles recommended for consideration for a basic library. Part J outlines books and publications that are sources of information about graphic design, graphical analysis, and computer graphics. Part K lists organizations, associations, and conferences concerned with graphics.

One author notes, "The basic ideas, the methods, and the principles of the book [on graphing data] transcend the medium used to implement them, but the reality is that the computer looms behind the book content because it is the medium of the present for many and of the future for almost all." (Cleveland, p. 2). This view is reflected in the materials below; but, attention is not on computer graphics exclusively. Given the main business of researchers and planners, and given deficiencies in the popular press, resources about graphical methods of data analysis are stressed.

A current how-to-do-it computer graphics book proclaims: "The combination of [a top-selling graphics software program] and the [a best-selling] computer relieves you of all such concerns [of understanding mathematics and graphic design]; now anybody can create sophisticated charts and graphs."(Lambert, 1986, p. xv). If the technology is so powerful and so easy to operate, why would anyone want or need an old fashioned library? The reality, of course, is that much of the technology is oversold, and the knowledge needed to make it work effectively is understated. We have the responsibility then of educating ourselves and our clientele about aspects of statistical analysis, graphic design and the like, in order to contribute effective graphics that further our analyses, presentations, and management functions.

As a prelude to the information that follows, some words of caution are in order. Publications about graphics are written by people from diverse backgrounds--by computer programmers and designers of graphic software, by researchers and statisticians, by artistically trained graphic designers, and by professional writers and consultants. The strengths and limitations of the writers' backgrounds inform and constrain their work. No single publication can do justice to the scope and complexity of graphics. Thus, readers would need to acquire a variety of materials in order to cover topics adequately and should be alert to possible biases and limitations.

Readers are advised to review new materials first hand before purchasing. Titles in this field are seldom very revealing about the nature and scope of their contents. Works with very similar titles might deal with manual graphic production from a graphic arts perspective <u>or</u> with computer generated graphics; they might be for micros <u>or</u> mainframe computers; they might deal with BASIC programs or stand-alone packages. Also, readers should be alert to possible price changes and other outdated information.

I: BUILDING A GRAPHICS LIBRARY--AN ANNOTATED BIBLIOGRAPHY

1. IF YOU COULD CHOOSE ONLY ONE BOOK

Tufte, Edward R. The Visual Display of Quantitative Information. Cheshire, CT: Graphics Press, 1983. (Hardcover, 107 pages, $32)

This book is simply the best. Written by a social science researcher, the book is about the design of statistical graphics; unlike many works, it shows strong concern for and competence in statistics as well as graphic design. The first section consists of a review of the relatively young art and science of statistical graphics. Numerous real illustrations from a variety of sources are included rather than relying merely on simple hypothetical examples. The selections range from "goofs to glories". Tufte deals well with issues of graphical excellence and integrity, and provides a framework for understanding factors causing differences in quality and effectiveness. For example, he depicts and argues against "chartjunk". The second section provides a language for understanding graphics and sound guidance grounded in theory, research, and professional practice.

This is not a step-by-step "how to do it" manual for producing graphics via the computer or by other means. More importantly, it provides the bases for visualizing the range of options and factors involved in the design and production of statistical graphics and for understanding the implications of the choices we face and of the decisions that have been made for us by the designers of our tools and technologies. This book is stronger with respect to printed graphics and less well oriented for designing "presentation" graphics to illustrate oral presentations.

Unlike many works, the value of this book will not diminish with age. In addition to its practical value, this book is intellectually and visually stimulating. Tufte achieves with this book what he expects of statistical graphics--a piece of work that has quality, integrity, and elegance. As he says himself, "this book is a celebration of data graphics."

2. FOR IN-DEPTH INSTRUCTION IN GRAPHIC DESIGN AND ANALYSIS

Cleveland, William S. The Elements of Graphing Data. Monterey, CA: Wadsworth Advanced Books, 1985. (Paperback, 324 pages, $18.95)

This book, written by an experienced Bell Labs researcher, is about graphing scientific data. Principles set forth are relevant both for designing charts for graphical data analysis and for presentations, and well grounded in research and theory. The illustrations are more relevant for analysis and written reports than for oral "presentation" graphics. Further, the conventions for handling elements such as titles, legends, and the like are those found more often in hard sciences rather than social science publications. The author, though, is clearly pragmatic rather than dogmatic about these matters. The book assumes knowledge of elementary statistics. Many of the graphical approaches presented are relatively new, or little known old ones. The first section is devoted to principles of graph construction. The second part covers a wide range of graphical analysis methods including for dealing with logarithms and residuals, and for univariate and multivariate data sets. The final section outlines a paradigm of graphic perception drawing from research and theory. Numerous examples drawn from real data sets are presented.

Little in Cleveland's book is specifically about computer graphics, but clearly the computer looms behind the book. A potential problem is the availability of preprogrammed software to do the graphical analysis methods outlined. [Note: Statgraphics is one microcomputer statistical software program that supports these newer graphical analysis methods; Sygraph, forthcoming, purports to do so as well.]

A outstanding companion book to Cleveland is that by Chambers et al (1985); see below. Those whose vision and practice of graphic analysis are limited to drawing a graph with spreadsheet software after conducting quantitative analyses should find these books eye opening and instructive.

3. A 1987 "GOOD BUY" FOR GETTING STARTED IN MICROCOMPUTER GRAPHICS
Prague, Gary N. and Hammitt, James E. Getting Great Graphics. Blue Ridge Summit, PA: Tab Books, Inc., 1985 (Paperback, 236 pages, $17.95)

If you have made a resolution to get started in computer graphics in 1987 and are looking for general information to help in the selection of software, and if you have an IBM PC/XT/AT or compatible equipment, then this may of use. Written by two computer professionals, this book assumes some knowledge of graphic forms and mathematics and some knowledge of microcomputers. Overall it is easy to read and not overly technical.

The first part covers the design and production of "business" graphics. Initial chapters also include an overview of basic types of graphs and a discussion of graphic components. In later chapters, the production and use of various types of graphs are treated in greater depth. The first section contains many examples produced with common microcomputer software and a dot matrix printer. Thus the reader gets an excellent idea of the style and quality of typical graphics made by recent best-selling (but not necessarily state-of-the-art) programs and hardware. The second section outlines the major types of microcomputer graphics software including stand-alone packages, integrated packages, text slide, and picture processors. Under each type of software a description of the four or five leading packages (1985-1986) is provided.

Graphic designers would find this book lacking because less attention is paid to the artistic aspects of design and production than to other elements. Some analysts would find it of lesser interest and value than other works because most of the examples contain very simple, hypothetical data. This book is more of an introduction and overview rather than a technical "how to do it" manual for particular software or hardware.

This book is suggested with several caveats. First, the software programs discussed are, for the most part, oriented to IBM PC equipment. While the authors do not tout IBM and related equipment directly, they are not forthcoming about this slant and its possible limitations. Second, any software reference such as this will become dated very quickly (if you are reading this after 1987, the second section would probably be of little value about specific products). Even now, there are a number of new, important packages which were not included. Third, the software and hardware section are descriptive and not analytic or evaluative. Thus, if you are facing purchase decisions you would still be advised to seek out more critical in-depth reviews.

4. IF YOU NEED HELP ON THE ARTISTIC SIDE OF GRAPHICS
White, Jan V. Using Charts and Graphs: 1000 Ideas for Visual Persuasion. New York: R.R. Bowker Co., 1984. (Paperback, 202 pages, $24.95)

At some point you will find that the options available with the computer are too limiting or that the artistic and persuasive implications of the choices available are unclear. Written by a graphic designer, this book is a useful resource for artistic ideas and aesthetic recommendations about statistical graphics. It is quite readable and visually interesting.

MacGregor, A.J. Graphics Simplified: How to Plan and Prepare Effective Charts, Graphs, Illustrations, and Other Visual Aids. Toronto: University of Toronto Press, 1979. (Paperback, 64 pages)

This little gem is a concise guide to the preparation of statistical charts. It covers the most basic graphic forms--when and when not to use them--and provides guidelines for selecting the best graphic form for the purpose. Those preparing statistical graphs for publication might find the section on media specifications and choosing illustrations of interest.

These two works do not deal explicitly with computer graphics; this does not diminish their value for ideas and design advice. The numerous illustrations are stylized, generic forms rather than complete, detailed graphics replete with numbers and labels. This is in keeping with the focus of the books which is clearly on the artistic side. However, the authors demonstrate competence in dealing with the statistical elements.

5. IF YOU ARE SEEKING A TECHNICAL OR ENGINEERING PERSPECTIVE
French, T. E., Vierck, C. J., and Foster, R. J. Graphic Science and Design. New York: McGraw-Hill, 1984. (Hardcover, 684 pages, $46.95)

This book is a classic text on engineering graphics and graphic science for students in engineering and technical programs. Four major sections include: basic graphics; space geometry; graphic solutions; and applied graphics in design. The parts on space geometry and graphic solutions are likely to be of most interest and value; these topics are generally not treated in other references. The section of graphic solutions includes a chapter on presenting and analyzing data and a chapter on the construction and use of graphic solutions of equations, including a part on nomographs.

6. FOR MORE COMPREHENSIVE REFERENCES ON STATISTICAL GRAPHICS DESIGN
Schmid, Calvin F. and Schmid, Stanton E. Handbook of Graphic Presentation. New York: John Wiley and Sons, 1979. (Paperback, 308 pages) and Schmid, Calvin F. Statistical Graphics. New York: John Wiley and Sons, 1983. (paperback, 212 pages, $26.50)

These are comprehensive works about the principles and practices of the design and production of statistical charts. Written by applied social science researchers, these volumes draw from multidisciplinary sources and the illustrations use real data. There is some overlap in the two books. The purpose of the Handbook is didactic, concerned with the design and production of a variety of graphic forms; while Statistical Graphics covers a wider range of "issues, problems, critiques, pitfalls, standards, innovations, solutions, principles, and practices". The latter book is supplementary and complementary to the older work.

These books predate much of the available computer software; thus manual production methods are included. This does not diminish their value as reference works. Those dealing in market research may find the discussion on statistical maps and the numerous examples of handling census data to be useful. Some higher education examples are included. Graphic designers would likely be disappointed in the degree to which artistic elements take a back seat to the scientific and statistical aspects of charts. Others may find their standards conservative, and somewhat pedantic.

7. IF YOU NEED ADVANCED INSTRUCTION IN GRAPHIC AND STATISTICAL ANALYSIS

Once research and analysis was largely descriptive and exploratory, and statistical graphics played an important role in this process. But as many advances in research design and analytic techniques were made during the first half of this century, the emphasis moved to hypothesis testing and confirmatory research and the use of statistical graphs waned. Recently a resurgence of exploratory data analysis has emerged along with a renewed interest in the use of graphics in analysis as well as in presentation.

Tukey, John W. Exploratory Data Analysis. Reading, MA.: Addison-Wesley Pub. Co., 1977. (Hardcover, 506 pages)

Chambers, John M., Cleveland, William S., Kleiner, Beat, and Tukey, Paul A. Graphical Methods for Data Analysis. Boston: Duxbury Press, 1983. (Paperback, 395 pages, $20.65)

Hoaglin, David C., Mosteller, Frederick, and Tukey, John W. Understanding Robust and Exploratory Data Analysis. New York: John Wiley and Sons, 1983. (Hardcover, 431 pages)

Hoaglin, David C., Mosteller, Frederick, and Tukey, John W. Exploring Data Tables, Trends, and Shapes. New York: John Wiley and Sons, 1985. (Hardcover, 414 pages)

Afifi, A.A. and Clark, Virginia. Computer-Aided Multivariate Analysis. Belmont, CA.: Lifetime Learning Publications, 1984. (Hardcover, 449 pages)

McClave, J.T. and Benson, P. G. Statistics for Business and Economics. San Francisco: Dellen Publishing Co., 1985. (Hardcover, 982 pages, about $45)

Barnett, Vic (Ed.). Interpreting Multivariate Data. New York: John Wiley and Sons., 1981. (Hardcover, 374 pages)

Wainer, Howard and Thissen, David. "Graphical Data Analysis". Annual Review of Psychology, 1981, Volume 32, pp. 191-214.

Brandenburg, Richard K. and Simpson, William A. "The Use of Computational Diagrams and Nomograms in Higher Education". The AIR Professional File. The Association for Institutional Research, Number 17, Summer 1984.

The Tukey book (1 [illegible]) is the cornerstone of the exploratory data analysis movement; many of the newer approaches rely upon graphical methods such as "stem and leaf" displays and "box and whisker" plots as a central aspect of analysis. The Wainer/Thissen article reviews and illustrates newer graphical approaches to analysis.

The two books by Hoaglin et al (1983, 1985) and Barnett (1981) are advanced texts that place more emphasis on the rationale and development of methods, including a number employing graphical data analysis, and place less emphasis upon illustrating their application and use. The McClave and Benson book is a standard text on business statistics. This is one of the few current texts that includes explicit references to the construction and use of graphics in statistical analysis. The one chapter on the graphical description of data is quite elementary but throughout the text numerous illustrations of statistical graphics are included.

For a research and planning office getting started in graphics, the most useful book could well be Chambers et al (1985) It combines an explicit use of graphical analytic methods with a sound approach to statistical methods. Written by four Bell Labs researchers, this book accommodates those who want to pursue seriously the field of graphical data analysis. The book assumes a knowledge of elementary statistics. Numerous real examples and diverse data sets are included along with tutorial exercises.

A second book of particular value to some offices is the work by Afifi and Clark. Written by and for behavioral and biomedical scientists, it assumes a central role for the use of graphics in statistical analysis. While there is no direct instruction about the construction of graph, the text employs many illustrations of statistical graphics. This practical book that could also be of interest because it illustrates the use of several popular statistical software programs such as SAS, SPSS, and BMDP which are available for microcomputers as well as mainframes. The book focuses on practical techniques such as data preparation and management, the selection of appropriate analyses, and interpretation of results. Real data sets are used throughout. Brandenberg and Simpson provide examples of other graphical approaches of interest. Likewise the book by French, et al (1984), discussed above, contains a chapter on the graphic solutions of equations, and provides instructions for constructing nomographs.

Graphical Statistical Analysis Software

Velleman, P. F. and Hoaglin, D. C. Applications, Basics, and Computing of Exploratory Data Analysis. Belmont, Ca.: Wadsworth, Inc. 1981 (Hardcover)

O'Keeffe, Linda and Klagge, Jay. Statistical Packages for the IBM PC Family. New York: Seybold Pub., Inc., 1986. (Paperback, 157 pages, $19.95)

Wright, Thomas. New Directions in Engineering/Scientific Graphics. San Diego: ISSCO, 1985. (Paperback, free)

Bridges, K.W. and Kim, Sam. Scientific Chart Design. San Diego, CA: ISSCO, 1985. (Paperback, 86 pages, $8.50)

Bridges, K.W. and Pitko, Jon. Design Ideas Using Data Tables. San Diego: ISSCO, 1986. (Paperback)

A problem for newer approaches to graphic analysis is the availability of computer software to support the graphics. Velleman et al (1981) provides Fortran subroutines for conducting many of the graphic analyses. Mainframe statistical software, for the most part, is geared to more traditional uses of graphics; the Wright and Bridges books instruct in the use of one of the most widely available mainframe graphics packages, TELL-A-GRAF.

A direction of note is the release of microcomputer versions of popular mainframe programs such as SPSS, SAS, and BMDP; these include traditional graphics capabilities. O'Keeffe and Slagge review nine statistical packages for the microcomputer, including an appraisal of their graphics capabilities. Currently there are many more software options for IBM equipment than for the Macintosh. Leading Macintosh programs include Statworks and Cricket Graph. For the IBM environment two programs supporting newer methods of graphical analysis include Statgraphics and Sygraph (forthcoming). The program Systat is available for both.

8. FROM THE ANNALS OF INSTITUTIONAL RESEARCH

Lins, L. Joseph. "Data Reporting" in Schietinger, E.F. (Ed.). Introductory Papers on Institutional Research. Atlanta, GA: SREB, pp. 173-193, 1968. (Paperback; also available from University Microfilms)

This volume consists of papers on basic functions of institutional research. While some material is dated, the chapter by Lins is still a sound, brief, basic introductory guide to the design, production and use of graphics. An added benefit is that the first part of Lins' chapter deals with the design and production of tabular presentations. Strengths, weaknesses and roles of tables, graphs, and prose are discussed.

9. IF YOUR SPECIALITY IS BUDGET AND FINANCE

Jarett, Irwin M. Computer Graphics and Reporting Financial Data. New York: John Wiley and Sons, 1983. (Hardcover, 360 pages) Also forthcoming as a John Wiley paperback, 1987, about $25.

This handbook is intended as a source of ideas and guidelines for the design of a Graphic Management Information System with particular focus on financial information. One chapter is devoted to standards for printed graphics to accompany financial statements recommended by the American Institute of Certified Public Accountants. As a comprehensive and well organized treatment of financial report graphics, this book has much to recommend it. However, readers should be aware that the illustrations are from business, that the suggested graphics standards differ in some respects from those of other experts, and many suggested applications would require very powerful and flexible programs to produce the graphics.

10. IF YOU NEED A STEP-BY-STEP "HOW TO DO IT" BOOK FOR THE COMPUTER

Nitz, Lawrence H. Business Analysis and Graphics with LOTUS 123. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1985. (Paperback, 206 pages, $17.95)

Osgood, William R. and Curtin. Dennis P. Business Graphics with LOTUS 123. Somerville, MA: Curtin and London, Inc.,1984. (Paperback, 202 pages, $20)

Curtin, D. P. and Alves, J. R. Planning and Budgeting with LOTUS SYMPHONY. Somerville, MA: Curtin and London, Inc., 1984. (Paperback, 186 pages, $20)

Lambert, Steve. Presentation Graphics on the Apple Macintosh. Belleville, WA: Microsoft Press, 1984. (paperback, 263 pages, $18.95) and Lambert, Steve. Presentation Graphics on the IBM PC and Compatibles. Belleville, WA: Microsoft Press, 1986. (paperback, 278 pages, $19.95)

McComb, Gordon and Smith Leslie S. Macintosh Graphics. New York: New American Library, 1985. (Paperback, 345 pages, $16.95)

The first three books are representative of a number devoted to particular integrated software with graphics capabilities. Those involved in business and financial applications may find these most useful. A strength in the illustrations is the direct linkage between the analysis and graphics. How-to-do-it books for dedicated microcomputer graphics software are just beginning to appear. The two by Lambert are devoted solely to instructions for producing graphs with the Chart software by Microsoft, a best-selling microcomputer graphics program.

The McComb/Smith work is a reference encyclopedia for Macintosh graphics. However, the focus is more on pictorial graphics supported by MacDraw and MacPaint than on statistical graphics; sections on Basic and Pascal are included. There is an appendix of graphics resources for the Macintosh.

11. IF YOU HAVE TO GIVE THE PRESENTATION AS WELL AS CREATE THE GRAPHS

Humes, James C. with Paller, William. How to Give the Best Presentation of Your Life. San Diego, CA: Integrated Software Systems Corporation, 1983. (paperback, 44 pages, $3.95)

Those inexperienced in public speaking may find this a helpful beginning resource. Written by a corporate communications consultant with the assistance of a graphics professional, this is for the manager. Topics include: how to package a talk, how to control fear, how to use humor, how to deal with hostile questions and bad situations, and how to get and use the right visuals. Some will find this superficial and manipulative, and some will disagree with some of the graphics advice. A quality reference in this area has not been found. Kodak has several publications, including one on preparing slides and one similar to the Humes book.

12. IF YOU REALLY WANT TO DO SOME PROGRAMMING YOURSELF

Waite, Mitchell. Computer Graphics Primer. Indianapolis: Howard W. Sams, 1979. (Paperback, 179 pages, $14.95)

Grillo, John P. and Robertson, J. Douglas. Graphics for the Macintosh: An Idea Book. New York: CBS Computing Books. Holt, Rhinehart, and Winston, 1985. (Paperback, 210 pages, $17.95)

Waite, Mitchell and Morgan, Christopher L. Graphics Primer for the IBM PC. Berkeley, CA: Osborne/McGraw-Hill, 1983. (Paperback, 440 pages, $21.95)

Lord, Kenniston W. Graphics with the IBM PC. Glenview, IL: Scott, Foresman and Company, 1985. (Paperback, 304 pages, $19.95)

Ford, Nelson. Business Graphics for the IBM PC. Berkeley, CA: SYBEX, Inc., 1984. (Paperback, 256 pages, $9.95)

There are many publications covering beginning instruction in graphics programming, generally in BASIC. The quality of available programming books is highly variable; users are urged to review possible acquisitions in person rather than sight unseen. The Waite (1979) and Grillo books are oriented to Apple products while the Waite book (1983), and the Lord and Ford books are directed at IBM PC and compatible products. The Ford book focuses on statistical graphs while the others have a more general graphics orientation.

In addition to programming instructions, the Lord book provides a basic introduction to several popular dedicated graphics software packages including BPS Business Graphics and EnerGraphics; there is not much overlap between this book and the Prague book in Number 3. Also, the Waite (1979) book discusses graphics technology and equipment, the latter is somewhat dated regarding specific products.

13. IF YOU HAVE TO COPE WITHOUT A COMPUTER
Craver, John S. Graph Paper From Your Copier. Tuscon, AZ: H.P. Books, 1980. (Paperback, 232 pages, $12.95)

This book would be a valuable resource for those who do not have access to a computer. At the same time, because of its approach and scope, it has the potential for filling a niche even in a high technology office. The first 25 pages are devoted to guidelines for drawing statistical graphs. Basic topics are discussed at a level that would be useful to and easy to grasp by those with little or no knowledge about producing graphs. Topics covered include: data collection, conversion, and rounding; determining scales and grids; and similar primary areas. In addition, more advanced or unusual topics such as log, semi-log, and 3-D graphics; isometric and orthographic projections; and triangular-coordinate grids are discussed. These areas are covered in few publications. The final 200 pages contain graph paper masters designed for reproduction on a copier. Samples include: simple cross-sectionals, time series, log and semi-log, 3-D's, polar coordinates, probability grids and some maps. A caveat about this book is in order. Graphs constructed on reproduced grids or on classic commercial graph paper cannot yield high quality graphics for presentation and publication largely because the excess number of grid lines detract from clearly showcasing the data. However, these forms may be adequate for draft designs and for some analysis.

14. IF YOU WANT TO DESIGN A GRAPHICS INFORMATION SYSTEM
Sprague, Ralph H. and Carlson, Eric D. Building Effective Decision Support Systems. Englewood Cliffs, NJ: Prentice-Hall, 1982. (Hardcover, 317 pages)

Bertin, Jacques. Graphics and Graphic Information Processing. Berlin: deGruyter, 1977. (Hardback, 267 pages)

Blake, George B. "Graphic Shorthand as an Aid to Managers," Harvard Business Review, March-April 1978, pp. 7-12.

Dickson, Gary W. and Lehman, John A. "Building Effective Management Graphics," Insight, Summer 1986, pp. 10-12.

Jarett, see above in Number 9, and ISSCO references under Number 3.

Larson, James A. "A Visual Approach to Browsing in a Database Environment." IEEE Computer Graphics and Applications. Volume 6, Number 6, June 1986, pp. 62-72.

Graphics capabilities are recognized a important components of a decision support system or executive information system. Graphics literature is just beginning to emerge. Sprague and Carlson and Bertin, provide useful conceptual frameworks for thinking about these matters. Articles in Insight about "production graphics" and other applications are of value.

J: GRAPHICS AND COMPUTING PUBLICATIONS

A rich variety of resources are available for those interested in computer graphics and applications. The publications listed below differ in scope, focus, and technical level. Most people find that different resources are useful at different stages of experience. Publications devoted to a single vendor's products or to a single type of system are differentiated from general publications covering a number of systems.

Most of the materials are available on the newsstand and in libraries. Offices may qualify for free subscriptions to some magazines. The monthly publications listed below tend to have articles on graphics two to four times a year. The weeklies tend to have feature articles on graphics about once a month, with special buyer's guides or supplements on graphics two to four times a year.

1. Weeklies-General

<u>InfoWorld</u>
$39 a year (51 issues)
InfoWorld
P.O. Box 1018
Southeastern, PA 19398

For those microcomputer users wanting to keep up to date on developments and news, <u>InfoWorld</u> is one of the most timely and readable publications. This tabloid magazine would be of interest and value to a wide range of users. It is not devoted to a particular brand of hardware or software, but has the greatest coverage for IBM and Macintosh products. In addition to industry news and new product descriptions, there are numerous reviews of individual products; more software is reviewed than equipment. The norm is for single critiques rather than for comparative reviews of related products in a single issue, but prior product ratings are included each week. There are no regular features on graphics, but graphics software is described and reviewed periodically. Examples of recent articles are:

a. Buyers Guide to Presentation Graphics. Vol. 9, Iss. 12, March 23, 1987.

b. Special Report on Presentation Graphics Software. Volume 8, Issue 38, September 22, 1986.
c. Special Report on Statistics Software. Vol. 8, Iss. 35, Sept. 1, 1986.

<u>Computerworld</u>
$44 a year (58 issues)
CW Communications
Box 9171
Framingham, MA 01701-9171

The primary audience for this weekly tabloid is MIS professionals. Its focus is news and information about mainframe and mini computers more so than for microcomputers. The bulk of each issue is devoted to brief information items; there are no regular product reviews. Each issue also contains an in depth treatment or special report of a particular subject such as graphics. Several times a year there are supplements on special topics such as graphics. Examples of graphics features include:

a. Special supplement on graphics: Vol. 20, No. 19a, May 14, 1986.
b. Feature article on graphics: Volume 20, Number 17, April 21, 1986.
c. Special supplement on CAD/CAM: Volume 20, Number 11a, March 13, 1986.
d. Special supplement on graphics: Volume 19, Number 15A, April 17, 1985.
e. Special report on graphics systems: Volume 19, No. 12, March 25, 1985.

2. Weeklies-Specific System Products

PC Week

$120 a year (51 issues) An office may qualify for free subscription.
PC Week
One Park Avenue
New York, NY 10016

For those with IBM PC's or compatibles, this weekly tabloid is one of the most timely and informative resources available; some information about Macintosh and other products is included. A major portion of each issue is devoted to brief items about trends, issues, and new products. Also, there are special feature articles and regular sections (Buyer's Guides, Focus on ...) that treat specific areas such as monitors, boards, printers, plotters, and specific types of software. Buyer's guides are comprehensive comparative descriptions of features of software or hardware rather than critical comparative reviews of performance. Nonetheless, these guides, with comprehensive glossaries of terms, are helpful in providing information about factors and capabilities to consider in software and equipment selection. At least once a month there is a substantive article, guide, or focus section on a topic or area related to graphics. Recent graphics and related features include:

a. Buyer's Guide/Focus on Statistical/Analysis Software. Vol. 4, No. 11, March 17, 1987.
b. Buyer's Guide/Focus on Graphics Software. Volume 4, Number 10, March 10, 1987.
c. Buyer's Guide on Statistical Software. Volume 3, Number 38, September 23, 1986.

d. Special Supplement on Graphics. Volume 3, Number 33, August 19, 1986.
e. Buyer's Guide on Color Plotters. Volume 3, Number 23, June 10, 1986.
f. Focus on Graphics. Volume 3, Number 22, June 3, 1986.

g. Focus on Graphics; Buyer's Guide on Decision Support Systems (including graphics features). Volume 3, Number 18, May 6, 1986.
h. Buyer's Guide on Statistical Software. Vol. 3, No. 15, April 15, 1986.
i. Focus on Graphics. Volume 3, Number 3, January 21, 1986.

j. Focus on Graphics Software. Volume 3, Number 6, February 11, 1986.
k. Focus on CAD/CAM. Volume 3, Number 5, February 4, 1986.
l. Buyer's Guide to Freehand Graphics. Volume 3, No. 16, April 22, 1986.

m. "The Do's and Don'ts of Presentation Graphics"; Buyer's Guide to Freehand Graphics. Volume 2, Number 31, August 4, 1985.
n. Graphics Buyer's Guide. Special supplement, Section 2. Volume 2, Number 46, November 19, 1985.

3. **Monthlies/Bi-Weeklies--General**

Personal Computing
$18 a year (12 issues)
Hayden Publishing Company,Inc.
10 Mulholland Drive
Hasbrouck Heights, NJ 07604

This is a general publication for personal and microcomputer users, covering a wide variety of hardware and software systems. Contents include feature articles about trends and issues, how-to-do-it and applications articles, and product announcements and reviews. Products tend to be reviewed, in brief, one at a time rather than in comparison with others. Reviews are critical and analytical. Graphics products are featured and reviewed from time to time. Examples include:

a. O"Malley, Christopher. "Driving Home Your Point," Volume 10, Number 8, August 1986.
b. Byrne, Richard B. "Getting the Picture with Graphics," Volume 9, Number 12, December 1985.
c. Stahr, Lisa B. "Graphically Speaking," Volume 8, Number 11, Nov. 1984.

Software News
$40 a year (12 issues) An office may qualify for a free subscription.
Software News
Circulation Department
P.O. Box 542
Winchester, MA 01890

This publication focuses on microcomputer software, providing information about new products and descriptive comparisons rather than critical reviews. A regular monthly feature is the "Corporate Best Sellers List" of software. There are occasional brief articles and reviews about graphics software. For example, see:

a. Three articles on graphics: mainframe and microcomputing comparisons, characteristics desired by users, and a list of about 75 software vendors. Volume 5, Number 1, January 1985.

BYTE
$21 a year (12 issues)
BYTE Subscriptions
POB 590
Martinsville, NJ 08836

This venerable publication is devoted to "small systems". The articles tend to be fairly technical. Reviews, which tend to be critical assessment and not just descriptions, cover both individual products and comparisons of several related products. There are periodic articles about graphics issues and products. A recent example is:

a. Special issue on graphics hardware. Volume 10, Number 12, November 1985.

4. **Monthlies/Bi-Weeklies--Specific System Products**
There are one or more publications focused on the equipment and supporting software of each major microcomputer manufacturer. It behooves the reader to know that some publications are directly or quite closely associated with the manufacturer, while others are clearly independent. Some are supported by publishing houses while others are by user groups. Listed below are examples of publications oriented to IBM microcomputers (and to compatibles) and to Apple products. As noted in the preface, this focus is because of the large installed market for these products.

PC WORLD
$24 a year (12 issues)
Subscription Department
PO Box 51833
Boulder, CO 80321-1833

This magazine bills itself as the comprehensive guide to IBM personal computers and compatibles. Articles on graphics include:

a. Graphics Forum. Volume 5, Number 2, February 1987.
b. Articles and reviews of graphics programs. Vol. 4, No. 2, Feb. 1986.
c. Annual review issue. Volume 3, Number 12, December 1985.
d. Wilcox, David L. "The Boom in Business Graphics," Volume 2, Number 5, May 1985.

PC Magazine
$35 a year (Bi-weekly)
PC Magazine
PO Box 2445
Boulder, CO 80322

This is a second major publication devoted to IBM microcomputing software and hardware. Each year there are several features and reviews of graphics programs and equipment. Articles and reviews include:

a. Review of 44 graphics packages. Volume 6, Number 5, March 10, 1987.
b. Animation and dynamic graphics. Volume 5, Number 18, October 28, 1986.
c. Lab tests and reviews of 24 plotters. Volume 4, No. 26, Dec. 24, 1985.
d. Review of 36 graphics packages. Volume 4, Number 11, June 11, 1985.
e. Several articles on graphics. Volume 4, Number 8, April 23, 1985.
e. Special report on business graphics. Volume 4, Number 1, Jan. 8, 1985.

Magazines devoted to Macintosh and other Apple products include:

Macworld
$19.97 and year (12 issues)
Macworld
Subscription Department
P.B. Box 5166
Boulder, CO 80321-1666

MacUser
$23 a Year (12 issues)
MacUser
25 West 39th Street
New York, NY 10018

The MACazine
$18 a year (12 issues)
Icon Concepts Corp.
P.O. Box 1936
Athens, TX 75751

MacBriefs
$12 a year (6issues)
MacBriefs
P.O. Box 2178
Huntington Beach, CA 92647-0178

A+
$24.95 a year (12 issues)
Box 2965
Boulder, CO 80322

See the Whole Earth Review, No. 50, Spring 1986 for a comparative review of the first four of these magazines.

LOTUS
$18 a year (12 issues)
Lotus Publishing Corporation
One Broadway
Cambridge, MA 02142

This is a monthly publication, in its second year of operation, dedicated to the users of LOTUS 123 and Symphony. It contains feature articles about applications using these products, plus regular columns such as on the use of macros, and information on the hardware, software, and publications. There are occasional articles about graphics, and announcements and advertisements about products that enhance the use of graphics.

5. **Monthlies/Quarterlies-Graphics**

Insight
$18 a year (4 issues) Provided without charge to CA/ISSCO users.
Computer Associated/Integrated Software Systems Corporation
10505 Sorrento Valley Road
San Diego, CA 92121

This is the house organ of one of the largest producers of mainframe graphics. It includes stimulating articles and features on real graphics applications.

Computer Graphics Today (an official publication of the National Computer Graphics Association)
$12 a year (12 issues)
Media Horizons Inc.
50 West 23rd St.
New York, NY 10010-5205

This is a news tabloid dedicated to graphics. It covers industry news and product announcements, but does not include focused product reviews. Examples of coverage are:

a. Directory of 200 companies offering nearly 600 pieces of literature on computer graphics software and hardware. Vol. 2, No. 12, Dec. 1985.
b. Directory of vendors of graphics workstations and terminals. Volume 2, No. 11, November 1985.

Computer Graphics and Applications
$120 a year (12 issues) Reduced prices are available for members of IEEE Computing Society, SIGGRAPH, ACM, and the National Computer Graphics Association.
IEEE Computer Society
10662 Los Vaqueros Circle
Los Alamitos, CA 90720-2578

This monthly publication is for those interested in more advanced, and more technical topics. In addition to articles, the magazine includes a New Products section (hardware, software, and literature) but these are announcements and descriptions rather than reviews; a Professional Calendar of conferences and workshops is also included.

6. **Buyer's Guides/Catalogs**

Each year a number of independent buyer's guides and catalogs are also published. These cover a full range of available software and hardware for specific brands of microcomputer equipment; generally a brief product description is included, but seldom are there comparative reviews. One example that does contain reviews is:

Whole Earth Software Catalog 2.0
$17.50 a year (4 issues)
Whole Earth Review
P.O. Box 15187
Santa Ana, CA 92705

7. Reviews

Several independent organizations publish periodic product listings and comprehensive comparative reviews of software and hardware. For example:

Datapro Reports
Quarterly Reports
Datapro Research Corp.
1805 Underwood Blvd.
Delran, NJ 08075

These detailed and costly reports are beyond the range of most offices, but might be available at the computing center, microcomputing education center, or in some libraries. In addition to comprehensive descriptions and reviews of products, the reports include information about the programs most active on the market, and comparative product ratings. Approximately ten of the best selling microcomputer graphics programs are reviewed and rated in the January 1987 volume.

8. Bibliographic Resources

a. Machover, Carl. "Background and Source Information about Computer Graphics". IEEE Computer Graphics and Applications. Volume 5, No. 1, January 1985.
b. Machover, Carl. Earlier versions of the article above appeared in IEEE CG&A. Volume 3, Number 1, January/February 1983, and IEEE CG&A. Volume 1, Number 1, January 1981.

K: GRAPHICS ORGANIZATIONS, ASSOCIATIONS, AND CONFERENCES

WORLD COMPUTER GRAPHICS ASSOCIATION
2033 M Street NW, Suite 333
Washington, DC 20036

This organizations sponsors or co-sponsors a number of international graphics shows and meetings each year.

NATIONAL COMPUTER GRAPHICS ASSOCIATION
8401 Arlington Blvd.
Fairfax, VA 22031

This organization sponsors a large annual meeting that includes hardware and software expositions, workshops, technical papers, and panels on topics of wide scope and interest, including business graphics, and statistical and analytical applications. It publishes Computer Graphics Today. There are a number of regional or state groups affiliated with NCGA. The more active groups meet monthly, usually featuring a speaker talking about applications, a new product demonstration, or a tour of a graphic design facility.

SIGGRAPH
Association for Computer Machinery/Siggraph
1133 Ave. of the Americas
New York, NY 10036

SIGGRAPH is a special interest group on computer graphics of the Association for Computing Machinery. There is a large annual conference and exhibition on computer graphics that features technical papers, panels, workshops, and exhibits; technical proceedings are published.

ISSCO WEEK/SEMINARS
Computer Associates International/Integrated Systems Software Corporation
10505 Sorrento Valley Road
San Diego, CA 92121

This manufacturer of mainframe graphics software sponsors a large annual meeting for users. Components include: workshops, seminars, panels, exhibits, and demonstrations related to their graphics software such as TELL-A-GRAPH and DISSPLA. The company also sponsors regular product and application briefings, free of charge, at a number of regional sites, as well as training workshops (at the trainee's or institution's expense). The company has issued a number of monographs and also publishes a graphics quarterly, Insight.

OTHER SOURCES

Other resources include: local microcomputer and software user groups, computer bulletin boards, and electronic conferences, and national electronic resources such as CompuServe and The Source.

L: CODA

What it means to be engaged in the field of statistical graphics has been expressed well:

"A graphic is not only a drawing; it is a responsibility, sometimes a weighty one, in decision-making. A graphic is not 'drawn' once and for all; it is 'constructed' and reconstructed until it reveals all the relationships constituted by the interplay of the data. The best graphic operations are those carried out by the decision-maker himself (Bertin, p. 16).

The proof of statistical graphics is not merely in their production, nor only in the viewing--but in the extraction and processing of information from them with clarity and accuracy.

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3. Bertin, Jacques. Graphics and Graphic Information Processing. Berlin: deGruyter, 1977.
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5. Cleveland, William S. The Elements of Graphing Data. Monterey, CA: Wadsworth Advanced Books and Software, 1985.
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7. French, Thomas E., Vierck, Charles J., and Foster, Robert J. Graphic Science and Design. New York: McGraw-Hill, 1984.
8. Harvard Presentation Graphics Manual. Mountain View, CA: Software Publishing Corp., 1986.
9. Humes, James C. with Paller, William. How to Give the Best Presentation of Your Life. San Diego, CA: ISSCO., 1983.
10. __________. Choosing the Right Chart. San Diego, CA: ISSCO, 1981.
11. __________. Choosing and Justifying the Right Graphics Software. San Diego, CA: ISSCO, 1982.
12. Lambert, Steve. Presentation Graphics on the IBM PC and Compatibles. Belleville, WA: Microsoft Press, 1986.
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KEEPING UP TO DATE-TALKING BACK TO THE EDITOR

The field of computer graphics is growing so rapidly that it is impossible for any individual to keep up with the field. One means is to share with your colleagues the "good news and bad news" about software, publications, applications and the like.

1. What books and publications should be added to the bibliography?

2. What graphics software are you using? What are its strengths and weaknesses? What equipment is required to run it?

3. Have you designed special graphics applications that other should know about? Describe or send materials.

4. Do you have a favorite example of an effective graph? Of a terrible graph? Send them along.

5. What topics would you like to see covered in possible future monographs or in AIR workshops, professional development opportunities?

Return to: R. Sue Mims, The Association for Institutional Research, 314 Stone Building, Florida State University, Tallahassee, Florida 32306.