To the Graduate Council:

I am submitting herewith a dissertation written by A. Faye Borthick entitled "Selection of Computers for Small Accounting Systems: An Interactive Multi-Criteria Approach." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Business Administration.

James H. Scheiner, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

SELECTION OF COMPUTERS FOR SMALL ACCOUNTING SYSTEMS: AN INTERACTIVE MULTI-CRITERIA APPROACH

A Dissertation

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Degree

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ABSTRACT

The research objective was to formulate an approach to match small business computers (SBCs) to accounting applications incorporating the complexity of a multi-criteria selection context. Heretofore, selection procedures for SBCs had been largely subjective and ad hoc.

The research comprised three phases:

1. Cluster analysis in conjunction with factor analysis to characterize the SBC population,
2. Mapping sample user requirements onto a subset of SBCs and
3. Implementation and execution of the analytic hierarchy process (AHP) for the multi-criteria selection of an SBC for the accounting functions of a hypothetical small business.

Cluster analysis failed to detect multiple, distinct well-defined clusters of SBCs, suggesting a form of market maturity for SBCs. Three factors were interpreted from factor analysis of product variables: capacity for concurrent use, execution speed and maximum I/O configuration. Factor analysis of user opinion variables gave three factors: satisfaction of expectations, perceived competence and constraints on operation.

Sample user requirements for accounting applications for the three product variables were mapped onto the SBC population with logical operations to identify a feasible subset of SBCs. An attribute hierarchy was composed from the factor variables with the overall objective of selection of an SBC. The interactive implementation of the AHP included marginal analysis.

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CHAPTER I

MOTIVATION

The Selection Problem

Potential users of small business computers (SBCs), computers costing $50,000 or less, face a difficult selection decision because no controlling links exist between specifications of performance for components of computing systems and contributions of the systems to the productivity of individuals and organizations. The crux of the matter is that there is "no generally-accepted way of measuring data processing work" (Phister, 1979, p. 554).

The experience to date reveals that "preoccupation with equipment decisions seems to have impeded progress by diverting attention from areas that really determine success" (Ein-Dor and Segev, 1981, p. 65). Three of these areas are the degree of conformance of the computer system to the structure of the organization (Mansour, 1978), the difficulty of implementation (Lucas, 1981), and the appropriateness of management practice (McFarlan, 1981; Raysman, 1981). King and Schrems found problems in computer system budgeting including "difficulties of assigning costs and benefits, failure to identify alternatives, failure to specify the critical characteristics demanded of the system, and social and political realities" (1978, p. 33). After considering several approaches to determining the financial benefits of a computerized information system, Kleijnen observed that "(d)eveloping an adequate model, however, remains an art!" (1980, p. 192). Thus,

as of 1980, there was no paradigm for computer selection clearly superior to competing approaches.

The complexity of SBC selection makes it inappropriate to treat the problem as a special case of capital budgeting. What is needed is a way of evaluating SBCs in terms of the multiple criteria which have been identified as influencing the overall success of the computer system. The criteria include objective factors, such as price, hardware configuration and delivery date, and subjective factors, such as software performance, fit of the system with the organizational structure and individual and organizational productivity. This research considers SBC selection a multi-criteria decision.

Importance of Research

Research on SBC selection is important to users because of (1) the growing proportion of company resources devoted to computing systems, (2) the critical nature of system performance as computing pervades company operations and (3) the increasing number of small businesses using computer systems. Datapro forecast that SBC shipments in the U.S. would approach $4 billion by 1982, representing almost 50,000 systems (1981b, p. M11-050-201).

Independent accountants have a threefold interest in SBC selection on behalf of their clients: (1) the provision of management advisory services, (2) a professional obligation and (3) a professional liability. Management advisory services comprise planning, selection and implementation of client systems (Barfield, 1976; Blankenship and Schaller, 1976; Boer and Barcus, 1981; Holmes, 1979; Schwartz, 1979).

The professional obligation invokes the duty to insure that the systems with which they are associated meet appropriate standards (AICPA, 1981; Bjork, 1975) such as safeguarding assets, maintaining data integrity, and achieving objectives effectively and efficiently (Weber, 1982). Whether in an audit, review or compilation engagement, the professional liability spans the potential loss of reputation and payment of damages if a client were able to prove that the accountant were party to misrepresentation of a system which did not perform as promised by the vendor. Independent accountants are also interested in SBC selection on behalf of their use in their own organizations.

SBC vendors should be interested in selection research because they do not want their products to be at a competitive disadvantage due to poor selection procedures. In the long run, reputable manufacturers do not want users to choose their systems if unsuitable because of the risk of user dissatisfaction.

Research Objectives

The research question associated with SBC selection is whether a more effective way to select SBCs exists than the largely subjective and ad hoc procedures used currently. Cohen (1980), Osborne (1981) and Shaw (1981) provide examples of current practice. The purpose of this research is to formulate an approach to accomplish the matching of SBCs with their intended accounting uses which incorporates the complexity of the multi-criteria context with a degree of objectivity not previously attained.

The means of achieving the research objective is the following sequence:

1. Cluster analysis of SBCs and determination of discriminant functions for each cluster (or factor analysis to characterize a continuum),
2. Mapping of forecasts of business transactions in small business accounting applications onto the factors identified in the cluster analysis and
3. Formulation of an interactive analytic hierarchy process for the multi-criteria selection of SBCs for accounting applications in small businesses.

Presentation of Research

Chapter II describes previous research germane to the accomplishment of the research objective. The methodology for achieving the research objective is detailed in Chapter III. The results, presented in Chapter IV, demonstrate how the research objective was accomplished. Chapter V contains a summary and a discussion of the results.

CHAPTER II

PREVIOUS RESEARCH

Small Business Computers

Using 1970-77 data, Cale, Gremillion and McKenney (1979) were unable to establish a simple price versus power relationship for SBCs. The variables in their regression analysis were price, memory size, direct access storage capacity and the year the system was introduced. Although failing to find a a relationship for SBCs for the entire 1970-77 period, they did find:

1. A stable price/performance relationship for general purpose computer systems, defined as the large and intermediate systems manufactured by the seven largest computer companies, and
2. A price/performance relationship for small business computers which began to stabilize in 1974. They attributed the pre-1974 absence of a model to market immaturity reflected in the lack of consistent pricing policies across manufacturers.

For 1976-77, Cale, Gremillion and McKenney found the SBC model predicting lower prices for the same memory/direct access capacity than did the one for general purpose systems. They ascribed the cost differential to:

1. The more limited purpose nature of SBCs, reducing the number of different services the vendor must provide and

2. The lesser complexity of SBCs, allowing compressed design and development cycles with the result of more rapid introduction of improved systems (1979, p. 232).

Fedorowicz (1981) found minor discrepancies in the Cale, Gremillion and McKenney regression model. After accounting for the errors, she reached the same general conclusion, namely, that in the main cost was the best estimate of computer system performance.

Workload and Processing Capacity

Several procedures have been suggested and used for representing a set of jobs or applications processed by a computing system in a given time period, called a workload. Workload characteristics embody the demands jobs place on the system for memory, processor time, input/output devices and other resources.

Benchmarks. Joslin (1965) proposed benchmark jobstreams for which representative jobs are chosen. The benchmark can be validated for its statistical distribution characteristics against average resource usage. Benchmark results are a common means of evaluating alternative computer systems for expansion or replacement. In practice, one selects jobs for the benchmark which are deemed representative and which are portable in the sense that the job (comprising the program, the data and specialized resources) can be reproduced easily. Jobs can also be selected on a statistical basis as suggested by Shope, et al. (1979) with adjustment to achieve representativeness.

Synthetic workloads. The alternative to composing a benchmark from actual jobs is to create a synthetic workload, a contrived workload whose essential characteristics match those of the actual workload. The use of benchmarks and synthetic workloads is the same, as an abbreviated but faithful surrogate for the actual workload to evaluate performance of proposed computer systems. Techniques for constructing synthetic workloads include, for example, estimation of joint probability distributions of demands (Shreenivasan and Kleinman, 1974); construction of job scripts comprising sequences of processor intervals and I/O sequences (Mead and Schwetman, 1978); and clustering to model the workload (Agrawala and Mohr, 1978). Amer (1979) suggested experimental designs based on binomial distributions for estimating confidence intervals for statements about the accuracy of proposed selections.

Workload characterizations have customarily been applied to large computing systems. A substantial difficulty in applying them to SBCs is that the potential user may have neither extant jobs from which to compose a benchmark nor computer job accounting data from which to construct a synthetic workload.

Software physics. The lack of actual jobs and computer accounting data also precludes use of software physics, a theory concerned with the meaning and use of computer measurement data (Kolence, 1975, 1976). Since there are no data, software physics cannot relate software work (a quantification of the workload) to software power (a quantification of the rate at which a computer system performs software work).

Observing that forecasts for new applications were the most difficult to develop accurately, Kolence proposed that software physics be expanded to include characterizations of new applications based on natural forecast units (NFU). An NFU is "any natural business transaction or similar quantity which can be correlated directly with the capacity usage of the corresponding application to be forecasted" (Kolence, 1976, p. 1-14). This approach has not been developed for the general case, however, "due to the lack of sufficient empirical data" (Kolence, 1976, p. 1-15). Ivey (1979), however, applied the NFU concept to forecast academic computing capacity requirements based on student enrollment and the number of faculty.

Requirements analysis. Recent attempts to structure requirements analysis, the specification of what users want in terms of data flows and processes, are Miyamoto and Yeh's (1981) requirements engineering methodology and DeMarco's (1979) structured analysis. Davis (1982) explored the selection of an information requirements determination strategy and observed that organizational complexity and constraints on human information processing dictate a contingency approach to requirements analysis. The product of such techniques is a requirements document, but no direct way to map the requirements onto capacity usage exists.

Summary. Extant techniques for relating workload to processing capacity depend on the existence of performance and accounting data for the applications themselves. Hence first time computer users cannot avail themselves of capacity forecasting based on workload

characterizations. Requirements analysis also fails as a forecast method for capacity usage.

Multi-Criteria Models: Optimization

Multi-attribute decisions are those whose outcomes have several dimensions of value. Quantitative multi-attribute models depend on decision makers specifying their preferences over the decision variables. The preference function V(x), where x = (x(1), x(2), ..., x(n)) is the vector of the outcome variables, is continuous and real-valued such that V(x") > V(x') if and only if x" is preferred to x'. For V which is differentiable, smooth and concave, the optimal alternative is the feasible vector x* which maximizes V(x*).

Global preference functions. The global procedure requires that the decision maker's preferences be specified in terms of "percentage rates of change of the tradeoffs along the indifference curves" (Oppenheimer, 1978, p. 677). The two global preference functions which have been derived are the sum-of-exponentials and the sum-of-powers. The former implies that a decision maker who is indifferent between any x' and x" is also indifferent between (x' + d) and (x" + d) where d = (d(1), d(2), ..., d(n)). The latter implies that decision makers become less sensitive to substitutions among attributes as they accumulate more of each attribute. Applied to small regions, the sum-of-exponentials and sum-of-powers preference functions are reasonable. Applied globally, however, the preference models are very restrictive, viz., they require specification of the tradeoffs along indifference curves (Oppenheimer, 1978).

Local preference functions. In contrast with the global model, local preference functions do not require specification of tradeoffs along indifference curves. They do require the existence of a concave, differentiable preference function, but its form need not be known. Geoffrion, Dyer and Feinberg (1972) used an interactive form of the Frank-Wolfe algorithm to maximize V(x) over a convex, compact constraint set X (Frank and Wolfe, 1956). Using tradeoff assessments, they determined, at each iteration, a feasible direction of improvement and moved in the direction of the resulting gradient. They obtained optimality when no improvement was possible in any feasible direction. In practice, V(x) need not be specified, only the tradeoff assessments at a finite number of outcomes.

The speed of convergence of the Frank-Wolfe algorithm is a function of its linear approximation of the true objective. The rate of convergence is known and bounded, but since the linear approximations "are poor proxies for the true objective, the maxima they generate are poor trial points for the true solution. As a result, the sequence progresses slowly toward the true optimum" (Oppenheimer, 1978, p. 678).

Proxy functions. Oppenheimer (1978) combined the global and local preference models, obtaining a procedure which converges faster than the local model. He used global preference functions, sum-of-exponentials and sum-of-powers, as local proxies to indicate feasible directions of movement. Convergence of the proxy approach is assured by concavity of the preference function, the convexity of the feasible region and a convergent feasible directions algorithm. The sum-of-exponentials and

sum-of-powers functions require more parameters than the linear approximation. The additional parameters are obtained from the tradeoffs assessed at each iteration.

Arbitrary weights. Zionts and Wallenius (1976) developed an interactive mathematical programming method for solving the multiple criteria decision problem where the overall utility function is assumed to be unknown explicitly but is assumed implicitly to be a concave function of the objective functions. The constraint set is convex. The method generates a composite objective or utility function from an arbitrary set of weights, and then produces a Pareto-optimal solution to the problem. The decision maker receives a set of possible tradeoffs, with some objectives increased and some decreased, and states whether each tradeoff is desirable, undesirable or neither. With the responses, the procedure constructs a new set of consistent weights and determines an associated efficient solution. The decision maker receives a new set of tradeoffs, and iteration continues until an overall optimal solution obtains with respect to the decision maker's implicit utility function.

Certainty only. The approaches described above apply to decision making under certainty. Uncertainty, however, is more characteristic of the problem of interest here, the selection of small business computers, than is certainty. That is, the decision makers are unable to specify with certainty the values of alternative outcomes. Under uncertainty, the objective function is the expected utility of a lottery rather than a preference function. As of 1978, the state of the art does not admit a technique for approximating an expected utility integral "to ensure a

feasible direction of improvement in the decision space" (Oppenheimer, p. 688).

Inconsistencies. A conspicuous aspect of optimization models is the absence of explicit consideration of the treatment of inconsistent preferences. Some authors, e.g., Zionts and Wallenius, observed that inconsistency did not seem to be a problem in practice, but their experience was limited to a few situations and to a few test cases. What one would like to have is a measure of the degree of conflicting preferences as an indication of the preferential complexity of the problem.

Parameter estimation. The tradeoff assessments required of the decision maker at each iteration of the Geoffrion, Dyer and Feinberg local preference procedure are estimates of marginal rates of substitution (MRS) between the criteria. It was originally thought that decision makers could readily specify a set of MRS in contexts with which they were familiar. Geoffrion, Dyer and Feinberg assumed this to be the case in their application of the method to the operation of an academic department.

In another experiment, however, Wallenius found that managers familiar with the experimental context (planning production, inventory and labor for a fictitious company) had difficulty estimating the MRS. Indeed, Wallenius found that an unstructured approach, essentially an automated trial-and-error procedure, "competed successfully with the more sophisticated methods in terms of most measures" (1972, p. 1394). In the unstructured approach, the decision maker entered a vector of criterion values at each iteration, and the computer program informed

the decision maker whether the choice was feasible or not. The subjects explored the criterion space until they could no longer improve the objective value.

Wallenius speculated that the performance of the unstructured approach would decline if the complexity of the problem increased, e.g., with a reduction in the set of feasible solutions or with an increase in the number of decision-relevant criteria. He recommended more experiments to resolve the issue and additional research to "adjust the methods to match the characteristics of a human decision-maker and vice versa" (Wallenius, 1972, p. 1394).

Binary preferences. Wehrung (1978) proposed the use of binary preference relations as a way to simplify the estimation of the MRS for the Geoffrion, Dyer and Feinberg algorithm. He also demonstrated weaker convergence criteria. The drawback to the proposal is that consistent preferences are required. As yet, no one has tested whether inconsistency is a problem in practice for binary preference relations used as proxies for MRS.

Computer Selection by Weights and Scores Models

An early approach to the selection of computer systems was that of weights and scores models such as those proposed by Joslin (1968) and Sharpe (1969) and refined by Lucas and Moore (1976). The basic technique requires that one divide the characteristics, both objective and subjective, of the computer system into classes, each of which is subdivided to the desired degree of fineness. A weight is attached to each descriptor in accordance with its relative importance at that level.

The weights are scaled so that the sums of the weights at each level are constant, e.g., 1 or 10. The candidate systems are scored according to the degree they possess the desired characteristics. For each candidate, the product of a weight and its corresponding score are combined with other such products according to the tree structure of the descriptors. The system with the highest score is the one selected (Timmreck, 1973, pp. 210-1).

The weights and scores approach is better than ad hoc methods to the extent it imposes completeness in that each aspect of the system is considered explicitly. The approach has, however, some of the deficiencies of the mathematical programming models. It assumes that weights and scores can be assigned with certainty and that they are constant over the planning horizon. The designation of the weights is a complex mental process because the system selector is, in effect, forced to evaluate each descriptor while maintaining consistency across all weights.

Accepting the psychological experiments (Miller, 1956) showing that an individual cannot compare more than seven objects (plus or minus two) simultaneously without being confused, one concludes that any method requiring more than 9 concurrent discriminations is deficient in the sense of overtaxing the subject's mental capabilities. Hence, the lack of consistency and the lack of a measure of its extent detract from the efficacy of the weights and scores approach.

Analytic Hierarchy Process (AHP)

Saaty's (1977 and 1980) analytic hierarchy process is a method for deriving weights for criteria according to their relative contribution to an overall objective. The method mitigates certain aspects of deficiencies discussed earlier, namely, the requirement for specification of preferences under certainty, the inability to treat inconsistent preferences and the difficulty of making complex tradeoffs.

The object of the analytic hierarchy process (AHP) is to use weights or priorities "to allocate a resource among the activities or simply implement the most important activities by rank if precise weights cannot be obtained ... (i)f one decision is required, the option with the highest weight is selected" (Saaty, 1977, pp. 234-5). The AHP is appropriate for multi-criteria decision problems which have quantitative factors and qualitative factors on which one can impose, at best, an ordinal scale. Hong and Nigam (1981) applied the method to the selection of financial modeling software with satisfactory results.

Summary

No simple price versus power relationship has been found for SBCs. Cale, Gremillion and McKenney (1979) inferred that a stable relationship would exist when the market for SBCs matured.

Methods for solving the capacity problem, the task of matching requirements with computer systems having appropriate capabilities, have required a processing history as the basis for a characterization of the workload. This applied to use of both benchmarks and synthetic

workloads. Requirements analysis yields a specification of data flows but does not address the capacity question.

In practice, use of optimization models and the weights and scores models has not yielded satisfactory procedures for the solution of multi-criteria problems with both objective and subjective factors. The chief drawbacks to their use are (1) the requirement for consistent preferences and (2) the difficulty decision makers have in stating preference relations. The AHP, which has not been applied to computer selection, allows inconsistent preferences and reduces the burden of preference specification as compared to the optimization and weights and scores models.

CHAPTER III

METHODOLOGY

In the absence of a theoretical basis for group membership, cluster analysis was applied to indicate likely SBC group composition. Factor analysis was used to define the attribute space. Factor variables were the basis for the construction of the attribute hierarchy applied to the execution of the analytic hierarchy process (AHP) for SBC selection. Applied in this manner, use of the AHP was an improvement over prior SBC choice models in that it (1) reduced the compexity of selection, hence lessening the burden of preference specification, and (2) allowed inconsistent preferences.

Data

Data for the analysis was taken from Datapro Reports on Minicomputers (Datapro, 1981b), a widely-accepted independent reporting service. The most recent SBC material, dated March 1981, contained data on the 354 SBCs from 90 suppliers given in Table 21 in Appendix A. Datapro provided two kinds of data for SBCs, product data and user opinion data. Table 22 in Appendix B gives means and standard deviations for product and user opinion data.

Product Variables

Product data included word length, model, add-time, number of input/output (I/O) ports, memory size, cycle and access times, mass storage capacity, number of I/O devices, communications capabilities,

software support, pricing and availability. The product specifications available from Datapro suitable for analysis are described below.

Word length. The word length was the number of bits (binary digits) of data storable in or retrievable from memory during a single processor cycle. Eight and multiples of eight were common word lengths. A few systems, however, had word lengths which were not even multiples of four or eight. The odd bits, usually associated with parity or error detection, were subtracted from the word length to improve the comparability of subsequent analysis. The word length was missing in three percent of the cases.

Model. The model indicated the manufacturer and model of the system's central processing unit (CPU).

Add-time. Add-time was the time, in microseconds, required for obtaining the sum of two numbers. Although commonly used as a measure of system performance, add-times are a relatively simplistic indicator. For single workstation systems, the operator's keying speed is more likely to determine overall speed. For multi-operator systems, aspects of computer architecture may dominate the effect of instruction timing. In Cale, Gremillion and McKenney, the add-time effect was masked by other variables, such as memory and direct access storage capacities, correlated with and used as proxies for computer power (1979, p. 230).

In addition to their dependence on computer architecture, add-times did not apply to the same number of digits for each system. No

adjustment was made, however, for operand lengths since no rational basis for adjustment was available.

Thirty-four percent of the systems were initially missing add-times. Some of these systems used common CPUs, e.g., the Intel 8086, for which add-times were known. In such cases, the missing add-times were supplied. After these additions, thirty percent of the add-times were missing.

Input/output ports. An input/output (I/O) port was an interface for a peripheral device or a control unit for several devices. Hence, this was a measure of the I/O capability of the system. Two numbers were generally available, the number of ports on the basic system and the maximum number that could be installed on the system. Thirteen and twelve percent of the basic and maximum I/O port numbers, respectively, were missing.

The maximum number of I/O ports represented the largest number of physical ports that could be wired to the system. The number did not represent the maximum number which could be active at a time. The maximum number used in the analysis was Datapro's maximum number adjusted downward not to exceed the number of concurrent jobs for the system since each device typically requires a job to drive it on SBC systems. The unadjusted maximum is the appropriate capacity for applications with intermittent use of devices, e.g., badge readers at multiple locations, but gives an inflated view of the ability of a system to support simultaneous access.

Memory. The amount of memory, or internal storage, was given in units of 1,024 (K) bytes. Two amounts were typically given, the memory on the basic system and the maximum memory for the system. All systems had basic memory capacities, and less than one percent were missing maximum capacities.

Cycle and access times. The cycle time, in microseconds, was the minimum interval between starts of successive accesses to the same memory location. Access time was the elapsed time between the CPU's request for data and subsequent receipt of the data. Like add-times, cycle and access times depended on the computer architecture. Sixteen percent of the cycle times and twenty-one percent of the access times were missing.

Mass storage. Mass storage was the capacity of magnetic disk units such as diskettes, cartridge disks, pack disks and fixed-head disks/drums. The capacities were given for an increment of each storage type, and the maximum storage was configured as the sum of maximum capacities. Five percent of the basic mass storage capacities and eleven percent of the maximum storage capacities were missing.

Workstations. A workstation was the set of devices for input and output customarily used by an SBC user or operator. Two quantities for workstations were presented, the maximum number and the number recommended by the manufacturer for efficient performance. The number for efficient performance was the one used in the analysis. Twelve percent of the workstation values were missing.

I/O devices. I/O devices included printers, tape drives and video terminals. Due to the variability in possible device configurations and the interchangeability of devices across systems, specific I/O device configurations were not considered in the analysis.

Communications. Communications was the capacity of the system to function in data communications networks. Datapro specifications included (1) the maximum number of communications lines, (2) the type, i.e., synchronous and asynchronous, (3) the protocols supported and (4) the kinds of remote job entry terminal emulation. Like I/O device configurations, communications features varied across systems. In many cases, communications support was available from nonvendor sources. The communications variable included in the analysis was the maximum number of lines. As with the number of I/O ports described above, the maximum number of communications lines was adjusted downward not to exceed the number of concurrent tasks or jobs. Nine percent of the lines values were missing.

Software. Aspects of software support were (1) the available languages, (2) the maximum number of concurrent jobs, (3) firmware implementation of languages or the operating system, (4) the availability of accounting packages, industry applications and data base management systems and (5) file access methods. There was great variability in the quality of the software data. As was the case with communications support, many systems had nonvendor sources. Given the focus of the cluster analysis on the capacity question, the only aspect of software included in the product variables portion of the analysis was the

maximum number of concurrent jobs. Twenty-one percent of the systems were missing this value.

Pricing. Purchase prices were available for basic systems, the typical minimum configurations.

Availability. The time of availability was the month and year the first production models were delivered to customers.

User Opinion Variables

The SBCs rated in Datapro's user survey had from 2 to 99 ratings per system. In some cases, ratings for similar systems of the same vendor were aggregated. For more common systems, with a large number of ratings, the sample size was generally adequate. For less common systems, with a small number of respondees, the ratings may be biased due to small sample sizes. There was, however, no way to detect any bias, and Datapro screened each response for obvious discrepancies.

User opinion data were available for less than a third of the SBC population. The data comprised (1) average system satisfaction ratings on a 1 (poor) to 4 (excellent) scale where each response was equated to a 1, 2, 3 or 4 and (2) the percent of respondees indicating the existence of certain problems and advantages. The elements of the satisfaction ratings and the categories of problems and advantages are listed below. All the ratings and categories were used in the analysis.

System ratings. Datapro provided average system ratings for the following categories:

1. Ease of operation
2. Reliability of mainframe
3. Reliability of peripherals
4. Maintenance service
   A. Responsiveness
   B. Effectiveness
5. Technical support
   A. Trouble-shooting
   B. Education
   C. Documentation
6. Manufacturer's software
   A. Operating system
   B. Compilers and assemblers
   C. Applications programs
7. Ease of programming
8. Ease of conversion
9. Overall satisfaction (Datapro, 1981b, p. M07-100-431)

System ratings also included the percent of users who would recommend the system to another user.

Problems. The categories of significant problems were:

1. System proposed by vendor too small
2. Delivery and/or installation of equipment late
3. Delivery of required software late
4. System costs in excess of expected total
5. All promised software or support not provided

6. Promised program/data compatibility not attained
7. Promised terminals/peripherals compatibility not attained
8. Enhancements/changes to hardware/software hard to keep up with
9. Equipment excessively noisy
10. Power/cooling requirements excessive (Datapro, 1981b, p. M01-100-431)

Advantages. The categories of significant advantages were:

1. Users happy with response time
2. System easy to expand/reconfigure
3. System costs less than expected
4. Programs/data compatible, as promised
5. Terminals/peripherals compatible, as promised
6. Efficient power/energy use
7. Productivity aids keeping programming costs down
8. Database language effective
9. Delivery and/or installation of equipment ahead of schedule
10. Delivery and/or installation of software ahead of schedule (Datapro, 1981b, p. M07-100-431)

Structural variables. Datapro provided data for structural variables in addition to the user opinion data described above. The ones used in this research were:

1. Average life of the system in months,
2. Acquisition method: purchase, rental or lease from the manufacturer, and lease from a third party,

3. The percent of opinions from users whose principal applications were accounting functions and
4. The source of applications programs: inhouse personnel, manufacturer's packages, contract programming, manufacturer's personnel or proprietary software packages.

Cluster Analysis

In the absence of a theoretical basis for group membership, clustering and multidimensional scaling are two complementary means of determining natural groups of objects based on similarities or dissimilarities. Clustering provides a discrete combinatorial representation. Multidimensional scaling gives a spatial representation for the proximities. In general, clustering extracts information about small dissimilarities whereas multidimensional scaling reflects information about large dissimilarities (Kruskal, 1977, pp. 29-33).

For the purpose of SBC selection, one is interested in groups of systems with small dissimilarities. Hence cluster analysis is the more appropriate means of determining natural SBC groups and was used to find a small set of factors which parsimoniously described the attribute space. The analysis was performed in two phases, on product data and on opinion data.

Although an appropriate classification technique in the absence of a theoretical basis for group membership, cluster analysis itself does not have "a well-articulated body of statistical theory supporting it" (Blashfield and Aldenderfer, 1978, p. 289). Cluster analysis is still a predominantly heuristic approach to classification with competing views

on the constitution of good grouping. The multiplicity of competing views not only applies to the definition of a good classification and the algorithm for performing the cluster analysis but also to "the implications of the theories for the application of cluster analysis" (Blashfield and Aldenderfer, 1978, p. 289).

A means of mitigating the subjective aspects of the use of cluster analysis is to apply several methods and compare the results. Harris (1967) suggested the approach as the solution to the same dilemmas associated with the use of factor analysis. As Harman explained, there is "a basic indeterminacy in factor analysis--a infinitude of factorizations of a correlation matrix may account for the observed data equally well" (1967, p. 93). Harris recommended the conservative approach to decrease the likelihood of reliance on results that were a function of "the choice of tool or method" (1967, p. 289). Harris' conservative approach comprised:

1. Application of computational algorithms that differ in principle on the same data set,
2. Comparison of the results and
3. Exposition of only those results robust over all the methods (1967, p. 369).

Harris' conservative approach to yield the "maximum common denominator" (1967, p. 370) was applied to the cluster analysis of SBCs. With respect to computer algorithms for cluster analysis, the 354 systems in the SBC population comprised a large data set, beyond the capacity of most cluster programs. In addition, cluster algorithms typically delete cases with missing values of the cluster variables. Hence the cluster

procedures used were ones which (1) were suitable for large data sets and (2) did not delete cases with missing values. The treatment of cases with missing values was important because only a few of them had values for all variables. Cluster algorithms meeting these constraints were ones based on Hartigan's leader algorithm (1975) and MacQueen's k-means algorithm (1967) as implemented in the FASTCLUS procedure of the Statistical Analysis System (SAS) release 79.5 (SAS, 1981, pp. 6.1-6.16). FASTCLUS replaced each missing value with an adjusted value derived from the non-missing values for the observation.

Descriptive statistics were obtained for the product and opinion variables with the SAS procedure UNIVARIATE (SAS, 1979, pp. 427-32). The variables were also tested against normal (SAS, p. 429), uniform and Poisson (Hull and Nie, 1981, p. 224) distributions. The test statistics were Kolmogorov-Smirnov D or Z statistics.

The cluster analysis was performed:

1. On the SBC data after all variables had been standardized to a mean of zero and a standard deviation of one and
2. On factor loadings derived from the standardized data where means were substituted for missing values.

In harmony with Harris' conservative approach, factor loadings were obtained by several methods as the means of increasing the robustness of the factor interpretations. The methods for obtaining factor loadings were principal axis, oblique rotation, image analysis and maximum likelihood, obtained via the SAS procedure FACTOR (SAS, 1979, pp. 203-10) and the Biomedical Computer Programs P-Series program BMDP4M June 1981 revision (BMD, 1979, pp. 656-84).

Requirements Mapping

Requirements mapping entailed matching a set of hypothetical user applications for accounting functions to a subset of the SBC population for the product factors determined in the factor analysis. Kolence's (1976) NFU concept was the basis for specification of the requirements of the accounting functions. The mapping itself comprised logical operations on the values of product variables to find the union of all SBCs meeting the application requirements. An upper bound on the product variable values was chosen to yield a small subset of SBCs (7 ± 2) for subsequent examination in the AHP.

Analytic Hierarchy Process (AHP)

Multi-criteria decision procedures which could have been applied to SBC selection included optimization models, the AHP and weights and scores models, with the last category being developed principally for computer selection. The inadequacies of both optimization and weights and scores models for SBC selection have been demonstrated, namely, the inability to treat inconsistent preferences and the overly complex requirements for preference specification. Because AHP allows inconsistent preferences, provides a measure of the degree of consistency and demands less taxing preference specification than those of other choice models, AHP was used as the framework for the SBC selector's decision process. The process comprised preference hierarchy determination, preference specification, computation of attribute weights and ordering of alternative systems.

The hierarchy itself was constructed from the factors, product and opinion, characterizing the SBC population. The AHP was applied, with the product and opinion factor hierarchy, to choose an SBC satisfying sample requirements.

AHP structure. The AHP requires a matrix A whose elements are pairwise comparisons of n attributes or elements with respect to the relative importance of their contribution to a given objective. The judgment matrix A, whose weights are assumed to belong to a ratio scale, can be represented as follows:

$$A = \begin{array}{c|cccc} & A(1) & A(2) & \cdots & A(n) \\ \hline A(1) & w(1)/w(1) & w(1)/w(2) & \cdots & w(1)/w(n) \\ A(2) & w(2)/w(1) & w(2)/w(2) & \cdots & w(2)/w(n) \\ \vdots & \vdots & & & \\ A(n) & w(n)/w(1) & w(n)/w(2) & \cdots & w(n)/w(n) \end{array}$$

where $a(i,j) = w(i)/w(j)$ is the importance of attribute i relative to that of attribute j for all i and j. A is a reciprocal matrix, i.e., $a(i,j) = 1/a(j,i)$, and is everywhere positive.

Scale. The importance weights are given on a 1 to 9 scale, consistent with the assumed limitation of the mind to compare at most 7 $\pm$ 2 factors simultaneously (Miller, 1956). The AHP scale is given in Table 1.

TABLE 1

THE AHP SCALE AND ITS DESCRIPTION

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another
5	Essential of strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is strongly favored and its dominance is demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between two adjacent judgments	When compromise is needed
Reciprocals of above nonzero values	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, j has the reciprocal value when compared with i	

Source: Saaty, T. L. "A Scaling Method for Priorities in Hierarchical Structures," J. Mathematical Psychology, (June 1977), p. 246.

Consistency. Multiplying A by the transpose of the vector w = (w(1), w(2),..., w(n)) gives Aw = nw. If A is consistent, i.e., a(i,j)a(j,k) = a(i,k) for all i, j and k, then all the eigenvalues e(i) of A are zero except one, which is equal to n. The solution w is any column of A, which can be normalized so that its components sum to unity. The normalized column is the unique vector of weights w.

Inconsistency. In practice, however, A is not consistent because people's preferences are not consistent, and the problem Aw = nw becomes Aw = (emax)w where emax is the largest eigenvalue. As previously discussed, the weights being sought are given by the normalized eigenvector for the largest eigenvalue. By the Perron-Frobenius theorem, the eigenvalue exists and is greater than n. Indeed, the closer emax is to n, the more consistent the matrix. In this case, however, closeness is defined as being logically related rather than randomly chosen.

Consistency measure. Saaty's measure of the consistency or reliability of information in the judgment matrix has the form

$$c = (emax - n)/(n - 1).$$

The matrix is more consistent the closer c is to zero.

Recomposition. The AHP allows hierarchical decomposition of objects into clusters with as many levels as needed. Simon advanced the concept of hierarchy as a means of representing the interactions in complex systems, natural and artificial. Simon's thesis was

> ...that one path to the construction of a nontrivial theory of complex systems is by way of a theory of hierarchy. Empirically a large proportion of the complex systems we observe in nature exhibit hierarchic structure. On theoretical grounds we could expect

> complex systems to be hierarchies in a world in which complexity had to evolve from simplicity. In their dynamics hierarchies have a property, near decomposability, that greatly simplifies their behavior. Near decomposability also simplifies the description of a complex system and makes it easier to understand how the information needed for the development or reproduction of the system can be stored in reasonable compass (1981, p. 229).

The AHP follows from Simon's theory of hierarchy. One decomposes the hierarchy according to the proximity or similarity of the elements, performs pairwise comparisons on each cluster and subcluster, obtaining an eigenvector of weights for them, and recomposes the clusters. Given weights of elements in one level,

> ...(w)e generate a matrix of column eigenvectors of the elements in the level immediately below this level with respect to each element in this level. Then we use the vector of (weights of) elements in this level to weight the corresponding column eigenvectors. Multiplying the matrix of eigenvectors with the column vector of weights gives the composite vector of weights of the lower-level elements (Saaty, 1977, p. 278).

Marginal analysis. Saaty suggested that the AHP be extended to incorporate marginal analysis, that is, determination of the extent to which one prefers an increase in one element over another. He proposed first conducting the dominance analysis described above followed by the AHP applied to a corresponding marginal comparison matrix, whose elements specify one's preference for an incremental change in element i over an incremental change in element j. Such a procedure allows one to make marginal improvements (Saaty, 1980, pp. 93-5).

Computation. A matrix is irreducible if it cannot be decomposed into submatrices one of which is the zero matrix. A nonnegative, irreducible matrix is primitive if only if there is an integer $k \geq 1$ such

that the kth power of the matrix is positive. Pairwise comparison matrices are primitive.

Saaty proved that the desired eigenvector of weights is equal to the normalized row sums of the limiting power of a primitive matrix. This means that one can raise the matrix to successive powers until the difference between consecutive row sums is less than some small number and obtain the weights from the last iteration (Saaty, 1980, p. 179). Once the eigenvector is known, the eigenvalue can be evaluated from $Aw = (\lambda max)w$. For $n \leq 4$, Saaty gave analytic solutions for the principal eigenvalue and its eigenvector (1980, p. 95).

Summary

Cluster analysis with factor analysis was the means of characterizing the SBC population. The investigation used both product and opinion data. The product factors from the cluster analysis were the determinants of the mapping of sample user requirements onto a subset of the SBC population. Product and opinion factors composed the AHP hierarchy which was applied to the selection of an SBC for a sample set of requirements.

CHAPTER IV

RESULTS

The results of the research are explained in three sections:

1. Variables analysis,
2. Requirements mapping and
3. Application of the analytic hierarchy process.

The data analysis section interprets the results of cluster analysis of the SBC population. These findings were used as the basis for the mapping of capacity requirements onto a segment of the SBC population, discussed in the second section. Given the SBC subset determined through the requirements mapping, the application of the analytic hierarchy process demonstrated the selection of an SBC, explained in the third section.

Variable Analysis

Tests of distributions. Distributional tests applied to the data values did not detect any systematic patterns which might affect the results of cluster procedures. Table 2 contains the probabilities for the tests on product variables, and Table 3, the tests on opinion variables.

For product variables, none of the probabilities exceeded Ø.Ø1 for tests of adherence to normality. Five of the fifty opinion variables had probabilities exceeding Ø.Ø1 for normality where the largest was Ø.Ø66. This percentage is approximately the proportion of positive indications expected from a sample of opinion data. Three opinion

TABLE 2

PRODUCT VARIABLES DISTRIBUTION TEST PROBABILITIES

	Distribution		
Variable	Normal	Uniform	Poisson
Availability date	<Ø.Ø1	Ø.Ø	Ø.Ø
Access time	<Ø.Ø1	Ø.Ø	Ø.Ø
Add-time	<Ø.Ø1	Ø.Ø	Ø.Ø
Cycle time	<Ø.Ø1	Ø.Ø	Ø.Ø
Disk, basic	<Ø.Ø1	Ø.Ø	Ø.Ø
Disk, maximum	<Ø.Ø1	Ø.Ø	Ø.Ø
I/O ports, basic	<Ø.Ø1	Ø.Ø	Ø.Ø
I/O ports, maximum	<Ø.Ø1	Ø.Ø	Ø.Ø
Lines	<Ø.Ø1	Ø.Ø	Ø.Ø
Memory, basic	<Ø.Ø1	Ø.Ø	Ø.Ø
Memory, maximum	<Ø.Ø1	Ø.Ø	Ø.Ø
Price	<Ø.Ø1	Ø.Ø	Ø.Ø
Word length	<Ø.Ø1	Ø.Ø	Ø.Ø
Workstations	<Ø.Ø1	Ø.Ø	Ø.Ø

TABLE 3

OPINION VARIABLES DISTRIBUTION TEST PROBABILITIES

Variable	Distribution		
	Normal	Uniform	Poisson
Advantages			
Response time	>Ø.15	Ø.Ø6	Ø.Ø
Ease of expansion	<Ø.Ø1	Ø.Ø	Ø.Ø
Cost under expectation	<Ø.Ø1	Ø.Ø	Ø.Ø
Program/data compatibility	<Ø.Ø1	Ø.Ø	Ø.Ø
Terminal/peripheral compatibility	<Ø.Ø1	Ø.Ø	Ø.Ø
Energy use	<Ø.Ø1	Ø.Ø	Ø.Ø
Productivity aids	<Ø.Ø1	Ø.Ø	Ø.Ø
Database language	<Ø.Ø1	Ø.Ø	Ø.Ø
Equipment on schedule	<Ø.Ø1	Ø.Ø	Ø.Ø
Software on schedule	<Ø.Ø1	Ø.Ø	Ø.Ø
Problems			
System too small	<Ø.Ø1	Ø.Ø	Ø.Ø
Equipment late	<Ø.Ø1	Ø.Ø	Ø.Ø
Software late	<Ø.Ø1	Ø.Ø	Ø.Ø
Cost over expectation	<Ø.Ø1	Ø.Ø	Ø.Ø
Vendor software support	<Ø.Ø1	Ø.Ø	Ø.Ø
Program/data compatibility	<Ø.Ø1	Ø.Ø	Ø.Ø
Terminal/peripheral compatibility	<Ø.Ø1	Ø.Ø	Ø.Ø
Change maintenance	<Ø.Ø1	Ø.Ø	Ø.Ø
Noise	<Ø.Ø1	Ø.Ø	Ø.Ø
Energy use	<Ø.Ø1	Ø.Ø	Ø.Ø
System ratings			
Ease of operation	<Ø.Ø1	Ø.Ø	Ø.Ø
Reliability of mainframe	<Ø.Ø1	Ø.Ø	Ø.Ø32
Reliability of peripherals	Ø.Ø66	Ø.Ø	Ø.ØØ2
Responsiveness of maintenance service	<Ø.Ø1	Ø.Ø	Ø.Ø
Effectiveness of maintenance service	<Ø.Ø1	Ø.Ø	Ø.Ø
Trouble-shooting	>Ø.15	Ø.Ø	Ø.Ø
User education	Ø.Ø11	Ø.Ø	Ø.Ø
User documentation	<Ø.Ø1	Ø.Ø	Ø.Ø

TABLE 3 (Continued)

Variable	Distribution		
	Normal	Uniform	Poisson
Manufacturer's operating system	<Ø.Ø1	Ø.Ø	Ø.Ø
Manufacturer's compilers and assemblers	<Ø.Ø1	Ø.Ø	Ø.Ø
Manufacturer's applications programs	<Ø.Ø1	Ø.Ø	Ø.Ø
Ease of programming	<Ø.Ø1	Ø.Ø28	Ø.Ø
Ease of conversion	<Ø.Ø1	Ø.Ø	Ø.Ø
Overall satisfaction	Ø.Ø16	Ø.Ø61	Ø.Ø
Expectations and Recommendations			
Met expectations--yes	<Ø.Ø1	Ø.Ø	Ø.Ø
Met expectations--no	<Ø.Ø1	Ø.Ø	Ø.Ø
Met expectations--undecided	<Ø.Ø1	Ø.Ø	Ø.Ø
Recommend to others--yes	<Ø.Ø1	Ø.Ø	Ø.Ø
Recommend to others--no	<Ø.Ø1	Ø.Ø	Ø.Ø
Recommend to others--undecided	<Ø.Ø1	Ø.Ø	Ø.Ø
Structural Aspects			
Average system life	<Ø.Ø1	Ø.Ø	Ø.Ø
Acquisition method:			
Purchase	<Ø.Ø1	Ø.Ø	Ø.Ø
Rental/lease from manufacturer	<Ø.Ø1	Ø.Ø	Ø.Ø
Lease from third party	<Ø.Ø1	Ø.Ø	Ø.Ø
Accounting as principal application	<Ø.Ø1	Ø.Ø	Ø.Ø
Source of application programs:			
Inhouse personnel	<Ø.Ø1	Ø.Ø	Ø.Ø
Manufacturer's packages	<Ø.Ø1	Ø.Ø	Ø.Ø
Contract programming	<Ø.Ø1	Ø.Ø	Ø.Ø
Manufacturer's personnel	<Ø.Ø1	Ø.Ø	Ø.Ø
Proprietary software	<Ø.Ø1	Ø.Ø	Ø.Ø

variables yielded more than a Ø.Ø probability of conforming to a Poisson distribution. Two of these, reliability of the mainframe (two-tailed probability of Ø.Ø32) and reliability of peripheral devices (two-tailed probability of Ø.ØØ2), are related to operating characteristics of hardware components. The closeness of the distributions to Poisson variates for these two variables suggested typical exponential failure rates for electronic components. One of the opinion variables, ease of programming, approached a uniform distribution (two-tailed probability of Ø.Ø28). None of the product variables had probabilities exceeding Ø.Ø for adherence to uniform or Poisson variates.

Cluster analysis of standardized product variables. Cluster analysis of product variables, standardized to mean zero, variance one, failed to produce multiple distinct, well-defined clusters. Plots of the clusters, two variables at a time, typically revealed no separation between clusters. Figure 1 for basic system price and number of workstations and Figure 2 for availability date and basic memory size illustrate the absence of multiple clusters. Plots for other pairs of variables had similar configurations with respect to multiple clusters. Cluster composition was similar across the two computational procedures, Hartigan's leader algorithm and MacQueen's k-means algorithm.

Table 4 contains the number of members in each cluster for each execution of the cluster algorithms on product variables. When the algorithms forced two or four clusters, half the clusters often had many members, and the other half, only a few members. For three clusters,

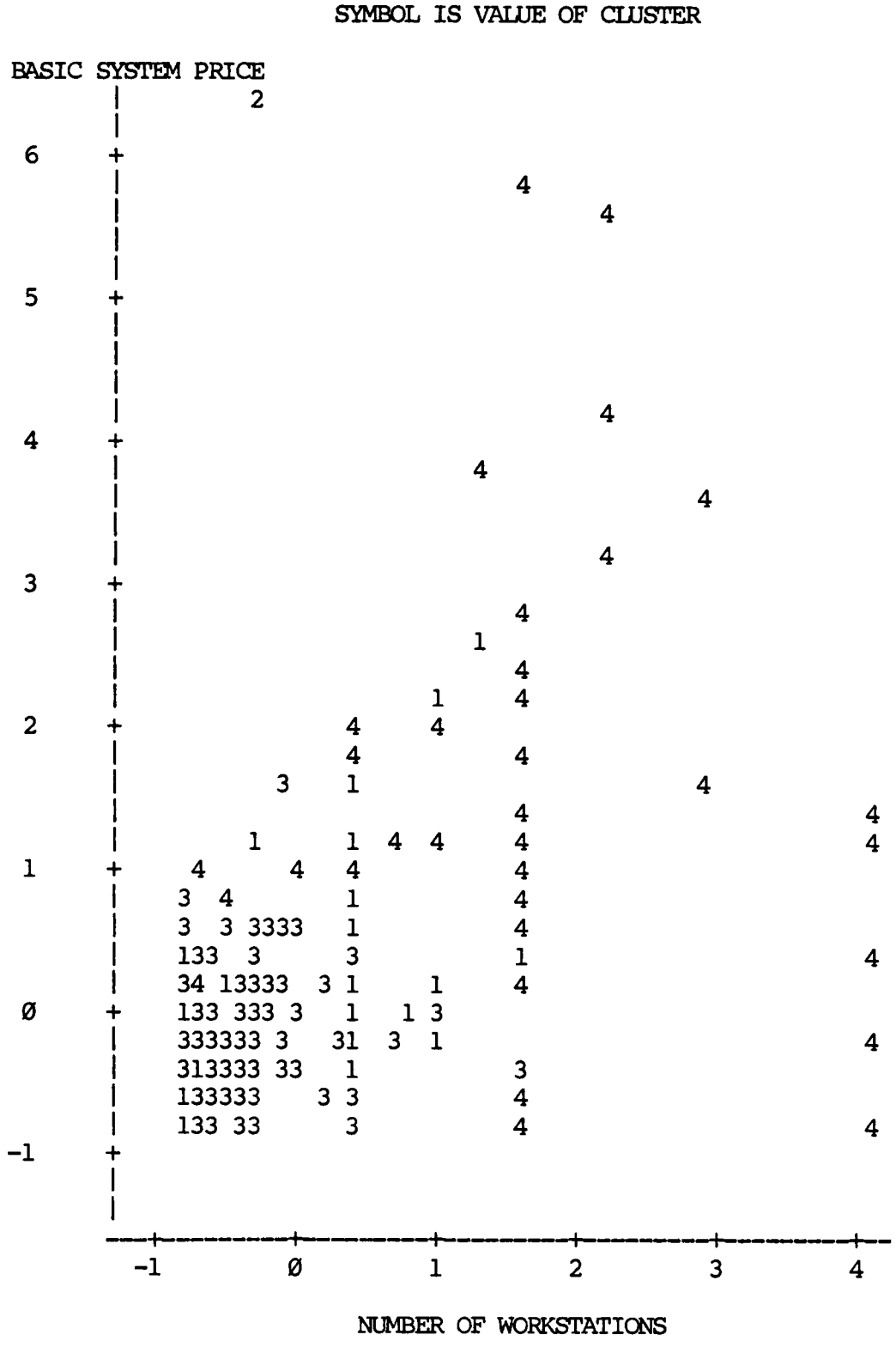

Figure 1. Product variables cluster plot: basic system price and number of workstations.

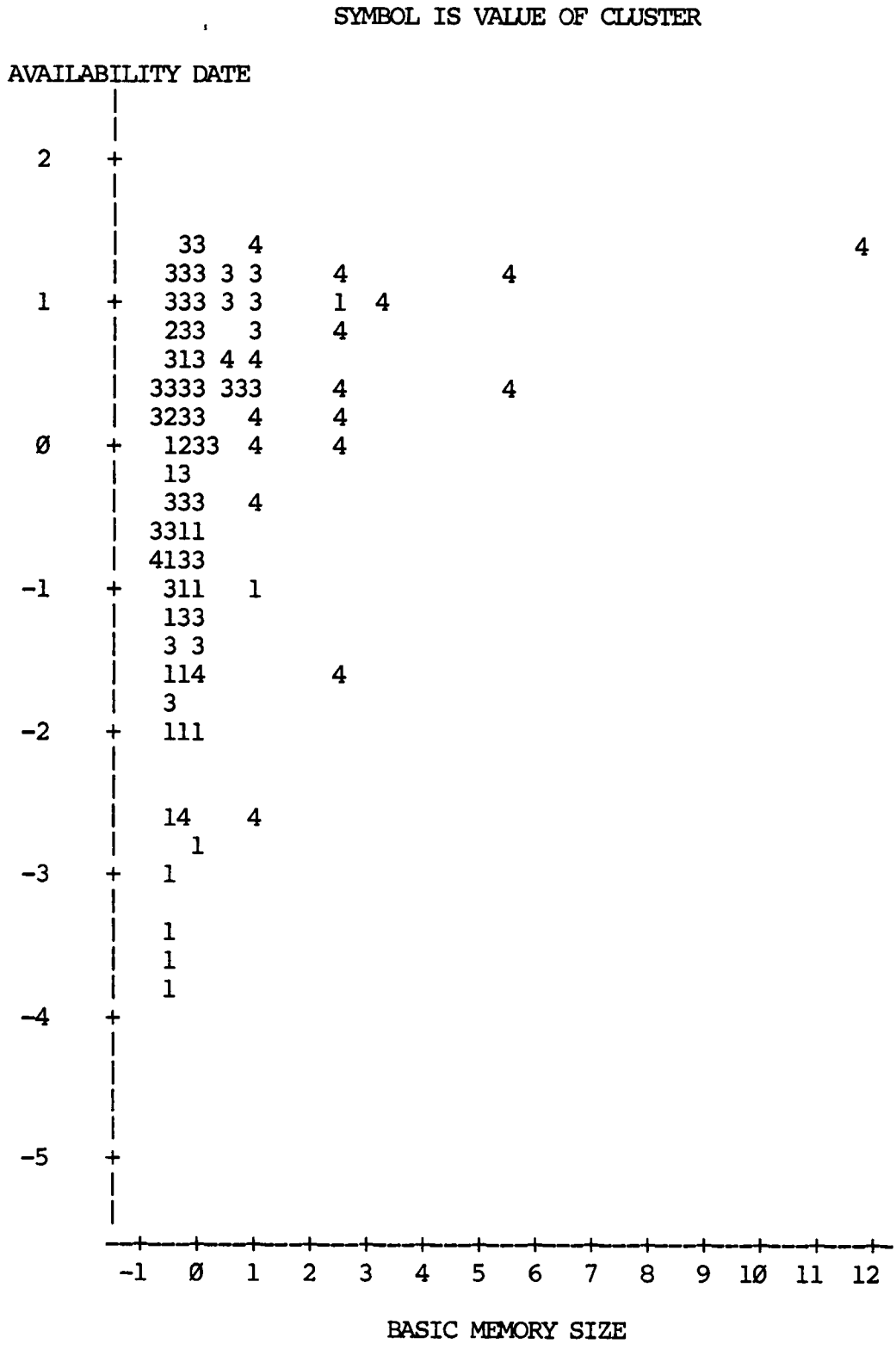

Figure 2. Product variables cluster plot: availability date and basic memory size.

TABLE 4

PRODUCT VARIABLES CLUSTER MEMBERSHIP

	Cluster Algorithm			
	Leader		K-Means	
Source	Cluster	Members	Cluster	Members
Standardized (Ø,1)	1	35	1	334
	2	319	2	2Ø
Standardized (Ø,1)	1	2	1	27
	2	11	2	19
	3	321	3	3Ø8
Standardized (Ø,1)	1	256	1	22
	2	78	2	5
	3	8	3	248
	4	12	4	79
Factor scores	1	353	1	35Ø
	2	1	2	4
Factor scores	1	11	1	3
	2	1	2	1
	3	342	3	35Ø
Factor scores	1	2	1	1
	2	343	2	1
	3	1	3	2
	4	8	4	35Ø

one or two of the clusters had many members and the remaining cluster(s) had few members.

The absence of multiple distinct, well-defined clusters is consistent with the hypothesis that the SBC market has matured. Market maturity means that continuous, or nearly continuous, performance capacities can be observed across the SBC population.

Factor analysis of product variables. Given the cluster analysis finding of one group rather than multiple groups, the attribute space for product variables was investigated with factor analysis. Prior to factor analysis, missing values were replaced with means. This is considered a conservative approach since the magnitude of factor scores varies inversely with the number of missing values.

The product variable factor pattern from the principal axis method is given in Table 5 for all eigenvalues greater than one. Loadings less than Ø.4 were omitted. Table 6 gives (1) the variance explained by each factor and (2) the single and cumulative portions of the variance explained.

Factors beyond the third did not satisfy Thurstone's criteria for a simple factor structure with respect to vanishing entries (Harman, 1967, p. 98). Three factors, however, accounted for only Ø.66 of the variance explained. A simpler factor structure, more nearly satisfying the Thurstone criteria, was produced with an oblique rotation. Table 7 presents the product variable factor pattern after oblique rotation for all eigenvalues greater than one.

TABLE 5

PRODUCT VARIABLES PRINCIPAL AXIS FACTOR PATTERN

	Factors					
Variable	1	2	3	4	5	6
Basic memory	.77					
Maximum memory	.8Ø					
Workstations	.73					
Basic system price	.78					
Cycle time		.98				
Access time		.98				
Maximum I/O ports			.59			
Maximum lines			.49		-.41	
Availability date			-.63			
Word length				.53		
Add-time				.56		.68
Basic disk				.45		-.71
Basic I/O ports					.77	

TABLE 6

PRODUCT VARIABLES VARIANCE EXPLAINED

	Factors					
Variance	1	2	3	4	5	6
Variance explained	2.86	2.Ø3	1.49	1.12	1.1Ø	1.Ø3
Portion	.3Ø	.21	.15	.12	.11	.11
Cumulative portion	.3Ø	.51	.66	.78	.89	1.ØØ

TABLE 7

PRODUCT VARIABLES OBLIQUE ROTATION FACTOR PATTERN

	Factors					
Variables	1	2	3	4	5	6
Basic memory	.86					
Maximum memory	.77					
Basic system price	.76					
Workstations	.62		.42			
Maximum disk	.44					
Cycle time		.99				
Access time		.99				
Maximum lines			.81			
Availability date			-.51			-.42
Basic I/O ports				.89		
Maximum I/O ports			.44	.61		
Basic disk					.89	
Add-time						.88

Product factor interpretation. The number of factors to be interpreted was determined from scree plots of the eigenvalues of correlation matrices. The plot of the eigenvalues from the image analysis, presented in Figure 3, indicated that the curve damped out after the third value. The eigenvalues of the principal axis analysis, presented in Figure 4, damped out after the fourth eigenvalue.

The factor structure from image analysis contained three factors. A fourth factor may be interpretable as suggested by the principal axis method, but only the three factors common to both methods were interpreted. Use of the more powerful maximum likelihood analysis was attempted, but the procedure converged to a local rather than the global maximum since the Hessian was not positive definite. Hence its eigenvalues could not be used as an independent bound on the number of factors for interpretation.

The first factor comprised the variables:

1. Basic memory,
2. Maximum memory,
3. Workstations (maximum efficient number) and
4. Basic system price.

The correlations between these variables were:

	Basic memory	Maximum memory	Workstations	Price
Basic memory	1.ØØ			
Maximum memory	.57	1.ØØ		
Workstations	.4Ø	.48	1.ØØ	
Basic price	.61	.57	.47	1.ØØ

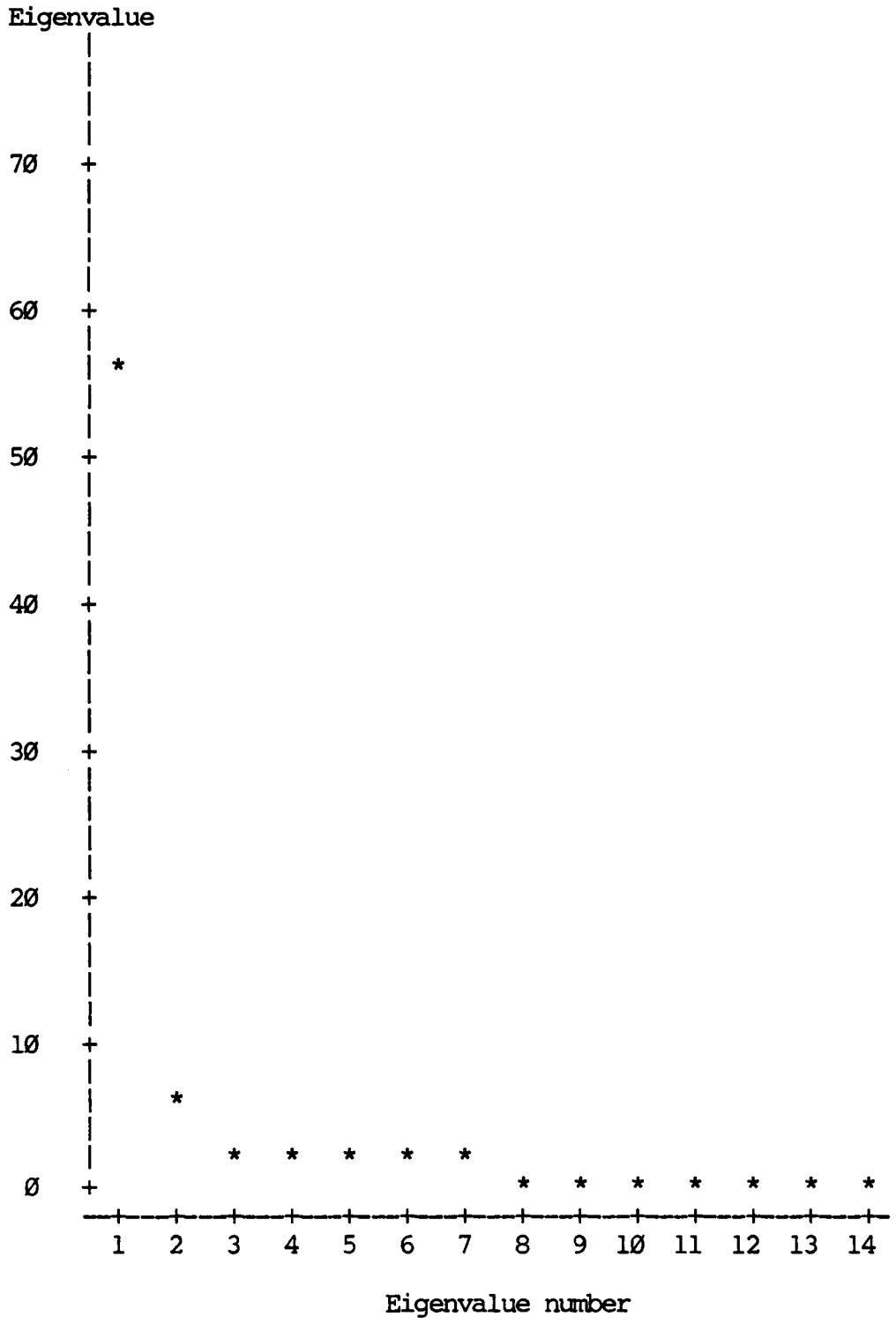

Figure 3. Product variables scree plot of eigenvalues of image analysis.

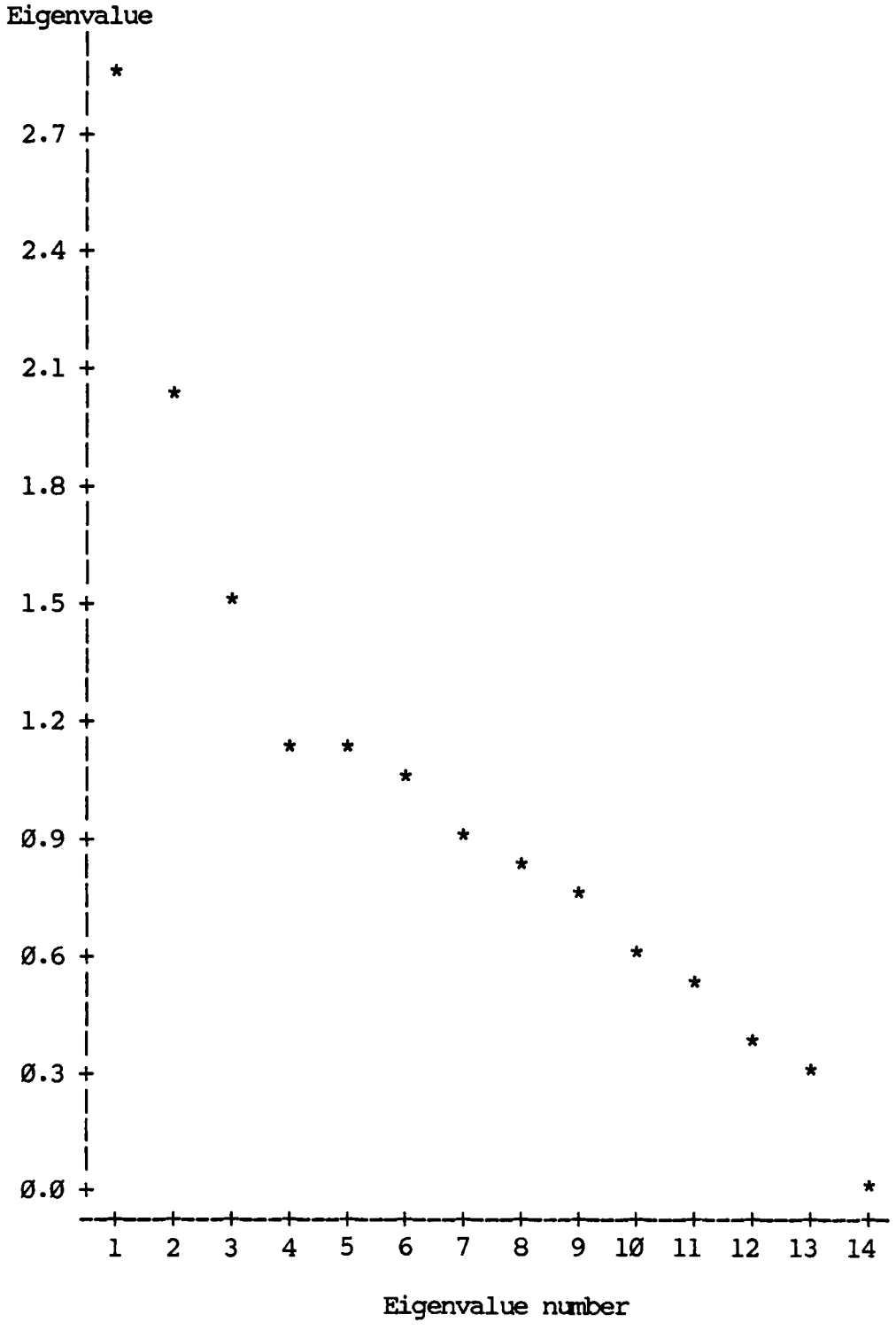

Figure 4. Product variables scree plot of eigenvalues of principal axis analysis.

The correlation between basic and maximum memory capacities follows from the practice of computer architects designing expandable systems. Some minimum memory size is required to support a minimal device configuration and a minimum number of concurrent jobs. Memory is theoretically expandable up to an addressing limit fixed by the computer architecture and effectively expandable up to the response capability of the central processor. The basic and maximum memory sizes thus tend to be proportional across systems.

For a system, each workstation typically requires a fixed memory allocation for device handling and workspace so that memory size and the number of workstations vary together. Basic system price and basic memory size had the highest correlation, Ø.61. Insofar as memory is a proxy for overall system capacity, one would expect basic memory to be highly correlated with basic system price.

The four variables loading principally on the first factor comprised a surrogate for the capacity of a system. Capacity for this factor was in the sense of the number of concurrent users who can access the system with no significant degradation of response time.

Cycle time and access time, correlated at Ø.98, composed the second factor, interpretable as a joint measure of central processor speed. One can view processor speed as a proxy for the rate at which a certain number of users, each using a separate workstation, would experience response from the system.

The third factor, composed of the variables maximum I/O ports, maximum lines and availability date, pertained to maximum attainable I/O configurations. The correlations between them were:

	Maximum I/O ports	Maximum lines	Availability
Maximum I/O ports	1.00		
Maximum lines	.26	1.00	
Availability date	-.14	-.14	1.0

The negative factor loading and correlations of availability date may be a function of an evolving SBC market. In the early years (before the mid-1970s), vendors may have announced SBC systems with larger configurations than were effectively attainable. As the vendors gained experience, they were better able to describe their systems realistically. The growing competitive pressure from increased numbers of knowledgeable users may have prompted the trend to claims of somewhat smaller I/O and lines configurations in relation to other system features.

The finding of three factors was robust across different methods of factor analysis. It is possible, however, that more than three factors were interpretable. Six factors had eigenvalues greater than one, and subsequent eigenvalues decreased only by approximately 0.1 through the thirteenth value. The gradual decrease in eigenvalues is a reflection of the absence of a sharp division between salient and less prominent aspects of product dimensions of SBCs. This supports the premise that selection of an SBC is a multi-criteria problem, especially with respect to capacity variables such as the ones encountered in the first three factors.

Cluster analysis of standardized opinion variables. Cluster analysis of user opinion variables, standardized to mean zero, variance one,

failed to produce multiple distinct, well-defined clusters. Plots of the clusters, two variables at a time, revealed no separation between adjacent clusters. Figure 5, for ease of conversion and overall satisfaction, and Figure 6, for user education and user documentation, illustrate the absence of multiple clusters. Plots for other variable pairs had similar configurations with respect to multiple clusters. Cluster composition was generally insensitive to the method of clustering, Hartigan's leader algorithm or MacQueen's k-means algorithm.

Table 8 contains the number of members in each cluster for each execution of the cluster algorithms on product variables. For two clusters, membership was about one half in each cluster. For three clusters, one group had few members while each of the other two clusters had about half the remaining members. For four clusters, two groups had few members while each of the other two groups had about half the members.

Factor analysis of opinion variables. Given the cluster analysis result of one group rather than multiple groups, the attribute space for opinion variables was investigated with factor analysis. The opinion variable factor pattern from the principal axis method is presented in Table 9 for all eigenvalues greater than two. Loadings less than Ø.4 were omitted. Table 1Ø gives (1) the variance explained by each factor and (2) the single and cumulative portions of the variance explained. The factors did not exhibit a simple factor structure by the Thurstone criteria although the first three factors accounted for Ø.72 of the variance explained.

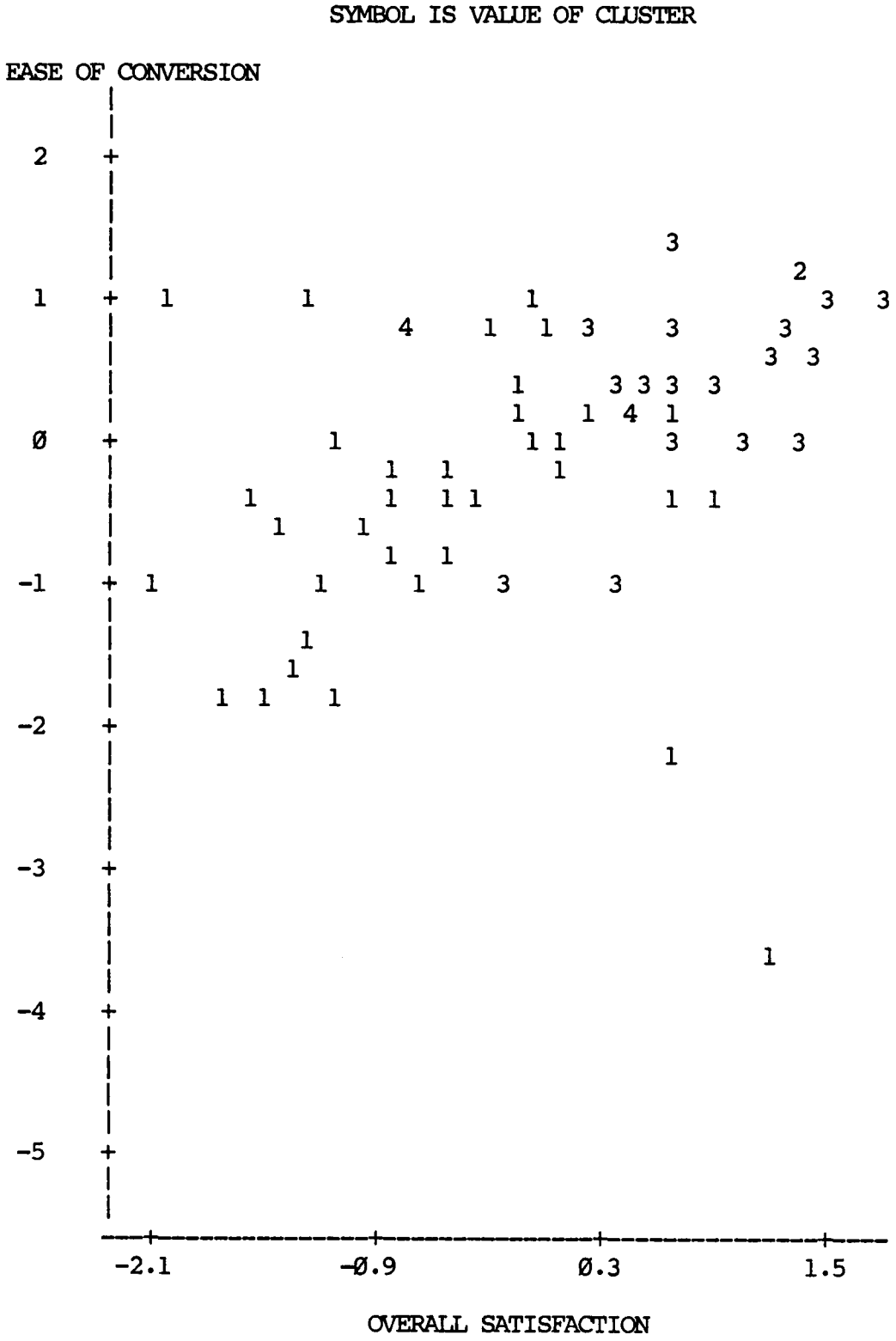

Figure 5. Opinion variables cluster plot: ease of conversion and overall satisfaction.

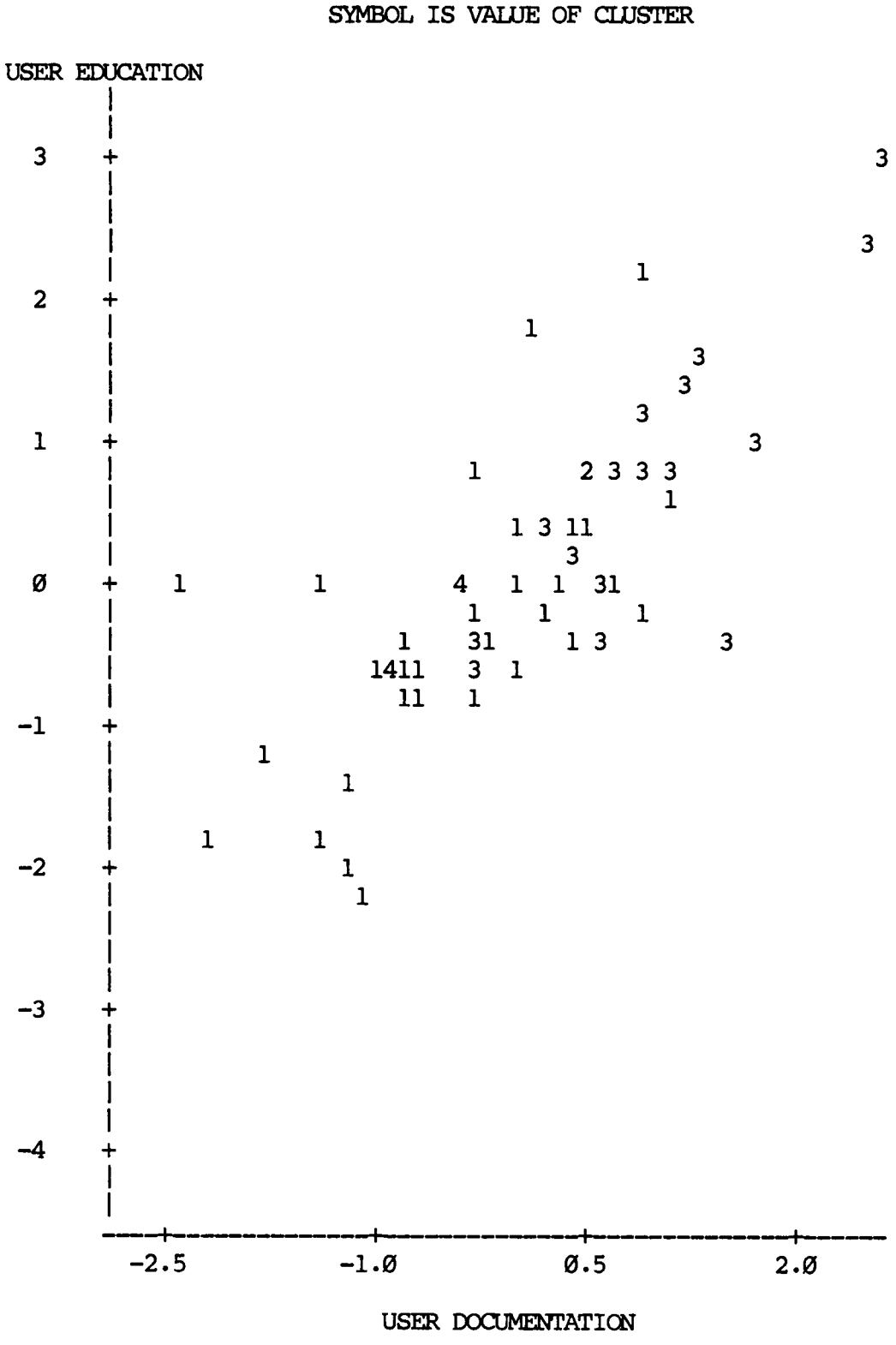

Figure 6. Opinion variables cluster plot: user education and user documentation.

TABLE 8

OPINION VARIABLES CLUSTER MEMBERSHIP

	Cluster Algorithms			
	Leader		K-means	
Source	Cluster	Members	Cluster	Members
Standardized (Ø,1)	1	73	1	43
	2	28	2	58
Standardized (Ø,1)	1	46	1	1
	2	53	2	56
	3	2	3	44
Standardized (Ø,1)	1	54	1	1
	2	2	2	57
	3	4Ø	3	42
	4	5	4	1
Factor scores	1	88	1	1Ø
	2	13	2	91
Factor scores	1	7	1	1Ø
	2	54	2	81
	3	4Ø	3	1Ø
Factor scores	1	2	1	1Ø
	2	7	2	8
	3	9Ø	3	73
	4	2	4	1Ø

TABLE 9

OPINION VARIABLES PRINCIPAL AXIS FACTOR PATTERN

Variable	Factors 1	2	3	4	5	6
*Met expectations--yes		-.83				
*Recommend to others--undecided		.92				
*Met expectations--no		.89				
*Recommend to others--yes		-.81				
*Ease of conversion		-.49				
*Reliability--manufacturer's applications programs		-.45				
Applications programs inhouse		.43				
*User education	.68					
*Advantage--software on schedule	.66					
*Documentation	.77					
Advantage--response time	.68					
Advantage--easy expansion	.42		.45			
Advantage--productivity aids	.71					
Advantage--database features	.55					
Advantage--equipment on schedule	.55					
Problem--software late	.60					
Problem--lack of support	-.72					
Problem--I/O compatibility	-.53					
Problem--noise	-.40					
Problem--energy use	-.46			.45		
Problem--peripheral reliability	.54					
Problem--maintenance response	.58					
Problem--maintenance effectiveness	.61					
Problem--trouble shooting	.79					
Reliability of operating system	.53					
Reliability of compilers/assemblers	.63					
Reliability of applications programs	.59					
Ease of programming	.71					
Overall satisfaction	.88					
Met expectations--no	-.75					
Recommend to others--no	-.67					
*Problem--program/data compatibility	-.41					

TABLE 9 (Continued)

Variable	Factors					
	1	2	3	4	5	6
Advantage--cost under expectation			.63			
Advantage--upward compatible			.56			
*Applications programs-- manufacturer's personnel			.42			
*Third party lease acquisition			.59			
Applications programs-- manufacturer's package				.47		
Applications programs-- contract programming				.54		
Problem--change maintenance				.42		
*Purchase acquisition					.53	
*Mfg. rental/lease acquisition			-.59			
Proprietary software					.44	
Problem--system too small					.48	
Reliability of mainframe					.44	
*Problem--cost over expectation	-.48					

Variable descriptions preceded by an asterisk (*) appear in the factor pattern for the oblique rotation.

TABLE 1Ø

OPINION VARIABLES VARIANCE EXPLAINED

	Factors					
Variance	1	2	3	4	5	6
Variance explained	11.71	5.17	3.75	3.24	2.44	2.28
Portion	.41	.18	.13	.11	.Ø9	.Ø8
Cumulative portion	.41	.59	.72	.83	.92	1.ØØ

The factor pattern for the rotated maximum likelihood analysis, presented in Table 11, more nearly satisfied the Thurstone criteria. The first factor, however, included the effects of several variables whose loadings were less than Ø.6Ø.

An oblique rotation of the principal axis solution gave a simpler factor structure with higher loadings than either the principal axis or maximum likelihood solutions. The oblique rotation was used below as the guide to factor interpretation for the opinion variables. Table 12 gives the opinion variable factor pattern for all eigenvalues greater than two. As was the case with product variables, the number of factors to be interpreted was derived from scree plots of eigenvalues. Figure 7 presents the eigenvalues from image analysis and indicates three eigenvalues before damping. Eigenvalues for the maximum likelihood solution, plotted in Figure 8, damped out after the third or fourth eigenvalue. Eigenvalues of the principal axis analysis solution, plotted in Figure 9, also damped out after the third or fourth eigenvalue. The common three eigenvalues were used as the guide to the number of factors to be interpreted.

The correlations for the rotated solution for the first three factors were:

	Factor 1	Factor 2	Factor 3
Factor 1	1.ØØ		
Factor 2	.Ø9	1.ØØ	
Factor 3	-.Ø5	-.24	1.ØØ

TABLE 11

OPINION VARIABLES ROTATED MAXIMUM LIKELIHOOD FACTOR PATTERN

	Factors					
Variable	1	2	3	4	5	6
Overall satisfaction	.84					
Advantage--productivity aids	.80					
Advantage--response time	.78					
Ease of programming	.69					
User documentation	.65					
Manufacturer's operating system	.62					
Advantage--software on schedule	.62					
Manufacturer's compilers & assemblers	.60					
Trouble--shooting	.55					
User education	.54					-.44
Met expectations--no	-.54					
Problem--software late	-.52					
Problem--vendor support	-.50					
Recommend to others--undecided		-.98				
Met expectations--undecided		-.93				
Met expectations--yes		.92				
Recommend to others--yes		.91				
Manufacturer's applications programs		.55				
Ease of conversion		.52				
Problem--cost over expectation			.91			
Problem--change maintenance			.70			
Manufacturer rental or lease acquisition				.95		
Purchase acquisition				.93		
Third party lease acquisition					.91	
Ease of operation					.67	
Applications programs from manufacturer's personnel					.58	
Recommend to others--no						-.79

TABLE 12

OPINION VARIABLES OBLIQUE ROTATION FACTOR PATTERN

Variable	Factors					
	1	2	3	4	5	6
Met expectations--yes	.95					
Recommend to others--undecided	-.95					
Met expectations--no	-.95					
Recommend to others--yes	.90					
Ease of conversion	.64					
Reliability--manufacturer's applications programs	.59					
User education		.81				
Advantage--software on schedule		.63				
Documentation		.58				
Problem--program/date compatibility			.95			
Problem--late equipment			.71			
Applications programs--manufacturer's personnel				.91		
Ease of operation				.86		
Third party lease acquisition				.72		
Purchase acquisition					.89	
Manufacturer's rental/lease acquisition					-.88	
Problem--change maintenance						.79
Problem--cost over expectation						.58

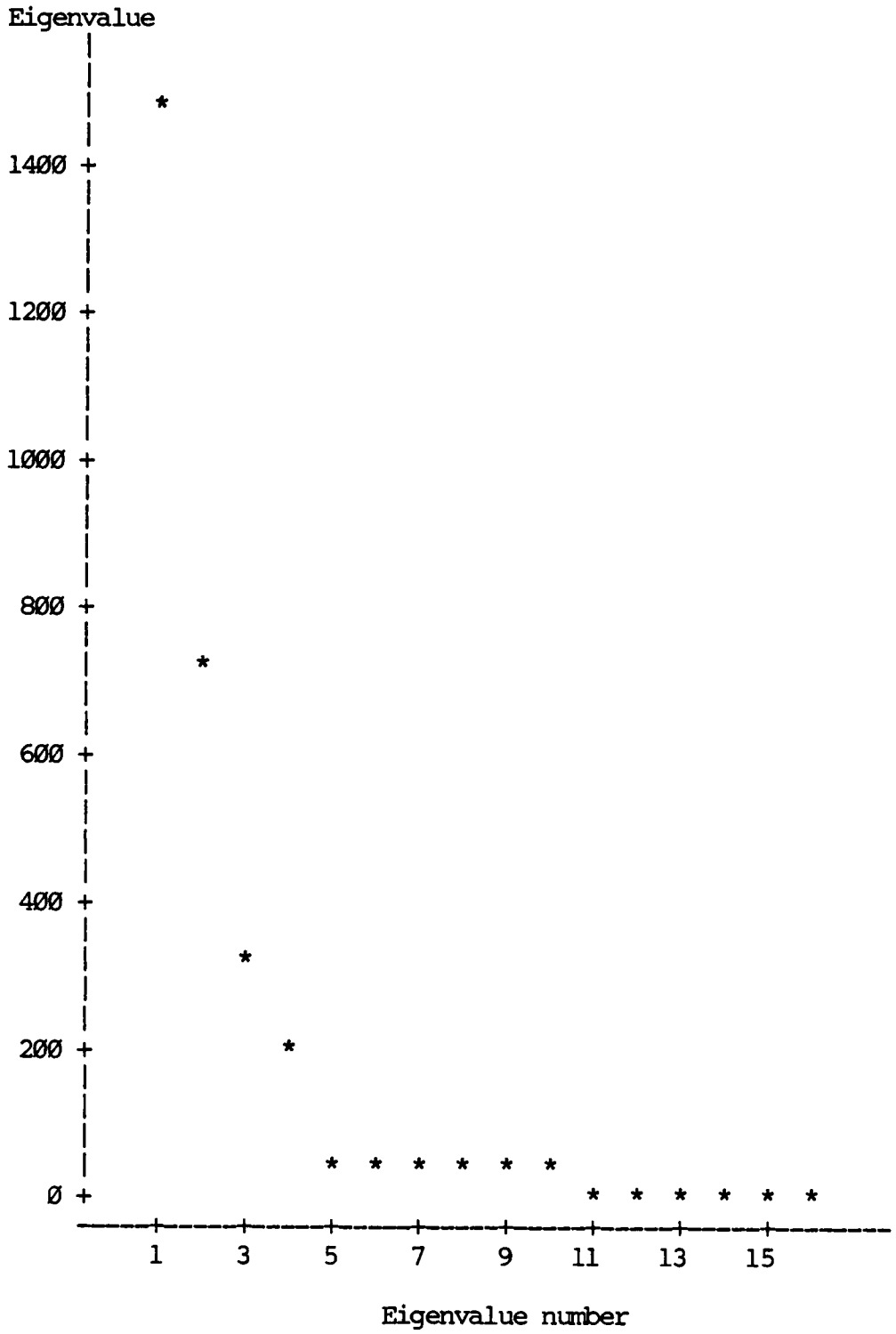

Figure 7. Opinion variables scree plot of eigenvalues of image analysis.

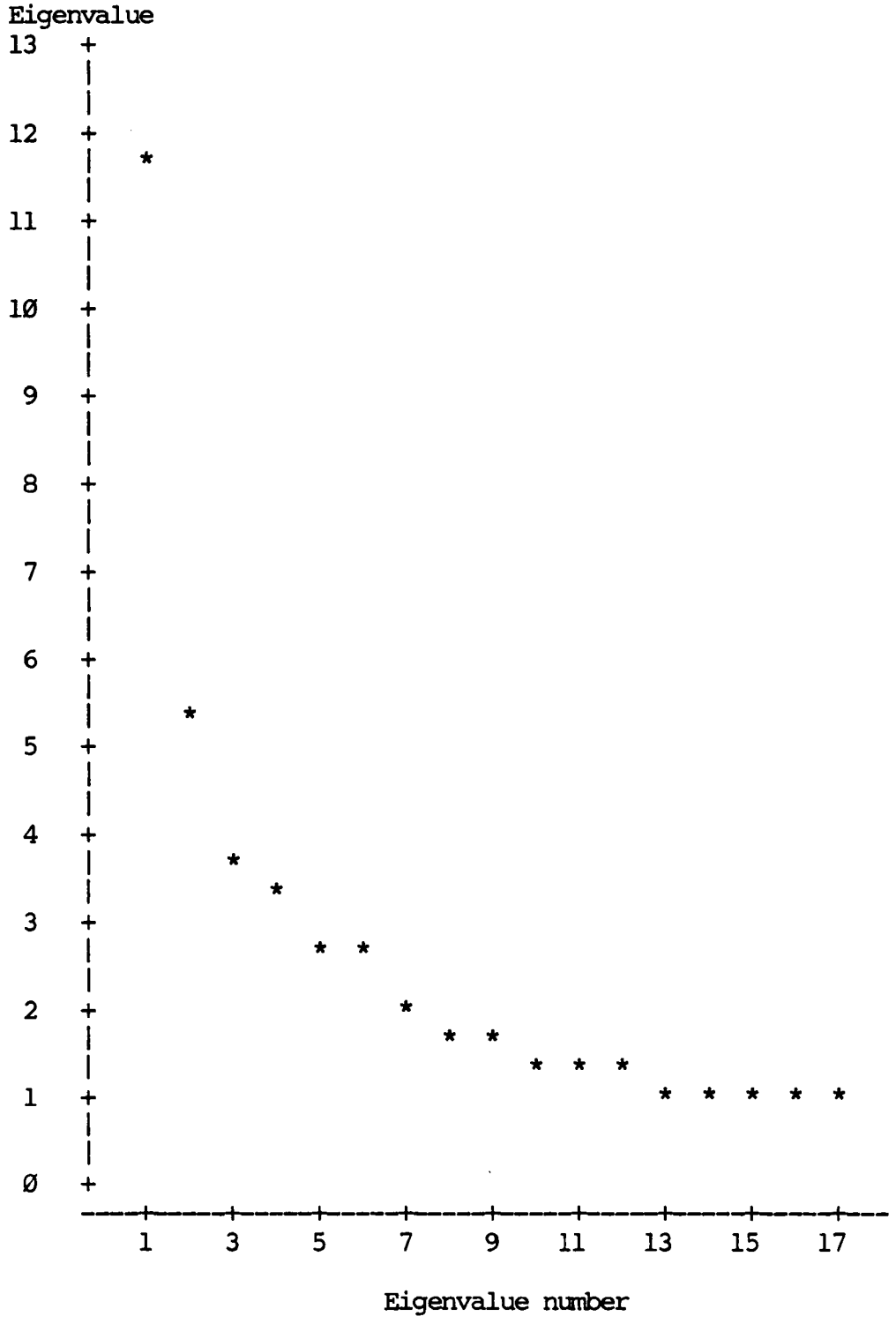

Figure 8. Opinion variables scree plot of eigenvalues of maximum likelihood analysis.

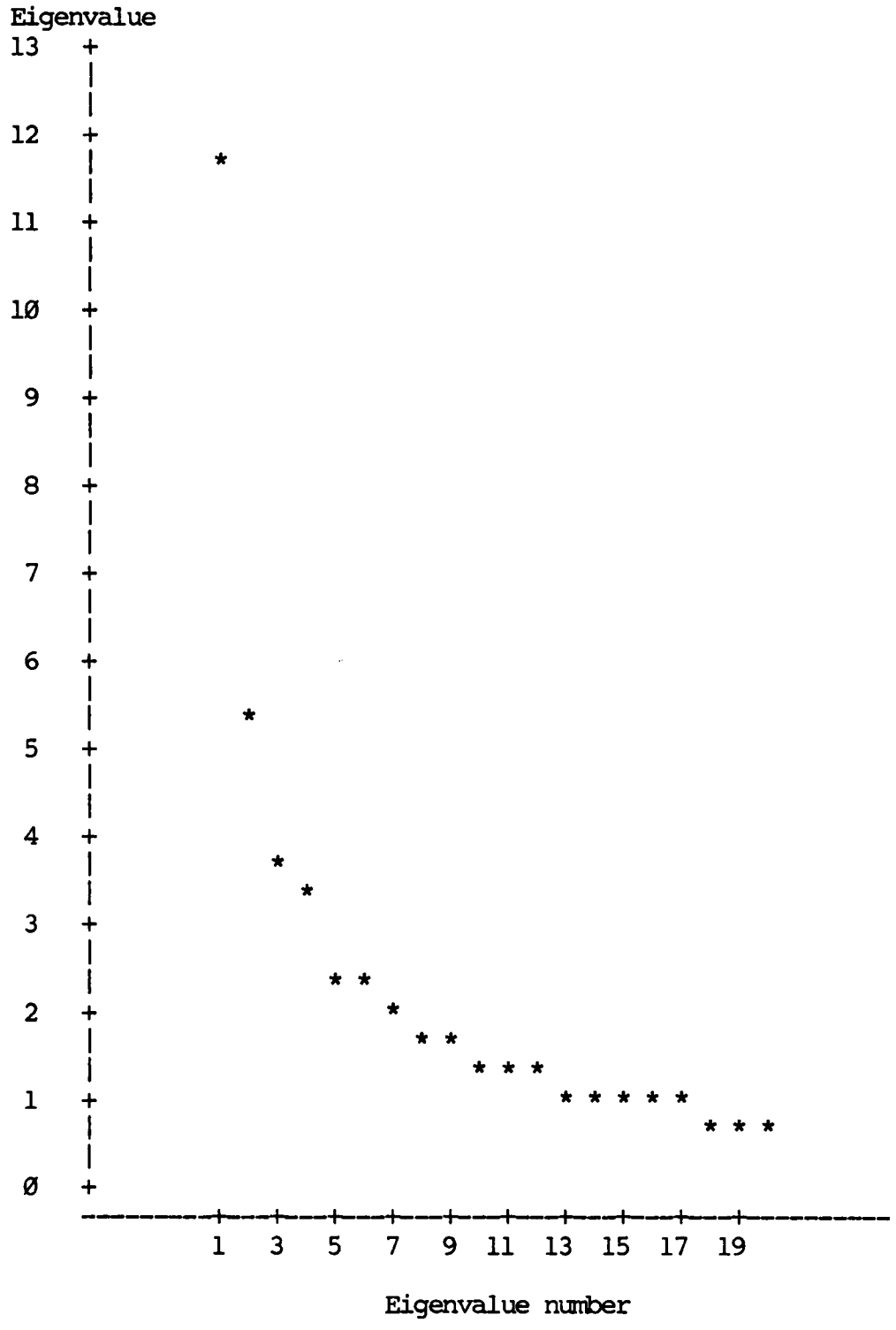

Figure 9. Opinion variables scree plot of eigenvalues of principal axis analysis.

Correlations with other factors were in the range Ø.Ø1 to Ø.27. The correlations were low enough to permit interpretation of the factors as principally independent concepts even though the rotation was not orthogonal.

The variables in the first factor (oblique rotation) are listed in Table 13. The variables met expectations--yes and met expectations--no were aspects of the same variable, the extent the system met the user's expectations. The correlation of the two was -Ø.88. The variables recommend to others--undecided and recommend to others-yes pertained to users' willingness to recommend their system to others. Their correlation was -Ø.89. The loadings on the variables ease of conversion and reliability of manufacturer's application programs were somewhat less than those on the other variables, but these two were still concerned with users' expectations of their use of a system. The variables loading on the first factor pertained in a general way to users' expectations of their systems.

Table 14 presents the variables loading on the second factor (oblique rotation). The variables user education and user documentation distinguished the level of users' perceived competence with the system. The variable advantage--software on schedule pertained to perceived competence in the sense that prompt software delivery enhances users' attempts to achieve proficiency in system use.

Table 15 presents the variables loading on the third factor. The variables problem--program/data compatibility and problem--late delivery of equipment were examples of constraints on effective operation of the system. A failure in either case can render a system ineffective.

TABLE 13

OPINION VARIABLES OBLIQUE ROTATION FACTOR 1: EXPECTATIONS

Variable	Loading
Met expectations--yes	.95
Recommend to others--undecided	-.95
Met expectations--yes	-.95
Recommend to others--yes	.90
Ease of conversion	.64
Reliability of manufacturer's applications programs	.59

TABLE 14

OPINION VARIABLES OBLIQUE ROTATION FACTOR 2: COMPETENCE

Variable	Loading
User education	.81
Advantage--software on schedule	.63
User documentation	.58

TABLE 15

OPINION VARIABLES OBLIQUE ROTATION FACTOR 3: CONSTRAINTS

Variable	Loading
Problem--program and data compatibility	.95
Problem--late delivery of equipment	.71

Relationship of product and opinion factors. The product factors interpreted from the factor pattern were:

1. Capacity of the system for concurrent use,
2. Execution speed and
3. Maximum attainable I/O configuration.

The opinion factors interpreted from the factor pattern were:

1. Satisfaction of users' expectations,
2. Users' perceived competence with a system and
3. Constraints on effective operation.

The first product factor, capacity of the system, can be expressed in terms of the number of concurrent users. The second, execution speed, pertained to the rate of completion of machine instructions by the central processor. The realization of full use of the capabilities represented by product factors depends partly on constraints on effective operation, an opinion factor. The opinion factor users' perceived competence with a system depends partly on how nearly users' expectations of the system match its actual capabilities and how well constraints on effective operation are avoided or overcome. Hence, the opinion and product factors are related. In a general sense, the opinion factors symbolized the degree users' expectations and demands have been satisfied with a system of given product capacities. The factors did not reveal, however, the extent users' prior expectations were consistent system capabilities. That is, users with expectations far lower than system capacities would likely be more satisfied and perceive a greater degree of competence with a system, whereas users whose

expectations exceeded system capacities would likely be less satisfied and perceive a lesser degree of competence.

Requirements Mapping

The procedure for mapping user requirements expressed as natural forecast units (NFUs) onto a subset of the SBC population comprised:

1. Translating the sum of requirements across applications into units of capacity for each of the factor variables identified in the cluster analysis,
2. For each factor variable, identifying the SBCs satisfying the capacity requirement,
3. Forming the intersection of SBCs satisfying all capacity requirements and
4. Selecting an upper bound on the number of SBC candidates consistent with the assumed limitation of the mind to compare at most 7 ± 2 factors simultaneously.

Sample requirements. The mapping procedure was applied with the following hypothetical small business user requirements for accounting functions:

1. Accounts payable: open item accounting for 200 vendors and 500 items initially with a growth capacity to 400 vendors and 1,000 items; automatic interface to general ledger; detail maintained by invoice number, purchase order number and check number for twelve months; selective printing of detail and checks by due date, amount or invoice; online entry, edit and

display of vendor accounts; debit and credit memos and adjustments.

2. Accounts receivable: open item accounting for 250 customers and 2,500 items initially with a growth capacity to 500 customers and 5,000 items; online entry, edit and display of customer open items; interface to general ledger, invoicing and job costing; online customer master file inquiry and maintenance; account aging and reporting; maintenance of sales, cash receipts, and debit and credit memo journals.
3. General ledger: automatic updating, for 200 accounts initially with growth capacity to 400 accounts, through accounts payable, accounts receivable, job costing and payroll; a 24-month history; financial statements consisting of balance sheet, income statement and sources and applications of funds; hierarchical company divisions.
4. Job costing: open item accounting for 500 jobs and 5,000 transactions initially with growth capacity to 1,000 jobs and 10,000 transactions for labor hours and dollars, material and equipment expenses, and service expenditures; online entry, editing and display of job costs by job; automatic interface to general ledger, accounts payable, accounts receivable, invoicing and payroll; job cost reports by division and account manager.
5. Payroll: accounting for 100 employees initially with growth capacity to 200 employees across hourly, weekly and monthly pay periods; automatic interface to general ledger, job

costing and accounts payable; online entry, edit and display of employee detail and compensation history; weekly, monthly and quarterly reporting; check production and detail reports.

6. Anticipated applications: inventory control; budgeting and forecasting.

Given the requirements for accounting functions, the following system operating characteristics and performance criteria were determined. The translation of the requirements is discussed in the next section.

1. Concurrency: Three workstations were required initially with growth capacity to six workstations. Shared access to printers for three workstations required two printers, and for six workstations, two or three printers depending on print speed. Up to the maximum number of workstations, any combination of accounting functions was accessible concurrently.
2. Communications: One data transmission line was required initially for remote access of the system for vendor maintenance. Use of a second line was anticipated for remote inquiry and display of files.
3. System overhead: Disk space for the operating system and the applications programs varied from 500 K bytes to 750 K bytes. Memory for the operating system varied from 32 K bytes to 48 K bytes. Disk space for system work areas and for backup and recovery doubled the amount of disk space for the system.

Translation. The translations of the NFUs for the accounting functions are explained below and summarized in Table 16.

1. Accounts payable: Existing software for the accounts payable features typically required a 32 K bytes of memory (Datapro, 1981a) across the range of vendor and transaction volumes. One workstation was required for each concurrent use of accounts payable, and each workstation consisted of a video terminal and shared access to a printer. Disk space, a function of the number of vendors and transactions based on 100 characters per vendor entry and per transaction, varied from 70 K bytes to 140 K bytes. Execution speed comprised two aspects, data entry at operator keying speed and program execution, a function of transaction volume, at one minute per 100 transactions.

2. Accounts receivable: Requirements for accounts receivable were analogous to those for accounts payable, that is, a 32 K partition, one workstation per concurrent user, data entry at operator keying speed and program execution at 100 transactions per minute. Based on 100 characters each for customer and item records, disk space requirements varied from 256 K bytes to 550 K bytes.

3. General ledger: Existing software for general ledger functions required 32 K byte partitions (Datapro, 1981a). With automatic interface to other accounting functions, operator interaction was required for control, for adjusting entries

TABLE 16

SAMPLE REQUIREMENTS MAPPING: ACCOUNTING FUNCTIONS

Function	Concurrent User Capacity	Execution Speed	Maximum I/O Configuration
Accounts payable	Memory: 32K/user Workstations: one per user Disk: 70K-140K	Data entry at operator speed Transactions: 100/minute	Video terminal: 1/workstation Printer: shared access
Accounts receivable	Memory: 32K/user Workstations: one per user Disk: 275K-550K	Data entry at operator speed Transactions: 100/minute	Video terminal: 1/workstation Printer: shared access
General ledger	Memory: 32K/user Workstations: one per user Disk: 20K-40K	Data entry at operator speed Reports: one per minute	Video terminal: 1/workstation Printer: shared access
Job costing	Memory: 48K-64K/user Workstations: one per user Disk: 550K-1,100K	Data entry at operator speed Transactions: 50/minute Reports: one per 2 minutes	Video terminal: 1/workstation Printer: shared access
Payroll	Memory: 32K/user Workstations: one per user Disk: 20K-40K	Data entry at operator speed Transactions: 100/minute Reports: one per 2 minutes	Video terminal: 1/workstation Printer: shared access

TABLE 16 (Continued)

Function	Concurrent User Capacity	Execution Speed	Maximum I/O Configuration
Anticipated applications	Memory: 32K per application	Data entry at operator speed	Video terminal: 1/workstation
	Workstations: one per user	Transactions: 100 per minute	Printer: shared access
	Disk: 100K-500K	Reports: one to two per minute	

and for initiation of financial statement production. Execution speed was one minute per report. At 100 characters per general ledger account, disk space varied from 20 K bytes to 40 K bytes.

4. Job costing: Existing job costing programs for job costing functions required a 48 K to 64 K partition for each user across the range of job volumes (Datapro, 1981a). Each concurrent job costing user required a workstation, with a video terminal for entry and display and shared access to a printer for reports. Based on 100 characters for each job header record and 100 characters for each transaction, job costing required from 550 K bytes to 1,100 K bytes of disk space. Execution speeds were operator keying speed for entry, 50 transactions per minute, and one set of reports in two minutes.

5. Payroll: Existing payroll programs required a 32 K partition (Datapro, 1981a). As with the other transaction-driven functions, payroll required one workstation per concurrent user, with shared access to a printer and data entry at operator speed. For 200-character employee records, payroll required from 20 K bytes to 40 K bytes of disk space. Execution speeds were 100 transactions per minute and one report in two minutes.

The sum of capacity requirements for each factor variable is presented in Table 17. For the first factor, capacity for concurrent

TABLE 17

TOTAL CAPACITY REQUIREMENTS BY FACTOR VARIABLE

Factor Variable	Capacity Requirements
Capacity for concurrent use	
Basic memory in bytes: 3 users	128 K to 144 K
Maximum memory in K bytes: 6 users	240 K to 272 K
Workstations	3 to 6
Maximum disk in bytes	6,240 K
Execution speed	
Data entry	operator keying speed
Transactions	50 to 100 per minute
Reports	0.5 to 1 per minute
Maximum I/O configuration	
Maximum lines	2
Maximum I/O ports	11 (6 video terminals, 3 printers and 2 disk drives)

use, basic memory was in the range 128 K bytes to 144 K bytes; maximum memory, in the range 240 K bytes to 272 K bytes; workstations, in the range 3 to 6; and maximum disk space, 6,240 K bytes. For the second factor, execution speed, data entry was at operator keying speed; transaction execution, from 50 to 100 transactions per minute; and report production, from one to two reports in two minutes. The third factor, maximum I/O configuration, yielded a maximum of two communications lines and a maximum of eleven I/O ports.

SBCs satisfying sample requirements. The numbers of SBCs satisfying the sample capacity requirements are given in Table 18. Except for the variables cycle time and access time comprising the execution speed factor, all variable mappings were performed directly from SBC variable values. The requirements for the rates of transaction processing and report generation could not be mapped to cycle and access times because of the lack of empirical data for the estimations. For the 169 systems supporting six or more workstations, the cycle time and access time variation was:

	Cycle time	Access time
Lowest cycle time	0.2 microseconds	0.2 microseconds
Highest cycle time	740 microseconds	740 microseconds
Lowest access time	0.2 microseconds	0.2 microseconds
Highest access time	740 microseconds	740 microseconds

TABLE 18

NUMBER OF SBCS SATISFYING SAMPLE CAPACITY REQUIREMENTS

Factor Variable	Number of SBCs Meeting or Exceeding Capacity Requirements
Capacity for concurrent use	
Basic memory: 128K bytes or more	100
Maximum memory: 240 K bytes or more	90
Workstations: 3 to 6	169
Maximum disk: 6,240 K bytes or more	298
All capacity for concurrent use requirements	59
Execution speed	
Data entry: 3 to 6 workstations	169
Transactions: 50 to 100 per minute	--
Reports: 0.5 to 1 per minute	--
All execution speed requirements	169
Maximum I/O configuration	
Maximum lines: 2	244
Maximum I/O ports: 11	171
All maximum I/O configuration requirements	152
Product factors	
All capacity for concurrent use variables	59
All execution speed variables	169
All maximum I/O configuration variables	152
All product factors	31

For the 31 SBCs satisfying all product factors, the cycle time and access time variation was:

	Cycle time	Access time
Lowest cycle time	Ø.2 microseconds	value missing
Highest cycle time	1.5 microseconds	Ø.8 microseconds
Lowest access time	Ø.4 microseconds	Ø.2 microseconds
Highest access time	Ø.95 microseconds	Ø.95 microseconds

SBCs satisfying all capacity requirements. Thirty-one SBCs satisfied the capacity requirements for all product factors. The price distribution for these 31 SBCs is presented in Figure 1Ø. The prices varied from $13,85Ø to $21Ø,ØØØ.

Upper bound on number of SBCs. In practice, a number of factors could be the basis for reducing the number of SBC candidates to a number consistent with the assumed ability of the mind to make at most 7 ± 2 simultaneous comparisons. For example, candidates lacking maintenance coverage in a given geographical area, candidates from a vendor in a poor financial position or candidates whose prices exceed an initial estimate by a large amount might be excluded from further consideration.

For this execution of the AHP, the number of SBC candidates was bounded from above with a maximum basic system price. An upper bound of $45,ØØØ yielded five SBCs with the variable values presented in Table 19.

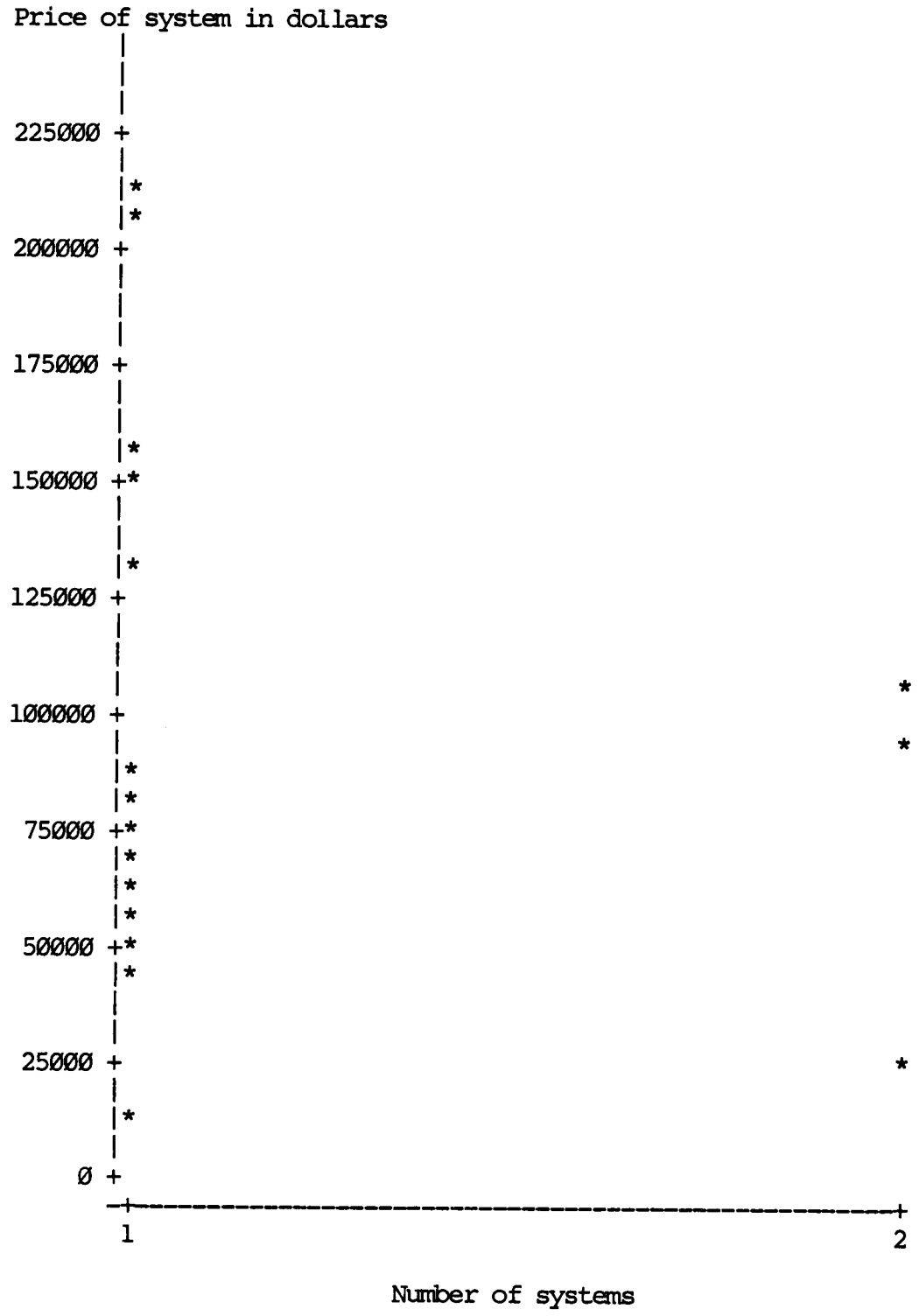

Figure 10. Price distribution of SBCs satisfying sample requirements.

TABLE 19

SBC CANDIDATES BOUNDED BY BASIC SYSTEM PRICE

Variable	SBC Candidate 1	2	3	4	5
Capacity for concurrent use					
Basic memory, K bytes	256	256	128	128	128
Maximum memory, K bytes	1,Ø24	512	512	512	2,Ø48
Basic system price	$13,85Ø	$22,ØØØ	$22,ØØØ	$43,ØØØ	$44,5ØØ
Workstations, number	32	32	11	16	16
Maximum disk, megabytes	1,6ØØ	8ØØ	8ØØ	4ØØ	25
Execution speed					
Cycle time, microsec.	Ø.4	Ø.66	Ø.66	Ø.6	Ø.74
Access time, microsec.	Ø.4	Ø.66	Ø.66	Ø.6	Ø.74
Maximum I/O configuration					
Maximum lines, number	64	3	3	32	16
Availability date	1/81	12/77	12/77	11/79	N/A
Maximum I/O ports	64	32	16	64	18Ø

Analytic Hierarchy Process

Application of the analytic hierarchy process (AHP) required:

1. Construction of an attribute hierarchy based on the factor variables determined in the cluster analysis,
2. Development of an interactive computer program for performing the AHP and
3. Execution of the AHP for the sample user requirements for accounting applications in a hypothetical small business.

Construction of attribute hierarchy. The results of the cluster and factor analysis were used to construct an attribute hierarchy for the execution of the AHP. Posed as an attribute hierarchy, sets of product and opinion factors were considered in small groups. With the AHP, ordinal preferences were maintained, and the selection required only a few simultaneous comparisons. Figure 11 for product factors and Figure 12 for opinion factors present the attribute hierarchy as a tree structure, based on the factor variables presented in Table 7, page 45, for product factors and in Table 12, page 60, for opinion factors.

The first level was the overall objective, the selection of an SBC. The second level had two nodes, product factors and opinion factors. At the third level, product factors expanded to:

1. Capacity for concurrent use,
2. Execution speed and
3. Maximum attainable I/O configuration.

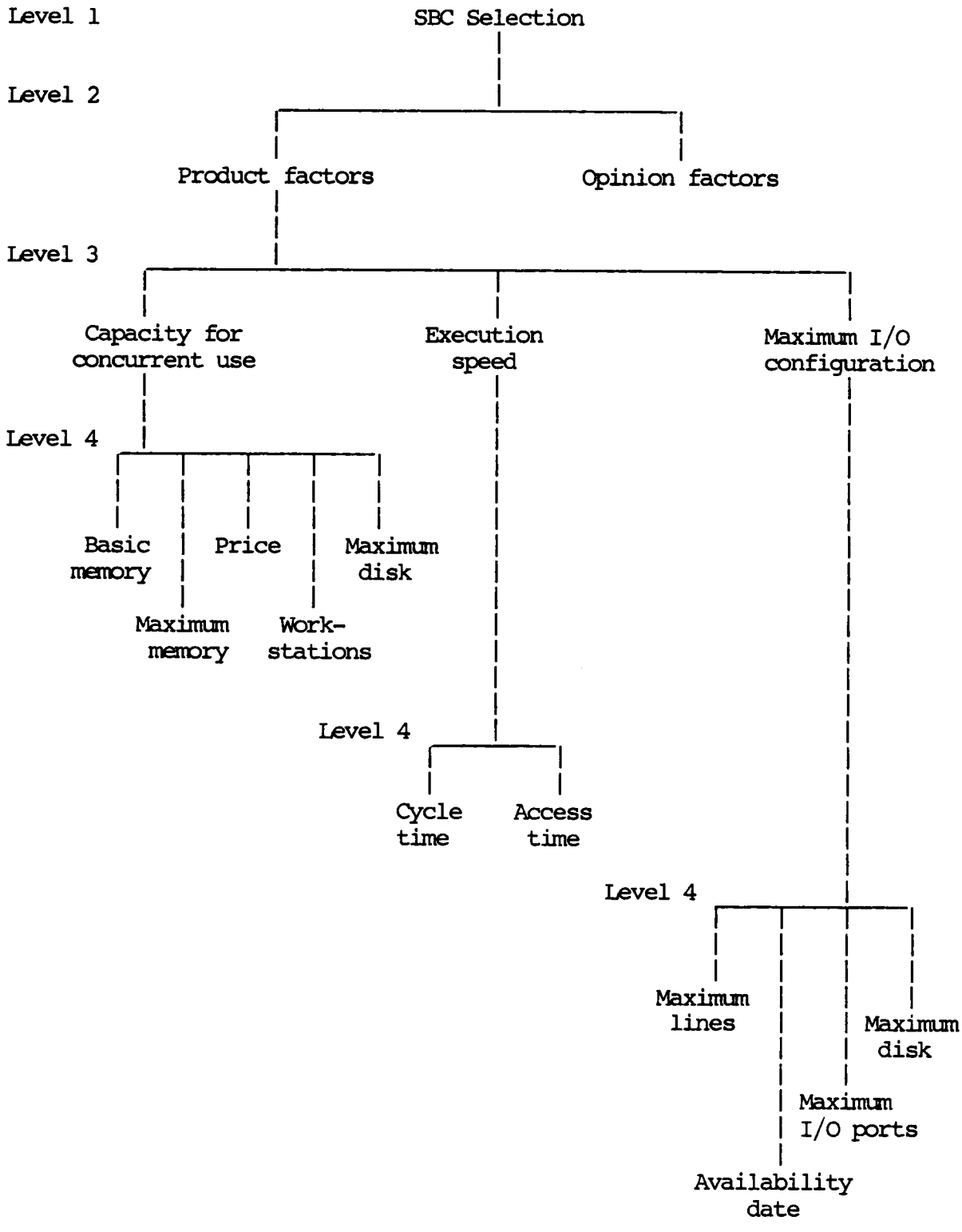

Figure 11. Product factor attribute hierarchy for selection of an SBC.

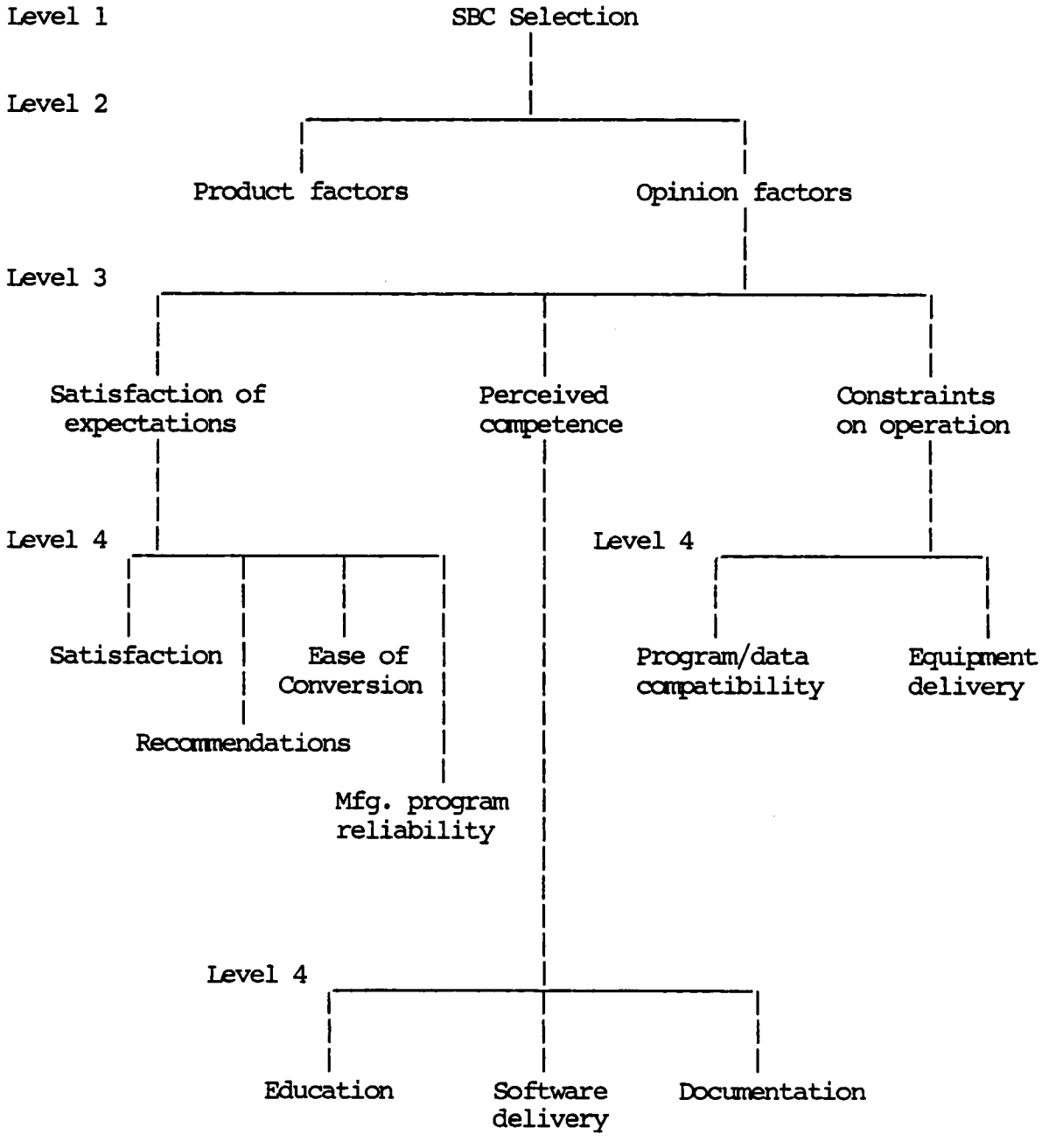

Figure 12. Opinion factor attribute hierarchy for selection of an SBC.

At the fourth level, capacity for concurrent use became:

1. Basic memory,
2. Maximum memory,
3. Basic system price,
4. Workstations and
5. Maximum disk.

Execution speed expanded to:

1. Cycle time and
2. Access time.

Maximum I/O configuration became:

1. Maximum lines,
2. Availability date,
3. Maximum I/O ports and
4. Maximum disk.

Opinion factors at the third level expanded to:

1. Satisfaction of expectations,
2. Perceived competence with a system and
3. Constraints on effective operation.

At the fourth level, satisfaction of expectations became:

1. Satisfaction of expectations,
2. Recommendations,
3. Ease of conversion and
4. Reliability of manufacturer's applications programs.

The node perceived competence expanded to:

1. User education,
2. Adherence to software delivery schedules and

3. User documentation.

The node constraints on effective operation became:

1. The degree of program and data compatibility and

2. Adherence to equipment delivery schedule.

At any level, additional nodes could be added as long as the number of entries does not exceed 7 ± 2. For example, suppose the fourth product factor in Table 7, page 45, had been interpreted. Then the entries at the third level for product factors would have been:

1. Capacity for concurrent use,

2. Execution speed,

3. Maximum attainable I/O configuration and

4. A concept embracing the fourth product factor.

At the fourth level, the fourth product factor would have been expanded to:

1. Basic I/O ports and

2. Maximum I/O ports.

In this way, nodes at any level could be expanded in accordance with later findings concerning the product or opinion attribute space and firm-specific requirements or preferences. In practice, the entries probably would be expanded to a greater level of detail than that used in this execution of the AHP.

AHP Computer Program and Execution

The AHP was implemented in an interactive PL/I program. Its structure consisted of the following segments:

1. Initialization and presentation of the attribute hierarchy,
2. Prompting for judgment matrices for the attributes at all levels,
3. Prompting for comparisons of each pair of candidate systems for each attribute at the lowest level of the hierarchy,
4. Computation and presentation of the solution for an iteration and
5. Prompting for marginal analysis of the solution vector through incremental changes in the attribute and candidate preferences.

Individual segments of the AHP program and their execution are described below. Figure 17 in Appendix C contains a complete execution of the AHP for the selection of an SBC from the feasible set of five SBCs chosen through requirements mapping.

Program complexity. The computer code was implemented for an attribute hierarchy of two and four levels. A four-level hierarchy was required for the SBC product and opinion variables. This implementation represented an extension of the complexity of multi-criteria problems which could be addressed with the AHP as published accounts of AHP use described its application to two-level hierarchies only. The computer code was independent of the problem context in that the hierarchy itself was entered as data.

Program verification. For the two-level case, the author's AHP program reproduced Saaty's results for the AHP applied to six attributes and three candidates for school selection (1977, pp. 265-7). Normalized

row sums of powered judgment matrices typically converged (absolute differences less than Ø.ØØØ1) within the 64th power for matrices of order six.

Dialogue conventions. In the AHP-system selector dialogues, prompts for responses were colons (:) followed by periods (.) at the end of AHP-generated lines or colons at the beginning of lines. The AHP program saved the attribute hierarchy, the judgment matrices for attributes and the comparison matrices of candidates with respect to attributes for reuse in subsequent executions of the AHP.

Initialization of the attribute hierarchy. Figure 13 presents the AHP-system selector dialogue prompting for the attribute hierarchy specified in Figures 11 and 12. The AHP program asked whether the attribute hierarchy had been entered previously and, if not, prompted the system selector for the hierarchy. Once entered, the hierarchy was presented.

Judgments of the attributes. The AHP program gave an opportunity for the system selector to view an explanation of the preference scale, as presented in Figure 14. The program asked whether the judgments for attributes had been entered, and, if not, prompted for them. In either case, the judgments were presented. The AHP program presented the weightings (the normalized eigenvector) and the consistency index for the attributes at each node and prompted for revision of the judgments.

```
Have you entered the attribute hierarchy? y for yes, n for no:
n
Enter name of the overall objective:
SBC Selection
Give the number of levels in the hierarchy:
4
Enter number of nodes at the second level:
2
Enter names of attributes at the second level, one per line:
product
:
opinion
Enter the number of nodes below product    :
3
One node per line, enter names of nodes below product    :
concurrent use capacity
:
execution speed
:
I/O configuration-maximum
Enter the number of nodes below concurrent use capacity        :
5
One node per line, enter names of nodes below concurrent use capacity  :
memory-basic
:
memory-maximum
:
price
:
workstations
:
disk-maximum
Enter the number of nodes below execution speed                :
2
One node per line, enter names of nodes below execution speed         :
cycle time
:
access time
Enter the number of nodes below I/O configuration-maximum       :
4
One node per line, enter names of nodes below I/O configuration-maximum:
lines-maximum
:
availability date
:
I/O ports-maximum
:
disk-maximum
Enter the number of nodes below opinion    :
```

Figure 13. AHP initialization of attribute hierarchy.

```
3
One node per line, enter names of nodes below opinion    :
satisfaction of expectations
:
competence-perceived
:
constraints on operation
Enter the number of nodes below expectations-satisfaction    :
4
One node per line, enter names of nodes below expectations-satisfaction:
satisfaction
:
recommendations
:
conversion ease
:
mfg. program reliability
Enter the number of nodes below competence-perceived      :
3
One node per line, enter names of nodes below competence-perceived:
education
:
software delivery
:
documentation
Enter the number of nodes below constraints on operation    :
2
One node per line, enter names of nodes below constraints on operation:
compatibility-program/data
:
equipment delivery

Overall objective of attribute hierarchy is SBC Selection
Nodes at the second level are:
                    product
                    opinion
          Nodes below product
                     concurrent use capacity
                     execution speed
                     I/O configuration-maximum
                     nodes below concurrent use capacity
                               memory-basic
                               memory-maximum
                               price
                               workstations
                               disk-maximum
                     Nodes below execution speed
                               cycle time
                               access time
```

Figure 13. (Continued)

Nodes below maximum I/O configuration
lines-maximum
availability date
I/O ports-maximum
disk-maximum
Nodes below opinion
expectations-satisfaction
competence-perceived
constraints on operation
Nodes below expectations-satisfaction
satisfaction
recommendations
conversion ease
mfg. program reliability
Nodes below competence-perceived
education
software delivery
documentation
Nodes below constraints on operation
compatibility-program/data
equipment delivery

Figure 13. (Continued)

```
Have you entered judgments for attributes?  y or n:
n
Do you want an explanation of the preference scale?  y or n:
y

Preference              Explanation

     1          Equal contribution
     3          Weak importance--one slightly favored over the other
     5          Strong importance--one strongly favored over the other
     7          Demonstrated importance--one strongly favored over the
                other with demonstrated importance
     9          Absolute importance--highest favoring of one over the other
2, 4, 6, 8      Intermediate values of judgments
Reciprocals     Opposite order comparisons

Enter your preferences in the form
digit digit
For example, to give the preference for
product   to opinion
where you slightly favor opinion    to product    enter
1 3

product   to opinion   :
1 1
concurrent use capacity       to execution speed              :
5 1
concurrent use capacity       to I/O configuration-maximum    :
5 1
execution speed               to I/O configuration-maximum    :
1 3
expectations-satisfaction     to competence-perceived         :
5 1
expectations-satisfaction     to constraints on operation     :
1 7
competence-perceived          to constraints on operation     :
1 5
memory-basic                  to memory-maximum               :
1 3
memory-basic                  to price                        :
1 7
memory-basic                  to workstations                 :
1 7
memory-basic                  to disk-maximum                 :
5 1
memory-maximum                to price                        :
1 5
memory-maximum                to workstations                 :
1 5
memory-maximum                to disk-maximum                 :
```

Figure 14. AHP prompting for judgments of attributes.

```
3 1
price                          to workstations          :
3 1
price                          to disk-maximum          :
3 1
workstations                   to disk-maximum          :
5 1
cycle time                     to access time           :
1 1
lines-maximum                  to availability date     :
3 1
lines-maximum                  to I/O ports-maximum     :
1 5
lines-maximum                  to disk-maximum          :
3 1
availability date              to I/O ports-maximum     :
1 7
availability date              to disk-maximum          :
5 1
I/O ports-maximum              to disk-maximum          :
3 1
satisfaction                   to recommendations       :
1 1
satisfaction                   to conversion ease       :
1 3
satisfaction                   to mfg. program reliability :
1 5
recommendations                to conversion ease       :
1 3
recommendations                to mfg. program reliability :
1 5
conversion ease                to mfg. program reliability :
3 1
education                      to software delivery     :
1 1
education                      to documentation         :
3 1
software delivery              to documentation         :
1 5
compatibility-program/data     to equipment delivery    :
3 1
```

Level 2 judgments for SBC Selection

		1 product	2 opinion
1	product	1.00	1.00
2	opinion	1.00	1.00

Figure 14. (Continued)

```
The eigenvalue is  2.ØØ  (Consistency value is  2.Ø)
The consistency of level 2 judgments is       Ø.ØØ
The weightings are     Ø.5Ø    Ø.5Ø

Do you want to change any preferences at this level?  y or n:
n

Level 3 judgments for product

                    1         2         3
                concurre  executio  I/O conf
              |-------------------------------
1  concurre   |    1.ØØ      5.ØØ      5.ØØ
2  executio   |    Ø.2Ø      1.ØØ      Ø.33
3  I/O conf   |    Ø.2Ø      3.ØØ      1.ØØ

The eigenvalue is  3.14  (Consistency value is  3.Ø)
The consistency of level 3 judgments under product          is  Ø.Ø7
The weightings are    Ø.7Ø    Ø.1Ø    Ø.2Ø

Level 3 judgments for opinion

                    1         2         3
                expectat  competen  constrai
              |-------------------------------
1  expectat   |    1.ØØ      5.ØØ      Ø.14
2  competen   |    Ø.2Ø      1.ØØ      Ø.2Ø
3  constrai   |    7.ØØ      5.ØØ      1.ØØ

The eigenvalue is  3.44  (Consistency value is  3.Ø)
The consistency of level 3 judgments under opinion          is  Ø.22
The weightings are    Ø.2Ø    Ø.Ø8    Ø.73

Do you want to change any preferences under product? y or n:
y
Enter a row number for the new preference:
1
Enter a column number for the new preference:
3
Enter preference for concurrent use capacity to I/O configuration-
maximum:
3 1
Do you have further changes at this level?  y or n:
n

Level 3 judgments for product
```

Figure 14. (Continued)

```
                    1          2          3
                concurre   executio  I/O conf
              |-------------------------------
1  concurre   |    1.00       5.00       3.00
2  executio   |    0.20       1.00       0.33
3  I/O conf   |    0.33       3.00       1.00

The eigenvalue is  3.04  (Consistency value is  3.0)
The consistency of level 3 judgments under product          is  0.02
The weightings are     0.64     0.10     0.26

Level 3 judgments for opinion

                    1          2          3
                expectat   competen   constrai
              |-------------------------------
1  expectat   |    1.00       5.00       0.14
2  competen   |    0.20       1.00       0.20
3  constrai   |    7.00       5.00       1.00

The eigenvalue is  3.44  (Consistency value is  3.0)
The consistency of level 3 judgments under opinion          is  0.22
The weightings are     0.20     0.08     0.73

Do you want to change any preferences under product? y or n:
n
Do you want to change any preferences under opinion? y or n:
n
Level 4 judgments for concurrent use capacity

                    1          2          3          4          5
                memory-b   memory-m   price      workstat   disk-max
              |-------------------------------------------------------
1  memory-b   |    1.00       0.33       0.14       0.14       5.00
2  memory-m   |    3.00       1.00       0.20       0.20       3.00
3  price      |    7.00       5.00       1.00       3.00       3.00
4  workstat   |    7.00       5.00       0.33       1.00       5.00
5  disk-max   |    0.20       0.33       0.33       0.20       1.00

The eigenvalue is  5.99  (Consistency value is  5.0)
The consistency of level 4 judgments under concurrent use  is  0.25
The weightings are     0.08     0.11     0.44     0.31     0.05

Level 4 judgments for execution speed
```

Figure 14. (Continued)

		1 cycle ti	2 access t
1	cycle ti	1.00	1.00
2	access t	1.00	1.00

The eigenvalue is 2.00 (Consistency value is 2.0)
The consistency of level 4 judgments under execution speed is 0.00
The weightings are 0.50 0.50

Level 4 judgments for I/O configuration-maximum

		1 lines-ma	2 availabi	3 I/O port	4 disk-max
1	lines-ma	1.00	3.00	0.20	3.00
2	availabi	0.33	1.00	0.14	5.00
3	I/O port	5.00	7.00	1.00	3.00
4	disk-max	0.33	0.20	0.33	1.00

The eigenvalue is 4.80 (Consistency value is 4.0)
The consistency of level 4 judgments under I/O configurati is 0.27
The weightings are 0.20 0.14 0.58 0.08

Level 4 judgments for expectations-satisfaction

		1 satisfac	2 recommen	3 conversi	4 mfg. pro
1	satisfac	1.00	1.00	0.33	0.20
2	recommen	1.00	1.00	0.33	0.20
3	conversi	3.00	3.00	1.00	3.00
4	mfg. pro	5.00	5.00	0.33	1.00

The eigenvalue is 4.34 (Consistency value is 4.0)
The consistency of level 4 judgments under expectations-sa is 0.11
The weightings are 0.10 0.10 0.47 0.33

Level 4 judgments for competence-perceived

		1 educatio	2 software	3 document
1	educatio	1.00	1.00	3.00
2	software	1.00	1.00	0.20
3	document	0.33	5.00	1.00

Figure 14. (Continued)

```
The eigenvalue is  3.87  (Consistency value is  3.Ø)
The consistency of level 4 judgments under competence-perc is  Ø.44
The weightings are     Ø.45    Ø.18    Ø.37

Level 4 judgments for constraints on operation

                    1         2
                 compatib  equipmen

              |-------------------
1  compatib   |    1.ØØ      3.ØØ
2  equipmen   |    Ø.33       1.ØØ

The eigenvalue is  2.ØØ  (Consistency value is  2.Ø)
The consistency of level 4 judgments under constraints on  is -Ø.ØØ
The weightings are     Ø.75    Ø.25

Do you want to change any preference under concurrent use ?  y or n:
n
Do you want to change any preference under execution speed?  y or n:
n
Do you want to change any preference under I/O configurati?  y or n:
n
Do you want to change any preference under expectations-sa?  y or n:
n
Do you want to change any preference under competence-perc?  y or n:
n
Do you want to change any preference under constraints on ?  y or n:
n
```

Figure 14. (Continued)

Comparisons of candidates with respect to attributes. As presented in Figure 15, the AHP program prompted the system selector for comparisons of pairs of the five candidate systems, chosen through requirements mapping, with respect to each of the lowest level attributes. If they had already been entered, the comparisons were displayed. The presentation of the weightings and consistency indices was followed by a request for revision to the candidate comparisons.

Solution and marginal analysis. Figure 16 presents a solution, the weightings for each candidate system, for SBC selection from the five candidates identified through requirements mapping. After each iteration, the program prompted the system selector for changes to the attribute judgments at all levels and to the candidate preferences. The largest weighting indicated the best system, and the lowest weighting, the least desirable system.

Table 20 presents candidate weightings of solutions for varying product to opinion variable preferences. For the strongest preference of product to opinion (9 to 1), the first system was the most preferred. This choice was partly a function of the first system's low price relative to that of the others. As the relative preference of product to opinion decreased, the weightings of the last four candidates increased so that for even preference (1 to 1) there was no clear choice of a best system. For the strongest preference of opinion over product (1 to 9), there was no decisive choice among the top three candidates, the second, third and fifth SBCs. The fourth system failed to be a contender for any level of product to opinion preference.

```
Have you entered comparisons of candidates with respect to attributes?
yes or no:.n
How many candidates are there?:.5
Enter preferences for candidate comparisons with respect to attributes
Attribute is memory-basic
Candidate 1 to 2:.1 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.3 1
Candidate 1 to 5:.5 1
Candidate 2 to 3:.3 1
Candidate 2 to 4:.3 1
Candidate 2 to 5:.3 1
Candidate 3 to 4:.1 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 1

Attribute is memory-maximum
Candidate 1 to 2:.3 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.3 1
Candidate 1 to 5:.1 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 1
Candidate 2 to 5:.1 3
Candidate 3 to 4:.1 1
Candidate 3 to 5:.1 3
Candidate 4 to 5:.1 3

Attribute is price
Candidate 1 to 2:.5 1
Candidate 1 to 3:.5 1
Candidate 1 to 4:.9 1
Candidate 1 to 5:.9 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.5 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.5 1
Candidate 4 to 5:.1 1

Attribute is workstations
Candidate 1 to 2:.1 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.3 1
Candidate 1 to 5:.3 1
Candidate 2 to 3:.3 1
Candidate 2 to 4:.3 1
Candidate 2 to 5:.3 1
```

Figure 15. AHP prompting for comparisons of candidates with respect to attributes.

```
Candidate 3 to 4:.1 3
Candidate 3 to 5:.1 3
Candidate 4 to 5:.1 1

Attribute is disk-maximum
Candidate 1 to 2:.3 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.3 1
Candidate 1 to 5:.5 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.3 1
Candidate 2 to 5:.5 1
Candidate 3 to 4:.3 1
Candidate 3 to 5:.5 1
Candidate 4 to 5:.5 1

Attribute is cycle time
Candidate 1 to 2:.1 1
Candidate 1 to 3:.1 1
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.1 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 1

Attribute is access time
Candidate 1 to 2:.1 1
Candidate 1 to 3:.1 1
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.1 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 1

Attribute is lines-maximum
Candidate 1 to 2:.3 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 5
Candidate 2 to 5:.1 5
Candidate 3 to 4:.1 5
Candidate 3 to 5:.1 5
```

Figure 15. (Continued)

```
Candidate 4 to 5:.1 1

Attribute is availability date
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 7
Candidate 1 to 5:.1 3
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 5
Candidate 2 to 5:.1 1
Candidate 3 to 4:.1 3
Candidate 3 to 5:.1 1
Candidate 4 to 5:.5 1

Attribute is I/O ports-maximum
Candidate 1 to 2:.3 1
Candidate 1 to 3:.5 1
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 1
Candidate 2 to 3:.3 1
Candidate 2 to 4:.1 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.1 3
Candidate 3 to 5:.1 3
Candidate 4 to 5:.1 1

Attribute is disk-maximum
Candidate 1 to 2:.1 3
Candidate 1 to 3:.3 1
Candidate 1 to 4:.3 1
Candidate 1 to 5:.5 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.3 1
Candidate 2 to 5:.5 1
Candidate 3 to 4:.3 1
Candidate 3 to 5:.5 1
Candidate 4 to 5:.5 1

Attribute is satisfaction
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 5
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 5
```

Figure 15. (Continued)

```
Attribute is recommendations
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 5
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 5

Attribute is conversion ease
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 5
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 5

Attribute is mfg. program reliability
Candidate 1 to 2:.1 3
Candidate 1 to 3:.1 3
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 3
Candidate 2 to 3:.1 1
Candidate 2 to 4:.3 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.3 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 3

Attribute is education
Candidate 1 to 2:.3 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.1 7
Candidate 1 to 5:.5 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 5
Candidate 2 to 5:.1 1
Candidate 3 to 4:.1 5
Candidate 3 to 5:.1 1
Candidate 4 to 5:.7 1

Attribute is software delivery
Candidate 1 to 2:.1 5
```

Figure 15. (Continued)

```
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 5
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 5

Attribute is documentation
Candidate 1 to 2:.3 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.1 7
Candidate 1 to 5:.5 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 5
Candidate 2 to 5:.1 1
Candidate 3 to 4:.1 5
Candidate 3 to 5:.1 1
Candidate 4 to 5:.7 1

Attribute is compatibility-program/data
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 5
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 5

Attribute is equipment delivery
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 5
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 5

Candidate preferences for attribute memory-basic
```

Figure 15. (Continued)

	1	2	3	4	5
1	1.00	1.00	3.00	3.00	5.00
2	1.00	1.00	3.00	3.00	3.00
3	0.33	0.33	1.00	1.00	1.00
4	0.33	0.33	1.00	1.00	1.00
5	0.20	0.33	1.00	1.00	1.00

The eigenvalue is 5.0 (Consistency value is 5.0)
The consistency of candidate judgments is 0.01
The eigenvector is 0.36 0.32 0.11 0.11 0.10

Do you want to change any preferences for this attribute? y or n:.y

Enter a row number for the new preference:.1
Enter a column number for the new preference:.5
Enter a preference for attribute memory-basic :
Candidates 1 5:.3 1
Do you have further changes for this attribute? y or n:.n

Candidate preferences for attribute memory-basic

	1	2	3	4	5
1	1.00	1.00	3.00	3.00	3.00
2	1.00	1.00	3.00	3.00	3.00
3	0.33	0.33	1.00	1.00	1.00
4	0.33	0.33	1.00	1.00	1.00
5	0.33	0.33	1.00	1.00	1.00

The eigenvalue is 5.0 (Consistency value is 5.0)
The consistency of candidate judgments is -0.00
The eigenvector is 0.33 0.33 0.11 0.11 0.11

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute memory-maximum

	1	2	3	4	5
1	1.00	3.00	3.00	3.00	1.00
2	0.33	1.00	1.00	1.00	0.33
3	0.33	1.00	1.00	1.00	0.33
4	0.33	1.00	1.00	1.00	0.33
5	1.00	3.00	3.00	3.00	1.00

The eigenvalue is 5.0 (Consistency value is 5.0)

Figure 15. (Continued)

The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.33 Ø.11 Ø.11 Ø.11 Ø.33

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute price

	1	2	3	4	5
1	1.ØØ	5.ØØ	5.ØØ	9.ØØ	9.ØØ
2	Ø.2Ø	1.ØØ	1.ØØ	5.ØØ	5.ØØ
3	Ø.2Ø	1.ØØ	1.ØØ	5.ØØ	5.ØØ
4	Ø.11	Ø.2Ø	Ø.2Ø	1.ØØ	1.ØØ
5	Ø.11	Ø.2Ø	Ø.2Ø	1.ØØ	1.ØØ

The eigenvalue is 5.2 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø4
The eigenvector is Ø.58 Ø.17 Ø.17 Ø.Ø4 Ø.Ø4

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute workstations

	1	2	3	4	5
1	1.ØØ	1.ØØ	3.ØØ	3.ØØ	3.ØØ
2	1.ØØ	1.ØØ	3.ØØ	3.ØØ	3.ØØ
3	Ø.33	Ø.33	1.ØØ	Ø.33	Ø.33
4	Ø.33	Ø.33	3.ØØ	1.ØØ	1.ØØ
5	Ø.33	Ø.33	3.ØØ	1.ØØ	1.ØØ

The eigenvalue is 5.2 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø5
The eigenvector is Ø.33 Ø.33 Ø.Ø7 Ø.14 Ø.14

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute disk-maximum

	1	2	3	4	5
1	1.ØØ	3.ØØ	3.ØØ	3.ØØ	5.ØØ
2	Ø.33	1.ØØ	1.ØØ	3.ØØ	5.ØØ
3	Ø.33	1.ØØ	1.ØØ	3.ØØ	5.ØØ
4	Ø.33	Ø.33	Ø.33	1.ØØ	5.ØØ
5	Ø.2Ø	Ø.2Ø	Ø.2Ø	Ø.2Ø	1.ØØ

Figure 15. (Continued)

The eigenvalue is 5.3 (Consistency value is 5.0)
The consistency of candidate judgments is Ø.Ø9
The eigenvector is Ø.42 Ø.21 Ø.21 Ø.11 Ø.Ø4

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute cycle time

	1	2	3	4	5
1	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
2	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
3	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
4	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
5	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.ØØ
The eigenvector is Ø.2Ø Ø.2Ø Ø.2Ø Ø.2Ø Ø.2Ø

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute access time

	1	2	3	4	5
1	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
2	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
3	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
4	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
5	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.ØØ
The eigenvector is Ø.2Ø Ø.2Ø Ø.2Ø Ø.2Ø Ø.2Ø

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute lines-maximum

	1	2	3	4	5
1	1.ØØ	3.ØØ	3.ØØ	1.ØØ	1.ØØ
2	Ø.33	1.ØØ	1.ØØ	Ø.2Ø	Ø.2Ø
3	Ø.33	1.ØØ	1.ØØ	Ø.2Ø	Ø.2Ø
4	1.ØØ	5.ØØ	5.ØØ	1.ØØ	1.ØØ
5	1.ØØ	5.ØØ	5.ØØ	1.ØØ	1.ØØ

Figure 15. (Continued)

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø1
The eigenvector is Ø.25 Ø.Ø7 Ø.Ø7 Ø.31 Ø.31

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute availability date

	1	2	3	4	5
1	1.ØØ	Ø.2Ø	Ø.2Ø	Ø.14	Ø.33
2	5.ØØ	1.ØØ	1.ØØ	Ø.2Ø	1.ØØ
3	5.ØØ	1.ØØ	1.ØØ	Ø.33	1.ØØ
4	7.ØØ	5.ØØ	3.ØØ	1.ØØ	5.ØØ
5	3.ØØ	1.ØØ	1.ØØ	Ø.2Ø	1.ØØ

The eigenvalue is 5.2 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø4
The eigenvector is Ø.Ø4 Ø.15 Ø.16 Ø.52 Ø.13

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute I/O ports-maximum

	1	2	3	4	5
1	1.ØØ	3.ØØ	5.ØØ	1.ØØ	1.ØØ
2	Ø.33	1.ØØ	3.ØØ	1.ØØ	1.ØØ
3	Ø.2Ø	Ø.33	1.ØØ	Ø.33	Ø.33
4	1.ØØ	1.ØØ	3.ØØ	1.ØØ	1.ØØ
5	1.ØØ	1.ØØ	3.ØØ	1.ØØ	1.ØØ

The eigenvalue is 5.1 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø3
The eigenvector is Ø.32 Ø.18 Ø.Ø7 Ø.22 Ø.22

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute disk-maximum

	1	2	3	4	5
1	1.ØØ	3.ØØ	3.ØØ	3.ØØ	5.ØØ
2	Ø.33	1.ØØ	1.ØØ	3.ØØ	5.ØØ
3	Ø.33	1.ØØ	1.ØØ	3.ØØ	5.ØØ
4	Ø.33	Ø.33	Ø.33	1.ØØ	5.ØØ
5	Ø.2Ø	Ø.2Ø	Ø.2Ø	Ø.2Ø	1.ØØ

Figure 15. (Continued)

The eigenvalue is 5.3 (Consistency value is 5.0)
The consistency of candidate judgments is 0.09
The eigenvector is 0.42 0.21 0.21 0.11 0.04

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute satisfaction

	1	2	3	4	5
1	1.00	0.20	0.20	1.00	0.20
2	5.00	1.00	1.00	5.00	1.00
3	5.00	1.00	1.00	5.00	1.00
4	1.00	0.20	0.20	1.00	0.20
5	5.00	1.00	1.00	5.00	1.00

The eigenvalue is 5.0 (Consistency value is 5.0)
The consistency of candidate judgments is -0.00
The eigenvector is 0.06 0.29 0.29 0.06 0.29

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute recommendations

	1	2	3	4	5
1	1.00	0.20	0.20	1.00	0.20
2	5.00	1.00	1.00	5.00	1.00
3	5.00	1.00	1.00	5.00	1.00
4	1.00	0.20	0.20	1.00	0.20
5	5.00	1.00	1.00	5.00	1.00

The eigenvalue is 5.0 (Consistency value is 5.0)
The consistency of candidate judgments is -0.00
The eigenvector is 0.06 0.29 0.29 0.06 0.29

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute conversion ease

	1	2	3	4	5
1	1.00	0.20	0.20	1.00	0.20
2	5.00	1.00	1.00	5.00	1.00
3	5.00	1.00	1.00	5.00	1.00
4	1.00	0.20	0.20	1.00	0.20
5	5.00	1.00	1.00	5.00	1.00

Figure 15. (Continued)

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.Ø6 Ø.29 Ø.29 Ø.Ø6 Ø.29
Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute mfg. program reliability

	1	2	3	4	5
1	1.ØØ	Ø.33	Ø.33	1.ØØ	Ø.33
2	3.ØØ	1.ØØ	1.ØØ	3.ØØ	1.ØØ
3	3.ØØ	1.ØØ	1.ØØ	3.ØØ	1.ØØ
4	1.ØØ	Ø.33	Ø.33	1.ØØ	Ø.33
5	3.ØØ	1.ØØ	1.ØØ	3.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.Ø9 Ø.27 Ø.27 Ø.Ø9 Ø.27
Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute education

	1	2	3	4	5
1	1.ØØ	3.ØØ	3.ØØ	Ø.14	5.ØØ
2	Ø.33	1.ØØ	1.ØØ	Ø.2Ø	1.ØØ
3	Ø.33	1.ØØ	1.ØØ	Ø.2Ø	1.ØØ
4	7.ØØ	5.ØØ	5.ØØ	1.ØØ	7.ØØ
5	Ø.2Ø	1.ØØ	1.ØØ	Ø.14	1.ØØ

The eigenvalue is 5.3 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø8
The eigenvector is Ø.2Ø Ø.Ø7 Ø.Ø7 Ø.59 Ø.Ø6
Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute software delivery

	1	2	3	4	5
1	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
2	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
3	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
4	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
5	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is -Ø.ØØ

Figure 15. (Continued)

The eigenvector is Ø.Ø6 Ø.29 Ø.29 Ø.Ø6 Ø.29
Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute documentation

	1	2	3	4	5
1	1.ØØ	3.ØØ	3.ØØ	Ø.14	5.ØØ
2	Ø.33	1.ØØ	1.ØØ	Ø.2Ø	1.ØØ
3	Ø.33	1.ØØ	1.ØØ	Ø.2Ø	1.ØØ
4	7.ØØ	5.ØØ	5.ØØ	1.ØØ	7.ØØ
5	Ø.2Ø	1.ØØ	1.ØØ	Ø.14	1.ØØ

The eigenvalue is 5.3 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø8
The eigenvector is Ø.2Ø Ø.Ø7 Ø.Ø7 Ø.59 Ø.Ø6
Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute compatibility-program/data

	1	2	3	4	5
1	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
2	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
3	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
4	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
5	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.Ø6 Ø.29 Ø.29 Ø.Ø6 Ø.29
Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute equipment delivery

	1	2	3	4	5
1	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
2	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
3	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
4	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
5	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.Ø6 Ø.29 Ø.29 Ø.Ø6 Ø.29
Do you want to change any preferences for this attribute? y or n:.n

Figure 15. (Continued)

```
Weights of candidates are

        1         2         3         4         5

     Ø.23      Ø.24      Ø.2Ø      Ø.12      Ø.21

Do you want to revise any preferences?  y or n:.y
Do you want to revise level 2 attribute preferences?  y or n:.y
Enter a row number for the new preference:.1
Enter a column number for the new preference:.2
Enter preference for product    to opinion    :.1 7
Do you have further changes at this level?  y or n:.n

Level 2 judgments for SBC Selection

                    1         2
                 product   opinion

                |
1  product       |   1.ØØ      Ø.14
2  opinion      |   7.ØØ      1.ØØ

The eigenvalue is  2.ØØ  (Consistency value is  2.Ø)
The consistency of level 2 judgments is      -Ø.ØØ
The weightings are     Ø.12    Ø.88

Do you want to change any preferences at this level?  y or n:.n
Do you want to revise level 3 attribute preferences?  y or n:.n
Do you want to revise level 4 attribute preferences?  y or n:.n
Do you want to revise candidate preferences?  y or n:.n

Weights of candidates are

        1         2         3         4         5

     Ø.11      Ø.27      Ø.26      Ø.1Ø      Ø.26

Do you want to revise any preferences?  y or n:.y
Do you want to revise level 2 attribute preferences?  y or n:.y
Enter a row number for the new preference:.1
Enter a column number for the new preference:.2
Enter preference for product    to opinion    :.7 1
Do you have further changes at this level?  y or n:.n
```

Figure 16. AHP solution and marginal analysis.

```
Level 2 judgments for SBC Selection

                    1          2
                 product    opinion

               |--------------------
1  product     |    1.00       7.00
2  opinion     |    0.14       1.00

The eigenvalue is  2.00  (Consistency value is  2.0)
The consistency of level 2 judgments is      -0.00
The weightings are     0.88    0.12

Do you want to change any preferences at this level?  y or n:.n
Do you want to revise level 3 attribute preferences?  y or n:.n
Do you want to revise level 4 attribute preferences?  y or n:.n
Do you want to revise candidate preferences?  y or n:.n

Weights of candidates are

        1         2         3         4         5

     0.35      0.22      0.15      0.13      0.16

Do you want to revise any preferences?  y or n:.y
Do you want to revise level 2 attribute preferences?  y or n:.y
Enter a row number for the new preference:.1
Enter a column number for the new preference:.2
Enter preference for product    to opinion   :.3 1
Do you have further changes at this level?  y or n:.n

Level 2 judgments for SBC Selection

                    1          2
                 product    opinion

               |--------------------
1  product     |    1.00       3.00
2  opinion     |    0.33       1.00

The eigenvalue is  2.00  (Consistency value is  2.0)
The consistency of level 2 judgments is      -0.00
The weightings are     0.75    0.25

Do you want to change any preferences at this level?  y or n:.n
Do you want to revise level 3 attribute preferences?  y or n:.n
Do you want to revise level 4 attribute preferences?  y or n:.n
Do you want to revise candidate preferences?  y or n:.n
```

Figure 16. (Continued)

```
Weights of candidates are

        1         2         3         4         5
     Ø.31      Ø.23      Ø.17      Ø.13      Ø.17

Do you want to revise any preferences?  y or n:.y
Do you want to revise level 2 attribute preferences?  y or n:.y
Enter a row number for the new preference:.1
Enter a column number for the new preference:.2
Enter preference for product    to opinion    :.1 3
Do you have further changes at this level?  y or n:.n

Level 2 judgments for SBC Selection

                    1         2
                 product   opinion

               |_____________________
1  product     |    1.ØØ      Ø.33
2  opinion     |    3.ØØ      1.ØØ
The eigenvalue is  2.ØØ  (Consistency value is  2.Ø)
The consistency of level 2 judgments is      -Ø.ØØ
The weightings are     Ø.75    Ø.25

Do you want to change any preferences at this level?  y or n:.n
Do you want to revise level 3 attribute preferences?  y or n:.n
Do you want to revise level 4 attribute preferences?  y or n:.n
Do you want to revise candidate preferences?  y or n:.n

Weights of candidates are

        1         2         3         4         5

     Ø.15      Ø.26      Ø.24      Ø.1Ø      Ø.24

Do you want to revise any preferences?  y or n:.n
```

Figure 16. (Continued)

TABLE 20

MARGINAL ANALYSIS OF AN AHP SOLUTION

	Candidate Weight				
Product to Opinion Preference	1	2	3	4	5
9 to 1	Ø.36	Ø.22	Ø.14	Ø.13	Ø.15
8 to 1	Ø.35	Ø.22	Ø.15	Ø.13	Ø.15
7 to 1	Ø.35	Ø.22	Ø.15	Ø.13	Ø.16
6 to 1	Ø.34	Ø.22	Ø.15	Ø.13	Ø.16
5 to 1	Ø.33	Ø.22	Ø.15	Ø.13	Ø.16
4 to 1	Ø.32	Ø.22	Ø.16	Ø.13	Ø.17
3 to 1	Ø.31	Ø.23	Ø.17	Ø.13	Ø.17
2 to 1	Ø.28	Ø.23	Ø.18	Ø.12	Ø.19
1 to 1	Ø.23	Ø.24	Ø.2Ø	Ø.12	Ø.21
1 to 2	Ø.18	Ø.26	Ø.23	Ø.11	Ø.23
1 to 3	Ø.15	Ø.26	Ø.24	Ø.1Ø	Ø.24
1 to 4	Ø.13	Ø.27	Ø.25	Ø.1Ø	Ø.25
1 to 5	Ø.12	Ø.27	Ø.25	Ø.1Ø	Ø.26
1 to 6	Ø.11	Ø.27	Ø.26	Ø.1Ø	Ø.26
1 to 7	Ø.11	Ø.27	Ø.26	Ø.1Ø	Ø.26
1 to 8	Ø.1Ø	Ø.27	Ø.26	Ø.1Ø	Ø.26
1 to 9	Ø.1Ø	Ø.27	Ø.26	Ø.1Ø	Ø.26

Summary

Separate cluster analysis of product and opinion variables failed to detect multiple, distinct well-defined clusters of SBCs, suggesting a form of market maturity for SBCs. Factor analysis of product variables yielded three factors: capacity for concurrent use, execution speed and maximum I/O configuration. Factor analysis of user opinion variables gave three factors: satisfaction of expectations, perceived competence and constraints on operation.

Sample user requirements for accounting applications were mapped onto the SBC population with logical operations for the three product factors. The requirements mapping identified a feasible subset of SBCs whose members satisfied he capacity requirements for the hypothetical small business. An attribute hierarchy was composed from the factor variables with the overall objective of selection of an SBC. The execution of the interactive implementation of the AHP demonstrated the selection of an SBC from the feasible subset of SBCs. Marginal analysis of a solution showed how system weightings varied with the level of relative preference between two attributes.

CHAPTER V

SUMMARY OF RESULTS

The research objective was to formulate an approach to match small business computers (SBCs) to accounting applications incorporating the complexity of a multi-criteria selection context. Heretofore, selection procedures for SBCs had been largely subjective and ad hoc.

The research comprised three phases:

1. Cluster analysis in conjunction with factor analysis to characterize the SBC population,
2. Mapping sample user requirements onto a subset of SBCs for the factors identified in the cluster analysis and
3. Implementation and execution of the analytic hierarchy process (AHP) for the multi-criteria selection of an SBC for the accounting functions of a hypothetical small business.

Cluster analysis failed to detect multiple, distinct well-defined clusters of SBCs. This result suggested a form of market maturity for SBCs where market maturity meant that continuous, or nearly continuous, performance capacities were observable across the SBC population.

Three factors were interpreted from factor analysis of SBC product variables: capacity for concurrent use, execution speed and maximum I/O configuration. Factor analysis of SBC user opinion variables gave three factors: satisfaction of expectations, perceived competence and constraints on operation.

Sample user requirements for accounting applications were mapped onto the the SBC population with logical operations for the three

product factors. The requirements mapping identified a feasible subset of SBCs whose members satisfied the capacity requirements for a hypothetical small business. An attribute hierarchy was composed from the factor variables with the overall objective of selection of an SBC. The execution of the interactive implementation of the AHP demonstrated the selection of an SBC from the feasible subset of SBCs.

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APPENDICES

APPENDIX A

TABLE 21

SBC VENDORS AND MODELS

Number	Vendor	Model
1	Alpha Micro	AM-1010
2	Alpha Micro	AM-1011
3	Alpha Micro	AM-1030
4	Alpha Micro	AM-1031
5	Alpha Micro	AM-1050
6	Alpha Micro	AM-1051
7	Applied Data Proc	Resource/100
8	Applied Digital Comm	ADC 102
9	Applied Digital Comm	ADC 103
10	Applied Digital Comm	ADC 104
11	Applied Digital Comm	ADC 202
12	Applied Digital Comm	ADC 400
13	Applied Digital Comm	ADC 401
14	Applied Digital Data S	MULTIVISION
15	Applied Digital Data S	MENTOR 4000
16	Applied Sys	ASC/80
17	Ardent Comp Pro	Ardent/10
18	Ardent Comp Pro	Ardent/CMD
19	AK Industries	AKI 903
20	AM Jacquard	J-100
21	AM Jacquard	J-500
22	Basic Four	Model 2000
23	Basic Four	Model 410
24	Basic Four	Model 510
25	Basic Four	Model 610
26	Basic Four	Model 730
27	Burroughs	B80
28	Burroughs	B90
29	Burroughs	B730/B720
30	Burroughs	B801
31	Burroughs	B810/B820
32	Burroughs	B920
33	Burroughs	B1815
34	Burroughs	B1855
35	Burroughs	B1860 CMS
36	Burroughs	B1885
37	Burroughs	B1900
38	Business Control	Sys 8/11
39	Business Control	Sys 80/2

TABLE 21 (Continued)

Number	Vendor	Model
40	BRD	Dolphin
41	BRD	Porpoise
42	BRD	Small Fry
43	BTI	BTI 5000
44	BTI	BTI 5000/ES
45	BTI	BTI 8000
46	Canon	EX-3
47	Canon	CX-1
48	Centurion Comp Corp	Cent III
49	Centurion Comp Corp	Cent 100
50	Centurion Comp Corp	Cent 200
51	Centurion Comp Corp	Cent 6000
52	Century Comp	Century 300
53	Century Comp	Century 400
54	Century Comp	Century 700
55	Century Comp	Century 900
56	Century Comp	CenturyX1000
57	Comp Automation	NM4/04
58	Comp Automation	NM4/10-30-90
59	Comp Automation	SyFA Sys50
60	Comp Automation	SyFA Sys300
61	Comp Automation	SyFA Sys1000
62	Comp Automation	SyFA Sys2000
63	Comp Automation	SyFA Sys2500
64	Comp Designed Sys	AdvisI-1432
65	Comp Designed Sys	AdvisI-2880
66	Comp Designed Sys	AdvisIV-3160
67	Comp Designed Sys	AdvisIV-4240
68	Comp Designed Sys	AdvisIV-532
69	Comp Hardware	2130
70	Comp Hardware	3230
71	Comp Hardware	4210
72	Comp Hardware	4800
73	Compal	8100
74	Compal	8200
75	Complete Comp Sys	CCS#9
76	Complete Comp Sys	CCS#10
77	Complete Comp Sys	CCS#11
78	Complete Comp Sys	CCS#12
79	Complete Comp Sys	CCS#14
80	Complete Comp Sys	CCS#22
81	Complete Comp Sys	CCS#26
82	Compucorp	600
83	Control Data	CYBER 18
84	Cybertek	Mamaser
85	CADO Systems Corp	Sys 20/21

TABLE 21 (Continued)

Number	Vendor	Model
86	CADO Systems Corp	Sys 20/22
87	CADO Systems Corp	Sys 20/24
88	CADO Systems Corp	Sys 20/28
89	CDA	MP/100
90	CDA	MP/200
91	CDA	Nova 4/C
92	CDA	Nova 4/X
93	CDA	S/140-M/600
94	Data Comm Corp	DCS
95	Data Comm Corp	DPS
96	Data Comm Corp	RTS
97	Data Comm Corp	TPS
98	Data Gen	CS/10 MOD C1
99	Data Gen	CS/10 MOD C3
100	Data Gen	CS/10
101	Data Gen	CS/30 MOD C1
102	Data Gen	CS/10 MOD C3
103	Data Gen	CS/40 MOD 1
104	Data Gen	CS/10 MOD C3
105	Data Gen	CS/40 MOD 4
106	Data Gen	CS/40 MOD C5
107	Data Gen	CS/40 MOD C6
108	Data Gen	CS/50 MOD C3
109	Data Gen	CS/50 MOD C5
110	Data Gen	CS/50 MOD C6
111	Data Gen	CS/60 MOD C3
112	Data Gen	CS/60 MOD C5
113	Data Gen	CS/60 MOD 6
114	Data Gen	CS/70 MOD C5
115	Data Gen	CS/70 MOD C6
116	Data Gen Synergist	M1000 MOD 10
117	Data Gen Synergist	N1000 MOD 15
118	Data Gen Synergist	M1000 MOD 30
119	Data Gen Synergist	M4000 MOD 30
120	Data Gen Synergist	M4000 MOD 40
121	Data Gen Synergist	M4000 MOD 50
122	Data Gen Synergist	M4000 MOD 60
123	Datapoint	1500
124	Datapoint	1800
125	Datapoint	3600
126	Datapoint	6600
127	Datapoint	8800
128	Dicom Ind	401
129	Digi-Log Sys	Sys 1000
130	Digi-Log Sys	Sys 2000

TABLE 21 (Continued)

Number	Vendor	Model
131	Digital Equip Corp	Datasys 150
132	Digital Equip Corp	Datasys 315
133	Digital Equip Corp	Datasys 325
134	Digital Equip Corp	Datasys 335
135	Digital Equip Corp	Datasys 336
136	Digital Equip Corp	Datasys 356
137	Digital Equip Corp	Datasys 358
138	Digital Equip Corp	Datasys 530
139	Digital Equip Corp	Datasys 540
140	Digital Equip Corp	DECstation78
141	Digital Equip Corp	DECstation88
142	Digital Sys	Galaxy/3
143	Digital Sys	Galaxy/5
144	Dimis	Total 100-10
145	Dimis	Total 100-30
146	Dimis	Total 100-70
147	Display Data Corp	in*sight
148	Distribution Mgmt Sys	BS 11/44
149	Distribution Mgmt Sys	BS 11/70
150	Distribution Mgmt Sys	BS 11/750
151	Distribution Mgmt Sys	BS 11/780
152	Durango	F-85
153	Dynabyte	5200
154	Dynabyte	5300
155	Dynabyte	5600
156	Dynabyte	5700
157	Dynabyte	5900
158	Evolution Comp Sys	210
159	Evolution Comp Sys	240
160	Evolution Comp Sys	260
161	Evolution Comp Sys	280
162	EZdata	SNAP
163	Four-Phase	IV/40
164	Four-Phase	IV/50
165	Four-Phase	IV/60
166	Four-Phase	IV/65
167	Four-Phase	IV/70
168	Four-Phase	IV/90
169	Gen Robotics	Gemini
170	Gen Robotics	Pegasus
171	Gen Robotics	Polaris
172	Gen Robotics	Tristar
173	Hewlett-Packard	250
174	Hewlett-Packard	300 Model 20
175	Hewlett-Packard	Series III
176	Hewlett-Packard	Series 30

TABLE 21 (Continued)

Number	Vendor	Model
177	Hewlett-Packard	Series 33
178	Hewlett-Packard	Series 40
179	Honeywell	Model 23
180	Honeywell	Model 33
181	Honeywell	Model 43
182	Honeywell	Model 47
183	Honeywell	Model 53
184	Honeywell	Model 57
185	Honeywell	Series 60-62
186	Ind Micro Sys	Series 5000
187	Ind Micro Sys	Series 8000
188	Infomark	S/1000
189	Infomark	S/2000
190	Infomark	S/4000
191	Infomark	S/6000
192	Infomark	S/8000
193	Infotecs	Control Cent
194	Infotecs	IMP
195	IBM	4952
196	IBM	4953
197	IBM	4955
198	IBM	System/3
199	IBM	System/32
200	IBM	System/34
201	IBM	System/38
202	IBM	5100
203	IBM	5110
204	IBM	5120
205	IBM	5280
206	IBM	8100
207	Keydata	Unity I
208	Keydata	Unity II
209	Keydata	Unity III
210	Keydata	Unity IV
211	Lazor Sys	L-10
212	Lazor Sys	L-30
213	Logical Machine	ADAM
214	Logical Machine	DAVID
215	Logical Machine	GOLIATH
216	Logical Machine	TINA
217	Mercator Bus Sys	Sys 4000
218	Mercator Bus Sys	Sys 4000
219	MicroFive	I
220	MicroFive	II
221	MicroFive	3000
222	Mini-Comp Sys	MICOS 100

TABLE 21 (Continued)

Number	Vendor	Model
223	Mini-Comp Sys	MICOS 200
224	Mini-Comp Sys	MICOS 300
225	Mitsubishi	8018
226	Mitsubishi	8028
227	Mitsubishi	8038
228	Mylee Digital Sci	Sys 3000
229	MCM Comp	POWER
230	New England Digital	ABLE/40/60
231	Nixdorf	8870/1
232	Nixdorf	8870/3
233	Northern Telecom	405
234	Northern Telecom	410
235	Northern Telecom	435
236	Northern Telecom	440
237	Northern Telecom	445
238	NorthStar	HRZ-2D32K
239	NorthStar	HRZ-2Q64K
240	NorthStar	HRZ-HD-18
241	NorthStar	SYS-IN
242	NCR	50 MOD 1
243	NCR	Century 75
244	NCR	Century 101
245	NCR	Century 151
246	NCR	499
247	NCR	7510
248	NCR	7520
249	NCR	7520 SBS
250	NCR	7530
251	NCR	8130
252	NCR	8140
253	NCR	8150
254	NCR	8230
255	NCR	8250
256	NEC Info Sys	Astra 205
257	NEC Info Sys	Astra 210
258	NEC Info Sys	Astra 230
259	NEC Info Sys	Astra 250
260	Olivetti	BCS 2025
261	Olivetti	BCS 2030FDU
262	Olivetti	BCS 2030FV
263	Olivetti	BCS 2030MDU
264	Omnidata	OMNI 2
256	Omnidata	OMNINET
266	Onyx	C8001
267	Onyx	C8001/MU
268	Onyx	C8002

TABLE 21 (Continued)

Number	Vendor	Model
269	Onyx	C5000
270	Pertec	PCC2000
271	Pertec	PCC8000
272	Pertec	PCC8500
273	Pertec	PCC9000
274	Pertec	PCC9500
275	Point 4 Data	Mark 3
276	Point 4 Data	Mark 4
277	Point 4 Data	Mark 5
278	Point 4 Data	Mark 8
279	Polymorphic Sys	8810
280	Polymorphic Sys	8813
281	Prime	450
282	Prime	550
283	Prime	650
284	Prime	750
285	Prime	150
286	Prime	250
287	Prime	500
288	Prime	1000
289	Prime	5000
290	Programmed Control	PROPHET21M1
291	Programmed Control	PROPHET21M2
292	Programmed Control	PRPHT21EXT2
293	Qantel	Series 100
294	Qantel	Series 200
295	Qantel	Series 300
296	Qantel	210
297	Qantel	950
298	Qantel	960
299	Qantel	965
300	Qantel	970
301	Qantel	975
302	Qantel	1400
303	Qantel	1400-2
304	Qantel	1450
305	Qantel	1450-2
306	Quodata	Q620
307	Quodata	Q850
308	Quodata	Q970
309	Ql	Lite/IWS
310	Ql	Microlite 40
311	Ql	Microlite 80
312	Rexon	RX-20
313	Rexon	RX-30
314	Scientific Data Sys	420

TABLE 21 (Continued)

Number	Vendor	Model
315	Sentinel	30
316	Sentinel	40
317	Sentinel	50
318	Sentinel	80
319	Smoke Signal Broad	822
320	Smoke Signal Broad	9522
321	Smoke Signal Broad	9524
322	Smoke Signal Broad	9822
323	Smoke Signal Broad	98W32
324	Sperry Univac	BC/7-600
325	Sperry Univac	BC/7-700
326	Sperry Univac	BC/7-800
327	Sperry Univac	BC/7-900
328	Stratmar Bus Solutions	STRATTEXT
329	Stratmar Bus Solutions	SUPERVISORII
330	Systel Comp	REPORT/80
331	STC Sys	4000
332	STC Sys	5000
333	Terak	8510A
334	Texas Instruments	DS990 MOD1
335	Texas Instruments	DS990 MOD2
336	Texas Instruments	DS990 MOD4
337	Texas Instruments	DS990 MOD6
338	Texas Instruments	DS990 MOD8
339	Texas Instruments	DS990 MOD20
340	Texas Instruments	DS990 MOD30
341	TECHNICO	SS16
342	TECHNICO	TI32-8H
343	TECHNICO	TI32-14H
344	Wang	VS Sys
345	Wang	VS-100
346	Wang	2200 LVP
347	Wang	2200 MVP
348	Wang	2200 SVP
349	Wang	2200 VP
350	Xerox	Diablo 3000
351	Xerox	Diablo 3200
352	Xerox	510
353	Zilog	MCZ 1/50
354	Zilog	MCZ 2/ZNET

APPENDIX B

TABLE 22

VARIABLE STATISTICS

Variable	Number	Mean	Standard Deviation
Product Variables			
Availability date	326	6808	742.8
Access time	281	6.7	53.7
Add-time	249	31.6	155.3
Cycle time	299	5.4	51.2
Disk, basic capacity	337	63.8	188.2
Disk, maximum capacity	315	6529.6	108158
I/O ports, basic	309	7.6	17.7
I/O ports, maximum	313	29.8	52.2
Lines, communications	323	24.7	51.8
Memory, basic	354	109.2	161.0
Memory, maximum	353	512.4	1031.1
Price	318	40062.7	44882.4
Word length	343	14.4	7.2
Workstations, number	312	11.4	12.8
Opinion Variables: Advantages			
Response time	101	53.3	23.9
Ease of expansion	101	66.7	21.4
Cost under expectation	101	19.3	15.3
Program/data compatibility	101	27.1	17.6
Terminal/peripheral compatibility	101	110.1	924.6
Energy use	101	26.6	56.7
Productivity aids	101	35.0	23.1
Database language	101	22.4	24.4
Equipment on schedule	101	16.0	13.8
Software on schedule	101	13.8	11.6
Opinion Variables: Problems			
System too small	101	11.4	11.5
Equipment late	101	14.2	13.2
Software late	101	11.1	11.5
Cost over expectation	101	7.3	9.7
Vendor software support	101	12.3	14.2

TABLE 22 (Continued)

Variable	Number	Mean	Standard Deviation
Program/data compatibility	101	5.5	7.6
Terminal/peripheral compatibility	101	2.3	4.6
Change maintenance	101	8.4	9.1
Noise	101	7.1	12.9
Energy use	101	2.8	4.8
Opinion Variables: System Ratings			
Ease of operation	101	4.2	5.1
Reliability of mainframe	101	3.5	.4
Reliability of peripherals	101	3.2	.3
Responsiveness of maintenance service	101	3.2	.5
Effectiveness of maintenance service	101	3.1	.4
Trouble-shooting	101	2.8	.5
User education	101	2.7	.4
User documentation	101	2.6	.4
Manufacturer's operating system	101	3.3	.4
Manufacturer's compilers and assemblers	101	3.3	.5
Manufacturer's applications programs	101	2.9	.5
Ease of programming	101	3.3	.4
Ease of conversion	101	3.0	.6
Overall satisfaction	101	3.0	.6
Opinion Variables: Expectations and Recommendations			
Met expectations--yes	101	75.3	27.7
Met expectations--no	101	6.2	7.9
Met expectations--undecided	101	16.9	23.9
Recommend to others--yes	101	74.8	28.2
Recommend to others--no	101	10.3	11.9
Recommend to others--undecided	101	14.1	22.0
Opinion Variables: Structural Aspects			
Average system life	101	41.3	161.1
Acquisition method:			
Purchase	101	70.4	22.7
Rental/lease from manufacturer	101	17.5	24.0
Lease from third party	101	12.3	11.8
Accounting as principal application	101	74.4	18.8

TABLE 22 (Continued)

Variable	Number	Mean	Standard Deviation
Source of application programs:			
Inhouse personnel	101	70.9	20.8
Manufacturer's packages	101	26.1	21.5
Contract programming	101	34.1	19.6
Manufacturer's personnel	101	3.8	7.3
Proprietary software	101	34.0	23.6

APPENDIX C

```
Have you entered the attribute hierarchy? y for yes, n for no:
n
Enter name of the overall objective:
SBC Selection
Give the number of levels in the hierarchy:
4
Enter number of nodes at the second level:
2
Enter names of attributes at the second level, one per line:
product
:
opinion
Enter the number of nodes below product    :
3
One node per line, enter names of nodes below product    :
concurrent use capacity
:
execution speed
:
I/O configuration-maximum
Enter the number of nodes below concurrent use capacity        :
5
One node per line, enter names of nodes below concurrent use capacity  :
memory-basic
:
memory-maximum
:
price
:
workstations
:
disk-maximum
Enter the number of nodes below execution speed                :
2
One node per line, enter names of nodes below execution speed        :
cycle time
:
access time
Enter the number of nodes below I/O configuration-maximum      :
4
One node per line, enter names of nodes below I/O configuration-maximum:
lines-maximum
:
availability date
:
I/O ports-maximum
```

Figure 17. Execution of the AHP for SBC Selection.

```
:
disk-maximum
Enter the number of nodes below opinion    :
3
One node per line, enter names of nodes below opinion    :
satisfaction of expectations
:
competence-perceived
:
constraints on operation
Enter the number of nodes below expectations-satisfaction    :
4
One node per line, enter names of nodes below expectations-satisfaction:
satisfaction
:
recommendations
:
conversion ease
:
mfg. program reliability
Enter the number of nodes below competence-perceived      :
3
One node per line, enter names of nodes below competence-perceived:
education
:
software delivery
:
documentation
Enter the number of nodes below constraints on operation    :
2
One node per line, enter names of nodes below constraints on operation:
compatibility-program/data
:
equipment delivery

Overall objective of attribute hierarchy is SBC Selection
Nodes at the second level are:
                    product
                    opinion
          Nodes below product
                     concurrent use capacity
                     execution speed
                     I/O configuration-maximum
                     nodes below concurrent use capacity
                               memory-basic
                               memory-maximum
                               price
                               workstations
                               disk-maximum
                     Nodes below execution speed
```

Figure 17. (Continued)

```
                    cycle time
                    access time
               Nodes below maximum I/O configuration
                    lines-maximum
                    availability date
                    I/O ports-maximum
                    disk-maximum
          Nodes below opinion
               expectations-satisfaction
               competence-perceived
               constraints on operation
               Nodes below expectations-satisfaction
                    satisfaction
                    recommendations
                    conversion ease
                    mfg. program reliability
               Nodes below competence-perceived
                    education
                    software delivery
                    documentation
               Nodes below constraints on operation
                    compatibility-program/data
                    equipment delivery

Have you entered judgments for attributes?  y or n:
n
Do you want an explanation of the preference scale?  y or n:
y

Preference              Explanation

     1          Equal contribution
     3          Weak importance--one slightly favored over the other
     5          Strong importance--one strongly favored over the other
     7          Demonstrated importance--one strongly favored over the
                other with demonstrated importance
     9          Absolute importance--highest favoring of one over the other
2, 4, 6, 8      Intermediate values of judgments
Reciprocals     Opposite order comparisons

Enter your preferences in the form
digit digit
For example, to give the preference for
product   to opinion
where you slightly favor opinion    to product    enter
1 3

product   to opinion   :
1 1
concurrent use capacity       to execution speed              :
```

Figure 17. (Continued)

```
5 1
concurrent use capacity        to I/O configuration-maximum    :
5 1
execution speed                to I/O configuration-maximum    :
1 3
expectations-satisfaction      to competence-perceived         :
5 1
expectations-satisfaction      to constraints on operation     :
1 7
competence-perceived           to constraints on operation     :
1 5
memory-basic                   to memory-maximum               :
1 3
memory-basic                   to price                        :
1 7
memory-basic                   to workstations                 :
1 7
memory-basic                   to disk-maximum                 :
5 1
memory-maximum                 to price                        :
1 5
memory-maximum                 to workstations                 :
1 5
memory-maximum                 to disk-maximum                 :
3 1
price                          to workstations                 :
3 1
price                          to disk-maximum                 :
3 1
workstations                   to disk-maximum                 :
5 1
cycle time                     to access time                  :
1 1
lines-maximum                  to availability date            :
3 1
lines-maximum                  to I/O ports-maximum            :
1 5
lines-maximum                  to disk-maximum                 :
3 1
availability date              to I/O ports-maximum            :
1 7
availability date              to disk-maximum                 :
5 1
I/O ports-maximum              to disk-maximum                 :
3 1
satisfaction                   to recommendations              :
1 1
satisfaction                   to conversion ease              :
1 3
satisfaction                   to mfg. program reliability     :
```

Figure 17. (Continued)

```
1 5
recommendations                to conversion ease              :
1 3
recommendations                to mfg. program reliability     :
1 5
conversion ease                to mfg. program reliability     :
3 1
education                      to software delivery            :
1 1
education                      to documentation                :
3 1
software delivery              to documentation                :
1 5
compatibility-program/data     to equipment delivery           :
3 1

Level 2 judgments for SBC Selection

                    1         2
                 product   opinion

              |-------------------
1  product    |    1.00      1.00
2  opinion    |    1.00      1.00

The eigenvalue is  2.00  (Consistency value is  2.0)
The consistency of level 2 judgments is       0.00
The weightings are     0.50    0.50

Do you want to change any preferences at this level?  y or n:
n

Level 3 judgments for product

                    1         2         3
                 concurre  executio  I/O conf

              |-----------------------------
1  concurre   |    1.00      5.00      5.00
2  executio   |    0.20      1.00      0.33
3  I/O conf   |    0.20      3.00      1.00

The eigenvalue is  3.14  (Consistency value is  3.0)
The consistency of level 3 judgments under product        is  0.07
The weightings are    0.70    0.10    0.20

Level 3 judgments for opinion

                    1         2         3
                 expectat  competen  constrai
```

Figure 17. (Continued)

```
                |
1  expectat     |    1.00       5.00       0.14
2  competen     |    0.20       1.00       0.20
3  constrai     |    7.00       5.00       1.00

The eigenvalue is  3.44  (Consistency value is  3.0)
The consistency of level 3 judgments under opinion          is  0.22
The weightings are    0.20    0.08    0.73

Do you want to change any preferences under product? y or n:
y
Enter a row number for the new preference:
1
Enter a column number for the new preference:
3
Enter preference for concurrent use capacity to I/O configuration-
maximum:
3 1
Do you have further changes at this level?  y or n:
n

Level 3 judgments for product

                    1          2          3
                concurre   executio   I/O conf

                |
1  concurre    |    1.00       5.00       3.00
2  executio    |    0.20       1.00       0.33
3  I/O conf    |    0.33       3.00       1.00

The eigenvalue is  3.04  (Consistency value is  3.0)
The consistency of level 3 judgments under product          is  0.02
The weightings are    0.64    0.10    0.26

Level 3 judgments for opinion

                    1          2          3
                expectat   competen   constrai

                |
1  expectat    |    1.00       5.00       0.14
2  competen    |    0.20       1.00       0.20
3  constrai    |    7.00       5.00       1.00

The eigenvalue is  3.44  (Consistency value is  3.0)
The consistency of level 3 judgments under opinion          is  0.22
The weightings are    0.20    0.08    0.73
```

Figure 17. (Continued)

```
Do you want to change any preferences under product? y or n:
n
Do you want to change any preferences under opinion? y or n:
n
Level 4 judgments for concurrent use capacity

                    1          2          3          4          5
                 memory-b   memory-m   price      workstat   disk-max
               |-------------------------------------------------------
1  memory-b    |    1.00       0.33       0.14       0.14       5.00
2  memory-m    |    3.00       1.00       0.20       0.20       3.00
3  price       |    7.00       5.00       1.00       3.00       3.00
4  workstat    |    7.00       5.00       0.33       1.00       5.00
5  disk-max    |    0.20       0.33       0.33       0.20       1.00

The eigenvalue is  5.99  (Consistency value is  5.0)
The consistency of level 4 judgments under concurrent use  is  0.25
The weightings are      0.08     0.11     0.44     0.31     0.05

Level 4 judgments for execution speed

                    1          2
                 cycle ti   access t
               |-------------------
1  cycle ti    |    1.00       1.00
2  access t    |    1.00       1.00

The eigenvalue is  2.00  (Consistency value is  2.0)
The consistency of level 4 judgments under execution speed is  0.00
The weightings are      0.50     0.50

Level 4 judgments for I/O configuration-maximum

                    1          2          3          4
                 lines-ma   availabi   I/O port   disk-max
               |-------------------------------------------
1  lines-ma    |    1.00       3.00       0.20       3.00
2  availabi    |    0.33       1.00       0.14       5.00
3  I/O port    |    5.00       7.00       1.00       3.00
4  disk-max    |    0.33       0.20       0.33       1.00

The eigenvalue is  4.80  (Consistency value is  4.0)
The consistency of level 4 judgments under I/O configurati is  0.27
The weightings are      0.20     0.14     0.58     0.08

Level 4 judgments for expectations-satisfaction
```

Figure 17. (Continued)

		1 satisfac	2 recommen	3 conversi	4 mfg. pro
1	satisfac	1.00	1.00	0.33	0.20
2	recommen	1.00	1.00	0.33	0.20
3	conversi	3.00	3.00	1.00	3.00
4	mfg. pro	5.00	5.00	0.33	1.00

The eigenvalue is 4.34 (Consistency value is 4.0)
The consistency of level 4 judgments under expectations-sa is 0.11
The weightings are 0.10 0.10 0.47 0.33

Level 4 judgments for competence-perceived

		1 educatio	2 software	3 document
1	educatio	1.00	1.00	3.00
2	software	1.00	1.00	0.20
3	document	0.33	5.00	1.00

The eigenvalue is 3.87 (Consistency value is 3.0)
The consistency of level 4 judgments under competence-perc is 0.44
The weightings are 0.45 0.18 0.37

Level 4 judgments for constraints on operation

		1 compatib	2 equipmen
1	compatib	1.00	3.00
2	equipmen	0.33	1.00

The eigenvalue is 2.00 (Consistency value is 2.0)
The consistency of level 4 judgments under constraints on is -0.00
The weightings are 0.75 0.25

Do you want to change any preference under concurrent use ? y or n:
n
Do you want to change any preference under execution speed? y or n:
n
Do you want to change any preference under I/O configurati? y or n:
n
Do you want to change any preference under expectations-sa? y or n:
n
Do you want to change any preference under competence-perc? y or n:
n

Figure 17. (Continued)

```
Do you want to change any preference under constraints on ?  y or n:
n

Have you entered comparisons of candidates with respect to attributes?
yes or no:.n
How many candidates are there?:.5
Enter preferences for candidate comparisons with respect to attributes

Attribute is memory-basic
Candidate 1 to 2:.1 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.3 1
Candidate 1 to 5:.5 1
Candidate 2 to 3:.3 1
Candidate 2 to 4:.3 1
Candidate 2 to 5:.3 1
Candidate 3 to 4:.1 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 1

Attribute is memory-maximum
Candidate 1 to 2:.3 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.3 1
Candidate 1 to 5:.1 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 1
Candidate 2 to 5:.1 3
Candidate 3 to 4:.1 1
Candidate 3 to 5:.1 3
Candidate 4 to 5:.1 3

Attribute is price
Candidate 1 to 2:.5 1
Candidate 1 to 3:.5 1
Candidate 1 to 4:.9 1
Candidate 1 to 5:.9 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.5 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.5 1
Candidate 4 to 5:.1 1

Attribute is workstations
Candidate 1 to 2:.1 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.3 1
Candidate 1 to 5:.3 1
Candidate 2 to 3:.3 1
```

Figure 17. (Continued)

```
Candidate 2 to 4:.3 1
Candidate 2 to 5:.3 1
Candidate 3 to 4:.1 3
Candidate 3 to 5:.1 3
Candidate 4 to 5:.1 1

Attribute is disk-maximum
Candidate 1 to 2:.3 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.3 1
Candidate 1 to 5:.5 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.3 1
Candidate 2 to 5:.5 1
Candidate 3 to 4:.3 1
Candidate 3 to 5:.5 1
Candidate 4 to 5:.5 1

Attribute is cycle time
Candidate 1 to 2:.1 1
Candidate 1 to 3:.1 1
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.1 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 1

Attribute is access time
Candidate 1 to 2:.1 1
Candidate 1 to 3:.1 1
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.1 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 1

Attribute is lines-maximum
Candidate 1 to 2:.3 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 5
Candidate 2 to 5:.1 5
```

Figure 17. (Continued)

```
Candidate 3 to 4:.1 5
Candidate 3 to 5:.1 5
Candidate 4 to 5:.1 1

Attribute is availability date
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 7
Candidate 1 to 5:.1 3
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 5
Candidate 2 to 5:.1 1
Candidate 3 to 4:.1 3
Candidate 3 to 5:.1 1
Candidate 4 to 5:.5 1

Attribute is I/O ports-maximum
Candidate 1 to 2:.3 1
Candidate 1 to 3:.5 1
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 1
Candidate 2 to 3:.3 1
Candidate 2 to 4:.1 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.1 3
Candidate 3 to 5:.1 3
Candidate 4 to 5:.1 1

Attribute is disk-maximum
Candidate 1 to 2:.1 3
Candidate 1 to 3:.3 1
Candidate 1 to 4:.3 1
Candidate 1 to 5:.5 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.3 1
Candidate 2 to 5:.5 1
Candidate 3 to 4:.3 1
Candidate 3 to 5:.5 1
Candidate 4 to 5:.5 1

Attribute is satisfaction
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 5
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.5 1
```

Figure 17. (Continued)

```
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 5

Attribute is recommendations
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 5
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 5

Attribute is conversion ease
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 5
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 5

Attribute is mfg. program reliability
Candidate 1 to 2:.1 3
Candidate 1 to 3:.1 3
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 3
Candidate 2 to 3:.1 1
Candidate 2 to 4:.3 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.3 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 3

Attribute is education
Candidate 1 to 2:.3 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.1 7
Candidate 1 to 5:.5 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 5
Candidate 2 to 5:.1 1
Candidate 3 to 4:.1 5
Candidate 3 to 5:.1 1
Candidate 4 to 5:.7 1
```

Figure 17. (Continued)

```
Attribute is software delivery
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 5
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 5

Attribute is documentation
Candidate 1 to 2:.3 1
Candidate 1 to 3:.3 1
Candidate 1 to 4:.1 7
Candidate 1 to 5:.5 1
Candidate 2 to 3:.1 1
Candidate 2 to 4:.1 5
Candidate 2 to 5:.1 1
Candidate 3 to 4:.1 5
Candidate 3 to 5:.1 1
Candidate 4 to 5:.7 1

Attribute is compatibility-program/data
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 5
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 5

Attribute is equipment delivery
Candidate 1 to 2:.1 5
Candidate 1 to 3:.1 5
Candidate 1 to 4:.1 1
Candidate 1 to 5:.1 5
Candidate 2 to 3:.1 1
Candidate 2 to 4:.5 1
Candidate 2 to 5:.1 1
Candidate 3 to 4:.5 1
Candidate 3 to 5:.1 1
Candidate 4 to 5:.1 5

Candidate preferences for attribute memory-basic
```

Figure 17. (Continued)

	1	2	3	4	5
1	1.ØØ	1.ØØ	3.ØØ	3.ØØ	5.ØØ
2	1.ØØ	1.ØØ	3.ØØ	3.ØØ	3.ØØ
3	Ø.33	Ø.33	1.ØØ	1.ØØ	1.ØØ
4	Ø.33	Ø.33	1.ØØ	1.ØØ	1.ØØ
5	Ø.2Ø	Ø.33	1.ØØ	1.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø1
The eigenvector is Ø.36 Ø.32 Ø.11 Ø.11 Ø.1Ø

Do you want to change any preferences for this attribute? y or n:.y

Enter a row number for the new preference:.1
Enter a column number for the new preference:.5
Enter a preference for attribute memory-basic :
Candidates 1 5:.3 1
Do you have further changes for this attribute? y or n:.n

Candidate preferences for attribute memory-basic

	1	2	3	4	5
1	1.ØØ	1.ØØ	3.ØØ	3.ØØ	3.ØØ
2	1.ØØ	1.ØØ	3.ØØ	3.ØØ	3.ØØ
3	Ø.33	Ø.33	1.ØØ	1.ØØ	1.ØØ
4	Ø.33	Ø.33	1.ØØ	1.ØØ	1.ØØ
5	Ø.33	Ø.33	1.ØØ	1.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.33 Ø.33 Ø.11 Ø.11 Ø.11

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute memory-maximum

	1	2	3	4	5
1	1.ØØ	3.ØØ	3.ØØ	3.ØØ	1.ØØ
2	Ø.33	1.ØØ	1.ØØ	1.ØØ	Ø.33
3	Ø.33	1.ØØ	1.ØØ	1.ØØ	Ø.33
4	Ø.33	1.ØØ	1.ØØ	1.ØØ	Ø.33
5	1.ØØ	3.ØØ	3.ØØ	3.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)

Figure 17. (Continued)

The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.33 Ø.11 Ø.11 Ø.11 Ø.33

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute price

	1	2	3	4	5
1	1.ØØ	5.ØØ	5.ØØ	9.ØØ	9.ØØ
2	Ø.2Ø	1.ØØ	1.ØØ	5.ØØ	5.ØØ
3	Ø.2Ø	1.ØØ	1.ØØ	5.ØØ	5.ØØ
4	Ø.11	Ø.2Ø	Ø.2Ø	1.ØØ	1.ØØ
5	Ø.11	Ø.2Ø	Ø.2Ø	1.ØØ	1.ØØ

The eigenvalue is 5.2 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø4
The eigenvector is Ø.58 Ø.17 Ø.17 Ø.Ø4 Ø.Ø4

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute workstations

	1	2	3	4	5
1	1.ØØ	1.ØØ	3.ØØ	3.ØØ	3.ØØ
2	1.ØØ	1.ØØ	3.ØØ	3.ØØ	3.ØØ
3	Ø.33	Ø.33	1.ØØ	Ø.33	Ø.33
4	Ø.33	Ø.33	3.ØØ	1.ØØ	1.ØØ
5	Ø.33	Ø.33	3.ØØ	1.ØØ	1.ØØ

The eigenvalue is 5.2 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø5
The eigenvector is Ø.33 Ø.33 Ø.Ø7 Ø.14 Ø.14

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute disk-maximum

	1	2	3	4	5
1	1.ØØ	3.ØØ	3.ØØ	3.ØØ	5.ØØ
2	Ø.33	1.ØØ	1.ØØ	3.ØØ	5.ØØ
3	Ø.33	1.ØØ	1.ØØ	3.ØØ	5.ØØ
4	Ø.33	Ø.33	Ø.33	1.ØØ	5.ØØ
5	Ø.2Ø	Ø.2Ø	Ø.2Ø	Ø.2Ø	1.ØØ

Figure 17. (Continued)

The eigenvalue is 5.3 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø9
The eigenvector is Ø.42 Ø.21 Ø.21 Ø.11 Ø.Ø4

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute cycle time

	1	2	3	4	5
1	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
2	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
3	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
4	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
5	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.ØØ
The eigenvector is Ø.2Ø Ø.2Ø Ø.2Ø Ø.2Ø Ø.2Ø

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute access time

	1	2	3	4	5
1	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
2	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
3	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
4	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ
5	1.ØØ	1.ØØ	1.ØØ	1.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.ØØ
The eigenvector is Ø.2Ø Ø.2Ø Ø.2Ø Ø.2Ø Ø.2Ø

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute lines-maximum

	1	2	3	4	5
1	1.ØØ	3.ØØ	3.ØØ	1.ØØ	1.ØØ
2	Ø.33	1.ØØ	1.ØØ	Ø.2Ø	Ø.2Ø
3	Ø.33	1.ØØ	1.ØØ	Ø.2Ø	Ø.2Ø
4	1.ØØ	5.ØØ	5.ØØ	1.ØØ	1.ØØ
5	1.ØØ	5.ØØ	5.ØØ	1.ØØ	1.ØØ

Figure 17. (Continued)

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø1
The eigenvector is Ø.25 Ø.Ø7 Ø.Ø7 Ø.31 Ø.31

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute availability date

	1	2	3	4	5
1	1.ØØ	Ø.2Ø	Ø.2Ø	Ø.14	Ø.33
2	5.ØØ	1.ØØ	1.ØØ	Ø.2Ø	1.ØØ
3	5.ØØ	1.ØØ	1.ØØ	Ø.33	1.ØØ
4	7.ØØ	5.ØØ	3.ØØ	1.ØØ	5.ØØ
5	3.ØØ	1.ØØ	1.ØØ	Ø.2Ø	1.ØØ

The eigenvalue is 5.2 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø4
The eigenvector is Ø.Ø4 Ø.15 Ø.16 Ø.52 Ø.13

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute I/O ports-maximum

	1	2	3	4	5
1	1.ØØ	3.ØØ	5.ØØ	1.ØØ	1.ØØ
2	Ø.33	1.ØØ	3.ØØ	1.ØØ	1.ØØ
3	Ø.2Ø	Ø.33	1.ØØ	Ø.33	Ø.33
4	1.ØØ	1.ØØ	3.ØØ	1.ØØ	1.ØØ
5	1.ØØ	1.ØØ	3.ØØ	1.ØØ	1.ØØ

The eigenvalue is 5.1 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø3
The eigenvector is Ø.32 Ø.18 Ø.Ø7 Ø.22 Ø.22

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute disk-maximum

	1	2	3	4	5
1	1.ØØ	3.ØØ	3.ØØ	3.ØØ	5.ØØ
2	Ø.33	1.ØØ	1.ØØ	3.ØØ	5.ØØ
3	Ø.33	1.ØØ	1.ØØ	3.ØØ	5.ØØ
4	Ø.33	Ø.33	Ø.33	1.ØØ	5.ØØ

Figure 17. (Continued)

5	Ø.2Ø	Ø.2Ø	Ø.2Ø	Ø.2Ø	1.ØØ

The eigenvalue is 5.3 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø9
The eigenvector is Ø.42 Ø.21 Ø.21 Ø.11 Ø.Ø4

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute satisfaction

	1	2	3	4	5
1	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
2	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
3	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
4	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
5	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.Ø6 Ø.29 Ø.29 Ø.Ø6 Ø.29

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute recommendations

	1	2	3	4	5
1	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
2	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
3	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
4	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
5	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.Ø6 Ø.29 Ø.29 Ø.Ø6 Ø.29

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute conversion ease

	1	2	3	4	5
1	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
2	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
3	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ

Figure 17. (Continued)

4	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
5	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.Ø6 Ø.29 Ø.29 Ø.Ø6 Ø.29

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute mfg. program reliability

	1	2	3	4	5
1	1.ØØ	Ø.33	Ø.33	1.ØØ	Ø.33
2	3.ØØ	1.ØØ	1.ØØ	3.ØØ	1.ØØ
3	3.ØØ	1.ØØ	1.ØØ	3.ØØ	1.ØØ
4	1.ØØ	Ø.33	Ø.33	1.ØØ	Ø.33
5	3.ØØ	1.ØØ	1.ØØ	3.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.Ø9 Ø.27 Ø.27 Ø.Ø9 Ø.27

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute education

	1	2	3	4	5
1	1.ØØ	3.ØØ	3.ØØ	Ø.14	5.ØØ
2	Ø.33	1.ØØ	1.ØØ	Ø.2Ø	1.ØØ
3	Ø.33	1.ØØ	1.ØØ	Ø.2Ø	1.ØØ
4	7.ØØ	5.ØØ	5.ØØ	1.ØØ	7.ØØ
5	Ø.2Ø	1.ØØ	1.ØØ	Ø.14	1.ØØ

The eigenvalue is 5.3 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø8
The eigenvector is Ø.2Ø Ø.Ø7 Ø.Ø7 Ø.59 Ø.Ø6

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute software delivery

	1	2	3	4	5
1	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
2	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ

Figure 17. (Continued)

3	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
4	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
5	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.Ø6 Ø.29 Ø.29 Ø.Ø6 Ø.29

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute documentation

	1	2	3	4	5
1	1.ØØ	3.ØØ	3.ØØ	Ø.14	5.ØØ
2	Ø.33	1.ØØ	1.ØØ	Ø.2Ø	1.ØØ
3	Ø.33	1.ØØ	1.ØØ	Ø.2Ø	1.ØØ
4	7.ØØ	5.ØØ	5.ØØ	1.ØØ	7.ØØ
5	Ø.2Ø	1.ØØ	1.ØØ	Ø.14	1.ØØ

The eigenvalue is 5.3 (Consistency value is 5.Ø)
The consistency of candidate judgments is Ø.Ø8
The eigenvector is Ø.2Ø Ø.Ø7 Ø.Ø7 Ø.59 Ø.Ø6

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute compatibility-program/data

	1	2	3	4	5
1	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
2	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
3	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ
4	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø
5	5.ØØ	1.ØØ	1.ØØ	5.ØØ	1.ØØ

The eigenvalue is 5.Ø (Consistency value is 5.Ø)
The consistency of candidate judgments is -Ø.ØØ
The eigenvector is Ø.Ø6 Ø.29 Ø.29 Ø.Ø6 Ø.29

Do you want to change any preferences for this attribute? y or n:.n

Candidate preferences for attribute equipment delivery

	1	2	3	4	5
1	1.ØØ	Ø.2Ø	Ø.2Ø	1.ØØ	Ø.2Ø

Figure 17. (Continued)

```
2  |   5.ØØ     1.ØØ     1.ØØ     5.ØØ     1.ØØ
3  |   5.ØØ     1.ØØ     1.ØØ     5.ØØ     1.ØØ
4  |   1.ØØ     Ø.2Ø     Ø.2Ø     1.ØØ     Ø.2Ø
5  |   5.ØØ     1.ØØ     1.ØØ     5.ØØ     1.ØØ

The eigenvalue is  5.Ø      (Consistency value is   5.Ø)
The consistency of candidate judgments is    -Ø.ØØ
The eigenvector is    Ø.Ø6    Ø.29    Ø.29    Ø.Ø6    Ø.29

Do you want to change any preferences for this attribute?  y or n:.n

Weights of candidates are

        1         2         3         4         5

     Ø.23      Ø.24      Ø.2Ø      Ø.12      Ø.21

Do you want to revise any preferences?  y or n:.y
Do you want to revise level 2 attribute preferences?  y or n:.y
Enter a row number for the new preference:.1
Enter a column number for the new preference:.2
Enter preference for product    to opinion    :.1 7
Do you have further changes at this level?  y or n:.n

Level 2 judgments for SBC Selection

                  1         2
               product   opinion

             |
1  product    |   1.ØØ      Ø.14
2  opinion    |   7.ØØ      1.ØØ

The eigenvalue is  2.ØØ  (Consistency value is  2.Ø)
The consistency of level 2 judgments is      -Ø.ØØ
The weightings are     Ø.12    Ø.88

Do you want to change any preferences at this level?  y or n:.n
Do you want to revise level 3 attribute preferences?  y or n:.n
Do you want to revise level 4 attribute preferences?  y or n:.n
Do you want to revise candidate preferences?  y or n:.n

Weights of candidates are

        1         2         3         4         5

     Ø.11      Ø.27      Ø.26      Ø.1Ø      Ø.26

Do you want to revise any preferences?  y or n:.y
Do you want to revise level 2 attribute preferences?  y or n:.y
```

Figure 17. (Continued)

```
Enter a row number for the new preference:.1
Enter a column number for the new preference:.2
Enter preference for product    to opinion    :.7 1
Do you have further changes at this level?  y or n:.n

Level 2 judgments for SBC Selection

                      1          2
                   product    opinion

                 |-------------------
1  product       |    1.ØØ       7.ØØ
2  opinion       |    Ø.14       1.ØØ

The eigenvalue is  2.ØØ  (Consistency value is  2.Ø)
The consistency of level 2 judgments is       -Ø.ØØ
The weightings are      Ø.88     Ø.12

Do you want to change any preferences at this level?  y or n:.n
Do you want to revise level 3 attribute preferences?  y or n:.n
Do you want to revise level 4 attribute preferences?  y or n:.n
Do you want to revise candidate preferences?  y or n:.n

Weights of candidates are

        1          2          3          4          5

      Ø.35       Ø.22       Ø.15       Ø.13       Ø.16

Do you want to revise any preferences?  y or n:.y
Do you want to revise level 2 attribute preferences?  y or n:.y
Enter a row number for the new preference:.1
Enter a column number for the new preference:.2
Enter preference for product    to opinion    :.3 1
Do you have further changes at this level?  y or n:.n

Level 2 judgments for SBC Selection

                      1          2
                   product    opinion

                 |-------------------
1  product       |    1.ØØ       3.ØØ
2  opinion       |    Ø.33       1.ØØ

The eigenvalue is  2.ØØ  (Consistency value is  2.Ø)
The consistency of level 2 judgments is       -Ø.ØØ
The weightings are      Ø.75     Ø.25

Do you want to change any preferences at this level?  y or n:.n
```

Figure 17. (Continued)

```
Do you want to revise level 3 attribute preferences?  y or n:.n
Do you want to revise level 4 attribute preferences?  y or n:.n
Do you want to revise candidate preferences?  y or n:.n

Weights of candidates are

        1         2         3         4         5
     Ø.31      Ø.23      Ø.17      Ø.13      Ø.17

Do you want to revise any preferences?  y or n:.y
Do you want to revise level 2 attribute preferences?  y or n:.y
Enter a row number for the new preference:.1
Enter a column number for the new preference:.2
Enter preference for product    to opinion   :.1 3
Do you have further changes at this level?  y or n:.n

Level 2 judgments for SBC Selection

                  1         2
               product   opinion

            |-------------------
1  product  |    1.ØØ      Ø.33
2  opinion  |    3.ØØ      1.ØØ
The eigenvalue is  2.ØØ  (Consistency value is  2.Ø)
The consistency of level 2 judgments is      -Ø.ØØ
The weightings are     Ø.75    Ø.25

Do you want to change any preferences at this level?  y or n:.n
Do you want to revise level 3 attribute preferences?  y or n:.n
Do you want to revise level 4 attribute preferences?  y or n:.n
Do you want to revise candidate preferences?  y or n:.n

Weights of candidates are

        1         2         3         4         5

     Ø.15      Ø.26      Ø.24      Ø.1Ø      Ø.24

Do you want to revise any preferences?  y or n:.n
Do you want to save the ending judgments for attributes?  y or n:.n
Do you want to save the ending candidate preferences?  y or n:.n
AHP ends for SBC Selection
```

Figure 17. (Continued)

VITA

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She was employed by The University of Tennessee Computing Center (UTCC) as a programmer and as a supervisor while completing all requirements except the dissertation for the degree Doctor of Philosophy in Management Science. While on educational leave from UTCC, she received the Master of Business Administration degree and the Doctor of Business Administration degree, both from The University of Tennessee, Knoxville. She was awarded the Certificate in Data Processing and has passed the examinations for the Certified Management Accountant and the Certified Public Accountant.

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