Measuring Information-Oriented Productivity and Performance

by

David T. Hill

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APPROVED:

Harold A. Kurstedt, Jr., Chairman

C. Patrick Koelling

Steven E. Markham

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(ABSTRACT)

This research attempts to answer the question of how to measure the performance of management tools. This study integrates qualitative and quantitative research by developing a set of definitions and a set of indicators for information-oriented performance measurement and by validating the indicators with a statistical analysis. Criteria for measuring organizational system performance are borrowed from Sink (1985) and operationalized for measuring information-oriented performance. The operational measures are applied to a set of information documents. The documents are evaluated by four different groups of subjects. The evaluations are compared to the calculations from the operational measures to address the validity of the measures. The evaluations support the productivity, input quality, and output quality measures. The evaluations don't support the efficiency and effectiveness measures. Further refinement of the validation procedures is suggested before further refinement of the performance measures. This research makes two general contributions: a foundation for further development of performance measures for management tools and recommendations for future research.

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Finally, I dedicate this thesis to my parents. Their support provided me the opportunity and encouragement to reach my goals.

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Introduction

Research Objectives

Leedy (1985: 4) says, "Research begins with a problem in the form of a question in the mind of the researcher." For this study, the research question is, "How can we measure the performance of management tools?" The purpose of measuring the performance of management tools is to use the results to improve the tools' performance. This research has three objectives:

1. To develop a set of definitions for information-oriented performance measurement.

2. To develop a set of indicators for measuring information-oriented performance.

3. To validate the indicators by using them to measure the information-oriented performance of a set of information documents (management tools), having subjects evaluate the documents, and statistically analyzing the results.

I need to define some of the terms used above:

- *Management tool.* Management tools include everything we use to manage such as information systems, guides and rules, plans, procedures, budgets, forecasts, organizational structures, etc.

- *Information document.* An information document is any management tool portraying its information and data in written form. I chose a structured form like a table because it's easier to distinguish between units of information and data.

- *Information-oriented performance.* Information-oriented performance is the measure of how well a management tool meets its goals and objectives.

Problems Addressed

In this study, I develop and test measurements of information-oriented performance for a set of information documents. This problem can be divided into five subproblems:

1. Define information-oriented performance and its criteria, and develop operational measures (indicators) for the criteria.

2. Construct a set of information documents for testing the indicators.

3. Use the indicators to measure the performance of the test documents.

4. Have subjects evaluate the documents.

5. Validate the indicators by comparing the measurements with the evaluations.

Type of Research

This study is an integration of qualitative and quantitative research. The qualitative part of the research is developing a set of definitions and a set of indicators. This part of the research yields theoretical developments. The quantitative part of the research is validating the indicators. This part of the research yields empirical findings. The empirical findings provide feedback about the theoretical developments.

Hypotheses

Sink (1985) defines seven criteria for measuring operational performance: effectiveness, efficiency, quality, productivity, profitability/budgetability, innovation, and quality of work life. I use Sink's criteria to develop measures for information-oriented performance. I develop and test hypotheses for the effectiveness, efficiency, quality, and productivity measures in terms of information-oriented performance. Developing and testing hypotheses for the quality of work life, innovation, and profitability/budgetability measures is beyond the scope of this research, but I develop definitions for these three measures. The hypotheses for the effectiveness, efficiency, quality, and productivity measures are:

- If we increase the ratio of useful information to good information on the document, we'll increase the effectiveness of the document.

- If we increase the ratio of useful data to good data on the document, we'll increase the efficiency of the document.

- If we increase the ratio of good information to total information on the document, we'll increase the output quality of the document.

- If we increase the ratio of good data to total data on the document, we'll increase the input quality of the document.

- If we increase the ratio of total information to total data on the document, we'll increase the productivity of the document.

Research Scope

This study tries to validate measures (indicators) for information-oriented performance. I design a set of information documents for validating the indicators. I don't generalize the results to other information documents or management tools (although they may be).

This study develops indicators for performance measurement. I try to show how we can measure the performance of a management tool. I leave performance evaluation and improvement of management tools for future research.

Importance of the Study

The importance of measuring the performance of a management tool is using the results to improve the tool's performance. Two ways to improve the performance of a management tool come to mind: redesign the tool or make better use of the tool. Before we can improve the performance

of a management tool, we need to be able to measure its performance. This research attempts to lay the foundation for further development of performance measures for management tools.

Assumptions

This study requires several assumptions. The assumptions, supported in the literature review, are:

- The purpose of measuring the performance of a management tool is to use the results to improve the tool's performance.
- The Management System Model is acceptable as a workable, cognitive map of a manager's domain of responsibility.
- The goal of a management tool is to provide useful information.
- Information and data can be characterized by three key attributes: accuracy, timeliness, and relevance.
- Operational performance criteria can be used to develop information-oriented performance criteria.
- Sink's (1985) operational performance criteria are suitable for my purposes.

Literature Review

The Management System Model

Kurstedt (1985) has developed a framework, called the Management System Model (MSM), for describing and understanding a manager's domain of responsibility. The framework describes the relationship between who manages (a manager), what is managed (operations), and what is used to manage (management tools). Management tools convert data to information. A manager converts information to action.

I divide the MSM into three areas of performance: personal/professional, operational, and information-oriented. Personal/professional performance is concerned with the performance of an individual in managing his or her domain. Operational performance is concerned with the performance of the physical things the individual manages. Information-oriented performance is concerned with the performance of the tools the individual uses to manage his or her domain. The performance of the whole I call organizational performance (See Figure 1 on page 7).

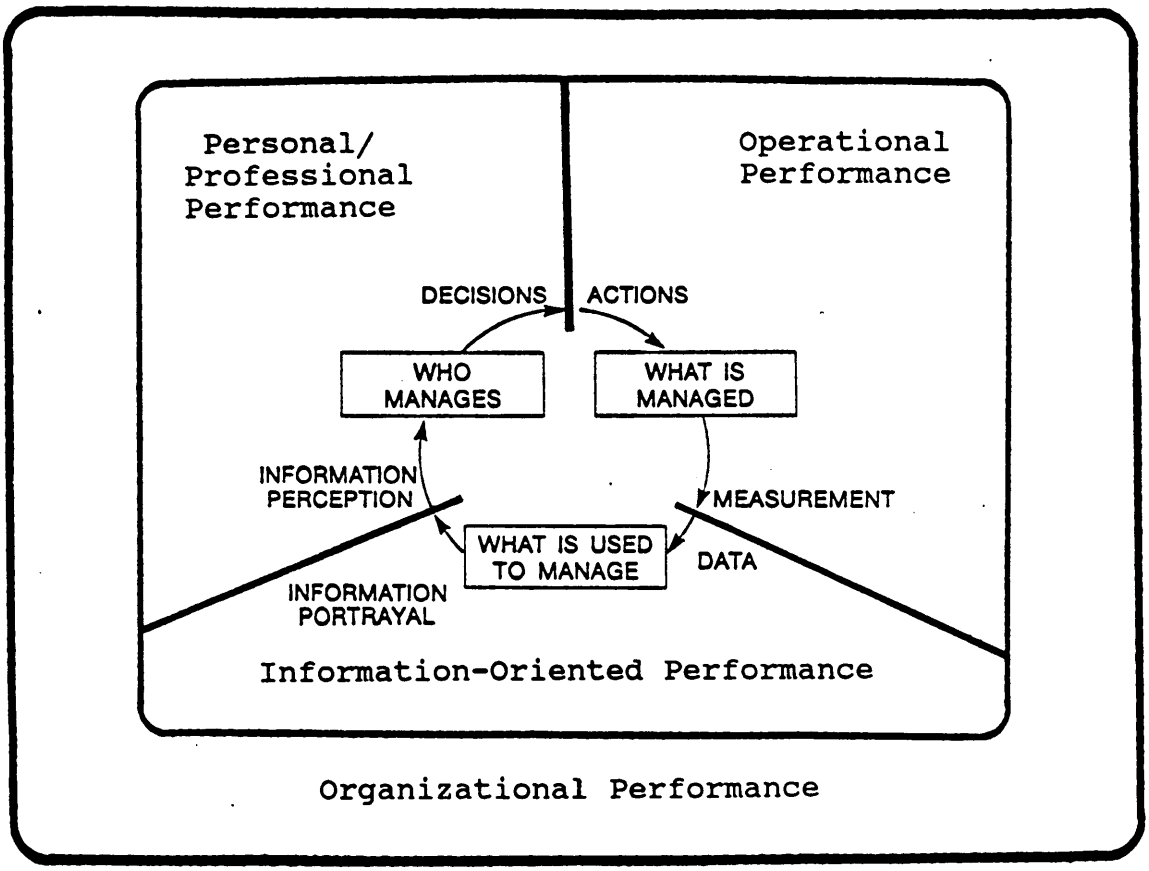

Figure 1. The Management System Model can be divided into three areas of performance.

Productivity and Performance Measurement

Productivity measurement is not new. Most of the literature focuses on company-level productivity measurement (Craig and Harris, 1973; Davis, 1955; Kendrick and Creamer, 1965; Sumanth, 1984; Van Loggerenberg and Cucchiaro, 1981-82). Some of the literature extends productivity measurement to the industry and national levels (Gollop, 1982; Sumanth, 1984). I use these references to understand productivity and performance measurement in general and to develop standard terminology.

Productivity is a confused term (Craig and Harris, 1973; Davis, 1955; Sink, 1983; Sumanth, 1984). Productivity doesn't equal performance. Productivity is one of several performance measures (Richardson and Gordon, 1980; Sink, 1983). Kaplan (1984) and Solomons (1965) stress the need for nonfinancial performance measures (such as productivity). Packer (1983) and Richardson and Gordon (1980) stress the need for other measures of performance besides productivity. These authors imply we have to be careful about using a closed set of criteria and about exactly what the criteria apply to.

Some people have developed criteria for manufacturing performance measurement (Kaplan, 1983; Richardson and Gordon, 1980; Sink, 1985). Manufacturing performance is concerned with performance of a factory. Other people have developed criteria for white-collar performance measurement (Sink, Das, and Coleman, 1987; Thor, 1985; Tuttle and Romanowski, 1987). White-collar performance is concerned with performance of an office. These authors have developed criteria for what I call operational performance. Sink's (1985) criteria have been shown to be comprehensive for manufacturing performance measurement (Mallak, 1985).

People have developed criteria for managerial performance measurement (Campbell, Dunnette, Lawler, and Weick, 1970; Strassmann, 1985). Managerial performance is concerned with the per-

formance of an individual in managing his or her domain. I call managerial performance personal/professional performance.

I develop criteria for information-oriented performance measurement. A management tool is a mechanism for producing information from data. In a factory, we have inputs (raw materials), transformation processes (operations converting raw materials into finished goods), and outputs (finished goods). Similarly, in an office, we have inputs (data), transformation processes (management tools converting data to information), and outputs (information). This idea is not new. Simon (1960: 5) says, "We can think of white-collar organizations as factories for processing information." In Strassmann's (1976) nine steps for productivity management of information resources, he also considers information processing services as industrial processes. We can borrow the idea of a conversion process from operations and apply it to management tools. Likewise, we can borrow performance criteria from operations and, with slight modification, apply them to management tools. I use this literature to support the transferability of operational performance to information-oriented performance.

In measuring operational performance, we need to worry about product performance (Do the widgets meet the specifications?) as well as process performance (making the widgets). Similarly, in measuring information-oriented performance, we need to worry about product performance (Does the information document meet the specifications?) as well as process performance (making the information document). The question we need to ask ourselves is, "Are we measuring the performance of the product or the process?" This distinction hasn't been made in other work, so I won't make it here. However, a product is a function of the process producing it, so we're probably measuring the performance of both the product and the process.

I use Sink's (1985) operational performance measurement criteria to develop measures for information-oriented performance. Sink's criteria are comprehensive and, with slight modification, suit my needs best. Keep in mind I'm measuring the performance of the tools, not the people using

the tools. Based on this and the manufacturing analogy previously discussed, I borrow operational performance criteria and not personal/professional performance criteria.

Some people have discussed relationships among performance measures. Miller (1984) says profitability equals productivity plus price recovery. Van Loggerenberg and Cucchiaro (1981-82) say productivity equals capacity utilization plus efficiency. Packer (1983) and Richardson and Gordon (1980) agree productivity measures stress efficiency and neglect effectiveness, but effectiveness may be more important for success. Sumanth (1984) says productivity is a function of effectiveness over a function of efficiency. Sink (1987) says productivity integrates effectiveness, efficiency, and aspects of quality. I describe relationships among performance measures by grouping them into input, transformation, and output combinations to try to make sense of how they work together.

Information Attributes

Many people have studied the characteristics of information (American Accounting Association, 1966; Burch and Grudnitski, 1986; Davis and Olson, 1985; Epstein and King, 1982; Gallagher, 1974; Godfrey and Prince, 1971; Hicks, 1984; Larcker and Lessig, 1980; Lucas, 1978; Murdick, 1980; Senn, 1987; Snavely, 1967; Swanson, 1974; Taggart and Silbey, 1986; Zmud, 1978). Napoliello (1987) reviewed seven of these references and found the most recognized information attributes to be sufficiency, reliability, and relevance. I reviewed eight more references and found the most recognized information attributes to be accuracy, timeliness, and relevance (See Figure 2 on page 11). We have two common attributes since accuracy and reliability are closely related.

Burch and Grudnitski (1986: 5) say, "The quality of information rests solidly on three pillars--accuracy, timeliness, and relevancy. These are the key attributes of information." I use these three attributes to classify information and operationalize my performance measures. No one talked

	Accuracy	Timeliness	Relevance	Sufficiency
AAA	X		X	
Burch and Grudnitski	X	X	X	
Davis and Olson	X			
Epstein and King	X	X	X	X
Gallagher	X	X	X	X
Godfrey and Prince		X	X	X
Hicks	X	X	X	
Larcker and Lessig			X	
Lucas	X			
Murdick	X	X	X	
Senn	X	X	X	X
Snavely	X	X	X	X
Swanson	X	X	X	
Taggart and Silbey	X	X		
Zmud	X	X	X	X
Totals	13	11	12	6

Figure 2. Accuracy, timeliness, and relevance are the most recognized attributes of information.

about characteristics of data but I extend accuracy, timeliness, and relevance to data classification also. The sufficiency attribute addresses the amount of information (or data). My performance measures are based on the amount of accurate, timely, and relevant information and data. Sufficiency is a higher level attribute considered in all the measures.

Evaluating Information and Information Systems

Many people have studied the evaluation of information and information systems. These studies range from evaluating the output of an existing information system to justifying the implementation of a new decision support system. I review these studies to understand what's been done related to my research.

An older evaluation method commonly referenced in the literature is called the "information economics" approach (Feltham, 1968; Mock, 1971). Szewczak and King (1987: 103) describe the information economics approach: "Aspects of this approach assume a quantitative measure of information value in terms of payoffs resulting from decisions that are made on the basis of given information." Zmud (1978: 188) comments on this approach: "Theoretically, the information economics approach is very appealing; realistically, it appears impractical." King and Epstein (1976) attempt to make the information economics approach more practical by developing an operational approximation.

People have studied cost/benefit analyses of information systems (Faerber and Ratliff, 1980; Keim and Janaro, 1982; King and Schrems, 1978; Litecky, 1981; Petersohn, 1981; Piron, 1982; Rockhold, 1982). Keim and Janaro extended Hirsch's (1968) work to develop a phased approach to cost/benefit analysis. Other people have studied alternatives to traditional cost/benefit analyses (Lindgren, 1981). Smith (1983) reviews four approaches: Incremental Analysis, Expected Value,

Value Analysis, and Benefit Profile. Gage (1986) and Keen (1981) recommend Value Analysis since it allows qualitative benefits to be considered without having to relate them directly to costs.

Frameworks have been developed for information system evaluation (Ahituv, 1980; Grindley, ?; Hamilton and Chervany, 1981a; King and Rodriguez, 1978; Martin and Fuerst, 1984; Spuck and Bozeman, 1980). Didis (1984), Keen (1975), and Stimler (1975) outline performance evaluation procedures for information systems. Ahituv, Munro, and Wand (1981) and Akoka (1981) present frameworks for selecting evaluation methods. Chandler (1982) and Hamilton and Chervany (1981b) present frameworks for considering multiple evaluator viewpoints in information system evaluation. Mason (1978) presents a framework for measuring information systems output.

Instruments have been developed for evaluating information and information systems (Blaylock and Rees, 1984; Epstein and King, 1982; Franz and Robey, 1986; Gallagher, 1974; King and Epstein, 1983; Larcker and Lessig, 1980; Neumann and Segev, 1979; Neumann and Segev, 1980; Srinivasan, 1985; Swanson, 1974; Szewczak and King, 1987). These instruments measure user perceptions of various attributes of information systems or the information output from the systems. Users are asked to evaluate each attribute on a five to seven point scale.

Larcker's and Lessig's study is the most closely related to my work. The other studies mentioned in this section aren't similar enough to my work to warrant discussing them in more detail. Larcker and Lessig develop an instrument (see Figure 3 on page 14) for measuring two dimensions of the perceived usefulness of information: perceived importance and perceived usableness. Perceived importance, measured by statements A, C, and F, is related to whether the information is relevant. Perceived usableness, measured by statements B, D, and E, is related to whether the information portrayal is unambiguous, clear, or readable. Later, I discuss how I use this instrument.

Larcker and Lessig recognize they ignore other dimensions of perceived usefulness such as information accuracy and timeliness, but control for these factors in their study. In my study, I measure

	completely disagree			neutral			completely agree
A. It would be extremely difficult to complete a specification decision without at least the information presented.	1	2	3	4	5	6	7
B. Extremely complex recalculations or adjustments are necessary in order to use the information presented to complete a specific decision.	1	2	3	4	5	6	7
C. The information presented is sufficient to complete a specific decision.	1	2	3	4	5	6	7
	none			about half			all
D. What portion of the information presented is in the correct form for completion of a specific decision?	1	2	3	4	5	6	7
E. What portion of the information presented is interpretable, without any recalculation or adjustment for the completion of a specific decision?	1	2	3	4	5	6	7
F. What portion of the information presented is essential for or instrumental in completing a specific decision?	1	2	3	4	5	6	7

Figure 3. Statements (or Questions) Used in Measurement of the Perceived Usefulness Construct: Adapted from Larcker and Lessig (1980).

accuracy, timeliness, and relevance, but control for usableness by making the test documents unambiguous, clear, and readable.

Developing the Measures

Performance Criteria and Operational Definitions

In this section, I develop measures for information-oriented performance. I present a qualitative definition for each of Sink's (1987) seven performance criteria. Then I present Sink's operational definition for each criterion (if available). Finally, I present my operational definition for each criterion.

I describe each criterion in terms of data used and information produced by a management tool. Information and data are different. Information is biased data. The bias occurs when data are compared to a set point or reference to generate information (Kurstedt, 1985).

I divide information and data into three classes: good, bad, and useful. Useful is necessarily good, but good isn't necessarily useful. I discuss the criteria for classifying information and data later.

Effectiveness: An Output Measure

Drucker (1974: 45) says, "Effectiveness is doing the right things." Effectiveness is an output measure. Sink (1987) defines effectiveness as actual output over expected output. I define information-oriented effectiveness as the amount of useful information produced by the tool over the amount of good information produced by the tool. We want our tools to produce the right information for our decisions. I call the right information useful information. Since useful is necessarily good, but good isn't necessarily useful, I measure the ratio of useful to good information.

Efficiency: An Input Measure

Drucker (1974: 45) says, "Efficiency is concerned with doing things right." Efficiency is an input measure. Sink (1987) defines efficiency as resources expected to be consumed over resources actually consumed. I define information-oriented efficiency as the amount of useful data used by the tool over the amount of good data used by the tool. We want our tools to use the right data to produce the right information. I call the right data useful data. Again, since useful is necessarily good, but good isn't necessarily useful, I measure the ratio of useful to good data.

Quality: An Input Measure and An Output Measure

Crosby (1979: 17) defines quality as "conformance to requirements." Sink (1987) defines five quality checkpoints:

1. Selection and/or management of upstream systems.
2. Incoming quality assurance.

3. In-process quality assurance.
4. Outgoing quality assurance.
5. Proactive understanding of customer's needs, expectations, etc.

Koelling, Tenjeras, and Riel (1987) define the sixth quality checkpoint as the process of managing the first five quality checkpoints. I use two quality checkpoints: one for inputs (data) and one for outputs (information). I define information-oriented input quality as the amount of good data used by the tool over the total amount of data, good and bad, used by the tool. I define information-oriented output quality as the amount of good information produced by the tool over the total amount of information, good and bad, produced by the tool.

Productivity: A Measure of Output over Input

Productivity is the ratio of outputs over inputs for a system over a period of time (Sink, 1987). I define information-oriented productivity as the total amount of information produced by the tool over the total amount of data used by the tool.

Profitability/Budgetability: A Measure of Outcome over Input

Sink (1987) defines two financial measures of performance: profitability for profit centers and budgetability for cost centers. Profitability is the ratio of revenues over costs. Budgetability is the relationship between budgets and goals, and actual costs and accomplishments. In developing a financial measure of information-oriented performance, I relate the value of the outputs from the tool to the cost of the inputs to the tool. I call it relative value since I'm measuring value relative to cost. Specifically, I define information-oriented relative value as the present unit value of the information produced by the tool over the present unit cost of the data used by the tool.

Innovation: A Measure of Successful Adaptation

Sink (1987) says innovation is the creative process of successfully responding to pressures, demands, and opportunities. Two measures of innovation are adaptation to internal needs and adaptation to external competition. I've developed a ratio for each. First, I'll look at adaptation to external competition. A tool is innovative if it successfully adapts to external competition from similar (standard) tools. This can be measured by the present value of the information produced by the tool over the present value of the information produced by a similar tool. Now I'll look at adaptation to internal needs. A tool is innovative if it successfully adapts to the changing needs of the user. This can be measured by the present value of the information produced by the tool over the original value of the information produced by the tool.

Quality of Work Life: A Measure of Response to the Environment

Sink (1987) says quality of work life is the affective response of employees to the overall work environment. Quality of work life is closely related to employee satisfaction. I obviously can't measure how satisfied a tool is with the quality of its work life, but I can measure the affective response of the tool to the physical work environment. A tool may have some specifications that must be followed for the tool to function properly. The tool's performance won't improve if we adhere to the specifications, but it's performance will decrease if we don't. For example, some computers must be kept in a cool and dry place. If we put our computer in a cool and dry place, it won't perform any better than it's built to, but if we put it in a hot and humid place, it probably won't perform up to its potential. Information-oriented "quality of work life" is then the extent to which the environment violates the specifications of the tool, or the relationship of the tool's environment to its limits (what it can stand). I call it tool response. Tool response can be measured by the tool's environment over the tool's limits.

Relationships Among Performance Measures

I describe relationships among performance measures by grouping them into input, transformation, and output combinations to try to make sense of how they work together. I multiply the ratios together since multiplication is a logical "and."

Input Performance

There are two input measures: efficiency and input quality. Multiplying these ratios together produces the input combination: the amount of useful data used by the tool over the total amount of data used by the tool.

Transformation Performance

There are four transformation measures: productivity, relative value (the profitability/budgetability surrogate), innovation, and tool response (the quality of work life surrogate). The productivity and relative value ratios can easily be multiplied together to get the present value of the information produced by the tool over the present cost of the data used by the tool. Multiplying this ratio by one or both of the innovation ratios and the tool response ratio gives the transformation combination.

Output Performance

There are two output measures: effectiveness and output quality. Multiplying these two ratios together produces the output combination: the amount of useful information produced by the tool over the total amount of information produced by the tool.

Total Performance

Now I combine all the ratios together to get the total performance ratio. Some of the ratios have like terms so I've applied dimensional analysis. The productivity ratio can be multiplied by the effectiveness and output quality ratios, and divided by the efficiency and input quality ratios, to get the amount of useful information produced by the tool over the amount of useful data used by the tool. This makes sense because we want our management tools to use only useful data to produce only useful information. Notice also I'm taking a measure of output over input (productivity), multiplying it by two output measures (effectiveness and output quality), and dividing it by two input measures (efficiency and input quality) to get a new measure of output over input. This ratio can easily be multiplied by the relative value ratio to get the present value of the useful information produced by the tool over the present cost of the useful data used by the tool. Finally, multiplying this ratio by one or both of the innovation ratios and the tool response ratio gives the total performance ratio. Trying to come up with one number isn't important. I'm just trying to make sense of how the measures work together.

The Good, the Bad, and the Useful

Now I define what I mean by good, bad, and useful. I use three attributes, accuracy, timeliness, and relevance, to classify information and data as good, bad, or useful.

I define good and bad information by the first two attributes: accuracy and timeliness. "Accuracy refers to information's freedom from error" (Hicks, 1984: 12). "Timely information is available when it is needed and has not become outdated through delay" (Senn, 1987: 37). I classify information as good if it's both accurate and timely. I classify information as bad if it's inaccurate, untimely, or both. Similarly, I classify data as good if it's accurate (free from error) and timely (available when needed and not outdated through delay). I classify data as bad if it's innaccurate, untimely, or both.

I define useful information by all three attributes: accuracy, timeliness, and relevance. "Information is relevant if an individual needs it in a particular [immediate] decision-making or problem-solving situation" (Senn, 1987: 39). Relevant information fulfills the decision-maker's unique requirements. I classify information as useful if it's accurate, timely, and relevant. Similarly, I classify data as useful if it's accurate, timely, and relevant (needed to produce information about a particular, immediate situation).

Keep in mind I want to classify the information and data as good, bad, or useful, so I'm not interested in how accurate, timely, and relevant the information and data are. I just want to know whether the information and data are accurate or inaccurate, timely or untimely, and relevant or irrelevant, so I can put them in one of the three classes.

Constructing Test Documents

In this section, I discuss the development of a set of documents for testing the ratios.

The Work Distribution Report: A Multi-Purpose Document

Originally, I intended to use Management Systems Laboratories' Work Distribution Report (WDR) to test the ratios. The WDR is a spreadsheet. Tasks for the week are listed in priority order down the vertical axis. Employees who will work on those tasks are listed across the horizontal axis. The proposed hours each person should allocate to each task are the elements of the matrix. I chose an information document with a structured form like a table for testing the ratios because it's easier to distinguish between units of information and data.

The problem with using the WDR to test the ratios is it's a multi-purpose document. A multi-purpose document has different purposes for different users. At the clerical level, the purpose of

the WDR is to establish priorities for tasks. At the operational level, the purpose of the WDR is to establish work expectation for individuals. At the tactical level, the purpose of the WDR is to allocate people to tasks. At the strategic level, the purpose of the WDR is to aid decisions on hiring or firing people.

Performance can only be measured as related to a purpose. Purpose defines relevance. In measuring the performance of a multi-purpose document like the WDR, we have to be careful about which purpose our measurements are related to. I decided to control for this by using a single-purpose test document.

The Priority List: A Single-Purpose Document

I designed a single-purpose document for testing the ratios. The document is a priority list for a manager. (See the sample document in the package in Appendix A.) I developed a set of rules for establishing the manager's priorities, defined a purpose for the document, and set up a scenario for evaluating the document. (See Appendix A for the rules, purpose, and scenario.) I developed the rules, purpose, and scenario to make the calculations repeatable by removing any subjectivity in determining which units of information and data are accurate, timely, and relevant.

Using the rules, purpose, and scenario, I calculated the ratios for the test document. (I discuss this in more detail in the next section.) Then I made modifications to the document and recalculated the ratios after each modification. The modifications included making errors, correcting errors, adding rows or columns, deleting rows or columns, making data and information outdated, and making data and information current. I learned how changes in the document affected different ratios.

Methodology for Using the Test Document

The remaining steps were to develop five versions of the test document, calculate the ratios for each version, have subjects evaluate the five documents, and statistically analyze the results. The exercise of modifying the document and recalculating the ratios helped me develop eight different documents. I chose five for testing the ratios based on what ratios they affected so the calculations would yield different results for different documents. The test documents are in Appendix A.

Using the Ratios to Measure the Performance of the Test Documents

In this section, use the package in Appendix A. It contains the sample document, rules, purpose, scenario, and test documents.

Quantifying Information and Data

The first step in measuring the performance of the documents is quantifying the information and data on the documents into countable units. Berube (1988) has developed a framework describing data, information, and the relationships between them. He defines a datum as a kernel and a set of specifiers. A kernel is the value of a measured attribute. Specifiers give meaning to the kernel. For example, on the sample document, "1/13/89" is a kernel. "Due Date" and "SE TIMS paper" are two specifiers for the kernel "1/13/89." Alone, "1/13/89" is meaningless. We include "Due Date" and "SE TIMS paper" to give "1/13/89" meaning: "1/13/89 is the *due date* for the *SE TIMS*

paper." On the sample document, each element in a column is a kernel. A kernel represents one datum. Each of five columns holds twenty kernels yielding one hundred units of data.

Berube defines a unit of information as the comparison of any two data. On the sample document, I define a unit of information as the comparison of any two rows. Each row contains five units of data, so each unit of information is made up of ten units of data. There are twenty rows, so there are twenty taken two at a time or one hundred ninety units of information.

One hundred units of data are used to make one hundred ninety units of information on the sample document. Other documents may use more or fewer units of data to make more or fewer units of information. For example, Test Document A has sixty eight units of data (four columns with seventeen kernels each) making up one hundred thirty six units of information (seventeen rows taken two at a time).

Determining Acccuracy, Timeliness, and Relevance

The next step is determining if each unit of information and data on the documents is accurate, timely, and relevant. Recall I define a unit of information or data as accurate if it's free from error, and timely if it's available when needed and not outdated through delay. I define a unit of information or data as relevant if it's needed in a particular, immediate, decision-making or problem-solving situation. The task categories determine which units of data are accurate. They can be used to check the task types and charge codes. The hierarchy of rules determines which units of information are accurate. It can be used to check whether tasks are prioritized correctly. The scenario and update rules determine which units of information and data are timely. They can be used to check whether the due dates are outdated. The purpose determines which units of information and

data are relevant. It can be used to check what information and data presented aren't needed for establishing the manager's priorities for the next four weeks.

Accuracy

Concerning which units of data are accurate, several types of data errors can occur on the documents. A task may be incorrectly categorized or assigned the wrong charge code number. Also, if a task is prioritized incorrectly, the priority number will be incorrect. These are data errors. Concerning which units of information are accurate, one type of information error can occur on the documents. If a task is prioritized incorrectly, each row out of order with that row is one incorrect unit of information. For example, on the sample document, if Senior Design Projects (row 9) was before DOE presentation (row 7), there would be two incorrect units of information: Senior Design Projects compared to DOE presentation and Senior Design Projects compared to IIE paper. Note DOE presentation compared to IIE paper is still in the correct order, and Senior Design Projects compared to all the other tasks is still in the correct order. I designed test documents A and B with errors to get some inaccurate units of data and information.

Timeliness

Concerning which units of information and data are timely, two things are important: whether each unit is current and whether each unit is available. Considering currentness, some units of data may be outdated. The scenario and the update rules may render some due dates outdated. Each outdated due date is an untimely unit of data. Also, if the data making up a unit of information is outdated, then that unit of information is also outdated. For example, if one due date on the sample document was outdated, then the row with that due date compared to any other row would be outdated information. There would be nineteen outdated units of information on the sample

document. I designed test documents A and B with outdated due dates to get some untimely units of data and information. Considering availability, some documents may not have all the data needed for establishing the manager's priorities. Here we run into the problem of how to count units of data we need but don't have. Test document D doesn't have a "type" column. Without the type column, we can't establish the manager's priorities. Since the types for each task are unavailable, they are untimely, so there are seventeen untimely units of data on test document D. If the data making up the information is unavailable, then the information is also unavailable, so every unit of information on test document D is untimely.

Relevance

Concerning relevance, which units of data and information are relevant is determined by the purpose of the document. The purpose of the document is to establish the manager's priorities for the next four weeks from the day he receives the document. Comparing any task (row) having a due date beyond that four-week period with any other task (row) yields one unit of irrelevant information. In the scenario, the manager receives the document on January 9, 1989. The purpose of the document is then to establish his priorities through February 3, 1989. Test documents B and E each have three tasks with due dates beyond February 3, 1989: SRG Literature Search, Lab Strategic Plan meeting, and Lab Brochure. Comparing each of these three rows with every other row yields fifty four units of irrelevant information on each document. The data making up these three rows are also irrelevant yielding fifteen irrelevant units of data on test document B and twelve irrelevant units of data on test document E. Looking at the hierarchy of rules, charge codes aren't needed for establishing the manager's priorities, the purpose of the document. Test documents B and C include charge codes for each task. Each charge code is one unit of irrelevant data yielding twenty units of irrelevant data on test document B and seventeen units of irrelevant data on test document C. Test document B has a total of thirty two units of irrelevant data.

Classifying Good, Bad, and Useful

The third step is classifying each unit of data and information as good, bad, or useful, and tallying the number of units in each class. If a unit of data or information is accurate and timely (whether relevant or irrelevant), it's classified as "good." If a unit of data or information is innaccurate, untimely, or both, it's classified as "bad." If a unit of data or information is accurate, timely, and relevant, it's classified as "useful." We have to be careful about adding the number of innaccurate units and untimely units to get the number of bad units because some units may be both innaccurate and untimely; we don't want to count them twice.

We can easily add up the number of good, bad, useful, and total units of data and information on documents A, B, C, and E, since they all have at least the data and information needed for establishing the manager's priorities. Document D doesn't have all the data and information needed for establishing the manager's priorities. Recall we counted the missing "types" for the tasks as seventeen untimely (bad) units of data. We have to account for data and information we need but don't have in the totals. I do this by using two totals for data and two totals for information:

- The total number of data units we have plus the number of data units we need
- The total number of data units we have
- The total number of information units we have plus the number of information units we need
- The total number of information units we have.

The total number of (information or data) units we have is the number of (information or data) units actually on the document. Document D actually has thirty four units of data and one hundred thirty six units of information. The total number of (information or data) units we have plus the number of (information or data) units we need is the number of (information or data) units actually on the document plus the number of (information or data) units not available but needed to establish the manager's priorities. The number of data units we have plus the number of data

units we need is fifty one (thirty four plus seventeen). The number of information units we have plus the number of information units we need is still one hundred thirty six since adding the "type" column doesn't change the number of rows. The two totals for data will be equal and the two totals for information will be equal for documents having at least the data and information needed for establishing the manager's priorities.

Calculating the Ratios

Using two different totals for data and two different totals for information requires slight modification of the input quality, output quality, and productivity ratios. I defined input quality as the amount of good data used by the tool over the total amount of data, good and bad, used by the tool. Since the total amount of data, good and bad, is the number of data units we have plus the number of data units we need, the input quality ratio becomes the number of good data units over the total number of data units we have plus the number of data units we need. Likewise, the output quality ratio becomes the number of good information units over the total number of information units we have plus the number of information units we need. I defined productivity as the total amount of information produced by the tool over the total amount of data used by the tool. These totals are the number of units of data and information actually on the document. The productivity ratio becomes the total number of information units we have over the total number of data units we have.

Using the number of good units, bad units, useful units, the total number of units we have plus the number of units we need, and the total number of units we have for data and information, I calculated the five ratios for each document. The calculations, shown in Appendix B, are summarized in Figure 4 on page 32.

Document:	A	B	C	D	E
Productivity	2	1.9	1.6	2.667	2.375
Input Quality	.838	.83	1	.75	1
Output Quality	.75	.763	1	0	1
Efficiency	1	.675	.8	1	1
Effectiveness	1	.703	1	0	.716

Figure 4. Summary of the Calculations for Each Document on Each Criterion

Having Subjects Evaluate the Test Documents

In this section, I discuss the subjects and the package they were given.

Four groups of subjects evaluated the test documents:

- undergraduates
- graduate students
- MSL managers
- MSL staff.

Each subject was given a package, shown in Appendix A, containing:

- demographic questions
- a scenario describing the manager and the priority list
- the rules for establishing the manager's priorities
- qualitative definitions of the five performance criteria
- the five test documents
- a scenario for evaluating the test documents
- a modified version of Larcker's and Lessig's (1980) instrument for rating each document

- two questions for rating each document
- a worksheet for ranking the documents on each performance criterion.

Subjects were asked to rate each document using a modified version of Larcker's and Lessig's (1980) instrument. The modified version of Larcker's and Lessig's instrument included statements A, C, and F (See Figure 3 on page 14) for measuring the perceived importance of information. I made up matching statements for measuring the perceived importance of data, since I define data and information differently.

Subjects were then asked to rate the documents by answering two questions about each one. The questions asked what things the subjects liked and disliked about each document.

Finally, the subjects were asked to rank each document against the five performance criteria. I developed a worksheet to use for ranking the documents on each performance criterion.

The modified Larcker and Lessig instruments, the questions, and the worksheet are in Appendix A.

Each subject was given a package and asked to return it in a week. The instructions weren't read to the subjects.

Validating the Ratios

Subject Demographics

This section summarizes the characteristics of the subjects who responded to the questionnaire (package). Figure 5 on page 36 shows how many subjects in each group returned their questionnaires.

Subjects reported their age, gender, educational status, whether they had ever held a paid, managerial position, and whether they ever had to set priorities in writing for their own work or for the work of others. Ages ranged from twenty years to fifty years, with fifty percent of the subjects being between twenty and twenty three. Thirty eight (71.1%) were males and fifteen (28.3%) were females. Of those in college, twenty six (49.1%) were working on bachelor's degrees, twelve (22.6%) were working on master's degrees, and two (3.8%) were working on doctoral degrees. Of those not in college, one (1.9%) had earned a high school diploma, five (9.4%) had earned a bachelor's degree, six (11.3%) had earned a master's degree, and one (1.9%) had earned a doctoral degree. Seventeen (32.1%) said they have held a paid, managerial position. Sixteen (30.2%) said they have had to set priorities in writing for their own work or for the work of others.

Group	Subjects	Distributed	Returned	Percent
1	Undergraduates	27	25	92.6%
2	Graduate students	26	12	46.2%
3	MSL managers	13	8	61.5%
4	MSL staff	15	8	53.3%
		81	53	65.4%

Figure 5. Questionnaire Response Rates By Group

Analyzing the Rankings

Friedman Test

Friedman's two-way analysis of variance by ranks was used to determine if there's a significant difference among documents (ranks) for each performance criterion. The null hypothesis for the Friedman test is there's no difference in the mean ranks. If there's at least one difference in the means, the null hypothesis is rejected.

The Friedman test was run for each criterion for five groups: males, females, those with managerial experience, those without managerial experience, and all the subjects. The null hypotheses for all five sets of tests were rejected at the .01 level of significance. All five groups found at least one difference among the documents for each criterion. Figure 6 on page 39, Figure 7 on page 40, Figure 8 on page 41, Figure 9 on page 42, and Figure 10 on page 43, show the mean ranks for all the subjects, managers, non-managers, males, and females, respectively.

Multiple Comparisons

Since the null hypotheses of no differences among documents were rejected, we want to know which documents differ significantly from which others for each criterion. Gibbons (1976) presents a formula for making multiple comparisons, simultaneous tests with an overall level of significance, using the sum of the ranks for each document. The formula is:

$$|R_i - R_j| \leq z\sqrt{\frac{kn(n+1)}{6}}$$

where

- k is the number of sets of rankings

- n is the number of treatments (documents)

- z is the point on the normal curve corresponding to a right-tail probability of $\alpha/n(n-1)$, since the total number of comparisons is $n(n-1)/2$

- R_i and R_j are the sums of the ranks for documents i and j, respectively.

At the overall α, all pairs of differences of rank sums larger than the right-hand side of the formula are significantly different pairs. Multiple comparisons were made for each group for each criterion at the .10 level. Figure 11 on page 44, Figure 12 on page 45, Figure 13 on page 46, Figure 14 on page 47, and Figure 15 on page 48 show the multiple comparisons for the productivity, input quality, output quality, efficiency, and effectiveness criteria, respectively. Pairs of documents not significantly different are underlined. The rankings according to the ratios are shown for comparison. The exact values of the ratios from the calculations are also given.

I'll discuss the rankings across groups for each criterion. I compare these with the rankings according to the ratios later. Looking at Figure 11 on page 44, the productivity rankings are highly consistent across all groups. Looking at Figure 12 on page 45 for the input quality rankings and Figure 13 on page 46 for the output quality rankings, documents C and E are ranked consistently high, document D is ranked consistently in the middle, and documents A and B are ranked consistently low. Looking at Figure 14 on page 47 for the efficiency rankings and Figure 15 on page 48 for the effectiveness rankings, C and E are ranked high, D and A are ranked middle to low, and B is ranked lowest. The underlines indicate people seemed to have more trouble distinguishing among the documents for the efficiency and effectiveness criteria.

Document	A	B	C	D	E
Productivity	2.77	4.42	3.49	2.44	1.87
Input Quality	3.75	4.32	1.96	2.98	1.98
Output Quality	3.89	4.28	1.99	3.01	1.83
Efficiency	3.18	4.02	2.57	3.38	1.86
Effectiveness	3.37	4.00	2.38	3.32	1.93

Figure 6. Mean Ranks for All Subjects

Document	A	B	C	D	E
Productivity	3.03	4.38	3.21	2.65	1.74
Input Quality	3.53	4.00	2.18	3.24	2.06
Output Quality	3.71	4.06	2.06	3.24	1.94
Efficiency	3.18	4.12	2.59	3.12	2.00
Effectiveness	3.71	4.24	1.94	3.06	2.06

Figure 7. Mean Ranks for Managers

Document	A	B	C	D	E
Productivity	2.65	4.44	3.63	2.35	1.93
Input Quality	3.86	4.47	1.86	2.86	1.94
Output Quality	3.97	4.39	1.96	2.90	1.78
Efficiency	3.18	3.97	2.56	3.50	1.79
Effectiveness	3.21	3.89	2.58	3.44	1.88

Figure 8. Mean Ranks for Non-Managers

Document	A	B	C	D	E
Productivity	2.96	4.46	3.51	2.05	2.01
Input Quality	3.86	4.28	1.97	2.76	2.13
Output Quality	3.99	4.25	2.14	2.83	1.79
Efficiency	3.26	4.11	2.71	3.00	1.92
Effectiveness	3.39	4.05	2.50	3.08	1.97

Figure 9. Mean Ranks for Males

Document	A	B	C	D	E
Productivity	2.30	4.33	3.43	3.43	1.50
Input Quality	3.50	4.43	1.93	3.53	1.60
Output Quality	3.63	4.37	1.60	3.47	1.93
Efficiency	2.97	3.80	2.20	4.33	1.70
Effectiveness	3.30	3.87	2.07	3.93	1.83

Figure 10. Mean Ranks for Females

All Subjects	E	D	A	C	B
Managers	E	D	A	C	B
Non-Managers	E	D	A	C	B
Males	E	D	A	C	B
Females	E	A	D	C	B
Ratio	D	E	A	B	C
Values	2.667	2.375	2	1.9	1.6

Figure 11. Multiple Comparisons for the Productivity Criterion: A = Document A, B = Document B, etc.

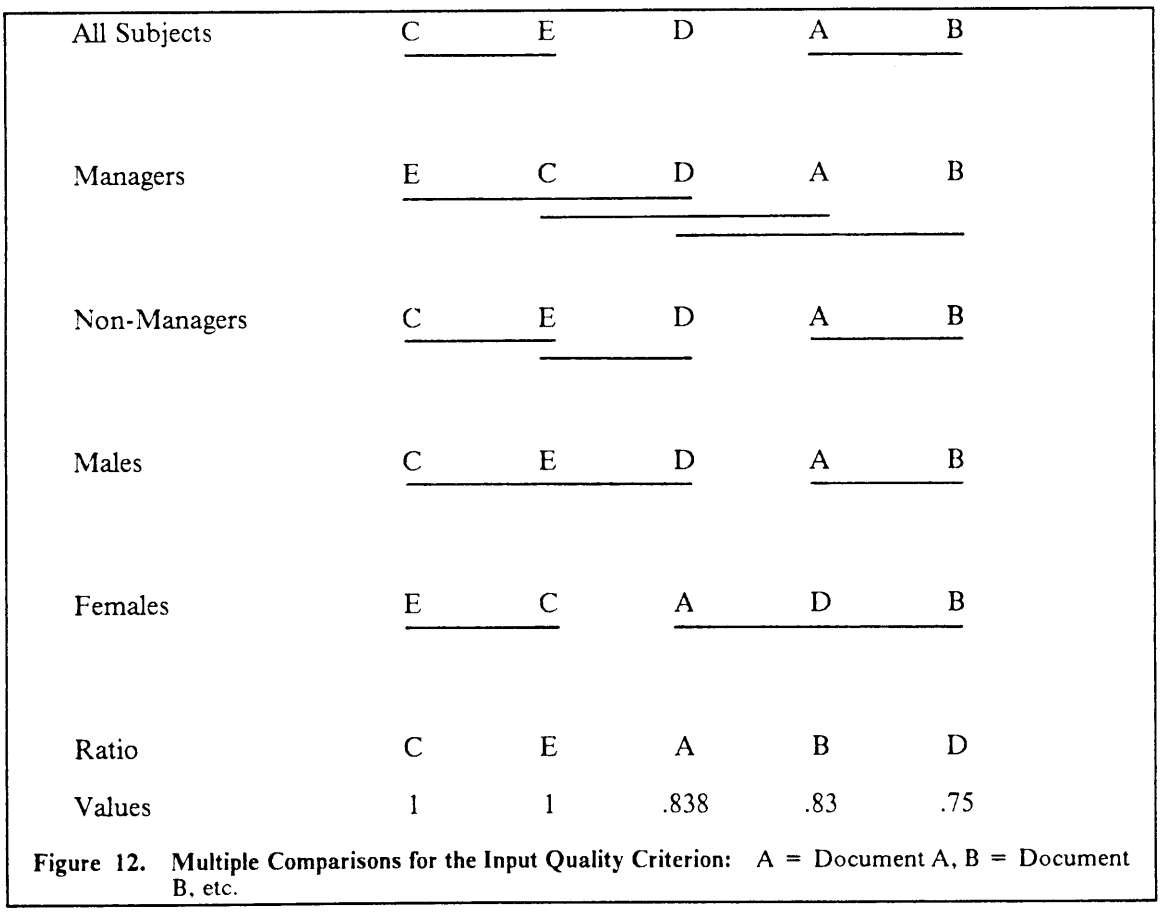

Figure 12. Multiple Comparisons for the Input Quality Criterion: A = Document A, B = Document B, etc.

All Subjects	E	C	D	A	B
Managers	E	C	D	A	B
Non-Managers	E	C	D	A	B
Males	E	C	D	A	B
Females	C	E	D	A	B
Ratio	C	E	B	A	D
Values	1	1	.763	.75	0

Figure 13. Multiple Comparisons for the Output Quality Criterion: A = Document A, B = Document B, etc.

All Subjects	E	C	A	D	B
Managers	E	C	D	A	B
Non-Managers	E	C	A	D	B
Males	E	C	D	A	B
Females	E	C	A	B	D
Ratio	A	D	E	C	B
Values	1	1	.85	.8	.675

Figure 14. Multiple Comparisons for the Efficiency Criterion: A = Document A, B = Document B, etc.

All Subjects	E	C	D	A	B
Managers	C	E	D	A	B
Non-Managers	E	C	A	D	B
Males	E	C	D	A	B
Females	E	C	A	B	D
Ratio	A	C	E	B	D
Values	1	1	.716	.703	0

Figure 15. Multiple Comparisons for the Effectiveness Criterion: A = Document A, B = Document B, etc.

Analyzing the Ratings

The ratings from the modified Larcker and Lessig (1980) statements were included as a validity check on the rankings. We'll have more confidence in the rankings if the ratings support them.

Factor Analysis

Ignoring the different documents, a factor analysis was conducted on the six modified Larcker and Lessig statements to see if they measure the same dimension. "Factor analysis performs the function of data reduction by grouping variables (statements) that are moderately or highly correlated with one another" (Borg and Gall, 1983). The eigenvalues for the resulting six factors (before rotation) were 2.587, 1.779, 0.942, 0.392, 0.188, and 0.113. An examination of these eigenvalues shows only two meaningful orthogonal dimensions underlying the set of six statements, i.e., dimensions with eigenvalues greater than 1.0. Accordingly, these factors were varimax rotated. Figure 16 on page 50 shows the rotated factor loadings. Statements 1, 2, 5, and 6 load on factor 1. Statements 3 and 4 load on factor 2.

An examination of statements 1, 2, 5, and 6 reveals these statements address whether the data and information presented is *necessary* for establishing the manager's priorities. An examination of statements 3 and 4 reveals these statements address whether the data and information presented is *sufficient* for establishing the manager's priorities. For discussion, factor 1 will be called the Necessary dimension, and factor 2 will be called the Sufficient dimension.

Statements	Factor 1	Factor 2
1	0.81368	-0.00329
2	0.84844	0.02590
3	-0.07241	0.95477
4	-0.02996	0.95629
5	0.78527	-0.14605
6	0.71414	-0.05194
Eigenvalue	2.58676	1.77874

Figure 16. Rotated Factor Loadings for the Larcker and Lessig (1980) Statements

Correlation Analysis

The Pearson Product-Moment Correlations were computed for the statements in each dimension. Correlation measures the strength of the relationship between two variables. The range of values for a correlation coefficient is + 1.0 to -1.0. A + 1.0 indicates a strong, direct relationship between the two variables. A -1.0 indicates a strong, inverse relationship between the two variables. A 0.0 indicates no relationship between the two variables. Figure 17 on page 52 shows the correlations between statements 1, 2, 5, and 6 for the Necessary dimension. Figure 18 on page 53 shows the correlation between statements 3 and 4 for the Sufficient dimension. All correlations are significant at the .01 level.

Reliability

Reliability concerns the internal consistency of the items in an instrument. Estimates of reliability based on the average correlation among items and the number of items within the instrument can be calculated using coefficient alpha. Coefficient alpha establishes an upper limit on the reliability of the instrument. The formula for computing coefficient alpha is:

$$r_{kk} = \frac{kr_{ij}}{1 + (k - 1)r_{ij}}$$

where

- r_{kk} is the reliability of the instrument
- k is the number of items in the instrument
- r_{ij} is the average correlation among the items.

Statements	1	2	5	6
1	---			
2	0.78847	---		
5	0.46199	0.43112	---	
6	0.27471	0.41043	0.65260	---

Figure 17. Pearson Product-Moment Correlation Matrix for the Necessary Dimension: All significant at the .01 level.

Statements	3	4
3	---	
4	0.83815	---

Figure 18. Pearson Product-Moment Correlation Matrix for the Sufficient Dimension: Significant at the .01 level.

Reliability values above .70 are preferred (Nunnally, 1978). Figure 19 on page 55 shows the reliability of the Necessary and Sufficient dimensions. Both are above the preferred level of .70 indicating adequate reliability of the items in each dimension.

Analysis of Variance

An analysis of variance was performed to see if any relationship exists between managerial experience and the ratings for each dimension for each document, and between gender and the ratings for each dimension for each document. A Necessary score and a Sufficient score were computed for each subject for each document by adding up the scores for each item in each dimension and dividing by the number of items in the dimension. These scores were used to run the analysis of variance. Duncan's Multiple Range Test was also performed to test the differences in the mean scores for each dimension for each document between managers and non-managers, and between males and females. Figure 20 on page 56 summarizes the results for managers and non-managers. Figure 21 on page 57 summarizes the results for males and females. The complete analysis of variance tables are in Appendix C.

Looking at Figure 20 on page 56, both managers and non-managers rated document D highest on the Necessary dimension and lowest on the Sufficient dimension. Recall document D has exactly what's needed for establishing the manager's priorities except it's missing the type column. Both managers and non-managers rated document B lowest on the Necessary dimension. Recall document B has the most extra data and information; it has the charge code column and three extra tasks (rows). Finally, both managers and non-managers rated document C highest on the Sufficient dimension. Duncan's test found no significant differences at the .05 level between mean ratings for managers and non-managers.

Dimension	Average Inter-item Correlation	Reliability
Necessary	0.50322	0.85871
Sufficient	0.83815	0.83815

Figure 19. Reliability Results for Each Dimension

Dimension	Document	F =	p-value	Mgr Mean	N-Mgr Mean	Difference?
Necessary	A	0.02	0.8789	5.2059	5.2500	No
Necessary	B	0.91	0.3436	4.2500	4.5278	No
Necessary	C	2.03	0.1607	4.4265	4.8958	No
Necessary	D	0.39	0.5345	6.0441	5.8264	No
Necessary	E	0.02	0.8909	5.8235	5.7778	No
Sufficient	A	0.13	0.7201	4.7941	4.6389	No
Sufficient	B	0.51	0.4778	5.1765	4.8750	No
Sufficient	C	2.29	0.1367	6.2059	5.7222	No
Sufficient	D	0.28	0.6007	3.0882	3.4028	No
Sufficient	E	0.45	0.5073	5.9412	5.6528	No

Figure 20. ANOVA Summary for Managers and Non-Managers with Duncan's Test for Differences in Means: Differences are significant at the .05 level.

Dimension	Document	F =	p-value	Male Mean	Female Mean	Difference?
Necessary	A	2.25	0.1400	5.1118	5.5500	No
Necessary	B	5.32	0.0252	4.2500	4.9167	Yes
Necessary	C	13.73	0.0005	4.4211	5.5667	Yes
Necessary	D	2.44	0.1244	6.0526	5.5000	No
Necessary	E	4.62	0.0363	5.5921	6.3000	Yes
Sufficient	A	0.03	0.8636	4.7105	4.6333	No
Sufficient	B	0.43	0.5160	5.0526	4.7667	No
Sufficient	C	0.35	0.5545	5.9342	5.7333	No
Sufficient	D	5.23	0.0264	3.6842	2.3333	Yes
Sufficient	E	0.00	0.9474	5.7368	5.7667	No

Figure 21. ANOVA Summary for Males and Females with Duncan's Test for Differences in Means: Differences are significant at the .05 level.

Looking at Figure 21 on page 57, males rated document D highest on the Necessary dimension, but lowest on the Sufficient dimension. Females also rated document D lowest on the Sufficient dimension. However, females rated document E highest on both dimensions, while males rated document C highest on the Sufficient dimension. Both males and females rated document B lowest on the Necessary dimension.

According to Duncan's test, four pairs of means are significantly different at the .05 level for males and females. Two of these differences are between the lowest mean ratings for each dimension. Both males and females rated document B lowest on the Necessary dimension, but males rated it significantly lower. Likewise, both males and females rated document D lowest on the Sufficient dimension, but females rated it significantly lower. The other two differences are between the mean ratings for documents C and E on the Necessary dimension. Both males and females rated E higher than C, but the magnitude of the mean ratings is significantly different.

Discussion

Responses Compared to Rankings

Before discussing the ranks for each criterion, it's worth mentioning what I learned from the responses to the questions about what the subjects liked and disliked about each document.

1. Many people misunderstood the markups on documents A and B. I intended the markups to be those made by the manager upon receiving the document, not made by the secretary before giving the document to the manager. This misunderstanding is probably why people ranked

documents A and B, especially document B (since it has more errors), consistently low across the five criteria.

2. Many people either didn't notice or liked the extra information (rows), especially on document E (since it doesn't have any errors). This information isn't relevant to the purpose of establishing the manager's priorities for the next four weeks from the day he or she receives the document. This misunderstanding is probably why people ranked document E consistently high across the five criteria.

3. Similarly, many people liked having the charge codes. The charge codes aren't needed for establishing the manager's priorities. This misunderstanding is probably why people ranked document C consistently high across all the criteria except productivity.

4. Finally, some people didn't like the essentials such as the task types or the priority numbers. Task types are needed to establish the manager's priorities. This misunderstanding, combined with the reasons for ranking documents A and B low and ranking documents C and E high, is probably why they ranked document D consistently near the middle, and not low, across the five criteria.

Responses Compared to Ratings

These responses are consistent with the results from the analysis of variance. Documents C and/or E, rated highest on one or both dimensions by all groups, are highly regarded. Document D, rated highest on one dimension and lowest on the other by nearly all the groups, is near the middle. Document B, rated lowest on one dimension by all groups, is disliked.

Ratings Compared to Rankings

In general, the results from the analysis of variance are consistent with the rankings by each group for the input quality, output quality, efficiency, and effectiveness criteria. These four criteria and the modified Larcker and Lessig (1980) statements are concerned with the accuracy, timeliness, and relevance of the data and information on the documents, not just getting the most information from the least data. Therefore, the ratings aren't expected to match the productivity rankings.

Managers' and non-managers' ratings match their rankings. They rated document C highest on the Sufficient dimension and document E high on both dimensions; they ranked documents C and E highest on the four criteria. They rated document B lowest on the Necessary dimension; they ranked it lowest on the four criteria. They rated document D highest on the Necessary dimension but lowest on the Sufficient dimension; they ranked it near the middle on the four criteria.

Males' and females' ratings also match their rankings. Males rated document C highest on the Sufficient dimension and document E high on both dimensions; they ranked documents C and E highest on the four criteria. Females rated document E highest on both dimensions; they ranked it highest on all the criteria except output quality. Males rated document D highest on the Necessary dimension but lowest on the Sufficient dimension; they ranked it in the middle on the four criteria. Females rated document D lowest on the Sufficient dimension; they ranked it near the middle on the input and output quality criteria but lowest on the efficiency and effectiveness criteria. Males and females rated document B lowest on the Necessary dimension; they ranked it lowest on the input and output quality criteria. On the efficiency and effectiveness criteria, females ranked document B low and males ranked document B lowest.

Rankings Compared to Ratios

The rankings support the productivity, input quality, and output quality ratios. Significant differences between the rankings and the input and output quality ratios are explained below. The rankings don't support the efficiency and effectiveness ratios. Some differences between the rankings and the efficiency and effectiveness ratios are explained below. Note the rankings are consistent across all five criteria, but the ratios aren't.

For productivity, documents D and E are ranked high, document A is ranked near the middle, and documents B and C are ranked low by both the subjects and the productivity ratio.

For input and output quality, C and E were ranked highest, but there's no significant difference between them for any group. This is consistent with the values calculated from the input and output quality ratios. C and E each have input and output quality values of 1.0. A, B, and D are ranked middle to low by the subjects and the ratios. There's no significant difference between A and B for any group. Similarly, the values calculated from the ratios for A and B are very close (A = .838 and B = .83 for input quality, and A = .763 and B = .75 for output quality). The subjects ranked D higher than A and B probably because of the markups on A and B. The ratios ranked A and B higher than D because of the availability of the data and information on D. For output quality, the subjects may have regarded the information provided on D as good, although by my definition of timeliness, none of the information on D is good.

For efficiency and effectiveness, the subjects again ranked C and E high and ranked A and B low. The ratios also ranked B low, although D was ranked lowest on effectiveness since by my definition of timeliness, none of the information is useful. For efficiency, there's no significant difference between ranks for A and D for any group, and, by the ratios, they each have efficiency values of 1.0.

Summary

The rankings, ratings, and responses are consistent for the five groups. They have convergent validity. Convergent validity refers to the agreement between two or more attempts to measure the same construct through different methods (Campbell and Fiske, 1959). The rankings, ratings, and responses also converge with the productivity, input quality, and output quality ratios, but not with the efficiency and effectiveness ratios.

Conclusion

Summary

This research attempted to answer the question of how to measure the performance of management tools by defining and operationalizing a set of measures (ratios). The ratios were tested on a set of information documents (management tools) and the results were compared with the evaluations of the set of documents by four different groups of subjects.

In the introduction, the measures were stated as hypotheses. The evaluations support the hypotheses for the productivity, input quality, and output quality measures. The evaluations don't support the hypotheses for the efficiency and effectiveness measures. Keep in mind we're comparing qualitative evaluations with quantitative measurements. Making quantitative measurements requires defining and operationalizing every variable. Some of the variables will be overlooked or absorbed into other variables in a qualitative evaluation. The evaluations can only support, not confirm, the ratios.

If we believe the evaluations, they suggest further refinement of the ratios may be necessary. If we believe the ratios, they suggest further refinement of the questionnaire and its administration may be necessary. I believe the latter should be tried before the former. Some suggestions for improving the questionnaire and its administration are made later.

Contributions of this Research

The contributions of this research are:

- the idea of measuring the performance of management tools
- developing a set of definitions for measuring information-oriented performance
- developing a set of indicators for measuring information-oriented performance
- developing a set of information documents for testing the indicators
- defining a unit of data and a unit of information
- developing a questionnaire for evaluating the information documents
- validating the indicators with the evaluations
- recommendations for future research (in the next section).

Recommendations for Future Research

Redoing the Validation

The quantitative part of this research, validating the ratios, could be done better by making these improvements in collecting the data:

1. A pilot study should be done on the questionnaire before it's distributed to the subjects. The results would be used to revise things people might misinterpret or not understand.

2. The questionnaire should be administered in a controlled setting. Groups of subjects should be recruited to take the questionnaire together in the same room at the same time. The researcher should administer the questionnaire in parts. For each part, the researcher should read the scenario and instructions, answer any questions, and allow the subjects to do what's asked.

Replicating this part of the study and incorporating these suggestions would enhance the data collected.

Using Real Documents

The ratios could be tested on real documents used by real managers. Data and information units will be different for different types of documents. Which units are accurate, timely, and relevant would have to be determined by the users. Using a real document, the researcher must be careful about whether the document has more than one purpose and what purpose the measurements are related to. Users may confuse purposes when evaluating a multi-purpose document.

Developing and Testing the Other Measures

The relative value, innovation, and quality of work life measures could be operationalized and tested. This would yield a complete set of performance indicators.

Generalizing the Measures to Other Tools

The measures could be operationalized for other management tools. They would also need to be validated for these tools.

Improving Tool Performance

Validated indicators could be used to measure, evaluate, and improve tool performance.

Evaluating Tool Users

Validated indicators could be used to develop good management tools for certain jobs. Candidates for the jobs could be evaluated by how well they use the tools.

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Appendix A. The Package

Demographic Information

Please answer the following questions about yourself:

Age: _____ years

Gender M / F

Educational Status (Check one):

_____ Earned high school diploma
_____ Working on a bachelor's degree
_____ Earned bachelor's degree
_____ Working on a master's degree
_____ Earned master's degree
_____ Working on a doctoral degree
_____ Earned doctoral degree

Have you ever held a paid, managerial position? Yes / No

If so, did you ever have to set priorities in writing for your own work or for the work of others? Yes / No

Scenario

You're a professor and laboratory director at a large academic institution. Every Monday you receive a list of your work priorities for the next several weeks. This document, produced for you by your secretary, lists tasks prioritized by type and due date, with their respective charge codes for accounting purposes. The purpose of this document is to establish your priorities for the next four weeks from the day you receive the document. Look at page _ for a sample document.

There are rules for how tasks should be categorized and prioritized, and for how often due dates for certain tasks should be updated. Tasks can be categorized as one of five types: Papers and Presentations (PP), Student-related (SR), Lab Management (LM), Faculty-related (FR), and Research-related (RR). Each category has a charge code for accounting purposes. Look at page _ to see how tasks should be categorized.

There is a hierarchy of rules for prioritizing tasks. First, tasks should be grouped by due date into high, medium, and low priority. Then, within groups, tasks should be prioritized by type (PP, SR, LM, FR, or RR). Finally, within types, tasks should be prioritized by due dates, with three exceptions. Look at page _ to see how tasks should be prioritized.

Due dates for certain tasks (look at page _) should be updated weekly.

To help me improve the document, I'll give you five different versions of the document and ask you to do three things regarding your preferences about the documents:

1. Answer six statements about each document.
2. Answer two questions about each document.
3. Rank each document against five criteria: effectiveness, efficiency, input quality, output quality, and productivity. Each criterion will be discussed later.

Each document is made up of data and information. Each element in a column is a datum. Look at the sample document on page _. Each of five columns holds twenty elements yielding one hundred units of data. Each row on the sample document contains five units of data. Each comparison of any pair of rows is one unit of information, so each unit of information on the sample document is made up of ten units of data. There are twenty rows, so there are twenty taken two at a time or one hundred ninety units of information on the sample document.

One hundred units of data are used to make one hundred ninety units of information on the sample document. Other versions of the document may use more or fewer units of data to make more or fewer units of information. For example, if we deleted one of the columns on the sample document, we'd only have eighty units of data (four columns with twenty elements each), but we'd still have one hundred ninety units of information (twenty rows). Keep in mind data are used to make information, so data are the inputs, and information is the output.

Now I'll discuss each of the five performance criteria.

Productivity: Productivity is the ratio of outputs over inputs for a system over a period of time. Recall data are the inputs and information is the output. There are different amounts of data and information on the documents you'll be evaluating. For productivity, we want the most output from the least input.

Quality: Quality is conformance to specifications or requirements. Quality concerns three things:

1. freedom from error
2. availability
3. currentness

There are two quality measures: one for inputs and one for outputs. Input quality is concerned with the freedom from error, availability, and currentness of the data. Output quality is concerned with the freedom from error, availability, and currentness of the information.

Quality is concerned with freedom from error. Several types of data errors can occur on the document. A task may be incorrectly categorized or assigned the wrong charge code number. Also, if a task is prioritized incorrectly, the priority number will be incorrect. These are data errors. One type of information error can occur on the document. If a task is prioritized incorrectly, each row out of order with that row is one incorrect unit of information. For example, on the sample document, if Senior Design Projects (row 9) was before DOE presentation (row 7), there would be two incorrect units of information: Senior Design Projects compared to DOE presentation and Senior Design Projects compared to IIE paper. Note DOE presentation compared to IIE paper is still in the correct order, and Senior Design Projects compared to all the other tasks is still in the correct order.

Quality is also concerned with availability. Some versions of the document you'll be evaluating may not have all the data you need to establish your priorities. When evaluating the documents, use the hierarchy of rules to compare what data you need for establishing your priorities to what data you have on each document. For this exercise, we'll only be concerned with the availability of the data, not the information.

Finally, quality is concerned with currentness. Some of the data on some of the documents you'll be evaluating may be outdated. You'll be given some information about when the due dates on the documents were updated. Use the update rules to see which due dates on which documents are outdated. If the data making up a unit of information is outdated, then that unit of information is also outdated. For example, if one due date on the sample document was outdated, then the row with that due date compared to any other row would be outdated information. There would be nineteen outdated units of information on the sample document.

For input quality, we want the data on the document to be free from error, available, and current. For output quality, we want the information on the document to be free from error, available, and current.

Efficiency: Efficiency is doing things right. Efficiency concerns using the right data to make information. Which data are the right data depends on the purpose of the document. Recall the purpose of the document is to establish your priorities. Some of the documents you'll be evaluating may contain data not needed for establishing your priorities. For efficiency, we only want data needed for establishing your priorities on the document.

Effectiveness: Effectiveness is doing the right things. Effectiveness concerns making the right information from the data. What information is the right information depends on the purpose of the document. Recall the purpose of the document is to establish your priorities for the next four weeks from the day you receive the document. Some of the documents you'll be evaluating may contain information not needed for establishing your priorities for the next four weeks. For effectiveness, we only want information needed for establishing your priorities for the next four weeks on the document.

Turn to page _ to begin evaluating the documents.

Sample Document

Priority List
Week of January 9-13, 1989

Priority	Task	Charge Code	Type	Due Date
1	SE TIMS paper	9-81	PP	1/13/89
2	Prepare for classes	5-47	SR	1/09/89
3	Teach classes	5-47	SR	1/11/89
4	Lab Work Distribution Report	0-28	LM	1/09/89
5	Lab supervision	0-28	LM	1/10/89
6	Graduate Student meeting	9-63	RR	1/12/89
7	DOE presentation	9-81	PP	1/25/89
8	IIE paper	9-81	PP	1/17/89
9	Senior Design Projects	5-47	SR	1/19/89
10	Write quizzes and tests	5-47	SR	1/16/89
11	Lab contract marketing	0-28	LM	1/30/89
12	Lab Budget meeting	0-28	LM	1/31/89
13	Promotion and Tenure meeting	5-21	FR	1/24/89
14	MSE activities	5-21	FR	2/01/89
15	SRG Academics meeting	9-63	RR	1/27/89
16	SRG Academics plan	9-63	RR	2/01/89
17	Dissertation Proposal meeting	9-63	RR	1/18/89
18	Lab Strategic Plan meeting	0-28	LM	2/10/89
19	Lab Brochure	0-28	LM	3/01/89
20	SRG Literature Search	9-63	RR	2/06/89

Task Categories

Papers and Presentations (PP, 9-81)

- DOE (Department of Energy)
- IIE (Institute of Industrial Engineers)
- SE TIMS (The Institute of Management Sciences)
- IEEE (Institute of Electrical and Electronics Engineers)
- ASEM (American Society for Engineering Management)

Student-related (SR, 5-47)

- Write quizzes and tests
- Prepare for classes
- Teach classes
- Senior Design Projects
- Grade quizzes and tests
- Advise students

Lab Management (LM, 0-28)

- Lab Strategic Plan meetings
- Lab Budget meetings
- Lab supervision
- Lab Work Distribution Report
- Lab Brochure
- Lab contract marketing
- Lab Eagle Feathers ceremonies

Faculty-related (FR, 5-21)

- MSE (Management Systems Engineering) activities
- Promotion and Tenure meetings
- Graduate Advisory Committee meetings

Research-related (RR, 9-63)

- SRG (Special Research Grant) Academics meeting
- SRG Academics plan
- SRG Literature Search
- Graduate Student meetings
- Dissertation and Thesis Proposal meetings
- Dissertation and Thesis Defense meetings

Hierarchy of Rules

1. Week Due Rules

    1. Anything due this week is high priority.
    2. Anything due after four weeks is low priority.
    3. Anything else is medium priority.

2. Between Type Rules

    Rank order types as follows:

    1. Papers and presentations (PP)
    2. Student-related (SR)
    3. Lab management (LM)
    4. Faculty-related (FR)
    5. Research-related (RR)

3. Within Type Rules

    Rank order by due date except:

    1. DOE presentations come before other presentations.
    2. Senior Design Projects come before other student-related.
    3. SRG Academics come before other research-related.

Updates

Due dates for the following should be updated weekly:

Lab supervision
Graduate Student meetings
Advise students

Evaluating the Documents

Here's the scenario for evaluating the five documents:

- Today is January 9, 1989.
- The purpose of the Priority List for the week of January 9-13, 1989 is to establish your priorities for the next four weeks (through February 3, 1989).
- The due dates on Documents A and B were updated December 30, 1988. The due dates on Documents C, D, and E were updated today, January 9, 1989.

Rating the Documents: Part 1

On the following pages, you'll be given each document followed by six statements or questions about each document. Please circle the appropriate number on the scale for each statement or question. Data errors and information errors are noted on the documents. Outdated due dates are also noted.

Test Document A

Priority List
Week of January 9-13, 1989

Priority	Task		Type	Due Date	
1	SE TIMS paper		PP	1/13/89	
2	Prepare for classes		SR	1/09/89	
3	Teach classes		SR	1/11/89	
4	Graduate Student meeting	RR	~~SR~~	1/12/89 ←	OUTDATED
5	Lab Work Distribution Report		LM	1/09/89	
6	Lab supervision		LM	1/10/89 ←	OUTDATED
7	DOE presentation		PP	1/25/89	
8	IIE paper		PP	1/17/89	
9	Senior Design Projects		SR	1/19/89	
10	Write quizzes and tests		SR	1/16/89	
11	MSE activities	FR	~~SR~~	2/01/89	
12	Lab contract marketing		LM	1/30/89	
13	Lab Budget meeting		LM	1/31/89	
14	Promotion and Tenure meeting		FR	1/24/89	
15	SRG Academics meeting		RR	1/27/89	
16	SRG Academics plan		RR	2/01/89	
17	Dissertation Proposal meeting		RR	1/18/89	

Statements and Questions about Document A

It would be extremely difficult to establish my priorities without at least the data presented.

completely disagree			neutral			completely agree
1	2	3	4	5	6	7

It would be extremely difficult to establish my priorities without at least the information presented.

completely disagree			neutral			completely agree
1	2	3	4	5	6	7

The data presented is sufficient to establish my priorities.

completely disagree			neutral			completely agree
1	2	3	4	5	6	7

The information presented is sufficient to establish my priorities.

completely disagree			neutral			completely agree
1	2	3	4	5	6	7

What portion of the data presented is essential for or instrumental in establishing your priorities?

none			about half			all
1	2	3	4	5	6	7

What portion of the information presented is essential for or instrumental in establishing your priorities?

none			about half			all
1	2	3	4	5	6	7

Test Document B

Priority List
Week of January 9-13, 1989

Priority	Task	Charge Code	Type	Due Date	
1	SE TIMS paper	9-81	PP	1/13/89	
2	Prepare for classes	5-47	SR	1/09/89	
3	Teach classes	5-47	SR	1/11/89	
4	Graduate Student meeting	9-63 ~~5-47~~ RR	~~SR~~	1/12/89 ←	OUTDATED
5	Lab Work Distribution Report	0-28	LM	1/09/89	
6	Lab supervision	0-28	LM	1/10/89 ←	
7	DOE presentation	9-81	PP	1/25/89	
8	IIE paper	9-81	PP	1/17/89	
9	Senior Design Projects	5-47	SR	1/19/89	
10	Write quizzes and tests	5-47	SR	1/16/89	
11	MSE activities	5-21 ~~5-47~~ FR	~~SR~~	2/01/89	
12	Lab contract marketing	0-28	LM	1/30/89	
13	Lab Budget meeting	0-28	LM	1/31/89	
14	Promotion and Tenure meeting	5-21	FR	1/24/89	
15	SRG Academics meeting	9-63	RR	1/27/89	
16	SRG Academics plan	9-63	RR	2/01/89	
17	SRG Literature Search	9-63	RR	2/06/89	
18	Dissertation Proposal meeting	9-63	RR	1/18/89	
19	Lab Strategic Plan meeting	0-28	LM	2/10/89	
20	Lab Brochure	0-28	LM	3/01/89	

Statements and Questions about Document B

It would be extremely difficult to establish my priorities without at least the data presented.

completely disagree			neutral			completely agree
1	2	3	4	5	6	7

It would be extremely difficult to establish my priorities without at least the information presented.

completely disagree			neutral			completely agree
1	2	3	4	5	6	7

The data presented is sufficient to establish my priorities.

completely disagree			neutral			completely agree
1	2	3	4	5	6	7

The information presented is sufficient to establish my priorities.

completely disagree			neutral			completely agree
1	2	3	4	5	6	7

What portion of the data presented is essential for or instrumental in establishing your priorities?

none			about half			all
1	2	3	4	5	6	7

What portion of the information presented is essential for or instrumental in establishing your priorities?

none			about half			all
1	2	3	4	5	6	7

Test Document C

Priority List
Week of January 9-13, 1989

Priority	Task	Charge Code	Type	Due Date
1	SE TIMS paper	9-81	PP	1/13/89
2	Prepare for classes	5-47	SR	1/09/89
3	Teach classes	5-47	SR	1/11/89
4	Lab Work Distribution Report	0-28	LM	1/09/89
5	Lab supervision	0-28	LM	1/10/89
6	Graduate Student meeting	9-63	RR	1/12/89
7	DOE presentation	9-81	PP	1/25/89
8	IIE paper	9-81	PP	1/17/89
9	Senior Design Projects	5-47	SR	1/19/89
10	Write quizzes and tests	5-47	SR	1/16/89
11	Lab contract marketing	0-28	LM	1/30/89
12	Lab Budget meeting	0-28	LM	1/31/89
13	Promotion and Tenure meeting	5-21	FR	1/24/89
14	MSE activities	5-21	FR	2/01/89
15	SRG Academics meeting	9-63	RR	1/27/89
16	SRG Academics plan	9-63	RR	2/01/89
17	Dissertation Proposal meeting	9-63	RR	1/18/89

Statements and Questions about Document C

It would be extremely difficult to establish my priorities without at least the data presented.

completely disagree						completely agree
1	2	3	neutral 4	5	6	7

It would be extremely difficult to establish my priorities without at least the information presented.

completely disagree						completely agree
1	2	3	neutral 4	5	6	7

The data presented is sufficient to establish my priorities.

completely disagree						completely agree
1	2	3	neutral 4	5	6	7

The information presented is sufficient to establish my priorities.

completely disagree						completely agree
1	2	3	neutral 4	5	6	7

What portion of the data presented is essential for or instrumental in establishing your priorities?

none			about half			all
1	2	3	4	5	6	7

What portion of the information presented is essential for or instrumental in establishing your priorities?

none			about half			all
1	2	3	4	5	6	7

Test Document D

Priority List
Week of January 9-13, 1989

Priority	Task	Due Date
1	SE TIMS paper	1/13/89
2	Prepare for classes	1/09/89
3	Teach classes	1/11/89
4	Lab Work Distribution Report	1/09/89
5	Lab supervision	1/10/89
6	Graduate Student meeting	1/12/89
7	DOE presentation	1/25/89
8	IIE paper	1/17/89
9	Senior Design Projects	1/19/89
10	Write quizzes and tests	1/16/89
11	Lab contract marketing	1/30/89
12	Lab Budget meeting	1/31/89
13	Promotion and Tenure meeting	1/24/89
14	MSE activities	2/01/89
15	SRG Academics meeting	1/27/89
16	SRG Academics plan	2/01/89
17	Dissertation Proposal meeting	1/18/89

Statements and Questions about Document D

It would be extremely difficult to establish my priorities without at least the data presented.

completely disagree						completely agree
1	2	3	neutral 4	5	6	7

It would be extremely difficult to establish my priorities without at least the information presented.

completely disagree						completely agree
1	2	3	neutral 4	5	6	7

The data presented is sufficient to establish my priorities.

completely disagree						completely agree
1	2	3	neutral 4	5	6	7

The information presented is sufficient to establish my priorities.

completely disagree						completely agree
1	2	3	neutral 4	5	6	7

What portion of the data presented is essential for or instrumental in establishing your priorities?

none			about half			all
1	2	3	4	5	6	7

What portion of the information presented is essential for or instrumental in establishing your priorities?

none			about half			all
1	2	3	4	5	6	7

Test Document E

Priority List
Week of January 9-13, 1989

Priority	Task	Type	Due Date
1	SE TIMS paper	PP	1/13/89
2	Prepare for classes	SR	1/09/89
3	Teach classes	SR	1/11/89
4	Lab Work Distribution Report	LM	1/09/89
5	Lab supervision	LM	1/10/89
6	Graduate Student meeting	RR	1/12/89
7	DOE presentation	PP	1/25/89
8	IIE paper	PP	1/17/89
9	Senior Design Projects	SR	1/19/89
10	Write quizzes and tests	SR	1/16/89
11	Lab contract marketing	LM	1/30/89
12	Lab Budget meeting	LM	1/31/89
13	Promotion and Tenure meeting	FR	1/24/89
14	MSE activities	FR	2/01/89
15	SRG Academics meeting	RR	1/27/89
16	SRG Academics plan	RR	2/01/89
17	Dissertation Proposal meeting	RR	1/18/89
18	Lab Strategic Plan meeting	LM	2/10/89
19	Lab Brochure	LM	3/01/89
20	SRG Literature Search	RR	2/06/89

Statements and Questions about Document E

It would be extremely difficult to establish my priorities without at least the data presented.

completely disagree			neutral			completely agree
1	2	3	4	5	6	7

It would be extremely difficult to establish my priorities without at least the information presented.

completely disagree			neutral			completely agree
1	2	3	4	5	6	7

The data presented is sufficient to establish my priorities.

completely disagree			neutral			completely agree
1	2	3	4	5	6	7

The information presented is sufficient to establish my priorities.

completely disagree			neutral			completely agree
1	2	3	4	5	6	7

What portion of the data presented is essential for or instrumental in establishing your priorities?

none			about half			all
1	2	3	4	5	6	7

What portion of the information presented is essential for or instrumental in establishing your priorities?

none			about half			all
1	2	3	4	5	6	7

Rating the Documents: Part 2

Please answer the following questions about the five documents:

What things do you like about Document A?

What things do you dislike about Document A?

What things do you like about Document B?

What things do you dislike about Document B?

What things do you like about Document C?

What things do you dislike about Document C?

What things do you like about Document D?

What things do you dislike about Document D?

What things do you like about Document E?

What things do you dislike about Document E?

Ranking the Documents

Use the worksheet on the next page to rank the five documents for each performance criterion.

Worksheet

Rank order the documents from highest to lowest for each criterion. Do this by entering the letter of the "best" document in the space marked "1", the "second best" in space "2", and so on. Put a circle around any ties.

Productivity: Which document makes the most information from the least data?

1	2	3	4	5

Input Quality: Which document has the best data (most free from error, most available, and most current)?

1	2	3	4	5

Output Quality: Which document has the best information (most free from error, most available, and most current)?

1	2	3	4	5

Efficiency: Which document has the best data for establishing your priorities?

1	2	3	4	5

Effectiveness: Which document has the best information for establishing your priorities for the next four weeks?

1	2	3	4	5

Appendix B. The Ratios Calculated for the Test Documents

The Ratios Calculated for Test Document A

		Yes	No
Data:	Accurate	59	9
	Timely	66	2
	Relevant	68	0
Info:	Accurate	131	5
	Timely	105	31
	Relevant	136	0

	Good	Bad	Useful	Total (Have + Need)	Total (Have)
Data:	57	11	57	68	68
Info:	102	34	102	136	136

Efficiency = Useful Data / Good Data = 57 / 57 = 1.0

Input Quality = Good Data / Total Data (Have + Need) = 57 / 68 = .838

Effectiveness = Useful Info / Good Info = 102 / 102 = 1.0

Output Quality = Good Info / Total Info (Have + Need) = 102 / 136 = .75

Productivity = Total Info (Have) / Total Data (Have) = 136 / 68 = 2.0

The Ratios Calculated for Test Document B

		Yes	No
Data:	Accurate	85	15
	Timely	98	2
	Relevant	68	32
Info:	Accurate	182	8
	Timely	153	37
	Relevant	136	54

	Good	Bad	Useful	Total (Have + Need)	Total (Have)
Data:	83	17	56	100	100
Info:	145	45	102	190	190

Efficiency = Useful Data / Good Data = 56 / 83 = .675

Input Quality = Good Data / Total Data (Have + Need) = 83 / 100 = .83

Effectiveness = Useful Info / Good Info = 102 / 145 = .703

Output Quality = Good Info / Total Info (Have + Need) = 145 / 190 = .763

Productivity = Total Info (Have) / Total Data (Have) = 190 / 100 = 1.9

The Ratios Calculated for Test Document C

		Yes	No
Data:	Accurate	85	0
	Timely	85	0
	Relevant	68	17
Info:	Accurate	136	0
	Timely	136	0
	Relevant	136	0

	Good	Bad	Useful	Total (Have + Need)	Total (Have)
Data:	85	0	68	85	85
Info:	136	0	136	136	136

Efficiency = Useful Data / Good Data = 68 / 85 = .8

Input Quality = Good Data / Total Data (Have + Need) = 85 / 85 = 1.0

Effectiveness = Useful Info / Good Info = 136 / 136 = 1.0

Output Quality = Good Info / Total Info (Have + Need) = 136 / 136 = 1.0

Productivity = Total Info (Have) / Total Data (Have) = 136 / 85 = 1.6

The Ratios Calculated for Test Document D

		Yes	No
Data:	Accurate	51	0
	Timely	51	17
	Relevant	51	0
Info:	Accurate	0	0
	Timely	0	136
	Relevant	0	0

	Good	Bad	Useful	Total (Have + Need)	Total (Have)
Data:	51	17	51	68	51
Info:	0	136	0	136	136

Efficiency = Useful Data / Good Data = 51 / 51 = 1.0

Input Quality = Good Data / Total Data (Have + Need) = 51 / 68 = .75

Effectiveness = Useful Info / Good Info = 0

Output Quality = Good Info / Total Info (Have + Need) = 0

Productivity = Total Info (Have) / Total Data (Have) = 136 / 51 = 2.667

The Ratios Calculated for Test Document E

		Yes	No
Data:	Accurate	80	0
	Timely	80	0
	Relevant	68	80
Info:	Accurate	190	0
	Timely	190	0
	Relevant	136	54

	Good	Bad	Useful	Total (Have + Need)	Total (Have)
Data:	80	0	68	80	80
Info:	190	0	136	190	190

Efficiency = Useful Data / Good Data = 68 / 80 = 1.0

Input Quality = Good Data / Total Data (Have + Need) = 80 / 80 = 1.0

Effectiveness = Useful Info / Good Info = 136 / 190 = .716

Output Quality = Good Info / Total Info (Have + Need) = 190 / 190 = 1.0

Productivity = Total Info (Have) / Total Data (Have) = 190 / 80 = 2.375

Appendix C. Analysis of Variance Tables

Source	DF	Sum of Squares	Mean Square	F =
Model	1	0.02248	0.02248	0.02
Error	51	48.90441	0.95891	
Corrected Total	52	48.92689		

R^2 = 0.00046 Pr > F = 0.8789

Figure 22. ANOVA of the Necessary Dimension for Document A by Managerial Experience

Source	DF	Sum of Squares	Mean Square	F =
Model	1	0.89099	0.89099	0.91
Error	51	49.72222	0.97495	
Corrected Total	52	50.61321		

R^2 = 0.01760 Pr > F = 0.3436

Figure 23. ANOVA of the Necessary Dimension for Document B by Managerial Experience

Source	DF	Sum of Squares	Mean Square	F =
Model	1	2.54386	2.54386	2.03
Error	51	64.01746	1.25524	
Corrected Total	52	66.56132		

R^2 = 0.03822 Pr > F = 0.1607

Figure 24. ANOVA of the Necessary Dimension for Document C by Managerial Experience

Source	DF	Sum of Squares	Mean Square	F =
Model	1	0.54740	0.54740	0.39
Error	51	71.38184	1.39964	
Corrected Total	52	71.92925		

R^2 = 0.00761 Pr > F = 0.5345

Figure 25. ANOVA of the Necessary Dimension for Document D by Managerial Experience

Source	DF	Sum of Squares	Mean Square	F =
Model	1	0.02417	0.02417	0.02
Error	51	64.81781	1.27094	
Corrected Total	52	64.84198		

R^2 = 0.00037 Pr > F = 0.8909

Figure 26. ANOVA of the Necessary Dimension for Document E by Managerial Experience

Source	DF	Sum of Squares	Mean Square	F =
Model	1	0.27824	0.27824	0.13
Error	51	109.33497	2.14382	
Corrected Total	52	109.61321		

R^2 = 0.00254 Pr > F = 0.7201

Figure 27. ANOVA of the Sufficient Dimension for Document A by Managerial Experience

Source	DF	Sum of Squares	Mean Square	F =
Model	1	1.04946	1.04946	0.51
Error	51	104.65809	2.05212	
Corrected Total	52	105.70755		

R^2 = 0.00993 Pr > F = 0.4778

Figure 28. ANOVA of the Sufficient Dimension for Document B by Managerial Experience

Source	DF	Sum of Squares	Mean Square	F =
Model	1	2.70120	2.70120	2.29
Error	51	60.25163	1.18140	
Corrected Total	52	62.95283		

R^2 = 0.04291 Pr > F = 0.1367

Figure 29. ANOVA of the Sufficient Dimension for Document C by Managerial Experience

Source	DF	Sum of Squares	Mean Square	F =
Model	1	1.14244	1.14244	0.28
Error	51	210.02737	4.11818	
Corrected Total	52	211.16981		

R^2 = 0.00541 Pr > F = 0.6007

Figure 30. ANOVA of the Sufficient Dimension for Document D by Managerial Experience

Source	DF	Sum of Squares	Mean Square	F =
Model	1	0.96042	0.96042	0.45
Error	51	109.85090	2.15394	
Corrected Total	52	110.81132		

R^2 = 0.00867 Pr > F = 0.5073

Figure 31. ANOVA of the Sufficient Dimension for Document E by Managerial Experience

Source	DF	Sum of Squares	Mean Square	F =
Model	1	2.06472	2.06472	2.25
Error	51	46.86217	0.91887	
Corrected Total	52	48.92689		

R^2 = 0.04220 Pr > F = 0.1400

Figure 32. ANOVA of the Necessary Dimension for Document A by Gender

Source	DF	Sum of Squares	Mean Square	F =
Model	1	4.77987	4.77987	5.32
Error	51	45.83333	0.89869	
Corrected Total	52	50.61321		

R^2 = 0.09444 Pr > F = 0.0252

Figure 33. ANOVA of the Necessary Dimension for Document B by Gender

Source	DF	Sum of Squares	Mean Square	F =
Model	1	14.11483	14.11483	13.73
Error	51	52.44649	1.02836	
Corrected Total	52	66.56132		

R^2 = 0.21206 Pr > F = 0.0005

Figure 34. ANOVA of the Necessary Dimension for Document C by Gender

Source	DF	Sum of Squares	Mean Square	F =
Model	1	3.28451	3.28451	2.44
Error	51	68.64474	1.34597	
Corrected Total	52	71.92925		

R^2 = 0.04566 Pr > F = 0.1244

Figure 35. ANOVA of the Necessary Dimension for Document D by Gender

Source	DF	Sum of Squares	Mean Square	F =
Model	1	5.38935	5.38935	4.62
Error	51	59.45263	1.16574	
Corrected Total	52	64.84198		

R^2 = 0.08312 Pr > F = 0.0363

Figure 36. ANOVA of the Necessary Dimension for Document E by Gender

Source	DF	Sum of Squares	Mean Square	F =
Model	1	0.06408	0.06408	0.03
Error	51	109.54912	2.14802	
Corrected Total	52	109.61321		

R^2 = 0.00059 Pr > F = 0.8636

Figure 37. ANOVA of the Sufficient Dimension for Document A by Gender

Source	DF	Sum of Squares	Mean Square	F =
Model	1	0.87948	0.87948	0.43
Error	51	104.82807	2.05545	
Corrected Total	52	105.70755		

R^2 = 0.00832 Pr > F = 0.5160

Figure 38. ANOVA of the Sufficient Dimension for Document B by Gender

Source	DF	Sum of Squares	Mean Square	F =
Model	1	0.43397	0.43397	0.35
Error	51	62.51886	1.22586	
Corrected Total	52	62.95283		

R^2 = 0.00689 Pr > F = 0.5545

Figure 39. ANOVA of the Sufficient Dimension for Document C by Gender

Source	DF	Sum of Squares	Mean Square	F =
Model	1	19.62595	19.62595	5.23
Error	51	191.54386	3.75576	
Corrected Total	52	211.16981		

R^2 = 0.09294 Pr > F = 0.0264

Figure 40. ANOVA of the Sufficient Dimension for Document D by Gender

Source	DF	Sum of Squares	Mean Square	F =
Model	1	0.00957	0.00957	0.00
Error	51	110.80175	2.17258	
Corrected Total	52	110.81132		

R^2 = 0.00009 Pr > F = 0.9474

Figure 41. ANOVA of the Sufficient Dimension for Document E by Gender

The vita has been removed from the scanned document