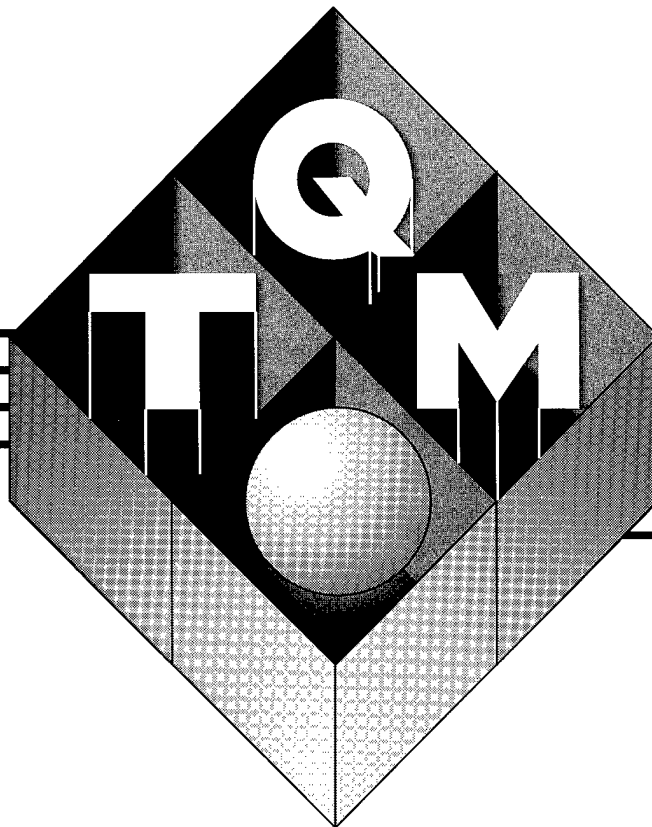


**US Army Corps
of Engineers**

Water Resources Support Center
Institute for Water Resources



Performance Measurement for the National Performance Review (NPR), Government Performance and Results Act (GPRA), and Army Performance Improvement Criteria (APIC)

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**PERFORMANCE MEASUREMENT FOR THE
NATIONAL PERFORMANCE REVIEW (NPR),
GOVERNMENT PERFORMANCE AND
RESULTS ACT (GPRA), AND ARMY
PERFORMANCE IMPROVEMENT
CRITERIA (APIC)**

by

**Rich Rodakowski
Management Analyst
Galveston District, Texas**

for

**U.S. Army Corps of Engineers
Water Resources Support Center
Institute for Water Resources
7701 Telegraph Road
Alexandria, VA 22315-3868**

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FOREWORD

This book was sponsored by the Operations and Maintenance Office, Office of the Chief of Engineers (OCE) as part of an ongoing nationwide effort to realign that organization with recent Federal Government initiatives directed toward improving government performance. Much to the foresight of the O&M leadership, these initiatives were actually started a few years (1988) before it became popular to restructure and improve government performance. The core focus of the initiatives was directed at developing an organizational performance change and measuring the results.

While the original subject of this text was directed at developing performance measures exclusively for the use of the O&M organization of the Army Corps of Engineers, it rapidly evolved into an all-purpose tool with applicability to all government elements. Performance measurement tools are universal in character. The data, context and units of measure may vary from one branch, division, or office to another, but the problems and tools of performance measurement are alike.

During the writing of the text, new topics of importance surfaced. The original driving force behind this effort spun from the Government Performance and Results Act (GPRA) and National Performance Review (NPR). The Army Performance

Improvement Criteria (APIC or the so-called Baldrige Criteria) came to the forefront adding to the significance of performance measurement. The new criteria were all added to the text without loss of continuity or intent. In fact, all three factors are complementary and have been integrated herein. The material is now comprehensive and designed to cover all needs from the O&M community within the Corps, to all government organizations and offices, and the mandates of NPR, GPRA and APIC. With this in mind, the following few pages will cover the historical context of the development of the O&M effort that sparked and funded the momentum behind this text.

The following paragraphs were taken from the initial charter for the program and describe the history, evolution, and plans of the process to date.

Historical Background

The steps in this process began six years ago (1988) when performance indicators were first introduced to the Corps of Engineers. The process was challenging in retrospect, but established the first set of performance indicators that were used in conjunction with Command Management Reviews. The process did move the Corps community forward and filled a management void for monitoring performance.



In 1991, the Corps of Engineers hired a contractor to complete a comprehensive study of the Operations and Maintenance program. The results of the study indicated that the Corps was moving contrary to current management theory. The development of data systems, standards of information management, workload tracking, and organizational structure reflected the independent tendencies of the different Districts and Divisions. The results were indicative of a need to develop Corps-wide standards of information management and performance measurement compatibility.

Government Actions on Performance Measurement

Two recent visible actions were taken to improve the internal management of the federal government. The report of the National Performance Review (Gore, 1993) recommends scores of actions to be taken by specific agencies to reduce costs, improve productivity, and provide better levels of service to the American public. This call for change includes establishing performance goals and related performance measures for the conduct of all "business" within federal agencies. All agencies will begin developing and using measurable objectives and reporting results as part of the fiscal year 1996 (FY96) budget submissions. Performance measurements provide the method to determine if past goals have been met. The second event was the Government Performance and Results Act (PL 103-62), hereafter referred to as GPRA, which initiates internal management reforms within

the federal government by setting program objectives and measuring program performance against these objectives. Each federal agency will submit a strategic plan for FY97 to the Director of the Office of Management and Budget that includes, among other specifications, a description of how performance objectives are to be achieved and measured.

The Government Performance and Results Act

The purpose of the GPRA is to improve internal management of federal programs and increase public confidence by systematically holding agencies accountable for results. It further aims to improve congressional decision making by providing more objective information on achieving statutory objectives and the relative effectiveness and efficiency of federal programs and spending. The GPRA provides for a series of pilot projects to test the costs and benefits of strategic planning, performance planning and reporting, and performance budgeting.

The Corps of Engineers Operation and Maintenance community has been selected by the Department of Defense as a pilot project to set up procedures and implement performance measurements as required by the GPRA. To meet the requirements of the pilot program, the Corps must have in place a strategic plan, a performance plan, and an evaluation system for the O&M program.



The Pilot Project Process

The Oregon Department of Transportation (ODOT) approach to performance management is recognized as a progressive method for improving the Corps performance measurement process. The O&M Task Force has recognized the value of the ODOT approach to defining Key Result Areas (KRA's). Adopting this process will not be easy, but the results will be fruitful, and the timing for implementing a revised process is coincidental with the recommendations of the National Performance Review and the GPRA.

The process is under development as a pilot program for Office of Management and Budget under the pilot programs provision of the GPRA. The process will set standards for other Department of Defense programs and federal agencies on how to develop a coordinated, multi-level performance management and reporting system. The Corps of Engineers Operation and Maintenance (O&M) community has embarked on the development of performance measures across multiple functional areas. The Performance Measure Implementation Plan involves a four-tier approach:

- ▶ National Leadership Team Workshop
- ▶ National Program Proponent Workshops
- ▶ District Leadership Workshops
- ▶ Project Site Workshops

The four-tier approach was developed by the Corps Performance Measurement and Data Management Task Force in conjunction with ODOT experts. The Operation and Maintenance Performance Measurement Implementation Plan, dated June 1994 (see Enclosure 1), was developed by the Task Force and provides a detailed description of the complete implementation program. The O&M community has adopted a project management structure, and performance measurements are essential to support that structure and other proposed improvements. The four-tier approach promotes the identification of specific performance measures at each management level of the Corps and facilitates review and feedback during development.

Tier I is the National Leadership Team and is central to the development of the remaining tiers, (see Figure 1). Tier II workshops are the National Program Proponent workshops and develop guidance for the Division and Headquarters level of management. Additionally, the products of the Tier II workshops will provide the lower tiers additional guidance for the development of measures at the District and project levels. Tier III workshops are for District Leadership Workshops and Tier IV workshops are for the project site level. The four-tier process selected by the O&M Task Force will ensure that performance measures reflect the management stance at each tier while maintaining alignment with the Corps mission and vision across all tiers. The development of a consensus within a tier is

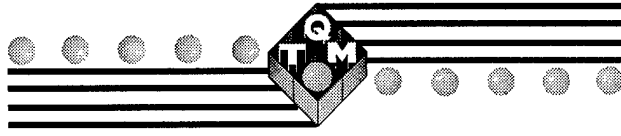


crucial to the performance measurement process.

The implementation of this process is intended to create a cultural change within the O&M community. Performance measures will not be developed on vague terms. The various workshop participants will establish pertinent purpose and mission statements, identify component programs that

support their specific purpose, develop relevant KRA's and formulate complementary performance measures. This approach requires top field managers to help develop KRA's and "buy in" to the process. ODOT is providing the Corps with technical assistance in the design and facilitation of a series of related workshops to be conducted during the summer and fall of 1994.





PREFACE

This book is about measuring organizational performance. *It is the only one of its kind in that it serves as one comprehensive resource reference written specifically for measuring government performance irrespective of the mission.* It goes well beyond the use of numbers and indexes to quantify resource inputs, efficiency, productivity, programs, output and outcomes. What struck me the most when writing it was the degree of overlap between the various subjects covered. The material is very holistic in character in that the subjects covered emulate a tightly knit web. For example, it was not possible to write about improvement in "program performance" by focusing solely on program-related activity improvements. An organization is a system; a group of processes and a cluster of complex, integrated and interdependent activities. Trying to improve one element in isolation without working on the entire system is like rearranging the chairs on the deck of the Titanic--the end results will be the same.

While the intended user of this book is the U.S. Army Corps of Engineers, the material can be readily adapted to any local, state or federal organization. There are about twenty concepts which keep reappearing over and over in reading the literature on TQM, continuous process improvements, and related materials. They represent *persistent themes*: key or core concepts needed to imprint cultural change in organizational behavior and are found in

"world class" organizations. They include the following:

The involvement of all employees

Measurement or metrics

Integration

Team building

Waste/Value added

Quality defined from the customer's perspective

Plan

Simplify

Vision

Systematic implementation

Continuous improvement

Benchmarking

Systems and Processes

Cycle time

Empowerment

Training/Education

Prevention

Cause and effect

Results/outcome

Quality as strategy



The material starts out with a brief description of organizational and planning characteristics such as structure, the nature of planning, the need to establish a vision, a mission statement, program targets to set goals and objectives and the purposes and uses of strategy and tactical and operational tools. It then moves into its prime purpose--the measurement of performance. The keys to arriving at the doorstep of "world class" status are engendered in integrating the twenty concepts listed above, with organizational and planning characteristics.

The enclosed techniques represent individual performance measurement--which can be used in a stand-alone approach or selectively aggregated into families of performance indicators. They cover methods for measuring program performance, financial performance, operational

performance, and project performance, among others.

Do not be distressed if, when reading the enclosed material, it seems to have no apparent connection with what is currently thought to be performance measurement. It does. The forces governing the operation of organizations have dramatically changed in recent years and current COE practices have not yet caught up. Read--no, study--the material and, after a short period of reflection, you will begin to make some sense of it all and begin applying the tools and methods discussed. They are powerful and, as research has shown, are being employed by "cutting edge" organizations as we move into the 21'st century.

With these ideas in mind, let us embark on a journey of performance measurement and customer driven quality outcomes. The journey is both humbling and awakening.





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I. INTRODUCTION

Recent Congressional findings have demonstrated that there is considerable waste and inefficiency in Federal programs which have resulted in the loss of confidence of the American people in the Government. This has reduced the Federal Government's ability to address critical public concerns. Federal managers are considerably restricted in their efforts to improve program efficiency and effectiveness because of inadequate strategic planning and information on program performance. In addition, congressional policy making, appropriation decisions, and program oversight are severely hampered by insufficient attention to *program performance* and *results*. In order to overcome these handicaps a number of public laws and Executive Orders were promulgated in 1993. They have turned the tide on the way government institutions and programs are managed.

The Government Performance and Results Act (GPRA), *National Performance Review (NPR)*, and the *Executive Order* entitled, *Customer Service Standards (CSS)*, were all initiated in 1993. In addition, the Malcolm Baldrige Award Criteria (as expressed in the Army Performance Improvement Criteria, APIC) was adopted by the Army in March 1995 for the ACOE and the Labor Management Partnership Agreement was promulgated by EO12871 in 1993. Collectively, they resulted in an increased emphasis on the measurement of government performance in terms of

effectiveness and efficiency. They also established a new foundation for strategic management and planning including the implementation of key organizational goals and tactical objectives designed around systems and continuous process improvements. There is a renewed emphasis on customer service and satisfaction. Resource utilization will be traceable from the input stage through the production process to the output and results stage. The new paradigm will re-engineer the way government does business through people, processes, and organization. The results of these actions are that performance measures and benchmarking will link the organizational mission, strategy, goals, and processes of government output and outcome with the needs and desires of the customer.

The Purpose of This Report

This report will emphasize performance measurement tools and techniques designed to assist those involved in performance planning and measurement activities. This includes all elements of the U.S. Army Corps of Engineers (COE), the office of Management and Budget (OMB), and the Government Accounting Office (GAO). Practitioners, Division Performance Methodologists and District Performance Specialist will find it particularly useful. It will aid in deciding what and how to measure performance in ways generally not familiar to those currently involved in the process. It



will include the measurement of both particular attributes and processes using simple measures, single and composite indices, control charts, statistical process control techniques, and benefit-to-cost analysis, among others. The more complex methods may be more appropriately adopted after the performance measurement program has gained widespread acceptance and applicability. They will be presented here for planning purposes and potential future use. Performance measurement actually consists of at least six components: **input measurement, effectiveness, efficiency, productivity, output, and outcome.**

Inputs are the resource factors that go into producing a product or service (Management Concepts Inc., 1995). They would include such items as raw materials, money, time, labor costs, knowledge, capital, technology, etc. **Effectiveness** measures whether or not, or to what degree, objectives were met [Management Concepts Inc., 1995]. It tests whether or not an organization is "*doing the right thing.*" **Productivity** is the relationship between the total value of products and services produced and the total amount of resource inputs used to produce them [Certo, 1989]. It is basically an index of output divided by input and typically measures cost per unit of output. **Efficiency** is the ratio of actual output to effective organizational capacity [Stevenson, 1993]. It determines if an organization is "*doing things right.*" **Output** is the amount or value of products or services created by the production process [Management Concepts Inc., 1995]. Finally, **outcome** (in a COE context) is the fulfillment of customer driven needs and desires by

making a completed engineering structure operational and able to perform its planned purpose [Management Concepts Inc., 1995]. A simplified example will help explain the differences between these concepts.

Branch "A" completed eight water resources reports during the last FY expending \$3,700,000 in total. Comparable branches throughout the COE have shown a capacity to complete 12 similar reports (effective capacity) in the same time frame using the same resource inputs. The management in Branch "A" originally set a goal to produce 10 reports during the FY, up from 9 the previous year. The branch employees 30 FTE'S.

In this example, resource inputs amounted to \$3,700,000 which consisted of the total cost of doing the work for that year. It includes labor, overhead, rents, utilities, materials, supplies, etc. The Branch's productivity amounted to: $\$3,700,000/30$ FTE's or \$123,333 expended per FTE (output per person). Actual output was 8 reports. The organization's efficiency was: $8 \text{ actual reports} / 12 \text{ report capability}$ or 66.7%. Effectiveness amounted to: $8 \text{ actual reports} / 10 \text{ report goal}$ or 80%. The outcome produced delays in satisfying customer needs stemming from 4 reports which did not get completed but could have. The outcome or results may be far more complicated and involved, but this is one of the immediate consequences of not operating efficiently or effectively. A close examination of this anecdote will clarify the value of each of the performance measurement tools discussed. These concepts will be covered in more detail later in the report.



Prior to delving into the specifics of tools and techniques, a model organizational business framework will be discussed as a reference and to set the stage for performance measurement. This will include brief discussions related to strategic management, setting goals and objectives, tactical planning and business operations and the production process. This background is necessary so that users can start measurement formulation and evaluation with an idealized model in mind. The connection between mission, programs, processes, output and outcome, and measurement must be made so as not to lose sight of why this effort is being done in the first place.

Benefits Of Performance Measurement Programs

There are many reasons to measure organizational performance but four are particularly outstanding and appropriate for today's total quality management perspective. Performance measurement forces institutions and people to focus on real as opposed to imaginary goals.

The first is in aiding and satisfying customer needs and wants. This may be the single most important mission. Institutions frequently tout customer satisfaction. The trouble is that proclamations often serve as advertising gimmicks rather than realities. By measuring customer satisfaction, the organization is compelled by survey results to behave as they advertise. It is actual performance that brings customers back. Word of mouth is a very powerful advertising scheme. The definition of a customer should reflect both external

customers (tax payers, partners, stakeholders, etc.) but should include internal customers (other branches, divisions, etc.) as well.

Performance measurement also allows an organization to monitor progress. It directs management to examine corporate systems and processes and leads to a continuous improvement ethos. It prevents activity fixation and results in activity tracking-and elimination by reducing the number of process step required to complete a task or work endeavor. This in turn reduces costs and increases the speed with which output is accomplished.

Benchmarking is the third reason for measuring performance. Benchmarking is essentially comparing your business practices and facts against the "best in the business". It is a standard of reference to drive change and foster competition. Management by facts is growing in use and this allows for an objective comparison between one organization's practices and another's. It is these comparative differences that focuses attention on problems and explains why one organization is out-performing another.

The fourth major reason to measure performance lies in *driving change*. Monopolies, for example, have no real competitors and as a result are not price competitive nor innovative. Product and service price, quality, product differentiation, flexibility, and timeliness are not characteristic of monopoly operations. Customers have no options or choices. Performance measurement drives change and tends to prevent organizational stagnation. The value of performance "measurement" has been well stated in the literature:



"If you do not have the components of excellence--statistical process control, continuous improvement, benchmarking, the constant pursuit of excellence, the capability of

knowing how to do the right thing the first time--then you don't even get to play the game" [Barker, 1992].





II. ORGANIZATIONAL PLANNING

Planning is problem resolution for the future in a dynamic environment [Hogans, 1991]. It describes what you intend to accomplish: vision, mission, goals, and objectives. It also states the how, when, where stated within the plan. The purpose of an organization is first expressed as a directional vision statement, accompanied by a general proclamation of mission, and finally delineated in terms of goals. These goals are more specifically defined by objectives. The plan's effect is to steer the organization and all its elements to move in the same, common direction; to focus effort.

The major plans of action to achieve vision, mission, goals, and objectives are called strategies. Strategies represent the interests of top management. They are chiefly concerned with long term activities designed to achieve objectives, but may also be directed at major short term actions. Strategic plans focus on three fundamental questions: (1) Where are we now? (2) Where do we want to go? (3) and, How do we get there?

Intermediate (tactical) plans and operational plans are concerned with the achievement of less significant goals and objectives and are typically the responsibility of middle and lower management. A tactical plan's prime purpose is directed at accomplishing objectives between strategies and operational plans. This function can be associated with regional Division offices in the Corps. Usually middle and lower

management efforts are trained on fulfilling upper management vision, mission, goal and objectives using more specific planning statements. Middle and lower management direct much of their energy at implementing strategic plans. Tactical plans portray intermediate time horizons.

Operational plans deal with day-to-day work efforts in time frames usually less than a year. They are the principle arena of lower management and commit much less resources than strategic and intermediate plans. Performance measurement is the cornerstone of activities at this level of planning [Hogans, 1991]. Managers are preoccupied with implementation of higher level goals and objectives. They are also concerned with the most efficient and effective use of the organization's resources through intermediate and operational planning. These functions are most indicative of District offices in the COE. Note that the delegation of accountability between the various levels of strategic, tactical, and operational planning and activities will vary depending upon the organizational structure. Figure 1 shows these interrelationships. The time horizon of strategic planning is usually one to five years; that for tactical planning is between two months and two years, and for operational planning is a year or less. The time frames will vary from organization to organization but these represent the generally accepted industry-wide norms [Higgins, 1991]. As change occurs more rapidly, the need for organizational planning requires



increased emphasis. This is further amplified during periods of delayering, and reorganization, and re-engineering when matters become increasingly difficult and complex. It is during vexing times that performance measurement becomes most valued because it helps maintain direction and focus.

Plans are frequently classified into two basic types: standing plans or single use plans [Hogans, 1991]. These are also depicted in Figure 1. Both are apparent in most organizations in one form or another. Standing plans are used to guide organizational activities which recur over time. They are driven by the use of policies, procedures, and regulations. These tend to instill discipline and keep the organization on track over extended periods of time. They prevent or minimize drift in goals and objectives. Examples of these might include Principles And Standards, Equal Employment Opportunity (EEO) guidance, Policy Digest and the numerous Engineering Regulations (ER's) which have had staying power over time.

Single-use plans are used once to accomplish a specific purpose and discarded. They may last a few days or ten years. Single use plans are of three type; strategic, intermediate (tactical), and operational plans. These are depicted in Figure 1 as well.

Strategic plans are the broad based plans requiring the extensive use of resources and, as described earlier, are aimed at achieving the major goals and objectives of an organization. They would include vision and

mission plans and longer term agency activities such as reorganization, performance measurement, performance plan development, etc.

Intermediate plans help convert strategies into operational activities. They include Divisional plans, specific flood control and navigation related programs, and complex projects. Examples would include a particular three year Feasibility report, the development of an open ended contract, etc.

Operational plans, on the other hand, focus on day-to-day, week-to-week, or monthly activities for a period of a year. They would include annual budgeting, meeting internal and external milestones for specified reconnaissance reports, sub-products for Feasibility Reports, Limited Re-evaluation Reports (LRR), General Reevaluation Reports (GRR), and personnel training, to mention a few. Operational plans are concerned chiefly with the production or transformation process.

Figure 2 shows a diagram depicting the above relationships. The diagram shows the characteristics associated with each level of management. The size of the rectangles represent the magnitude of responsibility for each management level. For example, upper management emphasizes long term planning of a strategic nature and focuses mostly on vision, mission, goals and objectives. Middle management is mostly energized on issues related to objective fulfillment, and lower management emphasizes rules and regulations.



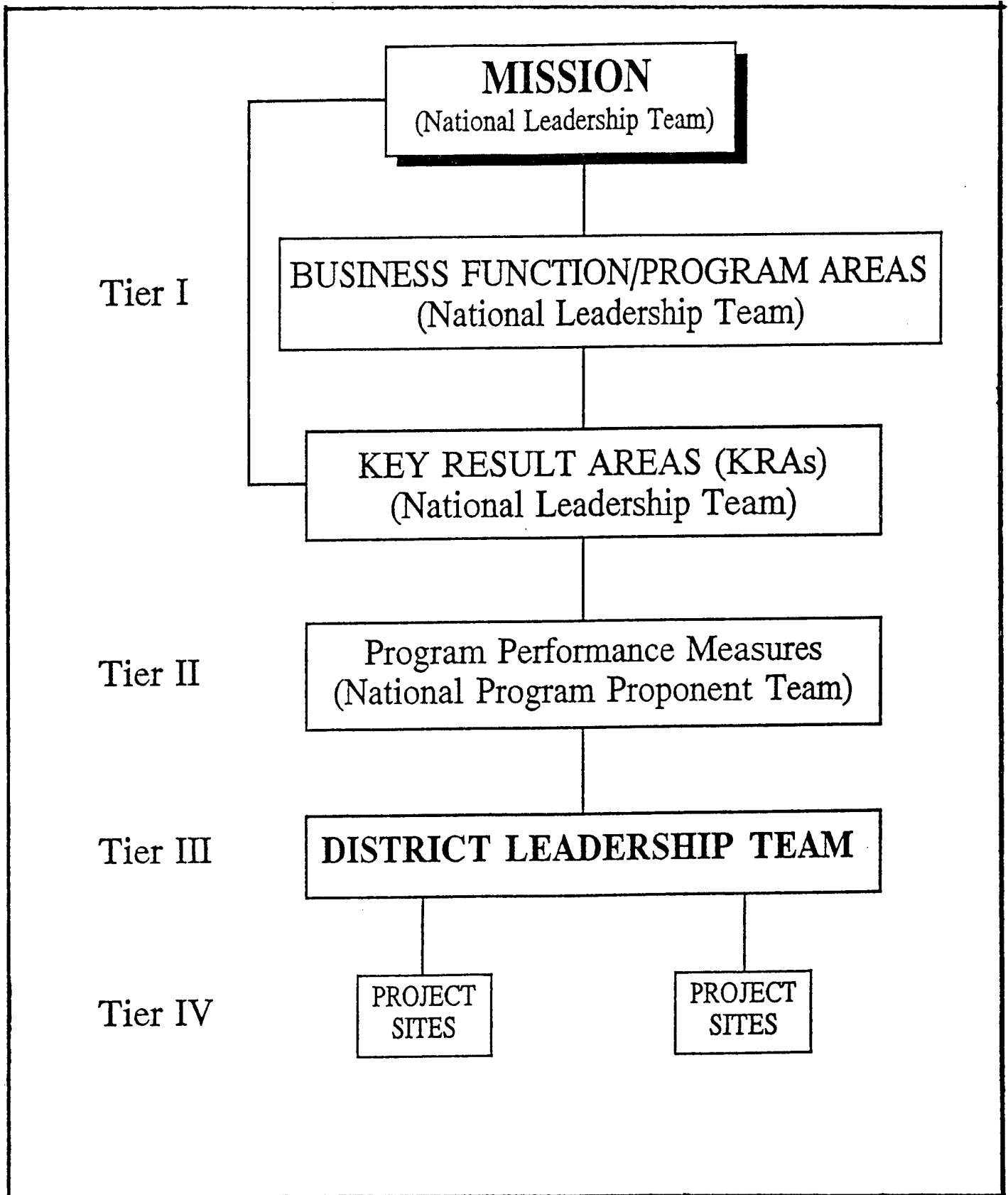


Figure 1 - Process Structure and Flow



MGT LEVEL	UPPER MGT		MIDDLE MGT	LOWER MGT
TIMEFRAME	LONG TERM		INTERMEDIATE TERM	SHORT TERM
PLANNING/MGT	STRATEGIC		TACTICLE	OPERATIONAL
VISION, MISSION, GOALS	#1 40-50%	#2 30-40%		#3 10-30%
OBJECTIVES	#4 25-30%	#5 40-50%		#6 25-35%
RULES/REG	#7 10-30%	#8 30-40%		#9 40-50%

Figure 2 - How Each Management Spends Time





III. PERFORMANCE MEASUREMENT AND PLANNING LINKAGES

The above narrative describes the basic business environment performance measurement is designed to evaluate. It is this *theoretical* or *model framework* that actual performance is to be gaged against. If vision, mission, goals, and objectives conform to strategic, tactical and operational plans then a link has been made that will allow organizational performance to be at its peak. Imperfect resource use will cause an adverse impact or distortion in this idealized system. It is often characterized as waste, inefficiency, rework, duplication of effort, and related anomalies. This distortion is detectable in misallocated resource inputs, yielding inefficiency, low productivity, ineffectiveness, reduced output, and the wrong results. Performance measurement quantifies and helps diagnose the departure of actual system performance from model or optimum system performance. According to such process experts as Edward Deming and Joseph Juran, management is 80 percent responsible for poor organizational performance problems while employees are responsible for the remaining 20 percent [Deming, 1982].

Results represent the impact of the organization on its customers. It is often difficult to measure results as they may take years to accrue. For example, a flood control plan may call for complete protection against a fifty year storm. A fifty year storm can be expected to occur, on the average, once every fifty years (a 0.02 probability in any one year). This means that the real

outcome or results can only be tested twice a century. Similar dilemmas exist for navigation, recreation, environmental assessment, water supply, hydropower, and other COE missions. Consequently, outcomes may not be known for long periods of time; but we can readily measure output. As previously stated, GPRA defines outcome as "an assessment of the results of a program as compared to its intended purpose". Outcomes can be short term, intermediate term, or long term measures of performance. One of the challenges of GPRA and APIC is to determine how to measure those performance attributes that are long term. Outcomes are plagued by the fact that they must be realized (actually happen) to be measured or knowable. Output is generally predictable and can realized in the near term. This assumes that projects do not have significant, construction additions or increments added in the future. It is in the *confirmation* of "intended purpose" that makes outcome difficult to verify. Analytical modeling and evaluation are simulations or emulations of expected results and not confirmation of those results.

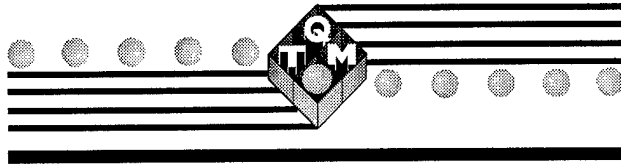
It needs to be stated at the outset that performance measurement has its weaknesses. For one, performance cannot usually be fully described by a single measure; it is a complex phenomenon. Secondly, risks and uncertainty are involved in projecting the future (part of the planning process). Risks can be accounted for by contingency planning and by statistical



estimation. Uncertainty, on the other hand, is the real unknown and is not quantifiable by definition. It represents the real threat to performance and planning. The best defense

against uncertainty is to include intermediate term planning to make mid point course corrections possible. This is one of the reasons plans need to be updated.





IV. IDENTIFYING PERFORMANCE MEASURES

In order for performance measurement to be successful, several questions need to be addressed. For example, what type of measure is it? What is the time frame for measurement? How often should measurements be taken? And, how plausible is implementation? These are important questions since such things as seasonality can have an impact on what is measured, the units of measure can differ for the same attribute, and what we intend to measure may not be controllable by the agency. Some attributes may be aesthetically desirable but may be useless in measuring performance.

There are a number of factors which need to be examined when doing performance measurement. It is necessary to know what resource inputs are being used, a map of processes and systems that are at work, the outputs expected, the outcomes anticipated, the ambient efficiency of operations, and the existing effectiveness of on-going operations. These all represent baseline conditions from which improvements can be measured. Performance measurement requires knowledge of all these characteristics to be fully useful. The user must also be cognizant of the time frames of measurements: short run, mid-term and long term events.

“Ideal” performance measures would satisfy fourteen criteria. They:

- ☐ Must communicate the progress towards satisfying vision, mission, program, key goals and objectives,
- ☐ Should be quantifiable to maintain objectivity,
- ☐ Must assign accountability in carrying out the measurement process,
- ☐ Must be acceptable to the organization,
- ☐ Must be credible and believable,
- ☐ Must be timely,
- ☐ Must be reliable and verifiable,
- ☐ Must be effective, have impact, and steer the organization toward improved strategy and performance,
- ☐ Should reflect constancy of purpose and continuous process improvement,
- ☐ Must be comparable to other measures for benchmarking purposes,
- ☐ Must be applicable and substantive,
- ☐ Should be used in conjunction with other measures,(one measure does not usually tell the story) and
- ☐ Must be understandable by those using and reviewing them.
- ☐ Must reflect variables over which there is at least some control.

The above criteria will aid in leading toward the development of effective performance measurement. It will not always be possible to satisfy all criteria. It will take several years of trial, error, and screening to find the measures appropriate for any particular organization. It is more likely that, as customer's needs change, performance measures will follow suit.





V. SYSTEMS AND PROCESSES

Performance measurement is strongly tied to systems and processes. All work emulates a process. Loosely defined, a system is a configuration of things or processes so inter-connected as to behave as one [Certo,1989]. A system is not possible without processes. Processes indicate some sort of work activity is taking place toward a desirable objective. Systems are made of processes working together in series or in parallel. In the context of business operations, resource inputs go through multiple processes called a *transformation* to produce outputs which have outcome targets. A COE District may be thought of as a system with each Division acting as a separate process and each Branch as a subprocess. In the simplest case a system and a process may be one in-the-same. In measuring the performance of systems and processes, one vital activity that must take place is system and process mapping. A process map is a flow chart of events and activities that take place during the transformation process. It is not possible to measure performance of a system or processes and make improvements unless the work activity steps are known. Mapping starts with a flow diagram of ambient or pre-improvement processes. Alternative systems and processes are also mapped on a flow diagram for comparative performance characteristics. Improvements represent decreases in the total number of tasks or improvements in the quality of the existing

activities within the system or process. This information will be useful later in the paper when a distinction is made between the performance measurements of attributes and those of processes.

Figure 3 shows the relationship between a system and a process. This example is very simple and is being used for illustration purposes. A system is the sum of its processes. There may be many processes comprising a system and in large organizations there usually are many sub processes which coalesce to form major process. The processes of interest are called "core" processes. These are the activities which are pivotal to an organization's strategic operations. They are the "jugular" central to mission accomplishments. Notice that the system depicted consists of four processes with each composed of an input, the production process itself (transformation), an output, and a feedback loop. The feedback loop is designed to correct or modify the input-transformation, process-output sequence as needed. This feedback could be due to customer comments concerning the quality of output. Notice that processes (1) and (4) are independent and complete in and of themselves. Processes (2) and (3) show inputs combining into the same process to produce an output. The dotted lines represent the boundaries of each process; those work endeavors which are indigenous to that process. Such relationships are possible and frequently found in systems analysis. Good test points for process performance



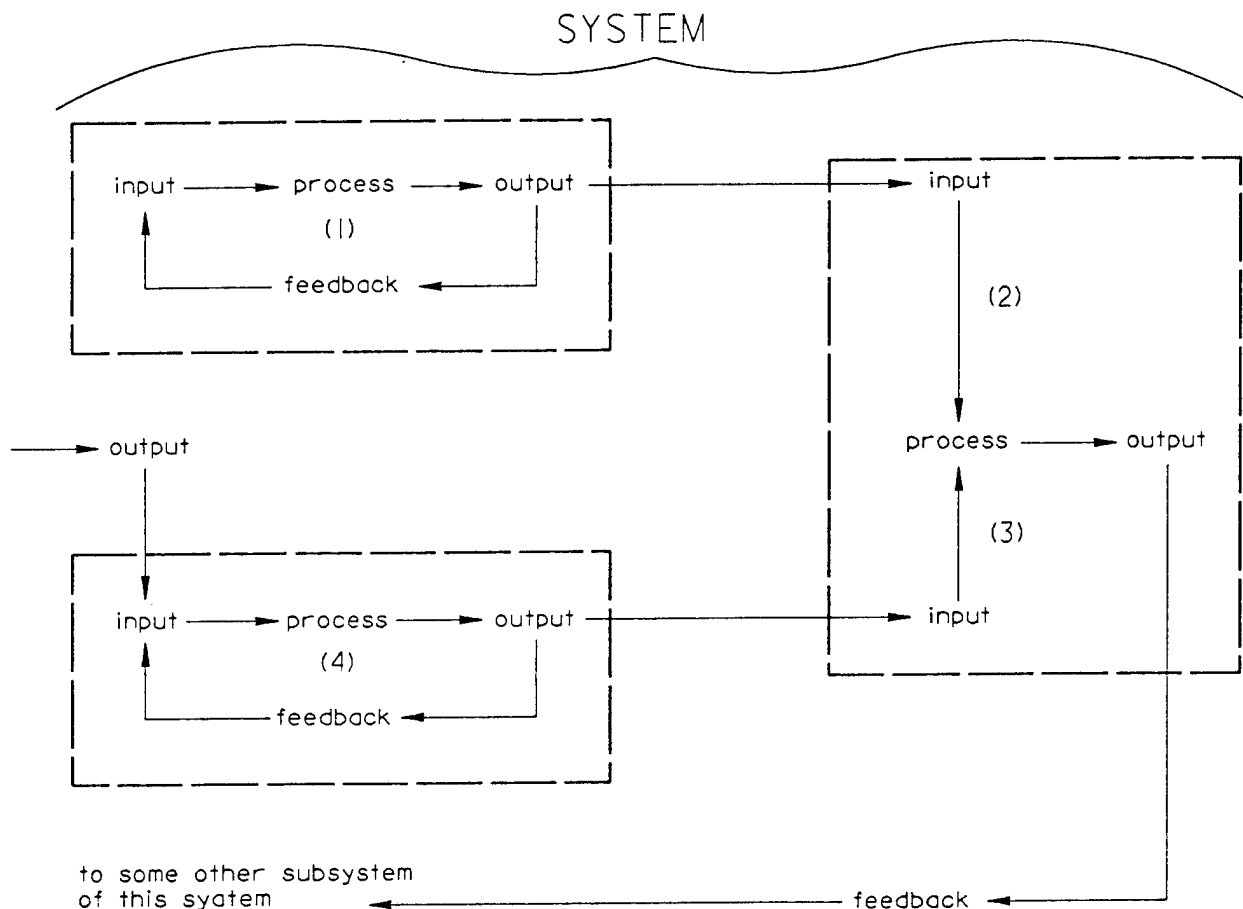


Figure 3 - Systems and Processes

measurement are at boundaries clearly marked at the beginning/end of a process (interface points). It should be emphasized that measuring output alone may be too late in the sequence of events. Performance measurement is designed to capture problems before they wind up in output. *Quality is to be designed into the process; not inspected out.* One example of this in COE operations is when hydraulic and hydrology data are combined with the economic data in a flood control study through computer modeling to produce average annual damages for an existing or future without condition channel

configuration. The results of this are then fed into another process (cost analysis) to determine a benefit-to-cost ratio. The system analysis can go on until the report is written or the project is constructed.

A good test to determine if an action is corrective or is just a quick fix is to observe if that action is directed at the output of a process or at the way the process operates. The former is a quick fix; the latter, a process improvement. One is corrective and the other is an organizational drug.

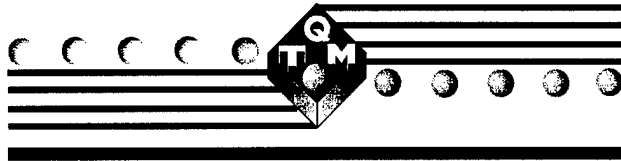
When a system or process is not working at peak performance this is called



process dysfunction. When they are not working at all, it is called *system or process failure*. Failures sometimes happen along an assembly line causing a shut-down of a

production process. Dysfunction is far more common because it represents systems and processes not operating in the most efficient and effective manner.





VI. ORGANIZATIONAL STRUCTURE AND PROCESS MANAGEMENT

The previous material was designed to acquaint the reader with standard business structure and processes. The performance analyst needs to be aware of what it is that he/she is really trying to measure and the complexities involved. System and processes are replete with many levels of management making the whole effort difficult to measure and correct. Organizational structure can dictate performance. The traditional vertical, command-and-control business structure is being attacked today as a leading cause of inefficiency and ineffectiveness. It defeats the purpose of performance improvements with its many disconnects and hand-offs when work passes from one branch or division to another. The horizontal structure is gaining in popularity because it is less autocratic and less bureaucratic. It also allows for empowerment of employees. The most recent change in favor of the horizontal structure is the new employee-to-management ratio criteria. It is designed to eliminate or at least reduce micro management and over-control authority. *One of the keys of performance improvements is not in just doing things right or doing the right things, but is simply aimed at getting rid of what does not need to be done in the first place* [Drucker, 1991]. An examination of Figure 4 shows how structure can impact performance of work activity. In the vertical, pyramid business structure, in order for an activity in office 1) to reach office 7 it must traverse (see darkened line) the chain of command through

offices 2, 3, 4, 5, and 6. This is not the case with the horizontal structure shown below it. There are two fewer steps in the flat organization even though 21 offices exist in both structures. This savings spread out over a year in a typical business environment can amount to substantial savings in delivery time to customers and in corporate operating expenses. The horizontal structure is less complex and naturally conducive to effectiveness and efficiency gains. Not only is there an absolute reduction in the number of production activities or steps, but the cross-functional complications are reduced. Territorial disputes, power structures, and "gaming" all decline. Even more enlightening would be the cross-functional capability of moving from office 1 to 7 directly as with self-managed teams. The number of layers of management are reduced as well, effectively reducing the dividing aspects of corporate fiefdoms. Waste, errors, redundancy, and rework naturally decline.

Figure 5 captures the gist of what it is that is being analyzed. If the system and its processes are performing smoothly, then all the performance measures will produce desirable results. Performance measures can quantify the driving characteristics at any point in the input-transformation-output--outcome sequence. *This quantitative feedback is what management needs to act upon. The process is sending a cause and effect signal to whoever is willing to measure and act on it.*



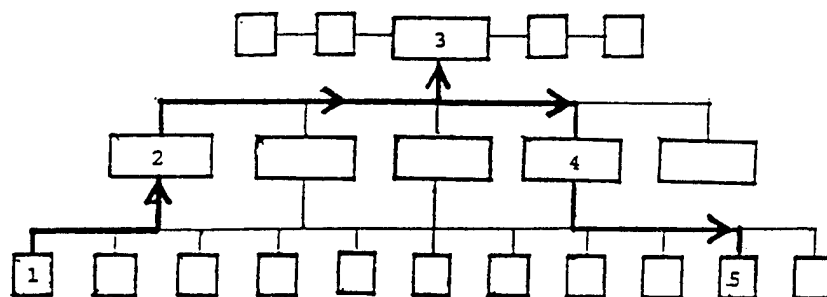
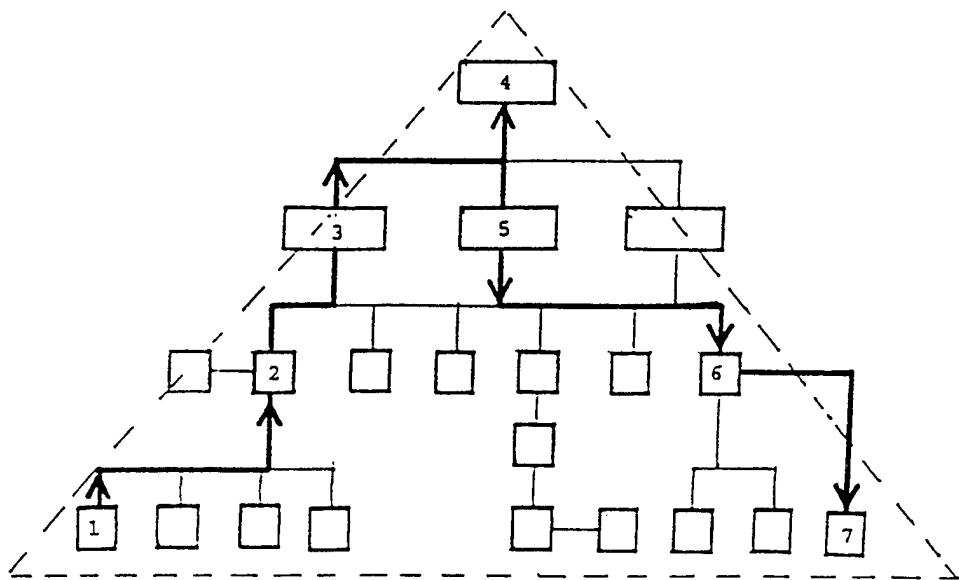


Figure 4 - Organizational Structure and Performance

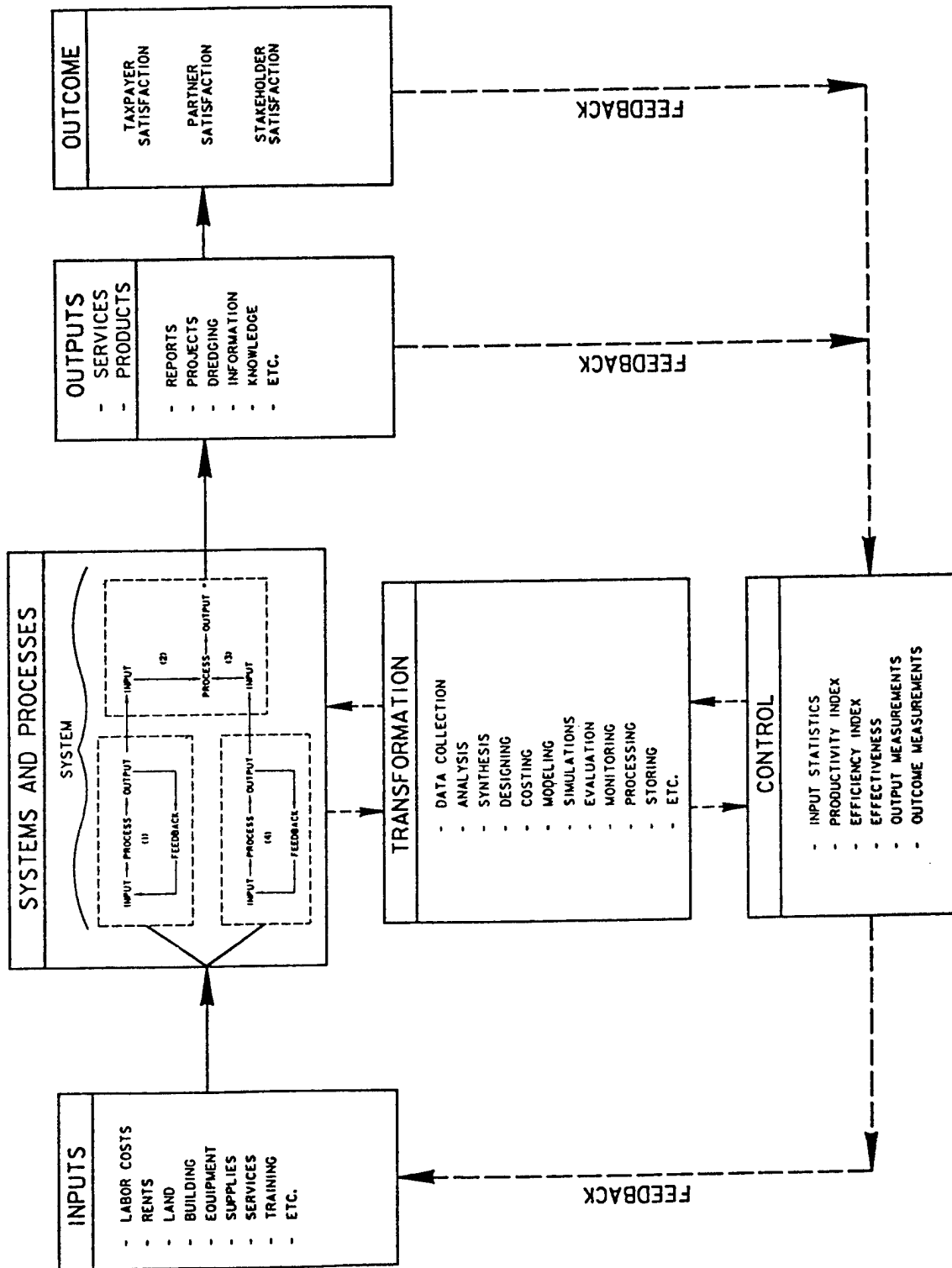


Figure 5 - Systems and Processes

The major problem in the past has been that no one was responsible or accountable for knowing and measuring the entire process. The private sector has as part of their corporate structures "operations departments" for this purpose. In addition, process mapping is tedious and difficult. Attention in the past has been focused on specialities within the system (Divisions, Branches, Sections, etc.) with little, if any, comprehensive, system orientation. Performance measurement changes that.

Figure 5 also shows examples of resource inputs which go into the transformation system to produce outputs and outcomes. As stated earlier, measurement of results is a measurement taken too late.

Resources have been expended, waste accumulated, redundancies completed, and rework waiting around the corner. Measurement must be taken at critical points along the process and of the process itself. Critical locations will depend upon the actual process being mapped. Once the problems with performance have been resolved and the solutions engineered in, then performance of processes and subprocesses can be reduced to periodic checks. The tools and techniques provided in the following paragraphs will enable management to quantify the adverse characteristics of various organizational structures and compare one structure with another for performance improvements.





VII. PERFORMANCE MEASUREMENT AND KEY RESULT AREAS

The use of Key Result Areas (KRA's) is a classic case of doing more with less. The most important concern for determining corporate thrust is to concentrate the resources and energy of the organization on a few KRA's with the highest return [Albrecht, 1985]. It is not necessary to tackle all problem areas. *This is called leveraging.* It pays dividends to concentrate on those problems and take advantage of opportunities which are most significant. Concentrate on objectives which are likely to have high payoff. Key leverage points found in "best practice" organizations are spotlighted, for example, by five KRA's: customer satisfaction, internal and external supplier effectiveness, program management, work-life quality, and cost per unit. Customer satisfaction is driven by product quality and customer perception. Supplier effectiveness means delivering a quality product or service on-time and within cost. The theme of program management is completion as scheduled and budget execution. Work life quality is connected with safety, moral, training, and EEO/AA accomplishments. Cost per unit is driven by dollars and full time employee (FTE) inputs. The type of KRA chosen will depend upon the organization and its goals and objectives.

Meaning of Critical, Core or Key Processes

Whenever someone speaks of key core or critical processes, they are usually

alluding to some basic or fundamental transformation system that leads to getting things done in the least costly, most effective manner. Waste minimization is described by waiting time, review time, rework and transit time. Management is often added to this list. Value-added is maximized and cycle-time is as short as practicable. Let us take a little mystery out of the notions of core processes and critical processes by examining the problem in the form of a maze as depicted in Figure 6. The resource input areas contain the human, equipment, land, leadership, resources needed to carry out a mission. The maze portion is really a depiction of the transformation processes. It is the heart of the subject at hand. The output/outcome represent the results in terms of products and services rendered by the this process.

Over time, the traditional pyramid or vertical organization become increasingly more bureaucratic, layered, regulation-riddled, and cycle-time/non-value-added crippled. The older the organization, the more likely this will be observed. Figure 6 begins to look familiar and descriptive of what the production or transformation process resembles. It is complex, appears to lack organization and a sense of direction, is stove pipe oriented, has many dead-ends and unnecessary paths, and often grows even more complex over time. It may also have more than one production path from the input stage to the output stage thereby increasing confusion. The complexity actually resembles a three dimensional maze rather than the one



TRANSFORMATION PROCESS

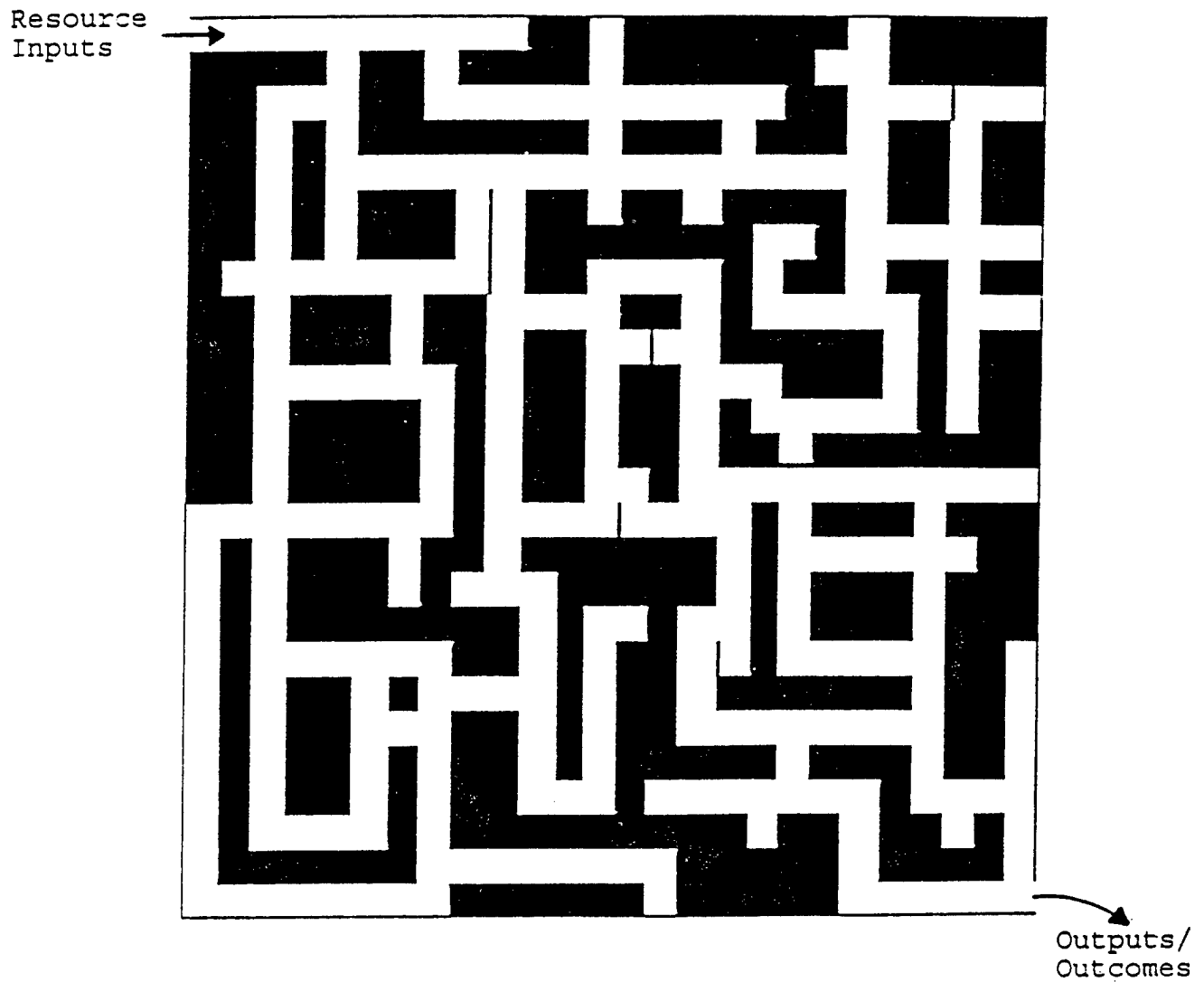


Figure 6 - Critical and Core Process Identification Maze



dimensional maze depicted. This is what the modern, Taylorist (command and control) organization resembles; a complex, frustrating maze without a map-the-production battleground.

The search for critical or core processes is a search through such mazes to find how to accomplish work in the most straightforward, simple process possible. This is the lost road in today's non-TQM organizations. It also explains the new emphasis on systems and process mapping (PERT or network

analysis), cycle-time, value-added, waste analysis, critical process identification, etc. Figure 7 shows what the objective of all the previously discussed NPR, GPRA, and APIC requirements are about; reengineer, realign, restructure, and adopt a new, simpler and disciplined business process roadmap reflecting today's competitive performance realities. The process is simplified, traverses fewer obstacles, and is much more direct in its approach to output. This simple maze is the core or critical process being sought.



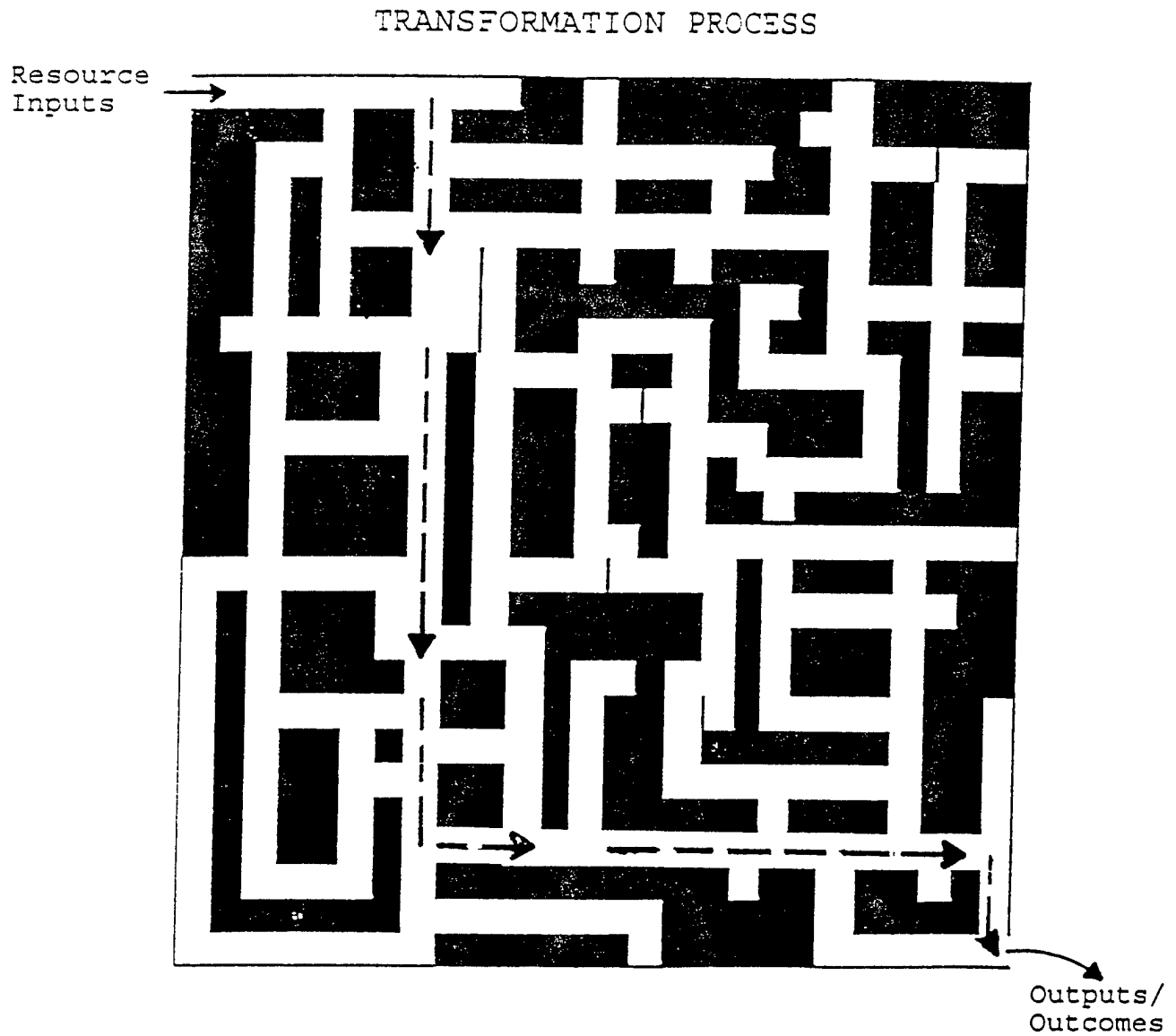


Figure 7 - Critical and Core Process Identification After Several Years of TQM



VIII. THE RISK OF USING SIMPLE NUMBERS, RATIOS AND PERCENTAGES

The use of raw data or simple numbers and ratios (percentages) is a frequently used form of analyzing business operations. What most managers and decision-makers do not know is how misleading this kind of data can be. It often leads to making the wrong decisions for the wrong reasons, leaving managers baffled as to why a decision they made a month ago did not produce the desired results. There are a number of reasons for this. They include [Wheeler, 1993]:

1. First, the size of percent differences between two numbers compared over time is directly related to the base of the numbers themselves. For example, to go from 100 to 110 points represents an increase of 10 and a percent change of 10%. To go from 300 to 310 is an increase of 10 as before but represents a 3.3% increase. Comparisons can be misleading and not very reliable because they do not take into consideration the value of the base number.
2. Period-to-period changes in numbers can be caused by two different forces. One is due to the natural variation in values stemming from random fluctuations that affect all measurements. The other is from changes in the indigenous operational process. Yet, in a

collection of data assembled over time, great attention is given during executive or Board meetings to changes in values as measures of performance when, in fact, these changes are random and may not be connected with operational process performance, equipment, employee performance or management influence at all. An increased production figure is believed to be a positive signal that things are going just fine, whereas, a decreased production figure signals something is amiss. An increasing figure may imply that things are going well when, in fact, there are underlying serious problems at hand. The increase may have no more meaning than the hourly fluctuation in daily temperature readings on a partly cloudy day. It does not indicate a pattern or trend at all. If action is taken to "correct" the declining production figure, it may be the wrong thing to do because such a change was random. Thus, acting on simple numbers, ratios and percent changes, generated from one period to another, can cause more problems than it solves. A problem is then created which did not exist before causing a snowballing or multiplier effect in an otherwise perfectly good production process. Changes in values are not



necessarily “signals” that something needs to be done, but are more likely to have come from random “noise”; something not to be acted upon. The diagnosis and detection of real process or performance changes is what this book is about. This does not imply that the use of such numbers is incorrect, but that they must be used in the proper context and supported with other tools of measurement.

3. When examining period-to-period changes in output (or any attribute), the usual assumption is made that whatever happened this period was related to things that happened during the period, since the last reading. This assumption may also be a frequently made big mistake. The consequences of what happened during a given period may have been cast in stone three or four periods earlier and its effects only beginning

to show up now. An unusual value in the past may have caused the unusual value currently observed.

4. Simple numbers alone (averages, percentages, ratios) only “count”; they do not convey knowledge about the process (how the count value came about). There are no clues on how to correct problems but only measure results. Not every change in output (either up or down) is a signal. Simple numbers, ratios and percentages are valuable assessment tools when used with other process analysis tools such as PERT charts, Shewhart and Demos Control charts, and Quality Functions Deployment, among others. All of these forms of performance measurement will be discussed. The reader needs to be aware of some of the potential failures when using simple numbers, ratios and percentages.





IX. SUMMARY OF PERFORMANCE MEASURES

Univariate Statistics

Univariate statistics--also called raw numbers--are the most commonly used form of presenting performance measurement data. They are the day-to-day numbers used by nearly everyone. Their value lies in their simplicity and straightforwardness, i.e., expenditures grew by \$2,500,000 this year over last year. This is a clear and understandable statement. Univariate statistics tell us a great deal about what we know at any point in time as well as in time series. Their weakness lies in the application of the numbers in the proper context, i.e., grew as compared to what or whom. They also do not express complex concepts or abstract ideas in-and-of-themselves and can be misleading.

Ratios

A ratio is a simple one number divided by another. It can be turned into a percentage by being multiplied by 100. It is perhaps the second most commonly used expression of organizational performance, productivity and efficiency. It is valuable for expressing the quotient relationship at a point in time compared to other ratios or is frequently used to show change over a period of time. It can be as simple as dividing one number by another or as complex as dividing multiple sets of mixed units of numbers by another multiple set of mixed numbers. It

can also be weighted for importance effect. It is generally easily understood.

Special Purpose Indexes

Special Purpose Indexes are nearly self-descriptive. They are designed to have a very specific, almost unique purpose. They usually require weighting based on some unique criteria. For example, an important factor in TQM today is Work Life Quality--an encompassing concept designed to express worker growth, development, and general happiness in the work environment. There are no known single indexes which measure this attribute. Thus, analysts generally need to "invent" an index to cover their specific organization or shop. An example of this will be given later in the text. Special purpose indexes are frequently found where attempts are being made to quantify or find a proxy for an aesthetic concept or an amenity impact.

Multifactor Indexes

Ordinarily, productivity indexes examine the relationship of one number or value to another. Multifactor indexes take into account multiple causes. For example, output per employee is a common single factor index of performance measurement. An example of a multifactor index is output divided by the number of employees and amount of equipment used--with both numerator and denominator expressed in



dollars. Here, the cause of output is being attributed to employee input and equipment input. In organizations which are very labor intensive, such as painters and carpenters, the simple ratio of output to labor input is very appropriate. In organizations which are both labor and capital intensive, performance is better measured by output divided by the combined value of labor and capital input. In turn, where capital (equipment) is the real producing agent, a good index would show output divided by the value of equipment; such as found in robotic factories. Multifactor indexes are very useful measures of performance and can be used to examine existing performance, benchmarked performance, or be used to observe performance growth over a span of time. While a single measure is often used in the numerator, the denominator can contain numerous inputs such as the value of labor, equipment, energy, education, etc. used to produce the output. Multifactor indexes are not always easy to develop and may be expensive to maintain but they contain a good deal of valuable information as to the cause agents of productivity improvements or declines. They will be covered extensively in this text.

Partial Factor Indexes

Partial factor productivity ratios are usually represented by dividing the value of output by the value of one input only. For example, expenditures per employee, reports completed per engineer errors made per drawing, et al. As alluded to above, they are most useful when one resource input dominates output. Families of single factor

indexes are frequently used to measure the performance of an organization, office, or shop. They are frequently easy to understand and require very little information.

Simple Average-of-Relative Indexes

This index is a simple ratio of the value of a performance number in a future period of some attribute divided by the value of the same attribute in a base year. It shows the growth or decline in a resource or output over time. The common anchor is the base year. This ratio is usually restricted in the sense that whatever is being measured in both the numerator and denominator must be in the same units. An analyst cannot mix, say, the cubic yards of concrete divided by tons of steel. This usually has no meaning unless someone needs to know the relationship of concrete to steel.

Weighted Aggregate Index

Weighted aggregate indexes represent a class of performance measurement techniques that have many positive attributes. They allow the user to mix units of measure, combine seemingly unlike units of measure, weigh the relative importance of a mix of resource inputs or outputs to reflect their relative importance, and can be used to benchmark in a current time period as well as be employed to measure or monitor performance over time. The Consumer Price Index is a classic example of this index. Here, a mix of over a hundred items in mixed units (dollars per pound, dollars per liquid ounce, dollars per yard, payments per month, et al) are combined to form one



measure of price performance (inflation/deflation) over time. This may be one of the most valuable performance measurement tools the COE can adapt. It is simple to use and extremely flexible--especially when many factors need to be considered in a performance index.

Efficiency

Efficiency is found by dividing the actual output of an organization by its effective capacity. It represents how well you are doing relative to your potential. The user needs to identify the units of measure and, more importantly, define effective capacity. Effective capacity represents the maximum amount of output given a process mix, scheduling problems, equipment maintenance, quality parameters, and other environmental factors. This may seem a little evasive to capture but is easily established by settling on a base or pre-defined set of circumstances to serve as the base condition. It is valuable because it shows changes in capability relative to the base condition over time--is the organization becoming more or less efficient?

Cycle Time Analysis

No other parameter may be more important than improving cycle time. It is a significant performance indicator and will likely become more important in the future. Cycle time is how long it takes to complete a product or service from the start date to the delivery date. Cycle time consists of processing time, transit time, waiting time,

review time, and rework time. Much more will be said on this matter later in the book.

Value Added

Next to cycle time, value added is the next most important attribute to measure and control. It is the value added during the production process from the day raw material and ideas are combined to intermediate processing to final delivery. In sum, it is the value of the supplies, labor knowledge, energy, equipment, etc., that goes into making a product or producing a service. It is why things cost what they do. It is a competitive factor in today's cost conscious world.

Waste Analysis

Probably the third most important attribute to measure is waste. Waste is not simply saving of paper clips and recycling paper but is far more evasive. Waste is connected to both cycle time and value-added. It is the added expenses that are passed on to the customer from non-value added activities such as excessive transit time, unnecessary review, frequent rework activities, and uncalled for waiting time. Waste is said to account for between 10% and 95% of value added costs (depending on the organization and what is being produced) with a mean value typically around 35% of an organization's budget. Much more will be said about this important performance measure.



Flexibility/Adaptability Analysis

Organizations which do not adopt to the new paradigms of the current surge in TQM and continuous improvement activities will not exist by the early part of the 21st century. This factor is one of the reasons why Japanese products and services have soared in the last 20 - 30 years. They have adopted the new tools, techniques, and procedures to produce high quality and low cost products and services. They have passed through the "cultural change" barrier that so haunts the West. The enclosed material discusses measures of adaptability in some detail not only as a specific subject but tacitly throughout the material.

Benchmarking

Benchmarking is the comparing of your performance with that of a competitor, a world class organization, the best in a class, or all of these references. It is a way of telling an organization where it stands relative to a reference point. It also allows an organization to set "stretch goals" to meet the challenge of knowing where they stand. There are a number of approaches to benchmarking and they are discussed in the enclosed material.

Shewhart Control Charts

The Shewhart Control Chart is most likely the single most important technique in a TQM, APIC toolbox. It allows the user to identify the problems associated with organizational quality performance, cycle time analysis, value-added analysis, and

waste--all in one package. It is a graphical tool and is used to diagnose and aid in locating performance problems in a dynamic sense. Most tools measure performance after the fact; after the product or service is already produced and in the customer's hands. The Shewhart control chart allows the analysts to observe problems as they occur; to detect and aid in diagnosing errors before they get built into the product or service. One of the shortcomings of Shewhart control charts is that the standard form allows observations of only one process at a time. The standard form still stands as one of the most powerful process analysis tools available today. An index of performance is calculated from process measurement using the Shewhart control chart.

Demos Control Charts

The Demos control chart is an expansion of the Shewhart control chart which allows the analyst to trace back through the system or process to other sub-process control charts to "pin down" the exact source of a problem. The text provides an example of this technique using extensive details.

PERT

The Program Evaluation and Review Technique (PERT) was originally designed to monitor the one-time scheduling of a large scale project. It was so successful that it became a tool which is adaptable to monitoring projects of all sorts. It was intended to serve as a program guide or map for complex projects but is now being used to



model alternative organizational procedures. It is also very useful in testing alternative plans and employing the "what if" to test cause and effect. It is ideal for process mapping as will be demonstrated in this text.

Benefit-to-Cost Ratio Analysis

The benefit-to-cost ratio technique is familiar to the COE. It is a technique that requires that the benefit of a proposed action and its costs both be developed to determine if an action or project is economically justified. If the benefits are divided by the costs with a result which is greater than 1.00, then the proposed action is justified on economic grounds. If the resulting ratio is equal to 1.00, then the proposed action is break-even. Finally, if the resulting ratio is less than one, the action is not justified. Both the benefits and cost must be in compatible annual terms. The technique is excellent for evaluating the impacts and justification for such actions as reengineering, realignment studies, downsizing or related activities and studies. Currently, there are very few credible studies ongoing which have evaluated organizational changes in this manner. In many cases, the original rationale was not objective.

Quality Function Deployment

Quality Function Deployment (QFD) is the "voice of the customer". It is a tabular technique for systematically determining customer wants and needs, the amount of these wants, how they are going to be achieved, what is going to be achieved, prioritizing goals and objectives, and

benchmarking--all in one technique. It is an excellent customer satisfaction tool easily employed or adopted to almost any production or service operation. QFD began as an engineering tool to assure that the development process led to a product that would meet customer expectations. It has developed into a holistic planning tool. It is also a preventive tool designed in part to prevent last minute surprises often associated with complex projects. It is highly recommended that the COE adopt this tool in its engineering and planning processes. The enclosed examples will provide a good deal of information in an applied example.

Quantification of Goals and Objectives

Many goals and objectives are developed in such a way that they are subject to subjective interpretation in purpose and in outcome. This often happens because they are developed in a "fuzzy" way. Many goals and objectives can be made more deterministic by constructing them in ways that allow for objective quantification of intent and outcome so that there are no misunderstandings. It is stated at the outset that not all goals and objectives are quantifiable; many that can be are not because the writer is not accustomed to preparing them in the proper format. The approach described in the text shows how to construct quantifiable goals and objectives. Users are encouraged to use this approach rather than continue the traditional "soft" unverifiable approach.



Customer Surveys

The least expensive and yet very powerful way to find out what is going on, or to produce data for a specified purpose is to generate a well developed survey. This device satisfies much of the GPRA and APIC requirements for listening to the voice of the internal and external customer. Surveys are also very amenable to statistical analysis and can be used to benchmark at a point in time against a competitor or other agency or, over time, to assess changes in behavior or perceptions. Well developed surveys are the key. A simple question is not always interpreted the same way by different people. The wording must be as specific as reasonably possible. In order to prevent bias, survey questions should be developed by an outside consultant and overseen by organization management and employees through their unions.

Pareto Charts

A seemingly trivial device, the Pareto chart, is extremely powerful. It is used to rank problems, ideas, and solutions for taking action. It is one of the most used tools by TQM organizations today. The last part of this book discusses the value and application of this approach to problem resolution. It is often used in conjunction with focus groups or brainstorming sessions. This is where its power is best unleashed.

Applicability of Performance Measurement Tools to Corps of Activities

Every performance measurement tool presented in this text is useful to COE activities. They are not theoretical tools but represent methods which have been time tested by actual application and all are currently being used by "cutting edge" and "world class" organizations. They produce results! Some are more applicable to certain facets of an organization than others.

Table 1 illustrates the usefulness of each tool to major COE requirements; present and future. Many of these COE requirements overlap to a considerable degree. This is apparent in the table. Rather than treat these requirements as separate tasks, it is advised that they all be absorbed into the Baldrige (APIC) criteria because, in fact, they belong there.

As they currently exist, some of the criteria have been in "paradigm paralysis" for some years and need to be re-vamped to conform with what works to make an organization the best in today's highly competitive environment. Whatever is done along these lines, **DO NOT MODIFY BALDRIGE (APIC) TO FIT THE CORPS: THE CORPS NEEDS TO BE CHANGED TO FIT BALDRIGE (APIC). TO DO OTHERWISE WOULD TOTALLY DEFEAT THE PURPOSE OF THE CONSTRUCTIVE CHANGE CURRENTLY TRANSFORMING THE ORGANIZATION FOR THE 21ST CENTURY. IT WOULD BE A STEP BACKWARD AND INSTITUTIONALLY DESTRUCTIVE.** The last three sentences above were typed in bold, italics, and underlined for good reason!



This is not an area for compromise. Bending the intent or using clever re-wording or interpretation of the Baldrige criteria to obtain "buy-in" would start a self-inflicted virus leading to a return of the bureaucratic

disease. Change the Corps to meet Baldrige. Do not change Baldrige to satisfy the Corps.

The following appendices will go on to describe the details of the previously discussed performance measures.



Table 1 - Usefulness of Performance Measurement Tools & Techniques, Organizational Performance

Method/Technique	GPRA	CFO	ACOE/APIC	CMR	MCP/AAS	Comments
► Univariate Statistics	8 - 10	8 - 10	8 - 10	8 - 10	8 - 10	Qualified ¹
► Ratios	8 - 10	8 - 10	8 - 10	8 - 10	8 - 10	Qualified ¹
► Special Purpose Indexes	3 - 4	3 - 4	4 - 5	4 - 5	4 - 5	Potential Bias
► Multifactor Indexes	Future	Future	Future	Future	Future	COE not ready
► Partial Productivity Indexes	Future	Future	Future	Future	Future	COE not ready
► Simple Avg-of-Rel Indexes	2 - 5	2 - 5	2 - 5	2 - 5	2 - 5	Limited/specialize
► Weighted Aggregate Indexes	8 - 10	7 - 8	9 - 10	9 - 10	7 - 8	-----
► Efficiency	Not yet fully developed					More research
► Cycle-Time Analysis	10+	8	10+	10+	5 - 8	Key/Core "vital"
► Value-Added Analysis	10+	8	10+	10+	5 - 8	Key/Core "vital"
► Waste Analysis	10+	8	10+	10+	10	Key/Core "vital"
► Flexibility/Adapt. Analysis	5 - 7	2	8	8	5	-----
► Benchmarking	10+	10	10+	10+	4 - 8	Key/Core "vital"
► Shewhart Control Charts	10+	10	10+	10+	7 - 8	Key/Core "vital"
► Demos Control Charts	10+	10	10+	10+	7 - 8	Key/Core "vital"
► PERT/Network Analysis	8 - 10	6 - 8	10	6 - 7	3 - 5	Good for process mapping
► BCR Analysis	8 - 10	8 - 10	8 - 10	3 - 4	3 - 4	Good for reeng'g/realignmt
► QFD	10+	4 - 5	10	6 - 7	5 - 7	Key/Core "vital"
► Quantifiable Goals/Obj.	8	6	10	10	7	Not exclusive
► Surveys (Customers)	10+	5	10+	5	4 - 6	Key/Core "vital"
► Pareto Charts	10	10	10	7	7 - 8	Very valuable
Suitability/Usefulness	Definitions					
0 = No value/limited use	GPRA: Government Performance Results Act					
5 = Recommended	CFO: Chief Financial Officers Act					
10 = Highly Recommended	ACOE/APIC: Army Performance Improvement Criteria					
	CMR: Command Management Review					
	MCP/AAS: Management Control Plans/Annual Assurance Statements					

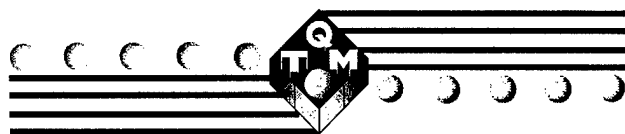


APPENDIX A

PERFORMANCE MEASUREMENT







A.1. PERFORMANCE TOOLS AND TECHNIQUES

All performance measures are faulty in that they cannot take into consideration all the factors that contribute to what it is they are measuring. In this context they are essentially proxies. There are also circumstances where performance measures provide contradictory readings. When measuring an attribute or characteristic, one measure may indicate an improvement while another may show matters deteriorating. This presents a good case for using more than two measures of the same thing and a good reason to use more than one technique or method. Using multiple measures of the same attribute often creates "families of measures". The number of ways to measure performance abound. Some methods are simple and effective and a few are so complex that one wonders if they are measuring anything at all. This appendix will focus on those which will allow COE analysts to do more with less. It will also envelop only those methods which are COE relevant. The COE is a government institution and not profit driven, consequently market price related performance techniques will not be covered. The reader may refer to the bibliography for private sector techniques and methods.

Measurement techniques will cover the areas of input quantification, productivity, effectiveness, efficiency, output, and outcome. All are needed to satisfy the spirit of the NPR, GPRA and the APIC programs.

Twenty tools and techniques will be presented with reference to others in the literature. The tools and techniques are: uses of raw data, partial and multifactor productivity indices, weighted relative aggregates productivity (cost and production) indexes, the benefit-to-cost ratio (BCR), network schematics or mapping, statistical process control (SPC), benchmarking, and customer surveys-internal and external, among others. *Collectively these tools and techniques, which are prevention-based, can be used to diagnose problems, quantify activities, produce continuous process control in a total quality management environment.* Also note that the methods presented in this report are useful for the performance measurement of projects, programs, financial management, business practices, KRA's, or systems and processes. Table 1a presents a comprehensive view of user utility for each type of performance measure. All are very suitable for graphical displays but some may be more or less appropriate for customer viewing.

There are three terms used throughout the discussions on index numbers which need to be defined. These are the terms aggregate, simple, and percentage relative or just relative. The word aggregate means the sum of a number of terms, items, or elements which make up a total. The term simple refers to an unweighted number. The term percentage relative or just relative is defined as the ratio of a current value to a base value;



this becomes a percentage relative when multiplied by 100.

There are also three basic types of index numbers including cost indicators (cost per unit), quantity indicators, and value indicators (cost per unit times quantity). The reader should keep in mind that one of the advantages of many of the indexes discussed in this book is that they allow for the inclusion of *multiple performance measures* to produce a *single index*. These will be used and explained throughout the following pages.

Inflation And Deflators

In the various indexes that will be discussed presently, the issue of adjusting monetary numbers such as costs and value needs attention. This adjustment is necessary to account for the oscillating value of the dollar over time. Correction involves dividing the unadjusted value by an appropriate price level index called a *deflator* which compensates for the changing purchasing power of money over time. It is necessary to make this correction so that real purchasing is being evaluated and not inflated dollars. This topic will be covered in more detail later in the report but needs to be mentioned here to increase awareness of the value of the index numbers being discussed.

Productivity and Efficiency Defined

Productivity and efficiency are both part of performance measurement. If you were to ask different disciplines what the meaning of each of these terms are, you would get different answers. Engineers, economists,

politicians, psychologists, sociologists, etc., view the world differently. All these perceptions are correct; it is a point of view that makes the difference. Because of this, this text will not attempt to precisely define each of these terms but will adopt a generic definition which better suits the diverse Corps population who will be likely to use this material. Even though definitions may differ somewhat, the tools which measure productivity and efficiency are virtually the same.

Productivity "*is a relationship between quantities of outputs from a system and quantities of inputs into the same system*" [Sink, 1985]. This is mathematically expressed as Output/Input. The real thrust behind productivity is to get out of a resource input more than the cost of the input. Families of productivity and efficiency measures are usually more useful than single measures. They present a mosaic of what is happening as compared to single measures, as mentioned earlier. Productivity growth is an increase in output that exceeds the growth in inputs. Efficiency "*is the degree the system utilized the "right" things or "the comparison between resources we expect or intend to consume in accomplishing specific goals, objectives, activities, and resources actually consumed*" [Sink, 1985].

Before proceeding it must be recognized that productivity increases occur for five circumstances:

1. Output increases while input decreases.
2. Output increases while inputs remain constant.



3. Output increases and input increases, but at a lower rate.

4. Output remains constant while input decreases.

5. Output decreases and input decreases, but at a more rapid rate.

With these working definitions in mind we can proceed with the measurement of productivity and efficiency; and later, with effectiveness.

Simple Univariate (RAW) Descriptive Statistics

Univariate data are the easiest to use, most direct, and most generally understood by analyst and customer alike. Raw data are simple unadjusted numbers. They are the numbers we use daily and often have one dimensional units of measure such as feet, dollars, kilowatts, acres, species, visitors, etc. They are used for graphs, tables and charts that display data so that they are easy to understand. They have little interpretation beyond simple description.

Univariate values are most useful when plotted and observed over time to expose trends and patterns in data. They are also useful in benchmarking (comparing your operation with the best in the business). Figure 1a portrays a typical example of raw data values plotted over time and used in benchmarking. In this example, District A is comparing a port located within its boundaries with that of a benchmark port located in another jurisdiction. Plotting the performance of "tons" over time shows that the growth in tonnage of Port A had surpassed that of the benchmark port in

1991. Both ports are showing increasing tonnages over time and both indicate a leveling trend which started around 1994. The performance of Port A has been better than that of the benchmark port as demonstrated by a more rapid growth from 1985 to around 1993. Notice also that a rapid spike in growth occurred in Port A in 1990. This sort of illustration shows the effectiveness of using simple data. They communicate a good deal of information. They are useful for examining historic trends, in forecasting; they point out unusual or extreme events, and are good for benchmarking. It is expected that they will be used frequently in performance evaluation. All of this could be valuable information in conducting studies of port expansion and in making a case for funding studies. Let us examine raw numbers from another perspective.

To state that the COE protected 2,000,000 acres of wetlands in fiscal year 1997 may be meaningless in itself. To state that the number of protected acres in fiscal year 1996 was 1,500,000 adds value to the information; there has been an increase of 500,000 acres which represents a gain of 33.3 percent over a one year period. The continued record keeping and plotting of this information over time makes this simple information highly valuable in defending program schedules and budgets. It represents essential feedback to the process, makes for excellent public relations, and is also valuable for benchmarking purposes. These numbers are powerful and useful but could also be very deceiving.

Simple numerical measures of performance may tell only part of the story.



TABLE 1a RELATIVE UTILITY OF PERFORMANCE MEASUREMENT TOOLS (METHODOLOGIST PERSPECTIVE) ²						
Method/Tool	Cost to Implement	Knowledge Required	Data Required	Information Obtained	Ease of Calculation	Understandable
Univariate Data	L	L	L	L	H	H
Single Factor Ratio Index	L	L	L	M	H	H
Multifactor Index	H	H	M	M	L	L
Weighted Index	L	M	M	H	M	M
BCR	M-H	H	M-H	H	L-M	M
PERT/Mapping ¹	H	H	M-H	H	L-M	H
SPC ¹	M-H	H	M-H	H	L-M	L-M
Benchmarking	M-H	M	M	M	L-H	H
Value Added Ana.	M	M	M	H	M	M
Effectiveness Meas.	L	M	M	H	L	H
Customer Surveys	M-H	M	M	H	M	H
L = Low M = Medium H = High Software is available which will reduce costs of use. Training is provided for knowledge & skill development and for universal consistency in use						



They do not tell how much labor resources were used as input, the capital (an economic term for equipment) expenditures required, any reference to quality characteristics of the attribute, the costs involved, the technology employed, or the knowledge required, among other factors. For example, the 500,000 acreage increase cited above may have cost twice as much per acre to preserve as did the previous 1,500,000 acres. The environmental characteristics of the acreage may be marginal as compared to prime, high quality wetlands preserved in the past. Under this scenario, the 500,000 acres may not present themselves as an impressive accomplishment. It must be emphasized that the presentation of simple numerical values must be carefully qualified. If the numbers are "clean" and developed under conditions comparable to past efforts, then raw data are a good measure. Otherwise, buyer beware. Despite their importance simple facts may be insufficient in providing a basis for action. Effective action is more a function of determining cause and effect connections among processes and between process and results.

The Use Of Ratios

The use of *ratios* is a technique most performance analysts are already acquainted with. A ratio is simply one number divided by another-the purpose is to determine or to create a relationship between a numerator and denominator for comparative purposes.

The usual association of two such numbers helps to determine what part or share one number is of another, to create a

percent by multiplying the dividend by 100, or measure changing relationships over time.

Ratios are functionally used to examine and explore *cross sectional data* or *time series data*. A cross sectional relationship is one which holds time constant to show comparative association at a point in time.

Table 2a provides an example of this type of association. In this example the ratios show that a COE district's Xerox expenses increase with FTE levels which might be expected. It also shows that this relationship grows out of proportion as district sizes approach 771 FTE's or larger. This is a cost-of-doing-business issue which may provide a clue to organizational operation and economies of scale. Why is this occurring? Is it due to more work or more bureaucratic waste? Notice that this analysis is for a given year only. No time has passed.

The use of time driven ratios are found by dividing the raw data value in succeeding years by the raw data value found in the base year. The general expression for this ratio is:

$$I = (C_n/C_o) \times 100 \text{ for cost analysis}$$

and

$$I = (Q_n/Q_o) \times 100 \text{ for quantity analysis}$$

where:

I = Index

C_n = Cost in year n ,

C_o = Cost in the base year,

Q_n = Quantity in year n ,

Q_o = Quantity in the base year

The data may be either input data or output data. Table 3a provides example of the use of time ratios. The ratios are useful



TABLE 2a
CROSS SECTIONAL ANALYSIS - 1997

(1) District Size (FTE's)	(2) Xerox* Expenses	(3) Ratio (2)/(1)
350	\$100,000	\$286/FTE
410	\$125,000	\$305/FTE
528	\$170,000	\$322/FTE
600	\$210,000	\$350/FTE
771	\$385,000	\$499/FTE
903	\$500,000	\$554/FTE

*Include purchases, maintenance, paper, etc.

for showing the change in the value of some factor being measured over time relative to a base or starting year value. They should not be used without elaboration as they can be misleading for reasons cited earlier in the discussion of raw data usage. If costs, price, values, or other dollar measures are used, care must be taken to adjust for inflation using price deflators. As the table illustrates, ratios can be developed based upon given year to base year values or from accumulative data to a base year value.

Special Purpose Indexes

There are circumstances where the previous performance indexes are not

applicable and another approach is needed. *Special purpose indexes* are designed to help fill this void. Like some of the previous indexes, special purpose indexes require weighting of values by using some criteria which is indicative of the importance of the numbers involved. This type of index also has the useful characteristic of being invariant to the units of measure being used. The procedure also does well in allowing the use of multiple variables to form one measure of performance. Table 4a presents an example application of the use of a special purpose index.

The example uses the KRA called *Work Life Quality (WLQ)*. Work Life Quality is concerned with issues related to employee



TABLE 3a - EXAMPLES OF TIME RATIOS

Year-to-Year Examples					
Example 1			Example 2		
Year	Deep Draft Vessel Delays	Ratio	Year	Flood Damage Prevented	Ratio
1990	5500 vessel hrs	1.00	1992	1,200,000	1.00
1991	5700	1.04	1993	1,400,000	1.17
1992	6000	1.09	1994	1,300,000	1.08
1993	5900	1.07	1995	1,200,000	1.00
1994	6200	1.13	1996	1,500,000	1.25
1995	6000	1.09			
1996	7100	1.29			
Cumulation Examples					
Example 3			Example 4		
Year	Cumulative Acres of Habitat Preserved	Ratio	Year	Cumulative Kwhrs Generated	Ratio
1970	100,000	1.00	1988	1,000	1.00
1980	125,000	1.25	1989	1,200	1.20
1990	160,000	1.60	1990	1,900	1.90
			1991	2,000	2.00
			1992	2,200	2.20
			1993	2,300	2.30
			1994	2,350	2.35
			1995	2,410	2.41
			1996	2,700	2.70



TABLE 4a SPECIAL PURPOSE INDEXES PROFESSION WORK LIFE ENVIRONMENT (STAFF SIZE: 100 FTE'S)					
Year	Employees in Self Directed Teams (40%) wt. 1	Hours of Training/ Yr (30%) wt.	Percent of Employee Ideas Used (20%) wt.	Average Incentive Award (10%) wt.	Composite Index Value
1996 (Base)	20	30	10	\$150	100.0
1997	30	50	30	\$200	183.0
1998	70	60	30	\$300	280.0
1999	20	30	5	\$100	87.0

1 Example Calculation

$$[(30/20)(0.40) + (50/30)(0.30) + (30/10)(0.20) + + (200/150)(0.10)] \times 100 = 183.0$$



safety, training, morale and EEO/AA progression. Suppose that four attributes were selected by management and employees to represent WLQ proxies. They include: self directed work teams, hours of training, employee ideas adopted, and the dollar amount of incentive awards given. These attributes are known to increase motivation, productivity, efficiency, and effectiveness. Consequently both management and employees gain by their use in measuring the WLQ. Each of these attributes needs a little explanation before proceeding with the point at hand.

Self directed teams go beyond normal teamwork practices in that employees make all the decisions and do all the planning for the projects to which they are assigned. Management serves to assist employees only at the request of the teams and then only in an advisory, teacher, and coach capacity. Employees are fully empowered. This is a highly desirable working environment for professional employees and in numerous studies, has proven to yield the greatest productivity and efficiency of all working relationships [Manz and Sims, 1993]. Self directed teams avoid the autocratic and bureaucratic nature of the traditional approach to organizational operations.

Training is another important WLQ characteristic and is closely interwoven with self directed work teams. Multi-disciplinary and multi-skilled employees are paramount to the success of the self-directed team. It is also known that training is a positive motivator for employees. Most seek training for increased development and personal growth. In addition, studies have shown that the

training of employees brings dividends to an organization in the long run.

The adoption of employee ideas is another known motivating factor. When employees know that management and leadership take their ideas seriously, they respond in a positive fashion. This goes hand-in-hand with incentive awards. Incentive awards need not be cash but may take a variety of forms including time off, honorary recognition, prestige, and increased responsibility and opportunity on the job.

The four attributes used in this example are not important to the technique per se. The essential idea is that there has been a consensus agreement between employees and management that these attributes are mutually beneficial and, more importantly, each attribute has been given an importance weight by mutual agreement as well. The number of employees belonging to working self directed teams has been given a weight of 40 percent, hours of training per year is given a weight of 30 percent, and the adoption of good employee ideas and incentive awards have been weighed 20 and 10 percent, respectively.

Column 5 of Table 4a represents the desired index measure used to gauge WLQ performance--an important KRA. It is evaluated by dividing given year values by base year values, multiplying the results of this by the weighting factor, and then summed across a row. As the value of the index rises over time, so does the WLQ. In this example, the index has risen from a base year (1996) value of 100.0 to a 1998 value of 280.0. From 1998 to 1999, the performance index has declined to 87 percent indicating that something has gone awry. The index is



sensitive to the change in weights and the number of attributes comprising the index.

This approach to index number development is very flexible but carries with it a risk of bias. The weights are susceptible to bias if not developed in a scientific, supportable or verifiable manner. The example in Table 4a was selected for a particular reason. Judgement can play a role in the development of the weights but the process of weight selection needs to evolve from consensus. Only then will the performance index carry with it real authority and support. Traditional weighting also plays an important role. Customer surveys, variable size, costs, demand, etc., can also be used as weights. These tend to be more scientific because their basis is in fact rather than judgement.

The special purpose index, like all the other indexes in this text, can be used to measure performance in KRA's, projects, programs, organizational operations and financial well-being. Weights can be developed by surveys, budget proportions, product demand, etc., depending upon its intended purpose. It should be used with care because the potential for subjectivity creeping in is all too real.

General Notes On Partial And Multifactor Indexes

Partial and multifactor indices convey more information than simple numerical values as measures of performance. A partial productivity measure looks at output as a function of a single input. Multifactor indexes look at output as a function of labor, capital and other resource inputs. If only one

resource input is used, the ratio is called a partial productivity measure. If more than one resource input is used, the ratio formed is called a multifactor productivity measure. If all resource inputs are used, the final ratio is called a total factor productivity measure. The distinction between the multifactor and total factor productivity measures is basically academic in terms of the resource input that are used by the COE. The single most significant resource input for the COE is professional labor.

Each can be used to spot check the performance at a point in an operation or to examine the final output of a total process. The output of process (1) and of process (4) in Figure 3 (see Systems and Processes) are good locations to conduct a spot process check. The output of processes (2) and (3) in Figure 3 are a good location to check the performance of the system. Partial and multifactor indexes are frequently quoted and used in the private sector. These indexes are often constructed as the ratio of output to input and are useful when benchmarking. They are also typically found in measuring organizational productivity. Mathematically the basic form of this index is [Stevenson, 1993]:

$$\text{Productivity} = \text{Output/Input}$$

Like simple numbers, partial productivity indexes are made more useful if plotted over time and used in benchmarking. One popular partial index is labor productivity and the second is capital productivity. Labor productivity is the most prevalent of all partial productivity measurements. It is generally defined as the



total value of products and services in deflated dollar terms of products per hour of labor input. This is due to the fact that labor input is involved in all facets of production and has been the most easily measured [Jerome, 1986]. It reflects output relative to labor hours worked or the number of employees used. Capital productivity, on the other hand, is the value of products and services produced in constant dollars of purchasing power per unit of capital services input. Capital productivity is a very useful productivity tool but as will be seen later, it is very difficult to develop.

An example of the construction of a partial labor productivity index would include:

- Number of engineer drawings/Man-years of labor = Number of drawings per man-year
- Number of design errors made/Number of employees = Number of design errors per employee

The issues are more involved than this but the examples do illustrate the general concepts and principles involved. This topic will be more fully developed in the paragraphs below.

Another useful characteristic of partial productivity ratios is their value to making forecasts. For example, if non-contract output to employee ratio is \$140,000 in output per employee then if the number of employees goes from 475 down to 450 the change in expenditure capability is downward

by: $[\$140,000(474-450)] = \$3,360,000$. More contracting would have to be done as more funding is to be executed. This is a good way to determine future planning needs required to off-set changes in FTE levels. Other ratios can be developed to assist in planning future organizational needs as well. These will become more apparent as the text continues.

Partial Productivity Measures

In measuring productivity, the value or quantity of outputs (products and services) is divided by resource inputs costs. *Partial productivity* measurement employs the total value or quantity of output divided by the total value or quantity of labor or some other single factor used. This approach makes assumptions about the single factor input-that it is the driving force of production activities. Care must be taken to describe the production process. For example, two employees using high technology equipment (computers) will be more productive than ten employees using hand calculators given the same tasks. This situation makes comparison of output per employee between organizations misleading. An uninformed observer may be misled in believing that the ten employees are unproductive or even lazy as compared to the two employee organization! The same misunderstanding may occur if the output per dollar of capital is used without qualification. If the assumption is made that two organizations have roughly equivalent capital resources, training, education, man-years of experience, etc. then output per employee comparisons are good benchmarks. Alternatively, these



may be cues for adopting benchmark practices. The index may be saying that your organization's training, experience base, capital resources and so-on are not up to par with those of the benchmark organization. This same assumption must be extended into the future if the same comparison partners are going to be used.

Table 5a provides an illustration of how partial productivity indexes are developed with a *one output scenario* using labor as the principle input. The example shows that the number of permit reports completed by an Operations and Maintenance Division has been increasing from 50 reports in 1997 to 65 reports by 1999. Labor inputs have also increased, moving from 400 employee-hours of work in 1997 to 420 employee-hours effort by 1999. The question to be answered is, is labor productivity increasing, decreasing, or static? This is an important concern because it is a measure of organizational productivity. Table 6a addresses the question. By dividing the number of reports produced in each out year by the quantity of reports produced in the base year (1997) and multiplying the results by 100, a percentage is formed producing the Output Indexes in column 2 of Table 6a. This ratio increases from 100.0 in 1997 to 130.0 by 1999. It states that output is increasing over time relative to the base year. Similarly, if the employee-hours for each out year in Table 5a are each divided by the employee-hours in the base year and the result multiplied by 100, another percentage is formed. This is the Input Index as shown in column 3 of Table 6a.

These values grow from 100.0 in 1997 to 105.0 in 1999. Labor input is also growing over time. If the output index is

divided by the input index for each year, a partial productivity index is formed as shown in the last column of Table 5a. This index progresses from 100.0 in 1997, to 117.1 in 1998, and to 123.8 by 1999. Productivity has increased rather dramatically. The task of multiplying each ratio by 100 is a convention which changes a decimal to a percentage and adds no other real value to the results. It is easy to see why the use of partial productivity measures is so popular.

Table 7a provides an example of productivity evaluation using *two outputs* instead of one as was the case in the partial productivity example developed above. More than two are also possible. It is still a partial productivity measure because the two factor outputs are two of the same resources, summed and divided by a single factor input. The example consists of two separate navigation channels in the same district undergoing periodic dredging by a Hopper dredge as part of an O&M operation. This task requires that a 60 foot channel depth be maintained at all times to facilitate vessel traffic and cargo deliveries. The year 1997 is the base year being used for time comparison. The raw data show that the output from the dredging operations results in the removal of 5,700,000 cubic yards of material from channels A and B in 1997 using a total of 281.1 employee-years of work. The same operation continues over time requiring the removal of 5,900,000 cubic yards of material in 1998 using 245.3 employee-years of labor, and the removal of 5,200,000 cubic yards in 1999 using 201.1 employee-years of effort. Both the amount of material removed and the labor resource input fluctuate over time. The question is, is



TABLE 5a
PARTIAL PRODUCTIVITY INDEX

(1) Year	(2) Output (Reports)	(3) Input (Labor Hours)
1997	50	400
1998	60	410
1999	65	420

TABLE 6a
PARTIAL PRODUCTIVITY INDEX

(1) Year	(2) Output Index	(3) Input Index	(4) Partial Productivity
1997	100.0 ¹	100.0	100.0
1998	120.0 ²	102.5	117.1 ³
1999	130.0	105.0	123.8

¹ Base Year: $(50/50) \times 100 = 100.0$ ² 1998: $(60/50) \times 100 = 120$ ³ $(120.0/102.5) \times 100 = 117.1$

this operation becoming more productive, less productive, or unchanged over the three year period?

Table 8a provides an examination of the above question by first weighing output unit labor requirements for the base year. This sets the standard or basis for evaluating labor input for the remaining two out years. For Channel A, the 136.0 employee-years of effort is divided by the 3,000,000 cubic yards

of material removed. For Channel B, the 145.1 man-years of effort is divided by the 2,700,000 cubic yards of material excavated. Both quotients are expressions of inputs per unit of output.

Table 9a carries the analysis one step further by multiplying the base year weighted output labor requirements previously calculated by output dredging quantities for each channel and year. The results are a



TABLE 7a
O & M Dredge Material Removal - 60 Foot Channel
(Program Performance)
Basic Data for Two Outputs

	(Output)	(Input)
1997 (Base Year)	Material Removed (cy)	Employee-Years of Effort
Channel A	3,000,000	136.0
Channel B	<u>2,700,000</u>	<u>145.1</u>
Total	5,700,000	281.1
1998		
Channel A	3,200,000	115.2
Channel B	<u>2,700,000</u>	<u>130.1</u>
Total	5,900,000	245.3
1999		
Channel A	3,500,000	90.2
Channel B	<u>2,700,000</u>	<u>110.9</u>
Total	5,200,000	201.1



TABLE 8a
WEIGHTED OUTPUT UNIT LABOR REQUIREMENTS

	Output 1997	Input 1997	Unit Labor Effort
Channel A	3,000,000	136.0	$136.0/3,000,000 = 0.000453$
Channel B	2,700,000	145.1	$145.1/2,700,000 = 0.000537$

weighted output with a basis anchored in 1997. When the total weighted output for each out year are divided by the base year weighted output, a partial table output productivity is created. This number by itself is a valuable index. In this case, it shows an upward (1998) trend followed by a downward (1999) trend in dredge material excavation relative to the base year. These data suggest that, over the three year period, there has been less shoaling and sediment build-up in the channels thus requiring less dredge material removal to maintain channel depths. As caveated earlier, a single index may not be telling the entire story. Table 10a, described below, adds additional valuable information.

Table 10a illustrates how the input indexes for each year are evaluated. The total employee-year inputs for each year are divided by the base period, employee-year inputs to form a productivity index of inputs. Notice that input productivity is also trending downward over time. This too, is valuable information but suffers the same incompleteness problem as all ratio indexes.

One additional step is needed to form the two output per unit labor series index.

Table 11a shows that, if each of the output indexes developed in Table 9a are divided by each of the input indexes in Table 10a, a ratio of output per unit labor input is formed. This is the two output partial productivity sought. It says that over the 1997-1999 period, the dredge removal operations have become more productive. The amount of output per unit labor input has increased. Stated another way, it is costing less to remove a cubic yard of material in 1999 than it did in 1997. This may be due to improved strategic, tactical, or operational planning, better process management techniques, more experienced labor, or better technology. It may also be a combination of a number of factors. It may stem from the establishment of more definitive goals and objectives as well. Hopefully, it was due to proactive management endeavor rather than happenstance. The reader can now imagine how this tool can be employed to measure changes in productivity and to test alternative management practices against existing



TABLE 9a
DETERMINATION OF OUTPUT INDEX
TWO OUTPUT EXAMPLE

	(Input)				
1997 (Base Year)	Base Year Unit Labor Effort	Output	Weighted Output	Productivity Index	
Channel A	0.000453	x 3,000,000	= 135.9		
Channel B	0.000537	x 2,700,000	= 144.9		
		Total	280.9	100.0	
1998					
Channel A	0.000453	x 3,200,000	= 144.9		
Channel B	0.000537	x 2,700,000	= 145.0		
		Total	289.9	103.2	
1999					
Channel A	0.000453	x 2,500,000	= 113.3		
Channel B	0.000537	x 2,700,000	= 145.0		
		Total	258.3	91.9	
¹ (289.9/280.9) x 100 = 103.2 ² (258.3/280.9) x 100 = 91.9					



TABLE 10a
DETERMINATION OF INPUT INDEXES

Year	Input Employee-Years	Productivity Index
1997	281.1	100.0
1998	245.3	87.3 ¹
1999	200.1	71.2 ²

¹ $(245.3/281.1) \times 100 = 87.3$ ² $(200.1/281.1) \times 100 = 71.2$

TABLE 11a
PRODUCTIVITY INDEXES

Year	Output Index	Input Index	Partial Productivity Output per Employee-Year Input
1997	100.0	100.0	100.0
1998	103.2	87.3	118.2 ¹
1999	91.9	71.2	129.1 ²

¹ $(103.2/87.3) \times 100 = 118.2$ ² $(91.9/71.2) \times 100 = 129.1$

practices to determine whether a newly implemented organizational structure, operational process, or new goals and objectives are having the desired effect. This fits the mandates of GPRA, NPR and APIC quite satisfactorily. Remember also that this technique is useful in measuring the productivity changes of a project, program, or business operation, KRA performance, or system and process performance.

Multifactor Productivity Indexes

Simply defined, *multifactor productivity* is the value of products and services, at constant prices, produced per combined use of labor, capital, and other inputs [Sink, 1983], [Thor, 1994], [Christopher, 1993]. Multifactor productivity is used to help overcome the shortfalls in the use of partial productivity measures. Partial productivity



measures such as labor, capital, energy, etc. fail to capture the role of multiple resource use as occurs when capital and labor are substituted for one-another or when their combined effect is greater than their simple sum. Comparing total output to one input overstates the importance of that input when all inputs have contributed to the output. If one or two inputs dominate the output process this situation is not critical, but, if multiple inputs are used, then a distortion in interpretation can result. Multifactor productivity reflects the *joint effects of a mix of labor, capital, and other resources* used to obtain a given output. These include the effects of not only labor and capital, but implicitly technology, management skills, economies of scale, knowledge, among others, as well. Multifactor productivity takes the general form:

$$\text{Productivity} = \text{Total Output} / [\text{Capital} + \text{Labor} + \text{Technology} + \text{Materials} + \dots + \text{N}]$$

where capital, labor technology, materials, and N are any resource *inputs* which the analyst wishes to include. Multifactor performance measurement has its basis in market oriented institutional analysis but can be adopted to fit the exploration of government "firms" as well.

Multifactor measures show changes in many factors of production per unit of output over a span of time. They are more complex to adopt and often require financial and economic adjustments before they are used. The most common factor in the denominator next to labor (and often included with labor) is capital.

Using *capital* is one of the more popular and most difficult variables to incorporate in productivity measurement. Capital is the *stock value* of buildings, equipment, inventory, and the value of land. The equipment aspect of capital often explicitly includes technology; this is most apparent in computer technology, FAX machines, Xerox equipment, etc. The communications "super highway" is, in part capital, and is one of the more significant reasons capital can add dramatically to productivity. All of these go into the production of products and services as does labor. Notice that, in order to evaluate this ratio, all values must be in the same units. In order to use capital to measure performance it must be converted into a service measure or flow concept. Labor (the verb), on the other hand, is already a service flow. This conversion can become an intractable problem involving a considerable degree of accounting experience and depreciation analysis. In order to use capital as a resource input cost along with labor, it must be converted from a physical asset into an annual rental price. This has the effect of transforming capital into a flow concept because it converts stock values into annual values. For example, what does a \$2,000,000 building (stock value) rent for on an annual basis (flow concept), is a stock-to-flow concept. By definition, rental income from constructing such a building must cover the cost of the owner to pay off the construction debt (mortgage). Hence annual rent collected converts stock value (building construction or purchase price) into an annual payment. The analyst must search the market for the rental cost of the equipment, buildings, inventory,



and land stock. Once converted into a flow, the process allows all capital to be aggregated into one capital input. Rental prices are termed in rates per constant dollar of capital stock. Each rental price is adjusted for constant dollar capital stock to obtain current dollar capital cost. These are then converted into value shares by various methods. The process is elaborate. Multifactor indexes, however, remain extremely valuable indexes to develop and use for measuring performance.

There is another simpler way to estimate capital flows which will allow it to be expressed in annual terms, added to labor input, and used together to produce a multifactor productivity ratio. The method is easier (but a little less accurate) than the rental price approach. In order to utilize multifactor analysis as a performance tool, an example of how to construct this very useful measure will be covered in the following paragraphs.

Table 12a illustrates an example of what information is needed and how it is employed to generate multifactor indexes. The example portrays the district level of organization and is close to reality as data were taken from several district budget packages, rounded and averaged. The table consists of four columns showing the resource information need, the year 1997, the year 1998, and the productivity indexes generated, respectively. There are also twenty rows showing how the information is used. Some of the rows are self explanatory but others will need elaboration.

Row 1 shows output or what a district might call its annual budget. It is the amount of funds received to carry out its mission.

Columns 2 and 3 show monies that are not part of the district's innate productivity but represent the work activities of others. Contract construction funds are mostly absorbed by construction activities-not Corps activities. Similarly, consultant contracts are work done by others that fill-in or enhance district work. Again, this does not represent funds directly used by a district--someone else is doing the work. The point to be made is that these portions of the budget must be deducted from total appropriations because they do not directly reflect work done by district employees, management or supervision. Since contract dollars do not reflect COE productivity and are removed from analysis for this reason, a cost adjustment must also be made for contract support expenses such as contract administration, monitoring, processing, etc. This is not shown as a separate line item but is included in items 2 & 3 of the table. We do not want to mix the productivity of work being done by others with that being done directly by the indigenous work force. This would distort the results by mixing our productivity with that of others. Thus the sum of these two exogenous funds need to be deducted from total appropriations as shown in row 4-adjusted output.

Prior to going further, a new concept needs to be introduced called "waste". As described earlier, "waste" consists of transit time, time, waiting time, review time, and rework time. These were mentioned earlier. These four factors can actually be measured by keeping track of how much time each employee spends on each and summed, say, by project. These topics will be covered



TABLE 12a
EVALUATION OF PARTIAL AND MULTIFACTOR PRODUCTIVITY RATIOS
 (Assume Dollar Value Adjusted for Inflation)

(1) Resource	(2) 1997 (Base Year)	(3) 1998	(4) Partial Productivity & Performance Ratio Col. (3)/(2)
1. Gross Output (Budget) (\$)	150,000,000	130,000,000	0.87
2. Construction Expenditure (\$)	-82,000,000	-60,000,000	0.73
3. Contracts for Labor (\$)	-5,000,000	-8,000,000	1.60
4. Adj. Output (1-2-3) (\$)	63,000,000	62,000,000	0.98
5. Input, Employees (or FTE's)	400	350	0.88
6. Avg. Cost Per Employee ¹ (\$)	105,000	108,000	1.03
7. Total Payroll Value (5 X 6)(\$)	42,000,000	37,800,000	0.90
7a. Payroll Adj for Waste (7 - \$ waste)	35,000,000 (-7,000,000)	35,800,000 (-2,000,000)	1.02
8. Input, Hours Per Yr (FTE X 2080)	832,000	728,000	0.88
9. Input, Capital ² (\$)	18,418,000	19,300,000	1.05
10. Depreciation Rate	6%	6%	-----
11. Depreciation Expenses (6% X 9) (\$)	1,105,000	1,158,000	1.05
12. Long Term Return on Market Investments	10%	10%	-----
13. Imputed Returns (10% X 9) (\$)	1,842,000	1,930,000	1.05
14. Annual Capital Input (11 + 1 3)(\$)	2,947,000	3,088,000	1.05
14a. Capital Adj. For Waste (14 - \$ waste)	2,247,000 (-500,000)	2,988,000 (-100,000)	1.33
15. Output Per Employee (7a/5)	87,500	102,286	1.17
16. Capital/Labor Ratio (9/5) or (14a/5)	46,045	55,143	1.20
17. Output Per Hour (4/8)	75.72	85.17	(1.13)
18. Output Per Sq. Ft. Bldg. (95,000 s.f.) 18.	663.16	652.63	(0.98)
19. Output/Capital Ratio (4/14)	21.38	20.08	0.59
20. Multifactor Productivity 4/ (7a + 14a)/4	0.59	0.63	1.07

1 Includes salaries and all other benefits 2 Includes buildings and other fixed and movable assets.



in more detail later in the text but a brief description is needed at this point. First, waste is described from the customer's vantage. It is anything which prevents them from getting the desired product and service at the least cost, on time, and of expected or better quality.

While transit time in the COE is a relatively minor delay factor it nonetheless takes time away from the customer receiving the product or service desired.

Waiting time is a major delay factor in the COE process. It is the time projects spend in the queue waiting to be processed. It is not uncommon for a study to wait months for data, decisions, priority, or higher level guidance.

Review time is another significant delay factor in work completion. It is the time projects and studies spend undergoing internal and external review. Review often results in lengthy "discussions" about methodology, technique, and regulatory fulfillment. It is the source of substantial delays and added expenditures.

Rework time is another resource-consuming effort. This involves corrections of errors, reformulation, redesign, etc., often following customer and higher level review and comment. The four major waste factors detract from getting things done. They cost unnecessary expenditures and delay product and service delivery. In some cases they constitute 80 to 90 percent of productive time; 6 to 7 hours out of a typical work day to produce nothing. This topic will be covered in more detail later in the text but suffice to say that it is a much larger issue than most management is aware of. The

following paragraphs provide a hint of the importance of waste.

Rows 5, 6, and 7 are connected. The number of employees is multiplied by their average compensation to arrive at the cost of labor input. This is total compensation including wages and salaries, retirement contributions, insurance, et al. Note also the meaning of this number. In the framework of what was discussed earlier, it represents the value of employee, management, and supervisory input providing needed public products and services--the studies, dredging management and other services provided by the COE. Row 7 shows a \$63,000,000 adjusted appropriation for the year 1996 and a \$62,000,000 adjusted figure for 1997. Row 7a is payroll adjusted for waste. The idea here is that due to waste 100 percent of work time is not actually provided and detracts from real payroll productivity. Time spent on transit activities, review, rework, and waiting are unproductive dollars. In 1997 this figure is shown to be \$7,000,000. The dollar figures used are hypothetical and used for illustration only.

Rows 9 through 14 represent an analysis of capital input to the development of the multifactor index. Row 9 represents the capital stock value of a district--the sum total of all that it is worth in terms of building, land, equipment, et al. This was mentioned earlier as the stock of material that must be converted to an annual flow value. To make this conversion, the value of the stock must be depreciated over time to show how much of each type of asset is being "used up" over time. Technically, this depreciation should be done by asset type such as land, buildings, equipment and other fixed and movable



break-outs. The reason for this is that different assets depreciate at different rates (a building may depreciate at 2 percent a year over 50 years whereas a computer may depreciate at 20 percent over five years). An added complication is that new equipment is constantly being bought and mixed with older equipment making the deployment of depreciation rates more difficult. The example here is simplified so as not to get lost in the forest for the trees. Depreciation represents a cost of doing business; assets are used up and their worth diminishes representing a cost. They must be replaced over time with new assets. The overall depreciation rate used here is estimated at 6 percent per annum. There are methods and sources to determine a more accurate figure. Row 14a is a reflection of waste expended in unproductive use of capital. It is quite similar to waste on the labor input side. When labor is wasted so is the capital used to support it. Thus, it is appropriate to deduct capital waste from capital productivity to reflect its true effect. In 1997 waste amounted to \$500,000 in capital used in unproductive endeavors.

Rows 12 and 13 are a little more complex. In this case the purchase of an asset or capital good is an investment. The cost of that investment is what the money expended to buy it could earn if invested elsewhere. In this case if the \$18,418,000 were invested in long term securities it would yield a 10 (example only) percent rate of return or \$1,820,000 in annual income-an imputed return of money. In other words, if the capital item purchased cannot earn at least 10 percent, invest the money in long term market securities. Since it is anticipated that your investment can exceed this rate of

return, the decision is to proceed with the investment. The land, equipment, building are then expected to yield a return greater than 10 percent otherwise it would not be rational to make an investment earning less. If the building is being leased, its rental value can be used as a substitute for annual mortgage expenses. If it is owned, then an equivalent building's rental value can be used as a proxy measurement for building costs. This is what economists call the opportunity *cost of capital*. The concept helps assure that the most efficient expenditures of funds are made. This too, is an annual figure. What is implicit in this is that the purchase or investment by the government in equipment, buildings, and land (i.e. a district) will yield at least 10 percent to the general public in terms of social good of water resources projects.

Row 14 provides the final value for capital cost. It is the sum of annual depreciation costs (\$1,105,000) and annual opportunity costs (\$1,842,000) or \$2,947,000. This, like the labor cost cited above, is a cost of doing business. It is capital stock cost converted from a "lump" value \$18,418,000 into an annual flow value so it can be added to labor cost. The concept is no different than converting the purchasing price of a home-say \$100,000 (capital cost) into annual mortgage payments (annual cost flow) of say \$400 per month times 12 months or \$4,800 per year. The same analysis holds true for the 1997 figures.

Rows 15 through 19 will be skipped for the moment so that the final multifactor index can be finalized. Recall that a multifactor index is the ratio of the value of output to the value of all inputs--the definition of



productivity described earlier. We developed only two inputs in this case, labor and capital, largely to simplify the analysis but also because labor and capital represent the vast majority of production costs--about 70 percent at the district level. We do not need to account for all factors of production to arrive at a performance indicator. As long as there is consistency in enumeration and the other factors of production (supplies, energy, etc) are not expected to dramatically change, we can utilize the main controllable factors in generating a performance measure. Our final multifactor index for 1997 is found by dividing the sum value of waste adjusted payroll and waste adjusted capital by adjusted output.. That is: $(\$35,000,000 + \$2,247,000)/\$63,000,000 = 0.59$. Notice that as waste decreases the numerator of the expression increases which is reflected in the index increasing. It should be recognized that the maximum value of this index in 1997 in this case would be: $(\$42,000,000 + \$2,947,000)/\$63,000,000 = 0.71$. Insight can be gained by examining the factors that result in an index of 1.00. The question is, why is there a difference between \$63,000,000 and the sum of labor and capital (\$44,947,000) or \$18,053,000. These are both valuable things to know. It is not the level of the index value that is of particular importance. It is the change from period to period that is important. The multifactor value for 1997 changed to 0.63 from 0.59. It rose because the number of employees declined and waste decreased substantially, driving down the cost of labor to a greater extent than output declined. The reader can now explore what drives productivity up and what drives it down.

Rows 15 through 19 contain valuable performance information most of which are spin-off values from calculating the multifactor index. Row 15 shows output per employee which is a partial productivity index. Notice that the numerator is waste adjusted. This index would also increase as waste decreases. It can be tracked over time and benchmarked with others for comparison.

Row 16 shows the amount of capital used by each employee. The adjusted or unadjusted ratio can be used depending upon what the user wants to use the information for. The question here is what capital improvements can be made to improve productivity? Clearly, we know that computers have done a great deal to improve productivity during the last twenty years. They can improve multifactor performance by driving down the cost of doing business--allow us to do more with less. Total cost may increase by purchasing more productive capital but cost per employee should go down. The relationship of capital to labor can be explored with the use of this ratio.

Output per hour is also a very useful analytical tool. It addresses the amount of output generated by each hour of process time. It can also be used to determine performance improvement over time and for benchmark comparisons.

Output per square foot of building space (row 18) is useful to determine the efficiency of space utilization. A good deal of comparative data is available on this factor. It is a frequently used index and a measure of efficiency and productivity.

Row 19 is the ratio of output to capital discussed earlier. Again the adjusted or



unadjusted versions can be used. It shows the partial productivity of output relative to capital input only. Since the capital cost involved in this example is small compared to labor input costs it has a small impact on productivity.

Column 4 has been ignored until now. Notice that the values in this column are generated by dividing the measures in the out year by those in the base year. This forms many of the ratio indexes discussed earlier and some of the partial productivity measures discussed as well.

The table is a very comprehensive look at an organization's over-all performance with important detailed information. The data can be used for year to year comparisons or can be benchmarked against other districts (division, offices, branches, et al). It shows the formation of many of the performance measures used by the private sector. It is designed to show the contribution of a number of resources to the expenditures of appropriations. In a public sector context, it is very useful in analyzing cost and as a cost control monitor. Variations of the tool are possible such as in monitoring overhead in relation to output. Output need not always be expressed in financial terms. It could just as well have been expressed in physical terms such as the number of reports, cubic yards of dredging, recreation visitors, etc. Since it is difficult to express white-collar output (services) in tangible terms it was left portrayed as a value-added service.

Factors that affect productivity usually include training, employee experience (knowledge), capital, technology, innovation, and management-especially management of processes. Knowledge is now believed to be

one of the most important tools for increasing productivity of the service worker [Drucker, 1991]. The impact of each of these will depend upon the organization and the customers served. "*Productivity is not working harder or longer, but working smarter*" [Drucker, 1991].

Simple Aggregate Indexes

The simple aggregate index takes two forms: the cost index and the quantity index. The *simple aggregate cost index* is one way of dealing with the problem of inflation mentioned earlier. It involves adding up all costs for each item included in the cost index during each succeeding period and dividing each of the sums by the sum of the process in the base year. For example, Table 13a shows three costs items (land purchases, concrete, and labor) used in the construction of a flood control project valued in the base year 1994.

If C_o represents the cost of an item in the base year and C_n the cost in a given year for which we are evaluating an index number, the simple aggregate index number is equal to:

$$I = \sum C_n / \sum C_o \text{ for cost analysis}$$

$$I = \sum Q_n / \sum Q_o \text{ for quantity analysis}$$

where:

I = Index value

C_o = Cost in base period

C_n = Cost in period n

Q_o = Quantity in base period

Q_n = Quantity in period n





TABLE 13a
SIMPLE AGGREGATE INDEX

YEAR	LAND COSTS	CONCRETE COSTS	LABOR COSTS	TOTAL COSTS	INDEX NUMBER
1994	\$25,000/Ac	\$7.00/cy	\$45.00/hr	\$25,052.00	100.0
1995	\$27,000	\$7.20	\$46.00	\$27,053.20	108.0
1996	\$32,000	\$7.45	\$44.00	\$32,051.45	127.9

The *simple quantity* index needs special attention. The relative influence of the quantity items in the index are not tied to their relative importance and the units of measurement are intermixed—the apples and oranges dilemma. Note that cubic yards of concrete cannot be added to per hour labor cost or land cost per acre. Each item is essentially given the same weight but clearly some of the values can be much larger than others. The influence is effectively inherent in the units in which items are quoted. This approach clearly has limited use. If the items being indexed are of the same units and order of magnitude is not important, this is an excellent tool. Units are being mixed and orders of magnitude are not being reflective of relative item importance to the total cost.

Simple of Average-of-Relative Index

It is possible to eliminate the influence of units in an index by first calculating the relative cost for each item and then finding the *average of relatives*. This is illustrated in Table 14a. The equation for this is expressed as:

$$I = \sum(C_o/C_n)/N \text{ for cost analysis}$$

$$I = \sum(Q_o/Q_n)/N \text{ for quantity analysis}$$

where:

- I = Index value
- C_o = Cost in base year
- C_n = Cost in year n
- Q_o = Quantity in base year
- Q_n = Quantity in year n
- N = Number of observations

While this approach overcomes some of the unit cost problems experienced earlier, it is encumbered by the problem of equal weights for each of the cost items. Both the simple aggregate and simple average-to-relative methods cannot contend with the problems of weights. The weights do not reflect the importance of the cost variables involved. Alternatively, each cost element is being weighed equally in the analysis. These problems can be overcome by use of a weighting process.

Weighted Aggregate Indexes (Laspeyres' Indexes)

The *weighted aggregate* index is designed to handle problems of item importance in the construction of index numbers. The most popular method is to use the cost or quantities produced during the base year. Note that this index can be used to evaluate both *cost factors* and *quantity factors*. In this manner the units in which the costs or quantity variables are being measured have no impact on the index. This technique is known as the *Laspeyres' index* and the basic expression for this index is:

$$L = \sum[(C_n Q_o / C_o Q_o)] \times 100$$

the cost index (base year quantity
wts)

$$L = \sum[(Q_n C_o / Q_o C_o)] \times 100$$

the quantity index (base year cost
wts)



TABLE 14a
SIMPLE AVERAGE-OF-RELATIVES INDEX

Year	Land Costs	Concrete Costs	Labor Costs	Total Costs	Index Number
1994	100.0	100.0	100.0	300.0	100.0
1995	108.0	102.9	102.2	313.1	104.4
1996	128.0	106.4	97.8	333.2	111.1

where:

- L = Index value
- C_n = Cost in out year n
- C_o = Cost in base year
- Q_n = Quantity in out year n
- Q_o = Quantity in base year

Table 15a demonstrates how to apply this index. In this example, project productivity will be explored using inputs and the *fixed quantity version* of the index. The example presents energy, capacity, and labor activity measured as inputs in kilowatt-hours (kWhrs), kilowatts (kW), and work hours, respectively. Notice that this index is a composite ratio in that it can provide a more complete picture of what is going on because it takes into account the diverse characteristics involved in measuring complex interactions. Simple ratios cannot simultaneously consider any more than one characteristic at a time. The KRA's examined

in this example are customer care and cost per unit; two entirely different items. The background issue and question lies in addressing the concern, is the O&M provision of hydropower to the community a productive endeavor? The question must be addressed to determine whether a needed expansion of energy for future use should come from hydropower or from coal fired plants. The required energy facilities (plant and equipment) can be constructed for about the same costs (added turbine vs a coal plant expansion). The operation and maintenance cost is the deciding variable. The hydropower operation is divided into three operating components: for energy generation it is the O&M cost per kW/hr, for capacity maintenance it is total cost per kW of capacity, and for labor cost it is the cost of labor.

Column (1) of Table 15a shows that we are examining energy costs over time for a *fixed amount* of energy-100,000,000 kWhrs. This is done so that we can check the cost of



TABLE 15a
WEIGHTED AGGREGATE COST INPUT INDEX: FIXED QUANTITIES
PROJECT PRODUCTIVITY

	(1) ENERGY KRA: CUSTOMER CARE			(2) CAPACITY KRA: CUSTOMER CARE				(3)		(4)	(5)
YEAR	O & M REVENUE PER Kwhr	100 x 10 Kwhrs	TIME RATIO	TOTAL REVENUE PER Kw	1,000 X 10 ⁶ Kw	TIME RATIO	LABOR COST PER HR	10 EMPLOYEE S (2080 HRS/YR)	TIME RATIO	TOTAL WEIGHT- ED COST	INDEX VALUE
1994	\$0.01000	\$1,100,000	100.0	\$0.0040	\$40,000	100.0	\$45.00	\$936,000	100.0	\$1,976,000	100.0
1995	\$0.01100	\$1,100,000	110.0	\$0.0045	\$45,000	112.5	\$46.00	\$956,800	102.2	\$2,101,800	106.4
1996	\$0.01300	\$1,300,000	130.0	\$0.0048	\$48,000	120.0	\$46.50	\$967,200	103.3	\$2,315,200	117.2
Etc.											



energy generation over time for a base year *fixed quantity*. This is no different than comparing what a house, automobile, or groceries of the same quantity used to cost in the "good old days". Note that the O&M cost per kWhr is increasing. If we multiply this constant amount of energy by increasing cost per unit, then we arrive at a total cost for each year for maintaining and operating energy output (excluding labor). Immediately the ratio of out year to base year can be determined as shown by the increasing values from 100.0 in 1994, to 110.0 in 1995, and to 130.0 by 1996. This is the ratio (over time) index discussed earlier. It shows that the cost of providing energy has increased by 10% in 1995 and by 30% by 1996 compared to the base period of 1994.

Column (2) shows essentially the same process but is applied to capacity cost over time. Capacity is fixed at 10,000,000 kW and the cost to maintain this capacity also increases. If we multiply this constant bundle of power by the increasing costs per unit, then costs are observed increasing from year to year for capacity as they were for energy. The time driven ratio shows the rate of cost increase.

Column (3) adds the labor component to hydropower costs. It is evaluated in the same manner as were energy and power with the ratio indicating an increasing rate.

To arrive at an aggregate productivity index for all three factors simultaneously, we add all the products as shown in Column (4). *Note that the size of the numbers are weighed by their relative importance.* Energy and labor dominate the figures, and this is reflected in the totals. The more significant numbers have the largest impact on the

totals. If the ratio of the base period (1994) sum in Column (4) is divided into the out year values, then an aggregate index for all three factors is created. The index values in Column (5) shows that prices are increasing in total. An examination of the values in Column (1) reveals that energy is the dominate factor because it is made up of large values and because its rate of growth is also the most significant.

Five important ideas are represented in Table 14a. First, the *units problems is avoided*. The factors in the weighing process turn all the units into total costs. Second, the *size problem is avoided* because each factor is weighted according to its relative size. Third, *all original data are retained* so that each factor can be examined individually for its effect on the total index; nothing is lost in computing the aggregate index. Fourth, the tables illustrated the use of three performance measures at one time. *There is nothing to prevent the user from employing 5, 6, or 10 aggregate measures* in one table. One last matter of utility is that this type of tabulation can be provided by each district to its division office where they can be *combined* to represent a division total. This is an excellent way to compare performance between COE divisions and a potential benchmark setter.

Table 16a represents another aggregate index evaluated in the same manner as in the previous example. It is a weighted output index using *fixed output quantities*.

Table 17a shows this process. If we divide the output and input aggregate indexes from Tables 15a and 16a respectively, we arrive at an index reflecting the definition of productivity: output/input. Used in this



TABLE 16a
WEIGHTED AGGREGATE OUTPUT INDEX: FIXED OUTPUT QUANTITIES

[illegible]

TABLE 17a FINAL OUTPUT/INPUT RATIO INDEX			
YEAR	INPUT INDEX	OUTPUT INDEX	FINAL PRODUCTIVITY INDEX
1994	100.0	100.0	100.0
1995	106.4	136.4	128.1
1996	117.2	164.2	140.1

manner, we observe that the new ratio goes from 100.0 in 1994, to 128.3 in 1995, and finally 140.1 by 1996. This shows that hydropower output is growing faster relative to O&M costs over time. Hydropower productivity is thus increasing over the three year period. To get the most from this analysis we would have to conduct the same calculations for the coal fired alternative as a reference or benchmark-the original comparison question.

The example provided in Tables 15a, 16a, and 17a employed weighted aggregate index methodology to evaluating the performance of a project. This project consisted of an O&M hydropower operation. It could have just as well been a flood control, navigation or other mission activity. Table 18a uses the same techniques for evaluating program performance. In this example only one table is used showing the

weighted aggregate program productivity index (*using fixed quantities*) without the input/output aspects as with previous examples. The three attributes being evaluated in this case are schedule slippages, unspent obligations, and late contractor payment penalties. The KRA for these three attributes are tied to program performance.

The "SCHEDULE SLIPPAGES" performance attribute shows that 12 months worth of slippages costs at least \$100,000 per slippage (average start up expenses, carry-over costs, etc.) and will cost the taxpayers \$1,200,000 in 1995. In 1996, this same 12 month slippage increases in value due to salary increases of \$110,000 yielding added costs of \$1,320,000 in tax burden. By 1998 and 1999, added costs climb to \$1,380,000 and \$1,440,000, respectively. The simple time ratio index alone shows what is happening. Costs relative to the base year





TABLE 18a
WEIGHTED AGGREGATE PROGRAM PRODUCTIVITY INDEX: FIXED QUANTITIES

YEAR	(1) SCHEDULE SLIPPAGES KSA: PROGRAM MGMT.				(2) UNSPENT OBLIGATIONS KSA: PROGRAM MGMT.				(3) LATE CONTRACTOR PAYMENT PENALTIES			(4)	(5)
	COST PER SLIPPAGE	12 MONTHS WORTH OF SLIPPAGE	TIME RATIO	AVG. AMOUNT EACH	4 PROGRAM BASIS	TIME RATIO	COST PER CONTRACT	15 LATE PAY PER YEAR	TIME RATIO	TOTAL WEIGHTED D COST	INDEX VALUE		
1995	\$100,000	\$1,200,000	100.0	\$500,000	\$2,000,000	100.0	\$20,000	\$300,000	100.0	\$3,500,000	100.0		
1996	\$110,000	\$1,320,000	110.0	\$500,000	\$2,000,000	100.0	\$15,000	\$225,000	75.0	\$3,545,000	101.3		
1997	\$115,000	\$1,380,000	115.0	\$500,000	\$2,000,000	100.0	\$13,000	\$195,000	65.0	\$3,570,000	102.0		
1998	\$120,000	\$1,440,000	120.0	\$500,000	\$2,000,000	100.0	\$11,000	\$165,000	55.0	\$3,605,000	103.0		

have increased by 10% in 1996, 15% in 1997, and 20% by the year 1998. A similar analysis is done for "UNSPENT OBLIGATIONS" and "LATE CONTRACTOR PAYMENT PENALTIES". The dollar cost totals are added horizontally and divided by the base year sum to provide the aggregate index value in column (5). The "SCHEDULE SLIPPAGES" problem overrides the other attribute resulting in an index value that is gradually rising from 100.0 in 1995 to 103.0 in 1998 despite decreasing "LATE CONTRACTOR PAYMENT PENALTIES". The previous example was designed to demonstrate three important factors. One, the weighted aggregate productivity index can be applied to program analysis. Secondly, a dominating attribute such as "SCHEDULE SLIPPAGES" will out-weigh a rapidly declining cost such as "LATE CONTRACTOR PAYMENT PENALTIES". Last, an input and an output table are not both needed to form a useful performance measure. Tables 19a and 20a show yet another application of the weighted aggregate index approach to performance measurement. The goal in this case is organizational performance (as opposed to project or program performance). The details are left to the reader, but two things are important to note in Tables 19a and 20a. One is that the index applies equally well to evaluating organizational performance. Two, notice that waste, rework and error in Table 19a are increasing from 1995 to 1996, then begin to decline in 1997. Table 20a shows the reason. Increased management effort in controlling these problems through the use of quality

control charts, personnel training, and review time have impacted the downward direction. Increased proactive management efforts have caused an impact; and it is measurable with the use of this index. The adverse output has been reversed by increased corrective inputs revealing the efficacy of this tool to show a cause and effect link.

Table 21a shows the relative impact of dividing the above calculated output and inputs (Tables 19a and 20a) to arrive at a final productivity index. It is taking relatively more corrective dollar input effort to get a dollars worth of process improvement. The effort is paying off because the magnitude of the decreases in waste, rework, and error outweighs costs.

Tables 22a and 23a are similar to other weighted aggregate productivity tables with the exception that *costs are fixed* rather than quantity. In this situation the analyst can observe the effects of varying quantities over time. In some circumstances costs are relatively stable and insensitive relative to quantity variances. That is a 5% change in quantity has a greater impact on total expenditures than a 5% change in costs. This is a phenomenon economists call elasticity. It occurs when costs are not directly proportional to quantities purchased or used. It is a situation frequently experienced in cost estimating although most cost estimators are not always aware of the concept. This form of productivity measurement is broadly used by many government agencies and the private sector of the U.S. economy.



TABLE 19a ORGANIZATIONAL PRODUCTIVITY PERFORMANCE WEIGHTED AGGREGATE INEFFICIENCY OUTPUT COST: FIXED QUANTITIES										
(1) WASTE KSA: INTERNAL COST				(2) REWORK KSA: INTERNAL COST				(3) ERRORS KSA: INTERNAL COST		
YEAR	COST OF DELAY PER MONTH	A 12 MONTH BASE DELAY	TIME RATIO	COST PER REPORT	A BASE 7 REPORT YEAR	TIME RATIO	ERROR CORRECTION COST/PAGE	A TYPICAL BASE 100 PAGE REPORT	TIME RATIO	TOTAL WEIGHTED COST
1994	\$25,000	\$300,000	100.0	\$100,000	\$700,000	100.0	\$6.00	\$600	100.0	\$1,000,600
1995	\$28,000	\$336,000	112.0	\$110,000	\$770,000	110.0	\$6.25	\$625	104.2	\$1,106,625
1996	\$28,000	\$336,000	112.0	\$108,000	\$756,000	108.0	\$7.00	\$700	116.2	\$1,092,700
										109.3

TABLE 20a ORGANIZATIONAL PRODUCTIVITY PERFORMANCE WEIGHTED AGGREGATE RESOURCE INPUT COST: FIXED QUANTITIES										
(1) QUALITY CONTROL CHARTS KSA: COST PER UNIT				(2) TRAINING KSA: COST PER UNIT				(3) REVIEW TIME KSA: COST PER UNIT		
YEAR	COST PER MONTH	12 MONTH BASIS	TIME RATIO	COST PER EMPLOYEE	BASE 50 EMPLOYEE PER YEAR	TIME RATIO	COST PER REPORT	A BASE 7 REPORT YEAR	TIME RATIO	TOTAL WEIGHTED COST
1994	\$3,000	\$36,000	100.0	\$800	\$40,000	100.0	\$7,000	\$49,000	100.0	\$125,000
1995	\$4,000	\$48,000	133.3	\$950	\$47,500	118.8	\$8,000	\$56,000	114.3	\$151,500
1996	\$4,800	\$57,600	160.0	\$1,100	\$55,000	137.5	\$9,000	\$63,000	128.6	\$175,600
										140.5



TABLE 21a
FINAL PRODUCTIVITY INDEX

YEAR	OUTPUT INDEX	INPUT INDEX	FINAL PRODUCTIVITY INDEX
1995	100.0	100.0	100.0
1996	110.2	121.2	90.9
1997	109.3	140.5	77.8

The Consequences of Declining Productivity

Many public institutions believe they are immune or cushioned from the consequences of declining productivity; to the point of not even measuring them. This leads to catastrophic results in the long run. Today, with the enormous interest in productivity and efficiency, this philosophy is beginning to take its toll. Declining productivity is a deadly trap! The cause and effect consequences are strong and clear. The spiral goes like this:

Productivity decreases(-) = Cost per unit output increases(-) = Less competitive(-) = Customers fade away (-) = Need declines(-) = Adverse impact on capital, materials, employees(-) = Further declines in productivity.....an so-on.

Increasing productivity has the opposite impact:

Productivity increases(+) = Cost per unit output decrease(+) = More competitive(+) = Customer demand grows(+) = Need increases(+) = Positive impact on capital, materials, employees(+) = Further improvements in productivity.

The effects of changes in productivity do not stop with productivity itself but spill over onto efficiency and effectiveness; our performance measures and the target of GPRA. Government institutions do not realize that the world has changed over the last two decades. The world is finding more and more substitutes for public works: contracting out, customers doing it themselves, more subsidies of capital for labor, foreign competition, etc.



TABLE 22a
ORGANIZATIONAL PRODUCTIVITY
WEIGHTED AGGREGATE INEFFICIENCY: FIXED COSTS

YEAR	(1) WASTE KSA: INTERNAL COST			(2) REWORK KSA: INTERNAL COST			(3) ERRORS KSA: INTERNAL COST			(4)	(5)
	MONTHS OF DELAY	A 25,000 DELAY COST PER MONTH	TIME RATIO	NUMBER OF RPTS	\$100,000 COST PER REPORT	TIME RATIO	NO. OF PAGES	\$6.00 PER PAGE COST	TIME RATIO	TOTAL WEIGHTED COST	INDEX VALUE
1995	4	\$100,000	100.0	5	\$500,000	100.0	100	\$600	100.0	\$600,000	100.0
1996	6	\$150,000	150.0	6	\$600,000	120.0	150	\$900	150.0	\$750,900	125.0
1997	10	\$250,000	250.0	7	\$700,000	140.0	200	\$1,200	200.0	\$951,200	158.4

TABLE 23a
WEIGHTED AGGREGATE RESOURCE COST: FIXED COSTS

YEAR	(1) QUALITY CONTROL CHARTS KSA: COST PER UNIT			(2) TRAINING KSA: COST PER UNIT			(3) REVIEW TIME KSA: COST PER UNIT			(4)	(5)
	NUMBER OF MONTHS	COST PER MONTH \$3000	TIME RATIO	NUMBER OF EMPLOYEES	AVG. COST PER EMPL. PER YEAR \$800	TIME RATIO	NUMBER OF REPORTS	COST PER REPORT \$7000	TIME RATIO	TOTAL WEIGHTED COST	INDEX VALUE
1995	6	\$18,000	100.0	50	\$40,000	100.0	4	\$28,000	100.0	\$86,000	100.0
1996	8	\$24,000	133.3	70	\$56,000	140.0	7	\$49,000	175.0	\$129,000	150.0
1997	10	\$30,000	166.7	100	\$80,000	200.0	11	\$77,000	275.0	\$187,000	217.4





A.2. KNOWLEDGE PRODUCTIVITY

Over 25% of the growth in productivity in the U.S. from 1948 to 1981 came from increases in education per worker [BLS, 1983]. This is a significant factor and should not be down-played. The usual response of management to low productivity growth is to employ more labor saving capital or work employees longer and harder. This is no longer the best response to the problem.

"In fact, knowledge is the only meaningful resource today. The traditional "factors of production"--land (i.e. natural resources), labor, and capital--have not disappeared, but they have become secondary. They can be obtained and obtained easily, provided there is knowledge. And knowledge in this new sense means knowledge as utility, knowledge as the means to obtain social and economic development" [Drucker, 1990].

Given the importance of this characteristic of productivity, it may be wise to develop and utilize a knowledge productivity index. Knowledge in the context of how it is being used today is defined to include: education, training, skill development, experience, information gathering, and information analysis and distribution. To be useful, knowledge must not only be "mechanical" in nature but "tacit" as well. *Tacit knowledge is the ability to merge academic training and experience to synthesize new knowledge.* It is part of the "information highway" and "cyberspace". Table 24a illustrates some of the more useful measures of knowledge. Notice that the

indicators can be group averaged or presented as an over-all average.

A knowledge "quick check" is demonstrated as follows: knowledge capability = average years formal schooling x average years of professional experience x no. of FTE's or (example: 15.6 average years formal schooling x 15.6 average years professional experience x 400 FTE's = 102,960 knowledge years). It contains less detail than the tabulated data but is none-the-less a fairly good indicator. The indicator blends the effect of academic training, career experience, and the number of personnel into one measure.

These can be used to "benchmark" against those organizations which are noted to be the best in a particular product or service as a guide-post. How are the leaders in business using knowledge to increase productivity, efficiency, and effectiveness? Comparisons of knowledge indicators against others and over time may yield some valuable information.

Efficiency

Efficiency is another simple but useful measure of performance. [Stevenson, 1993]:

$$\text{Efficiency} = \frac{\text{Actual Output}}{\text{Effective Capacity}}$$

Effective capacity is *the maximum amount of output given an activity or process mix, scheduling problems, equipment maintenance, quality parameters, etc.* [Stevenson, 1993]. Productivity and



efficiency are often confused. Efficiency pertains to getting the most out of a given set of resources [Stevenson, 1993]. Productivity pertains to effective use of all resources and is a narrower concept than efficiency. It is a subset of efficiency. It has been described as the ratio of resources expected to be consumed to resources actually consumed [Sink, 1985]. For example, efficiency would be described as using an engineer to draft engineering drawings given a drafting table, compasses, triangles, etc. If this is the only resource available to do that task, then it is an efficient operation. Productivity would be realized by using a technician to do the same task, working with a CAD system. An example of an efficiency calculation would go as follows:

The effective capacity of a new FAX machine is five pages per minute. The same FAX machine in your office is three years old and typically operates at three pages per minute. The efficiency of your machine is down to: $3 \text{ pages} / 5 \text{ pages} = .60$ or 60%.

Table 25a provides additional examples of calculating efficiency for different situations. If these ratios are under 1.00 this is an indication that performance improvements are warranted. They serve as indicators and diagnostic tools for motivating change. As the examples indicate, efficiency can be applied to project performance or organizational business practices. This is the case for all performance indicators presented in this report.



TABLE 24a
KNOWLEDGE PERFORMANCE INDEXES
(In-House Attributes Only) Last Years Figures

Knowledge Type	Measure	COE Office ¹ (1)	Comparison Benchmark (2)	Ratio (1)/(2) (X 100)
Baseline Education				
1. College Credit	Years/FTE	4.6	4.8	95.8
2. Prof. Licenses	% of Staff	88.4	76.1	116.3
			Group Avg.	106.0
Education Updates				
1. Seminar Hours	Hours/FTE	44.1	60.0	73.5
2. College Cr. Hrs. (See #1 Above)	Hours/FTE	0.1	0.1	100.0
3. Official Cross Training	Months/FTE	0.2	0.8	25.0
4. Prof. Papers Pub.	% of Staff	0.5	1.2	41.7
			Group Avg.	60.1
Information & Data Source				
1. Interlibrary Loan Sources Used	Volumns/FTE	890	1,090	81.7
2. CD-ROM Storage Available	MB	3 X 10 ⁶	2 X 10 ⁶	150.0
3. Internet Services	Hours Used/FTE	3.4	5.5	61.8
4. Technical Library Usage	Books checked out	0.9	1.4	64.3
5. Subscription checked out	Issues/FTE	1.1	2.6	42.3
			Group Avg.	80.0
Information Processing				
1. Avg. RAM available	MB	420	350	120.0
2. Avg. ROM available	MB	8	8	100.0
3. Avg. Speed	MHz	55	40	137.5
4. Avg. Computer Age	Months	32	46	69.6



TABLE 24a (Continued)
KNOWLEDGE PERFORMANCE INDEXES
(In-House Attributes Only) Last Years Figures

Knowledge Type	Measure	COE Office ¹ (1)	Comparison Benchmark (2)	Ratio (1)/(2) (X 100)
5. Avg. Printer Age	Months	36	48 ¹	133.3
6. Avg. Software Age	Months	18	12 ¹	66.7
			Group Avg.	100.0
Professional Experience/Skill Level				
1. 0 - 5.9 Years	Percent	8.0	7.0	114.3
2. 6.0 - 10.9 Years	Percent	10.9	13.0	83.8
3. 11.0 - 15.9 Years	Percent	30.0	40.0	75.0
4. 16.0 - 20.9 Years	Percent	40.1	35.0	114.6
5. 21.0 - 24.9 Years	Percent	7.0	3.0	23.3
6. 25.0 + Years	Percent	4.0	2.0	200.0
			Group Avg.	136.8
Productivity Tools In Use				
1. SPC Charts On-Going	Number	24	42	57.1
2. On-Going Network Charting	Number	10	8	125.0
3. PATs In Use	Number	6	10	60.0
4. GPRA Perf. M--- In Use	Number	30	18	166.7
5. Objectives Achieved	Percent	77	85	90.6
			Group Avg.	99.9
			Overall Avg.	97.1

¹ Columns (2)/(1) for items 5 and 6



TABLE 25a
EXAMPLES OF EFFICIENCY CALCULATIONS

Actual Output	Calculated Effective Capacity	Efficiency (X 100)
Eight reports generated by a staff of 30 in a particular branch for FY 97.	12 Reports	$8/12 = 66.7$
800 man-hours to design a spillway for a dam.	700 Man-Hours	$800/700 = 114.3$
1,000,000 annual visitors to a dam and reservoir in 1999.	1,100,000 Visitors	$1,000,000/1,100,000 = 90.9$
1,000 Kwhrs generated by a hydro-power plant in January.	1250 Kwhrs	$1000/1260 = 80.0$
4 wolves per 10,000 acres in a region of woods.	6 Wolves	$4/6 = 66.6$
Removal of 100,000 cy of material from a shallow draft channel requires 200 man-hours; 500/cy/man-hr.	550 Cy/man-hr	$500/550 = 90.9$
\$500,000 in overhead expenses for a district of 400 FTE's in the month of March.	\$400,000	$500,000/600,000 = 83.3$
Mailroom cost \$350,000 a year to operate.	\$275,000	$275,000/350,000 = 78.6$
A district inspected 30 dams in FY 1998.	25 Dams	$30/25 = 120.0$
It cost a district \$0.05 per page to print 200 volumes of a 150 page report.	\$0.053	$0.053/0.05 = 166.0$





A.3. DEFLATING DATA

The dollars used to estimate costs per unit, expenditures, budgets, values, and revenues for performance indexes *do not retain their base year purchasing power during periods of rising costs or during periods of deflation.* In order for an analyst to determine what a given amount of dollars will purchase relative to previous years, adjustments are necessary to arrive at real purchasing power. There are a number of prepared indexes periodically published by public and private institutions which can be used to adjust for changes in the value of the dollar over time. The Bureau Of Labor Statistics (BLS), the Engineering News Record (ENR), and the Federal Reserve Board (FRB) are three frequently used sources. There are also specific indexes designed for different purposes such as those used to adjust for wages, heavy construction costs, light construction, real estate, the consumer price index, wholesale price index, et al. The analyst must choose the one best suited for his or her specific purpose. You would not use a heavy construction index to adjust real estate prices, for example.

During inflationary periods prices or costs increase and erode dollar values. Alternatively, during periods of recession, the purchasing value of the dollar tends to climb. The following example will illustrate the principles and methods involved.

Suppose that a district's annual budget is increased from \$125,000,000 to

\$135,000,000 over a one-year period when the ENR cost indexes change from a relative value of 90 to a relative value of 125. What can be said about the \$10,000,000 increase in budget?

The ratio of the new budget to the old budget is: $\$135,000,000 / \$125,000,000 = 1.08$ or 108.0%. The dollar value of the budget went up by 8%. When adjusted for inflation using the ENR index the new real budget is: $\$125,000,000 / 125 = \$100,000,000$. The old budget is actually: $\$125,000,000 / 90 = \$1,388,889$. The ratio of the two real budget changes is: $\$1,388,889 / \$1,388,889 = .778$ or 77.8% which represents a real decrease in purchasing power. The dollars provided today are only able to buy 77.8% of what they bought a year earlier. Even though the money value of the budget has increased by \$10,000,000 over the period the real or purchasing power has actually declined. In other words, the \$135,000,000 now buys 77.8% of what the old \$125,000,000 procured in a previous year. Table 26a shows another example of how to deflate dollars (costs, budgets, expenditures, etc.). Notice that inflation over time has deteriorated the purchasing power of increasing dollar amounts (column 920 vs. column (4)). This is because inflation has risen faster than budgets. By the year 2001, the budget has risen faster than inflation returning the purchasing power of the budget



TABLE 26a
THE DWINDLING PURCHASING POWER OF THE DOLLAR
(1982 - 84 = 100)

(1) YEAR	(2) BUDGET	(3) COST INDEX	(4) REAL BUDGET
1996	\$125,000,000	158.0	\$79,113,924
1997	\$128,000,000	163.0	\$78,527,607
1998	\$130,000,000	166.1	\$78,266,105
1999	\$132,000,000	175.4	\$75,256,556
2000	\$135,000,000	187.8	\$71,884,984
2001	\$150,000,000	189.6	\$79,113,924

amounts to those of 1996-the comparative base year.

It is vital to adjust the dollar values of performance indexes that use price, costs, dollar values, etc. prior to using them to make performance indexes. If this is not done, then comparisons of performance will be distorted and, incorrect decision will likely be made. The unadjusted index will measure relative price changes and not actual productivity. This will adversely impact the goals, objectives, strategic, tactical, and operational characteristics of the organization

described earlier. It will likely filter through the entire system undermining the fabric and efficacy of decision making. Incorrect information is one of the performance problems GPRA mentions as a cause of reduced effectiveness and efficiency. In the face of performance measurement, this is not a desirable possibility. To make adjustments, the COE will also need to determine a base year as an anchor for relative comparisons. A study of the example in the table will show why this is so.





A.4. BASE YEAR SELECTION FOR PERFORMANCE MEASUREMENT

In initiating a performance measurement program care must be taken in selecting the base year to which comparisons of future performance will be calibrated. *The base year for indexes or indicators is the underlying framework for all future measurement.* If an inordinately active year is selected without forethought, future years may witness a decline in numerical value without or despite any action taken to influence or to control the outcome. The consequences are also true if an inordinately inactive year is chosen. This is best illustrated in Figure 2a. Suppose that the year 1994 is selected as a base year with activity level (1). Note that this year is below the historic performance trend (represented by the dotted line) for a particular index. This low value was due to some anomaly to which no one gave a second thought. Management is now prepared to embark on improving performance with the base year determined. The following years will witness increases in performance such as the year 1995. Management will be led to believe that its goals, objectives and decision making are right on target-the index has increased. However, management may be in for a surprise because the selected base year was well below par to begin with and would have likely increased in any event. While this performance may appear to be cause for celebration, continuance of these same goals, objectives and decision making may not be able to stop another decline in future years

because management endeavors were predicated on incorrect notions in the first place. Such a situation is observed in the year 1996. Now, confusion or paralysis sets in and a fresh approach will need to be developed. This all could have been avoided in the first place if a more suitable trend line base year were selected.

The year 1997 is also not a desirable base year selection for the opposite reasons. With this anchored base year selected management goes on to develop a congruent set of goals, objectives, and operating policies to embark on an otherwise sound performance program. Because an inadvertently active year was chosen as the bases to measure future performance, trouble arises in 1998. The index value drops from point (3) in 1997 to point (4) in 1998. This was not due to management incompetence but rather the selection of an unusual year. Confusion sets in and management searches for new goals, objectives and corrective actions on operating procedures. The antecedent performance plans developed in 1997 were perfectly good but are now incorrectly discarded.

Such incidents as those described above are possible if care is not taken to seek out a viable base year. The costs of the incorrect base year selection are high and can be avoided. Some study and care must be undertaken to be certain that the base year is one that can be lived with in the future.



In some cases the values of previous year numbers are subject to a high degree of volatility by the nature of the variable being measured and its vulnerability to political decisions. Deep draft navigation tonnage data is a case in point. The political arena in the past has often thrown data into extreme directions due to embargos, blockades, fear of conflict, etc. There are tools which can be

employed to determine or detect underlying trends and lead to wise base year selections. These tools include: moving and weighted averages, regression analysis, exponential smoothing, shift-share analysis, Box-Jenkins and Auto Regressive Integrated Moving Averages (ARIMA) techniques and a host of others.





A.5. CYCLE TIME INDEX AND VALUE-ADDED ANALYSIS

“**A**s a strategic weapon, time is the equivalent of money, productivity, quality, and innovation” [Stalk, 1988]. One of the more important performance indicators is that the *cycle time index*, also known as “Lead Time” [Management Concepts, Inc., 1995]. Cycle time is the total length of time used to complete an entire project. It measures how quickly we can accomplish our goals and objectives; complete our projects, functions, and programs. The word transformation was used earlier in this report and described as the activities we do from the resource input stage to the product or service completion stage. It is the sequence of events where people and equipment “add value” to raw materials and ideas to produce an output and eventually an outcome. This is called *process time*. This is how iron ore becomes steel which ultimately is used to produce a building or bridge. Non-valued activities such as rework and review time interfere with the transformation process and productive activities to increase cycle time resulting in delays in customer satisfaction and increased costs. There are a number of non-value added elements which can be measured to produce a cycle time index. These include *transit time* or inter-activity time (the time between activities or the time within activities when nothing gets done—simple waste), *wait time* (waiting for something to happen before proceeding), and *review time* or quality control time (which encompasses error detection) and *rework time*

(the time used to correct errors or make changes required by review authorities). More will be said about these issues in the paragraphs that follow.

As stated earlier, the idea behind continuous process improvement is to “do it right the first time”. Build quality into the systems, not inspect it out. The *Cycle Time Efficiency* index is written as follows:

$$\text{CTE} = \frac{\text{PROCESSING TIME}}{(\text{PROCESSING TIME} + \text{TRANSIT TIME} + \text{WAITING TIME} + \text{REVIEW TIME} + \text{REWORK TIME})}$$

For example, suppose it takes 12 months of actual processing time to produce a feasibility report in a planning division. The amount of time that report components expend undergoing a movement from one branch to another and waiting for intermediate inputs such as H&H analysis, cost analysis, etc, is determined to be 8 months. The waiting time due to guidance clarification and local sponsor inputs including meetings, etc. is found to be 4 months, and review time at the district level is another 4 months. Post report re-work time (report returned after higher level review and comment) due to plan formulation problems and the addition of new plan formulation alternatives, adds another 12 months. The cycle time efficiency index is: $12 / (12 + 8 + 4 + 4 + 12) = 0.30$ or 30.0%. A value of 1.00 for the index is the best that can be done. Given that a value of



1.00 is seldom practical, the reader can readily see the value of the index. This analysis can be done for nearly every activity in an organization; including planning, engineering, program performance, organizational performance, etc. Keeping records of how time is actually used is a vital part of process time improvement. Recall also that the term "customer" includes both internal and external clients.

The four major time delay types listed above can be broken into a variety of smaller categories. A list needs to be developed and standardized in some detail for consistency between organizational elements and consistency over time. More importantly, time losses can be converted into costs as a means of dramatizing their magnitude. For example, move time may have resulted in unnecessary expenditures of \$50,000, waiting time \$100,000, inspection time another \$75,000, and re-work time \$200,000. This yields a total dollar value of time lost of \$425,000 *in addition to the original report processing time* (the cost of doing it right the first time). This figure represents the dollar value of time lost. It is often simply called direct labor. Waste, expressed in terms of both time lost and the added cost of doing business, is one way to drive home the need for change. The performance indicators developed in previous paragraphs can also aid in detecting and locating time delay problems. In a sense, actual time lost is more damaging because it cannot be recovered; to an extent dollar losses can be replenished. Either way the customer pays unnecessarily.

Cycle time is more important in what the COE does than in many other organizations. This is because cycle time for most projects

is quite lengthy running typically 17 years from start to finish. The difficulty with long cycle times lies in the capricious events that can, and do, occur during the transformation process. For one thing, long cycle times mean a good deal of value-added input is accumulated before the final product or output (a project) is available to the public. This opens considerable opportunity for circumstances to change--sometimes radically. Engineering changes, planning changes, the public's perceptions change, guidance changes et al. This results in many restarts, setbacks, waiting time, reanalysis, chaos, and a host of other cost and time incurring events. It can lead to a loss of focus as employees and management search for a new sense of direction for the already accrued effort. *Work in progress* can simply come to a halt requiring a new momentum and sense of direction. Secondly, the work done by the COE is technically complex and involved compounding the situation especially since frequent progress checks are necessary to keep schedules on track. Third, long cycle times often result in unbalanced workloads and production bottlenecks. When one upstream work center completes its tasks there is an immediate influx of new activities for those next in line or further downstream in series related activities. This leads to a feast or famine work environment. Fourth and last, is that long cycle times are inherently inflexible. Several years of accumulated work is difficult to reconfigure and restart without dramatically impacting time schedules. It is a costly endeavor as well.

Value-added is a concept very closely linked to cycle time. Value-added is the



increase in the worth of a product or service as it progresses from an idea and raw materials into a completed output or service with attributes customers are expecting. The activities that take place between these two points is the transformation process where value is added by employee knowledge, work efforts, equipment, and materials to complete the product or service. As each step or activity progresses, cost and value accrue. At any point within the transformation process the value of the incomplete product or service is called its "book value".

Many of the events that take place during the transformation process more often than not add considerable unnecessary costs to the final product or service without providing value to the customer or require the customer to wait longer for the delivered product or service.. These events are not what the customer wants to pay for. These unnecessary tasks and activities are waste. Waste can also be viewed as "any process that increases costs but does not add value to the product" [Maskell, 1991]. It is one of the reasons that "95% of productive activities are non-value adding" [Maskell, 1991]. This proportion is made up of the wealth depleters mentioned earlier; transit time, waiting time, review time, and rework time. Instead of shrinking waste, traditional management's reaction is to increase productivity by forcing more work into an already nominal processing time frame (working harder and longer rather than smarter). This usually results in adverse conditions and a stressed system.

Table 27a illustrates the concepts. An employee has been assigned five projects (studies, assignments, etc.) to work on. The

table shows a one day slice of time out of the employee's work schedule. During that day the employee is able to spend four processing hours (value adding) on Project A, two processing hours on Project B, and two rework hours on Project E. The employee has worked a full eight hour day. Notice, however, that the remainder of the projects have spent the majority of time in non-value-adding activities. A full days work has only contributed to six hours of value-adding transformation. In total, six out of thirty-six hours of activities were productive; 83.3 percent of potentially value adding time was wasted on tasks which did not contribute to the value of the product or service to the customer.

Table 28a was taken from [Harrington, 1991] and provides another example of the way waste contributes to increased cycle time and subsequently increased process cost. These are not atypical situations but are none-the-less a profound finding. There is plenty of ground to do battle with cost reduction and cycle time savings. The work we do must be viewed through the eyes of the intended customer. The letter processing example may show that productive work is being done by the secretary while she waits for review, the bosses signature, et al, but the time delay is experienced by the customer. Both the index and the supporting table are excellent tools for diagnosis and presentation. They are the targets of GPRA and fulfill APIC mandates.

It is recognized that non-value-added tasks are necessary to run an organization. The necessary ones include record keeping, order forms, personnel record keeping, payroll work, budget analysis, etc. These are



TABLE 27a
WASTE AND VALUE ADDED CYCLE TIME
Non-Value Added Activities

(1) ROW NO.	(2) ACTIVITY STUDY OR PROJECT	(3) TRANSIT TIME ¹	(4) WAITING TIME ²	(5) REVIEW TIME ³	(6) REWORK TIME ⁴	(7) NON- VALUE ADDED TIME	(8) PROCESS TIME
1	A	0 Hrs.	0	0	0	0	(4)
2	B	0	6	0	0	6	(2)
3	C	0	8	0	0	8	0
4	D	4	0	4	0	8	0
5	E	6	0	0	(2)	8	0
	Totals	10	14	4	(2)	30	(6)

6/36 = 16.7% Process Time
83.3% Waste

- 1 Transit to/from reviewing officials, in-house, to locals, etc.
- 2 Equipment down-time, waiting for data input from others, waiting for guidance, meetings, other duties not tied to the 5 projects listed, etc.
- 3 Time spent for technical & review, errors, etc.
4. Review requirement changes, changes in input data, priority changes, formulation changes, etc.



TABLE 28 a
PROCESSING TIME VERSUS CYCLE TIME

Consider the cycle time of a letter-writing process:

Activity	Processing Time (Hours)	Cycle Time (Hours)
1. A manager estimates that it takes 12 minutes to write a one-page memo and place it in the outgoing basket.	0.2	0.2
2. The manager's secretary picks up outgoing mail twice a day, at 9 a.m. and 1 p.m. Average delay time is 12 hours.	0.1	12.0
3. The secretary assists three managers, answers phones, schedules meetings, processes incoming mail, retypes letters, and performs special assignments. All these activities have priority over typing. Average time before starting to type a letter is 26 hours.		26.0
4. The secretary types the memo and puts it into the manager's incoming mail.	0.3	0.3
5. Incoming mail and signature requests are delivered twice a day; at 9 a.m. and 1 p.m.		12.0
6. The manager reads incoming mail at 5 p.m.	0.1	17.0
7. The secretary picks up mail at 9 a.m.		16.0
8. Retyping is a priority activity and is returned in the 1 p.m. mail delivery. (Note: 60 percent of all letters are changed by managers.)	0.2	4.0
9. The manager reads and signs letters at 5 p.m.	0.1	4.0
10. The memo is picked up by the secretary at 9 a.m.	0.1	16.0
11. The memo is put in the copy file and held for the next trip to copy center at 2 p.m.	0.1	5.0
12. The secretary walks to the copy center, makes copies, and addresses envelopes.	0.1	.01
13. The secretary takes memo to mail box by 5 p.m.	0.2	2.5
14. Mail is picked up at 8 a.m.		15.0
15. The memo is held in the mailroom for afternoon mail delivery at 3 p.m.	0.1	17.0
16. Secretary 2 picks up mail and sorts at 4 p.m. Secretary puts memo in manager's incoming mail.	0.1	1.0
17. Secretary delivers incoming mail to manager 2 at 9 a.m.	0.1	14.0
18. Manager 2 reads mail at 5 p.m.	0.1	8.0
19. Manager 2 drafts answer and puts it into the outgoing mailbox, telling manager 1 to supply more information. It is classified "rush" because it is now overdue.	0.3	0.3
TOTAL	2.2	170.4

* Source: Harrington, Dr. H.J., Business Process Improvement. McGraw-Hill, Inc., 1991.



called *business value-added* tasks. The ones that show the highest potential for improvement lie in transit time, waiting time, review time, and rework time--they have no value-added characteristics from the customer's perspective.

The loss of time is one perspective of waste; the dollar losses may be even more staggering. Both rework and review, for example, are often more costly than the salary losses of the assigned employee who did the work originally. With rework and review multiple employees get involved; some higher graded managers and supervisors will add to the costs and there is time taken away from other projects. The multiplier effect ripples through the system and takes it toll.

The irony of this situation is that much of this is being charged to the direct labor

account--the mainstay of productivity and efficiency measurement. Overhead labor has been the traditional target for cost control but it is now clear it is not the only culprit, nor the most significant, in cost control efforts.

Cycle time can be improved and waste reduced often because they may be simply quantified and exposed. Exact measures are not necessary for effective cost control. In fact, since most organizations conduct their business by stovepipe or division, work consequently flows across divisions and offices making it difficult to pinpoint cycle time problem areas exactly. Any exposure or attention given to these issues will be the beginning of change. The single most important theme of the cycle time analysis is that quality is reduced and customer's expectations go unmet when waste is present.



APPENDIX B

BENCHMARKING





B.1. BENCHMARKING

Benchmarking has been elegantly defined as: "a continuous, systematic process for evaluating the products, services, and work processes of organizations that are recognized as representing the best practices for the purpose of organizational improvement" [Spendolini, 1992]. Benchmarking is not just the establishment of a performance or numerical target; it integrates the adoption and understanding of the process which made the benchmarked organization superior in the first place. Benchmark comparisons may be with an industry (COE) average, best competitor, world class performas, or best in a class. Others are possible. There are a number of ways to approach benchmarking including: *internal benchmarking*, *competitive*, *functional*, and *statistical benchmarking*. These will be discussed in due course.

Many benchmarking approaches are focused or directed at firms which are competing in the market place for private sector profits and market share. Such firms are driven by the *profit motive* in order to remain liquid and vendable. Such notions as market price, market demand, value added, customer et al, all have different connotations in the private sector than they do in the public sector of our economy. The role of government is to fill-in where there is *market failure*. In the context of public institutions this means that government needs to step in where markets do not exist or where it is in the *collective national interest* to provide a product or service. Classic examples are

defense, public health, police and fire protection, and pollution abatement. There are no "markets" for these services. The reason this issue is being surfaced is that there is considerable debate as to whether or not the government should benchmark against the private sector. The methods and motives driving the public and private sectors are very different; why should they be comparable? Further, the laws which govern the way the private sector operates are different from those under which public institutions operate. While there is merit to both positions, common ground is possible. We cannot expect government institutions to perform in the same manner as private sector institutions, but we can still benchmark against the private sector as a means of calibrating improvement. In other words, while we may not expect government to meet the same standards as the private sector, we can still use private sector performance results as a reference. In the context of this debate, let us evaluate the merits of each of the benchmarking types; internal, external, functional, and statistical.

Internal benchmarking is the comparison of one department's or branch's method of doing business against another's in the same organization. It is assumed that departments or branches operate and exist in different locations but the goal here is to seek-out business practices that are better in one department than anywhere else and adopt those practices throughout the corporate structure. For the COE this would require that districts and divisions exchange



information so that comparisons can be made. As is apparent, this must take place between departments and branches serving the same functions i.e. planning with planning, engineering with engineering, in different districts although "best practices" can be taken from different, unrelated organizations. The best way to do this is to establish common data and performance measures or indexes with at least several *benchmark "partners"*. This is a form of competition but is driven from within rather than externally. It also fosters communications. The best internal practices are discovered and transferred to other operations. Table 1b provides an example of four districts exchanging what they consider to be key organizational *cost drivers*. It is apparent from the data exchanged that some districts have something to learn from others. District "B" has something to gain from the others in the area of G&A costs (General and Administrative costs which includes personnel, legal, procurement, supply, administrative, office rental, equipment, etc.), district "C" has something to learn about annual equipment repair costs, and district "D" needs to look at what is driving direct labor. This exchange of information can lead to gains by all involved. It is possible to expand "partner" membership between other cities and districts by using price deflators to adjust for differences in the cost of living between cities. Such ready-made indexes are available on a monthly basis.

Competitive benchmarking requires that each element compare its business processes, products, and services with those of a competitor. This type of benchmarking alludes to a problem previously discussed;

many government activities are public goods and there are no real market competitors for such missions. However, contractors can be used in many cases as the benchmark for those activities that we have contracted in the past. The difficulty with this approach is in obtaining data. Most firms are not too willing to release information on the cost of doing business; there is a fear that such information will wind up in the hands of those with whom they themselves must compete. While some data are available in published sources which may be of value, it is usually too gross and non-specific to be of real use. There are organizations which collect and publish this kind of information as their business but once again, water resource organizations are difficult to come by and comparing yourself with "cousin" resource firms who produce similar outputs may be misleading. It may be possible to arrange agreements not to publish each others cost of doing business or business processes and practices but this may be limited in scope and a little tenuous. While the competitive approach is, in some sense, the best and most direct method of benchmarking, it is also the most difficult to contend with. Table 1b illustrated earlier provides an example of the type of comparisons which could be made if competitive benchmarking were instituted.

Functional or generic benchmarking is another approach. This technique involves identifying and comparing products and services of organizations that are not direct competitors. That is, find the *best in the business* regardless of similarity to yours and determine what can be adopted to fit your needs. This can be done for specific business practices such as cycle times, quality attributes, design practices, planning



techniques, etc. The real focus is on business processes rather than on specific services or products; but, all activities are fair game. Like the previous benchmarking measures, data may be difficult to obtain. Once again, Table 1b could be the comparative format used.

Table 1b can employ, not only univariate data, but also single and multifactor index numbers, efficiency measures, and other performance measures. The table could be structured by function, KRA, program or another desired format.

Statistical benchmarking may be the most viable approach. It involves securing key data from each and every district or division in the COE and constructing a distribution of performance activities. All COE elements would have to participate in order to establish a large enough sample size for statistical estimation and ranking. This would be a very powerful tool, fostering much competition. The data would be relatively easy to obtain since each district and division will be on a performance measurement program in the near future. We would have to be certain that all elements are using the *same accounting systems and practices* so that we do not compare apples with oranges. Such a technique would allow for comparisons against the organizational mean, establish modes and medians, percentile ranks, determine variances and standard deviations, and establish reliability of results. This could be done for each key parameter or KRA, etc. To a certain degree it would also allow for comparisons with private sector practices when such data became available. Tables 2b, 3b, and Figure 1b will serve as an illustration of this approach.

Table 2b shows a list of hypothetical data used to illustrate the use of statistical benchmarking. Column (1) represents a numerical value for each district in the COE. Column (2) is the General and Administrative (G&A) cost for each district. Columns (3), (4), and (5) are the frequency of observing each G&A cost, the percentage occurrence of each G&A cost, and the cumulative percentage of districts in the database, respectively. G&A costs are expressed in dollars per FTE and are found by dividing the sum total of district G&A expenditures by the total number of full time equivalent employees for each district.

Table 3b takes the data in Table 2b and summarizes it by assigning each G&A value to a class interval i.e. how many districts show a G&A cost of between \$15,000 and \$15,999, how many show a G&A cost of between \$16,000 and \$16,999, etc. The data have been adjusted for the cost of living in each city in which each district is located to prevent distortion of information. These dollar intervals are called *class intervals* in statistics. The count column are the number of districts observed in each class interval. The percent column shows the percentage of values in the count column. Notice the data following the table; various statistical characteristics are shown.

Figure 1b is the data from Table 3b plotted in the traditional frequency distribution format. The data are nearly normally distributed judging by the shape of the distribution and the proximity of the mean and median. The curve depicts a good deal of information which is ideally suited for a taxonomic arrangement of district expenditures on G&A. For example, those districts falling in the class interval between





TABLE 1b
BENCHMARK INDICATORS
EXAMPLE: AN ENGINEERING ORGANIZATION

Key Indicators ¹	Competitor (Corporate, District, Other)				
	A	B	C	D	Comments
Annual G&A Costs per FTE	\$17,500	\$25,600	\$18,200	\$16,700	Avg = \$19,500
Annual Direct Labor Cost per FTE	30,000	27,600	29,900	35,000	Avg = 30,625
Equipment Repair Costs per FTE	300	277	566	325	Avg = 367
Errors per Engineering Drawing	3	2	5	5	Avg = 3.75
Cost per Page of Typing	1.75	2.50	2.00	4.00	Avg = 2.56
Rework Costs per Employee/Year	1,150	1,175	1,300	1,225	Avg = 1,213
Calculated Waste per Employee/Year	3,000	3,800	2,700	2,900	Avg = 3,100
Accidents per 100,000 Empl-Years	2	1	4	4	Avg = 2.75
Percent of Funds Executed	98%	95%	88%	92%	Avg = 93.25
Schedule Slippage (Months)	0	2	1	1	Avg = 1.00
Employees per Manager	7 to 1	15 to 1	9 to 1	9 to 1	Avg = 10 to 1
Avg. Cycle-Time Per Report (months)	16.5	18.0	12.4	17.1	Avg = 16.0

¹ All costs adjusted for city of location.

TABLE 2b
UNIVARIATE PERFORMANCE DATA
(Ranked in Ascending Order)

(1) District	(2) G&A Cost/FTE	(3) Frequency	(4) Percent	(5) Accumulative Percent
1	\$15,000	1	2.8	2.8
2	\$15,200	1	2.8	5.6
3	\$16,000	1	2.8	8.3
4	\$16,400	1	2.8	11.1
5	\$16,700	1	2.8	13.9
6	\$17,000	1	2.8	16.7
7	\$17,200	1	2.8	19.4
8	\$17,400	1	2.8	22.2
9	\$17,800	1	2.8	25.0
10	\$17,900	1	2.8	27.8
11,12	\$18,000	2	5.6	33.3
13	\$18,100	1	2.8	36.1
14	\$18,200	1	2.8	38.9
15	\$18,400	1	2.8	41.7
16,17	\$18,600	2	5.6	47.2
18	\$19,000	1	2.8	50.0
19	\$19,200	1	2.8	52.8
20	\$19,500	1	2.8	55.6
21,22	\$19,600	2	5.6	61.1
23	\$19,700	1	2.8	63.9
24	\$19,800	1	2.8	66.7
25, 26	\$19,900	2	5.6	72.2
27, 28	\$20,000	2	5.6	77.8
29	\$20,100	1	2.8	80.6
30	\$20,500	1	2.8	83.3
31	\$20,700	1	2.8	86.1
32	\$20,800	1	2.8	88.9
33	\$21,000	1	2.8	91.7
34	\$21,400	1	2.8	94.4
35	\$21,600	1	2.8	97.2
36	\$22,600	1	2.8	100.0



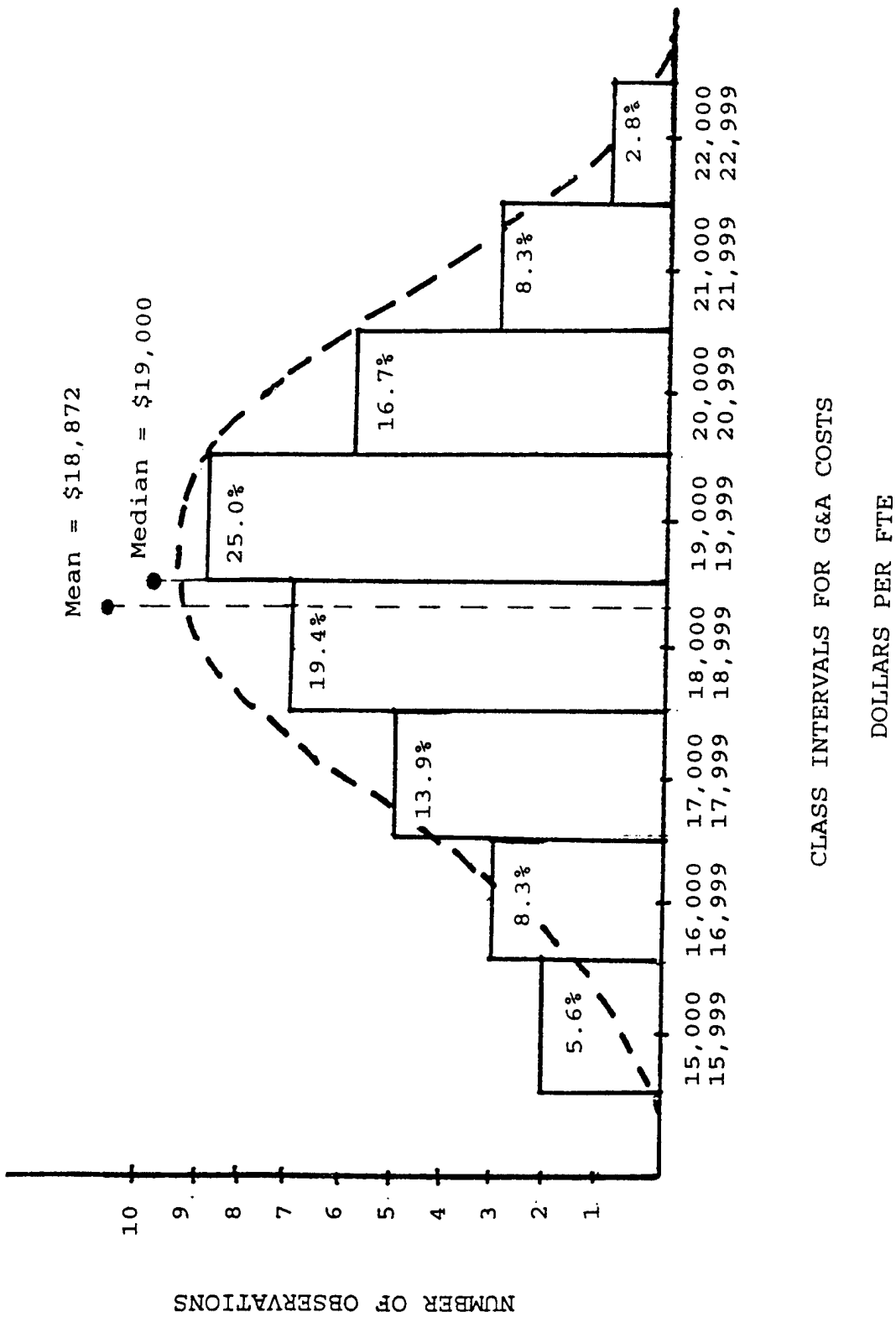


Figure 1b. - Frequency Distribution of General and Administrative Costs (G&A)



TABLE 3b
DISTRIBUTION OF PERFORMANCE ¹

RANGE	COUNT	PERCENTAGE %
\$15,000 - 15,999	2	5.6
16,000 - 16,999	3	8.3
17,000 - 17,999	5	13.9
18,000 - 18,999	7	19.4
19,000 - 19,999	9	25.0
20,000 - 20,999	6	16.7
21,000 - 21,999	3	8.3
22,000 - 22,999	1	2.8
	36	100.0

Mean = \$18,872

Mode = N.A.

Median = \$19,000

Std Dev = \$1,791

Sample Size = 36

Range = \$15,000 - 22,600

N. A. = Multiple Modes

¹ All data price adjusted for city of location.

\$15,00 and \$15,999 per FTE fall in the lowest 5.6% of all districts included in the sample count. In this case two districts fit this description. Thus their G&A costs are among the lowest 94.4% in the COE. The next group-with a class interval of G&A costs between \$16,000 and \$16,999-represent 8.3% of the districts and fall within the lowest 13.9% of all districts or; alternatively their G&A costs are lower than 76.1% of all districts. For comparison, those districts which fall into the class interval with G&A costs per FTE ranging

from \$22,000 to \$22,999 represent 2.8% of all districts and are in the upper 97.2% of all districts in terms of G&A costs. Clearly, those districts in the highest class intervals have something to learn from those in the lower G&A cost areas.

The point in all this is that internal benchmarking is possible with the statistical approach and measurements among and between districts can be made so that business processes can be compared. Notice also that other statistics are provided such as the mean, median, and the standard



deviation. This will allow for the ranking of districts in terms of performance for each KRA or attribute measured. For example, it is known that 68.3% of all the data points fall between one standard deviation of the mean. This means that 66.3% of the districts fall within the range of \$17,091 and \$20,663; this is the norm of the data. Similarly, statistical information states that 95.5% of the data must fall between two standard deviations of the mean. This carries a range of \$15,290 and \$22,454. Those districts falling outside this range represent the very best performers (below \$15,290 in G&A costs) and worst performers (above \$22,454). The value of the statistical approach to benchmarking is very powerful.

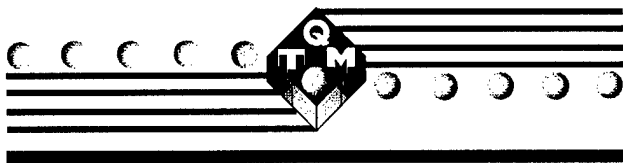
External benchmarking is also possible using the statistical approach. If we know that comparable private sector firms typically show a G&A cost per FTE of \$17,500, then we can compare this with the COE frequency distribution. In this case the private sector organizations fall within the class interval of \$17,000 to \$17,999. This means that they are better than average performers in G&A expenditures relative to the COE. They would fall approximately in the lower 17% of the cost curve.

Normalized Data

When employing benchmarking for comparative purposes, be certain your data is compatible with that of the benchmark's. It of little value to use information which is similar in name but quite different in actual content and meaning. For example, cost per

employee is a common marker for comparison. If you are using direct cost only and the benchmark organization is including fringe benefits as part of the cost of labor, the data are not comparable and would lead to incorrect conclusions and inappropriate goals and objectives. This difference would not only impact the level of the numbers, but the rates of change over time as well. This is not an isolated circumstance. Even though we all work for the same organization, accounting practices are not one hundred percent alike. They may differ by local custom or tradition and be taken for granted without the differences being readily apparent. Overhead in one district may be 28 percent, while in another, within the same division, it may be 30 percent; the difference may not be in operational practices but in accounting practices. These types of data compatibility problems can be found in non-financial data as well. In benchmarking or in competing for the ACOE award, this difference may be a deciding factor. The expense is not universal. The situation may be compounded when attempting to benchmark with another agency or organization because institutions which are non-governmental may even have altogether different definitions for the same cost category. The lesson is to be certain that when benchmark data are used as "*stretch targets*", goals or objectives, have local experts talk with one another to be certain that the data being used or "group shared" are congruous. This will save a lot of headaches later.





B.2. MEASURES OF FLEXIBILITY AND ADAPABILITY

One of the central credos of a high performance organization is its ability to adapt to change.

This is more true today than ever before because of the rapid change in technology and the shift toward customer satisfaction. Customers are not only demanding a higher quality product or service at a lower cost, but are demanding much faster cycle times. Improved cycle time may be the quintessential ingredient to an organization's survival in today's consumer environment. Adaptability and flexibility are difficult to measure and little research is available on the subject. This part of the text will describe adaptability and flexibility and provide several measures which can serve as proxies for their measurement. To simplify matters flexibility and adaptability will be viewed as the same notion. *Adaptability can be described as the ability of an organization to adjust or to accommodate new environments through the use of skill, knowledge or judgement.* There is also a connection with benchmarking. Prior to delving into the measures of adaptability a few additional concepts need to be introduced.

Service or knowledge work usually consists of three categories of projects. They include *recurring projects, long-term projects, and quick response projects* [Boyett and Conn, 1988].

Recurring work is characterized by the fact that it is regularly scheduled, usually involves a standard procedure, and has a standard due date or expected time-frame for completion [Boyett and Conn, 1988].

Typical examples would include periodic manpower reports, accounting or budgeting reports, status reports, et al. Such reports are expected to be completed on a weekly, monthly, or quarterly basis.

Long term projects extend over several months or years, usually have a schedule, process, or budget, and are usually one time projects [Boyett and Conn, 1988]. They have a standard or particular procedure unique to themselves even though the general process may be repetitious.

Quick response projects are the ones which are the most susceptible to measures of adaptability. They are generally not repetitive, typically demand a speedy response time (hours or days) and often do not have a standard procedure [Boyett and Conn, 1988]. Corps of Engineering personnel often refer to these projects as "flash fires". They are disruptive to ongoing, long term activities such as those described earlier. Within the context of cycle time, quick response projects may even be described as "waste" or non-value-added activity because they require employees to drop what they are doing and respond to the "fire". Quick response projects are most often not scheduled and typify a hospital emergency room mentality. Nearly every organization has to deal with them. There are no known direct measures of quick response for these type of work activities. Proxies are, however, useful.

There are several indirect measures of organizational adaptability. They include:



- ☐ The average completion time per quick response request,
- ☐ The ratio of the number of different disciplines available to an organization's total staff, times one hundred,
- ☐ The average number of quick response requests completed per unit of time,
- ☐ The ratio of bonafide skills available to the organization's total staff, times one hundred,
- ☐ The cumulative number of hours of multidisciplinary formal training completed.

Each of these will be described in turn.

The average completion time per quick response request measures the speed with which requests are handled relative to some over-all benchmark such as the mean completion time for previous quick response requests. This is similar to the application of the frequency distribution described earlier. By comparing the historic average completion time to current year response time one is able to determine if response time is improving relative to a base period of historic average completion times. This is purely a measure of time to complete a request. Figure 2b provides an illustration. There are two frequency distributions in the figure. One representing an historic time response to special requests with a mean response time of 30 hours. This distribution is the culmination of say the response times from last year or the accumulated response times from several previous years. The second distribution shows a mean of 10 hours and represents the results of a current year record. Note that the mean response time

has dramatically shifted-improved- over time from distribution one to distribution two. This is the kind of measurement needed to document improvements.

The ratio of the number of different disciplines available to an organization's total staff multiplied by one hundred is the percent of staff with different backgrounds; an indicator of multidisciplinary capability. This is a proxy for employee multi skill capability to respond to varying circumstances. The time it takes to respond is directly proportional to the technical capability to respond. A frequency distribution such as the one just described in Figure 2b could also be constructed to measure and display improvement over time.

A third measure is the average number of quick response requests completed per unit of time. This is another speed of response measure. Again the average is used because an individual response is almost meaningless to the measurement of improvement in response time over a historic pattern and as before, a statistical benchmark can be established. Another frequency distribution can be used here as well.

The ratio of bonafide skills available to total number of staff times one hundred is another capability measure. It is a measure of the percent of staff with multidisciplinary capability. This measure may include licensed individuals, sanctioned and documented cross-training in different skill areas, or some combined measures of both of these. The diversity of cross-training is more important than the degree of specialization in a particular skill in measuring response time to special requests. Once again, a tabular value can be used or a frequency distribution can be employed.



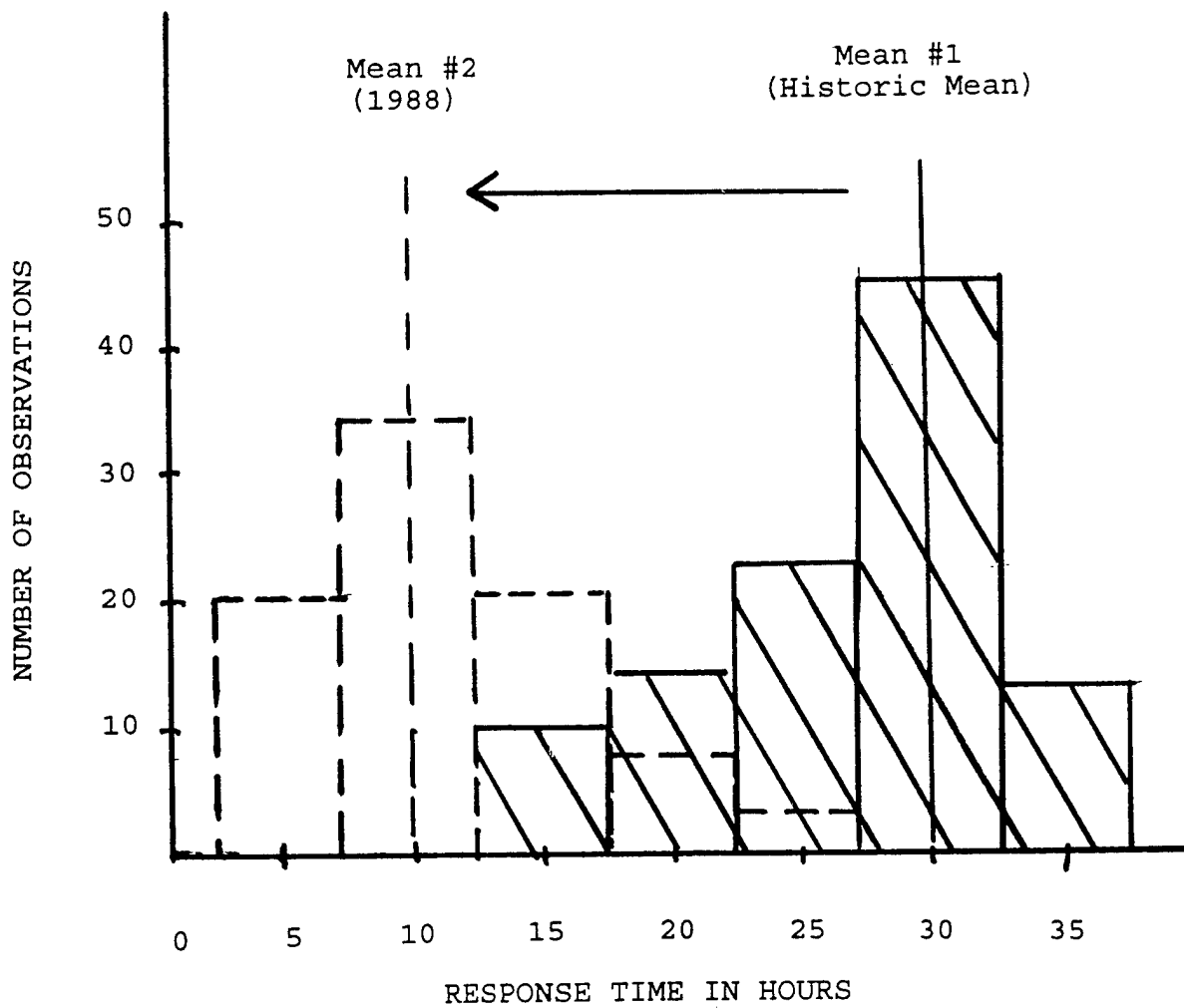


Figure 2b. - Measures of Adaptability and Flexibility



The cumulative number of hours of formal multidisciplinary training completed is also a measure of response capability. The more multidisciplinary training individuals have, the more they are capable of responding to requests outside their principle discipline. Cumulative hours is a good proxy for cumulative capability. If this training has not been used for a specified time-say two years-then it may no longer be applicable to the cumulative total for the organization. Unused skills and training diminish over time. Thus a running cumulative total (cumulative total less time depreciated hours not utilized) is a more accurate indicator of real capability. An adjustment must also be made for gains and losses in FTE's. Note the connection between adaptability and the concept of knowledge discussed earlier. This nexus is not passive nor accidental and signifies the importance of knowledge and training once again.

Although it is beyond the scope of this text to describe, the frequency distributions discussed above provide more information than indicated. Using "Z" scores, skew

analysis, risk concepts, and various kinds of test, more information is obtainable than described here. There are other measures of adaptability which may be useful in determining an organization's response to changing circumstances. For example, the number of changes in core management techniques put in place by management could be another measure of an ability to adjust. This would include many of the principles and practices covered in this text (continuous process improvement, SPC, performance measurement, and GPRA ideas made operational). From a technical viewpoint, the cumulative and absolute number of new tools and techniques used is another proxy for measuring adaptability.

The ability to accept change and engender new ways is a measure of survivability. The world has been in a new phase of cultural change since the 1970's which may be more significant than the Industrial Revolution of the past two centuries. Those not able to adapt will not survive.



APPENDIX C

PROCESS AND SYSTEM PERFORMANCE MEASUREMENT





C.1. SYSTEM PERFORMANCE MEASUREMENT AND PROCESS MAPPING

The Government Performance And Results Act of 1993 (GPRA) and the National Performance Review (NPR) and the APIC criteria mentioned earlier all emphasize the development of goals and objectives and measurement of organizational performance in achieving those goals. (Generally, these are increased efficiency, effectiveness, and outcome with considerable weight given to customer needs and wants.) In this section of the hand book, you will be given simple but effective tools and methods for measuring system and process performance. You will find that measurement usually focuses on those activities we define as "core" processes. These are the processes which are critical to the mission. They are either elements of the mission itself, or support activities which provide an indirect, but crucial, complement to the mission. Obviously, improvements in these processes can be expected to significantly affect productivity.

This part of the report will be used for exploring performance problems in complex management and technical systems and processes such as those found in the Army Corps of Engineers. A discussion of systems and processes was presented earlier and the reader may wish to review that section prior to reading the following paragraphs. This section will also show how benefits can be evaluated using *network analysis* (process mapping) and how to employ a *benefit-to-cost ratio (BCR)* to determine whether or not an alternative solution to a performance problem or system malfunction should be undertaken.

Or, which of a number of plausible solutions should be undertaken. The principle criteria are three: customer satisfaction, effectiveness, and efficiency.

Systems and Process Measurement

Two of the essential ingredients necessary for gains in performance are the application to processes and systems and the notions of continuous improvement and problem prevention. Process mapping is the important tool for this effort. Continuous improvement is the persistent day-to-day search for all organizational performance problems and the implementation of their solutions. This effort must embody the entire organization (employees and management) and be applied to all problems-large and small. It is this constant incremental effort (the concept of *kaizen* in Japanese) of finding even the smallest problem and its solution that, over time, adds up to significant improvements in effectiveness and efficiency. The reader should be aware that sudden and dramatic improvements (the concept of *hoshin* or break-throughs in Japanese) are part of the process and will occur along with incremental changes. They will likely be spontaneous or serendipitous rather than a planned part of change. All employees must be involved because it is they, each at their own tasks, that know where the problems are. Business process mapping and organizational problem solving can be done from the bottom up contrary to the classical



model of hierarchy, previously discussed. Management does not have the tacit knowledge that employees do. The effort to seek out and discover why something is not satisfying customers, needs to be continuous and not a one-time undertaking as is often the case in most organizations. This collective, continuous action leads to the reduction of waste, rework, and redundancy resulting in decreased cost of products and services and improved quality. This is the embodiment of continuous improvement and constancy of purpose.

The advantages of quantifying organizational operations are very convincing. The numbers tell us how much

change is taking place as a result of some corrective action and in what direction the performance is going. Another quality of measurement lies in benchmarking the results against the "best in the business" as previously discussed. Publication of the performance numbers serves as a motivating force for the organization. If performance improves over time, then this alone serves to encourage participation and provides a sense of ownership in the solution among employees. If performance decreases, this can serve to motivate as well by letting the organization know that its current effort or improvement program needs to change direction--feedback is vital.





C.2. A METHOD OF QUANTIFYING ORGANIZATIONAL OPERATIONS, INFRASTRUCTURE AND MEASUREMENT

A network methodology such as the *Program Evaluation And Review Technique (PERT)* is a tool originally developed to organize and monitor one-time, complex undertakings such as missile programs, housing projects, and large scale water resource programs and projects. It is easily modified and adapted for application to examining and monitoring organizational operations and the impacts of organizational structural changes and business operations. It fits the model of continuous improvement and constancy of purpose discussed above. It also is very functional in incorporating customer needs and wants and in evaluating improvements in product and service effectiveness and efficiency.

Prior to examining an application of the PERT methodology and how it applies to developing the benefits and costs of performance improvements, it is necessary to briefly discuss what it does and how. Figure 1c shows a simple operational flow of part of an organization. Let us start with some hypothetical process designed to transform resources into a product or service for customers. A goal is a broadly stated refinement of mission concerning key organizational issues. The goal in this case is to reduce operating costs. An objective as stated earlier is a specific statement of a goal elaborating the results anticipated. The objective in this case is to reduce plan formulation process costs by at least 5% over

the next five years without adversely impacting customer satisfaction (quality). It starts with "A" representing the initial event "A-B". The process of going from "A-B" requires an organization to expend resources to accomplish some activity or transform resources into products or services. These resources usually include management, money, employee labor, land, capital, technology, knowledge, etc. Once activity "A-B" is accomplished, the incomplete product or service must undergo additional transformation (move from one department or branch to another) as in this case of moving from "B" to "C" and from "B" to "F" and from "B" to "E". These three new activities further transform the product or service and add value as the product or service moves toward completion. The arrows represent direction of flow and the time it takes to go from event "A" to event "B" or from event "B" to event "C". Each event pair represents an activity which is to be accomplished. The number above or to the side of the arrow represents the time (i.e., 8 days, 8 weeks, 8 months, etc.) it takes between events and associated activities. The entire network in this simple system goes from event "A" to event "H" but passes through transformation processes "A-B, B-C, B-E, B-F, D-G, F-G and G-H" (from one office, branch, or division to another). This is the essence of the PERT process model. It is a "map" of the business process, what is accomplished, how it is



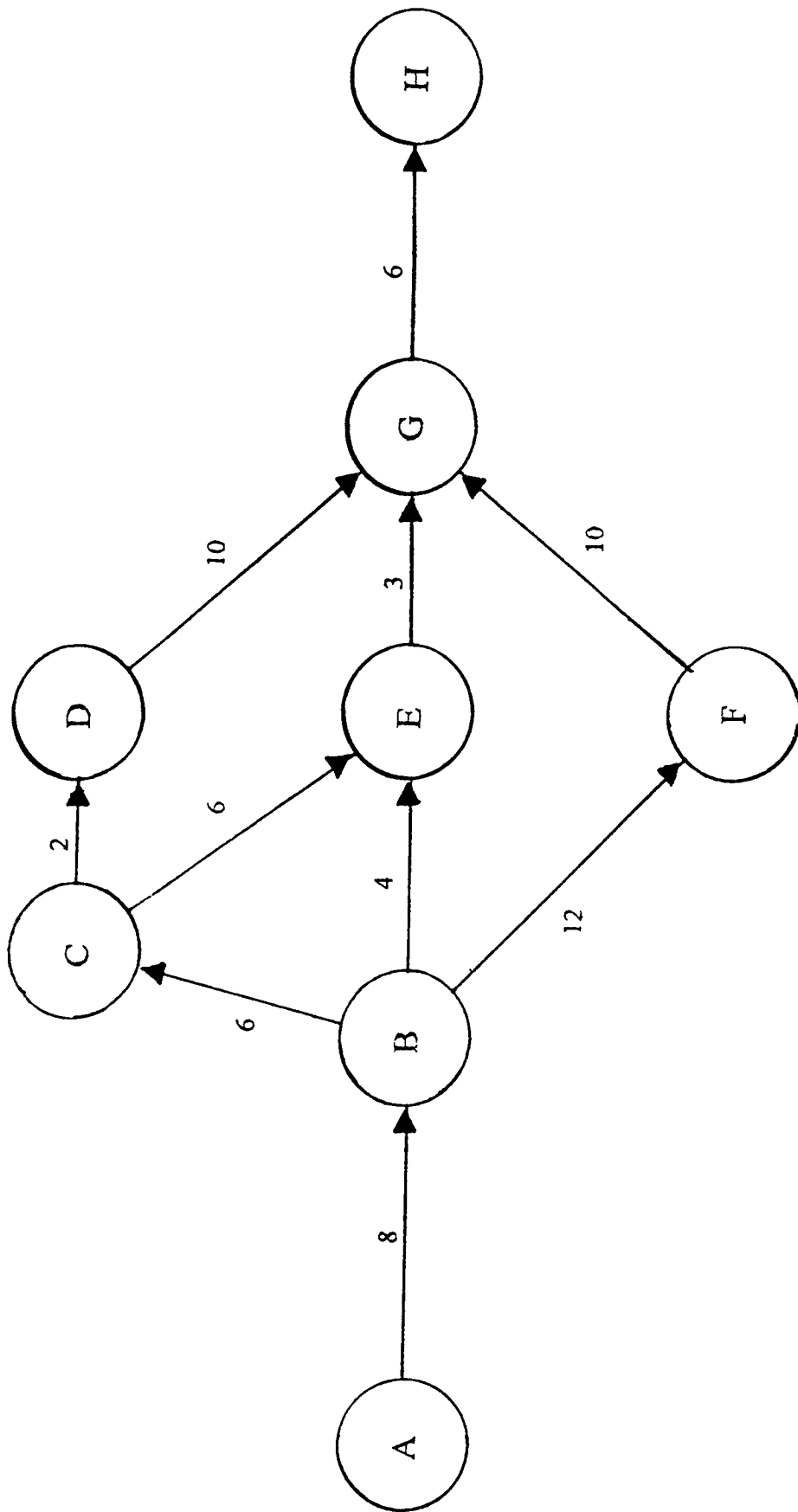


Figure 1c. - Existing Business Process Map



accomplished, the time it takes to accomplish, and if plotted as such, the sequence of events in some parallel or series fashion. The tie-in with customer satisfaction can be specified by letting event "A" represent a list of customer needs, wants, or specifications and event "H" represents the comparison of customer specifications with the final product or service. If the customer is not satisfied, it will be necessary to use this feedback to trace through the process to see where things went wrong and make appropriate adjustments.

One final point needs to be addressed concerning PERT analysis. The path of the longest time in the network or process is called the "critical path". Table 1c shows the various paths through the process or system with path "A-B-F-G-H" being the *critical path*. The user needs to compare this with some preestablished schedule to determine if the timing in the PERT can meet the specified deadline. PERT can be used not only to evaluate the steps and order in a process but can be employed to schedule completion times--another customer quality factor.

Table 2c shows some hypothetical data which will be adopted to illustrate how PERT can be used to map out and trace through a process which may represent a subsystem of a large organization. It is tied to Figure 1c discussed earlier. Column (1) of Table 2c represents the events and activities associated with Figure 1c. Column (2) shows the expected completion times for each of the activities. Column (3),(4),(5) and (6) show the number of personnel required to complete each activity, the hours per day of effort per person, the dollars per hour paid each employee (direct labor, indirect labor,

overhead, etc.) and the number of days worked per week, respectively. Column (7) represents the total cost of each activity. In this simplified illustration other resource such as capital, technology, raw materials, etc., are left out to avoid complicating the example but in reality all resource costs need to be included. Note that the total cost of completing the needed services or product for the customer are \$517,800.

Suppose that a re-analysis of the process in Figure 1c demonstrates that event "C" can be combined with event "D" to reduce the number of steps in the process and consequently reduce service or production costs. This may be possible due to the application of some new management technique which can enhance the productivity of the B-C activity thereby reducing operating costs. It could also stem from uncovering waste, redundancy, and excess review in the B-C activity. There are a host of tools which can be employed to explore and detect such problems including Shewhart control charts, Pareto charts, and cause-and-effect charts just to name a few. The cause notwithstanding, the new process illustrated in Figure 2c now yields a new operational cost as shown in Table 3c. Note that the events B-C, C-E, and C-D have been consolidated into activity B-D as part of the restructuring. As you trace through the costs and the events of restructuring, you will note that the new total costs for the same service or products is now \$460,800 which represents a savings of \$66,000. The net result is an 12.7% cost reduction. In this particular case there is no improvement in delivery time because the critical path is still the same (36 weeks) as before but total costs are none-the-less reduced.



**TABLE 1c
PERT TIME PATHS**

Events & Activities	Time (Weeks)
A-B-E-G-D	21
A-B-C-E-G-H	29
A-B-C-D-G-H	32
A-B-F-G-H	36 (Critical Path)

**TABLE 2c
RESTRUCTURED PROCESS COST BY ACTIVITY**

(1) ACTIVITY	(2) COMPLETION TIME (WKS)	(3) NO. OF PERSONNEL	(4) HOURS/DAY	(5) DOLLARS PER HR	(6) EFFORT (# OF DAYS)	(7) TOTAL COST
A-B	8	4	8	\$ 75	5	\$ 96,000
B-C	6	1	8	\$ 50	5	\$ 12,000
B-E	4	7	8	\$115	5	\$128,800
E-G	3	1	8	\$ 25	5	\$ 3,000
C-E	6	1	8	\$ 65	5	\$ 15,600
C-D	2	8	8	\$ 90	5	\$ 57,600
D-G	10	4	8	\$ 20	5	\$ 32,000
G-H	6	6	8	\$ 15	5	\$ 21,600
B-F	12	4	8	\$ 60	5	\$115,200
F-G	10	1	8	\$ 90	5	\$ 36,000
				TOTAL	=	\$517,800



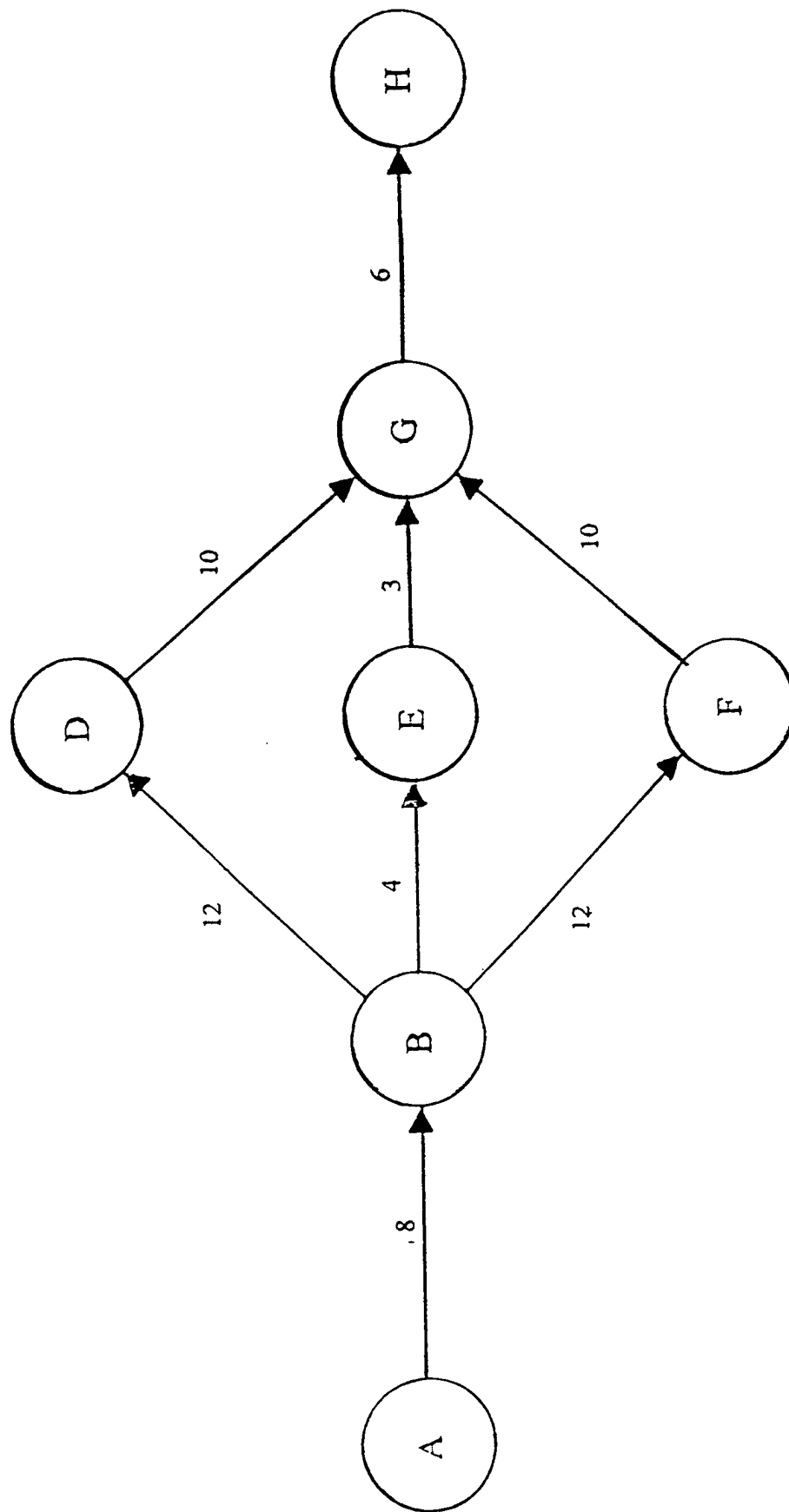


Figure 2c. - Improved Business Process Map

TABLE 3c
RESTRUCTURED PROCESS COST BY ACTIVITY

(1) ACTIVITY	(2) COMPLETION TIME (WKS)	(3) NO. OF PERSONNEL	(4) HOURS/DAY	(5) DOLLARS PER HR	(6) EFFORT (# OF DAYS)	(7) TOTAL COST
A-B	8	4	8	\$ 75	5	\$ 96,000
B-C ²	6	1	8	\$ 75	5	0
B-E	4	7	8	\$115	5	\$128,800
E-G	3	1	8	\$ 25	5	\$ 3,000
C-E ¹	6	1	8	\$ 65	5	0
C-D ¹	2	8	8	\$ 90	5	0
D-G	10	4	8	\$ 20	5	\$ 32,000
G-H	6	6	8	\$ 15	5	\$ 21,600
B-F	12	4	8	\$ 60	5	\$115,200
F-G	10	1	8	\$ 90	5	\$ 36,000
B-D ²	12	2	8	\$ 20	5	\$ 19,200
				TOTAL	=	\$451,800

$$(\$517,800 - \$451,800)/\$517,800 = 12.7\%$$

1 Processes Removed

2 Processes Added



The savings or benefit analysis requires several additional steps in order to show the full impact of the management change. The consolidation is expected to have a savings impact for at least five years into the future. Table 4c shows what this entails. Column (1) shows known *future studies* that will benefit from the new operating procedure. Column (2) shows the expected savings for each of five forthcoming studies. Columns (3) and (4) show the *discounting* effect used to take into consideration the *time value of money*. The sum of the discounted values is amortized over five years at 8-1/2%. If the average annual savings is expected to provide for longer term gains than a different *amortization period* could be used and vice versa. The final factor to consider is the cost of implementing the new operating procedure.

Table 5c shows estimated costs for putting the changes into effect. Costs should include *all resources* associated with the action. In this simplified example a few likely costs are shown to illustrate the concepts involved. Note that costs must undergo amortization as did benefits or savings. Costs are expected to be incurred as a one time expenditure so that no discounting over time is required. The \$140,400 cost is amortized at 8-1/2% for year five. Average annual costs are \$35,662. Finally, Table 6c shows that the proposed consolidation plan is more than justified from an economic perspective with a benefit-to-cost ratio of 1.60. This means that over the five year horizon the action will return \$1.60 for each \$1.00 invested.

Table 7c shows what a comparison of alternatives would look like. Alternative 1 is the plan previously discussed. Other plans show varying degrees of savings and costs but allow analysts to compare different ideas

against one-another on an economic basis. It should be added that other considerations aside from BCR's may need to be considered as well but this approach will lead to the most efficient solution. If the most efficient solution is not selected, than the analyst knows what is being given up in terms of lost benefits to obtain another, less economic solution. Note that the net gain and BCR for alternative 1 are the highest among the alternatives investigated.

Figure 3c shows a more probable or realistic subprocess of an organization. It is more complex and may have loops as illustrated by the double arrow activities: F-I, I-H and H-F where processes are cycled back and forth. Such a situation may occur in COE flood control formulation planning when hydrology data for a plan are given to an economist who then develops the benefits of the plan, which then goes to cost engineering only to discover that costs are too high and the projects BCR is less than unity. The process is repeated until a plan or set of alternatives finally evolves. This loop may go on for months before a final set of alternative flood control plans are sent to the next event or activity.

The power of the PERT process as described in the previous paragraphs is clear. *Customer driven input has been included, goals have been established and met, objectives have been fulfilled and a process change has taken place and proven justifiable. Furthermore, effectiveness (doing the right thing) has been integrated through customer input and efficiency (doing things right) has improved because costs have decreased.* There could have been several alternatives to investigate each with a different benefit-to-cost ratio as well as meritorious non-quantifiable attributes.



TABLE 4c
BENEFIT (SAVINGS) ANALYSIS OF PROPOSED PROCESS CHANGE

EXISTING PROCESS COST:	\$517,800
NEW PROCESS COST:	<u>451,800</u>
NET SAVINGS	= \$ 66,000

(1) FUTURE PROJECTS NO. _	YEAR	(2) EXPECTED NET SAVINGS	(3) PRESENT VALUE FACTOR ³		(4) PRESENT VALUE
1.	1996	\$66,000	0.921	=	\$60,786
2.	1997	\$60,000	0.849	=	\$50,940
3.	1998	\$75,000	0.783	=	\$58,725
4.	1999	\$35,000	0.722	=	\$25,270
5.	2000	\$44,000	0.921	=	\$29,260

TOTAL = \$224,981
INTEREST & AMORT = 0.254
AVG. ANNUAL SAVINGS = \$57,145

³ Interest and amortization @ 8-1/2% for 5 years



TABLE 5c
COST ANALYSIS OF PROPOSED PROCESS CHANGE

<u>COST ITEM</u>	<u>1995 COSTS</u>	
1. Cost of meetings & strategy sessions	\$ 10,800	
2. Cost of internal administration	5,000	
3. Cost of planning	8,000	
4. Cost of research, consulting fees	10,000	
5. Down-time due to process change-over	42,600	
6. Cost of new equipment	50,000	
7. Re-train employees	10,000	
8. Cost of furniture moving	2,000	
9. Miscellaneous expenses	<u>2,000</u>	
TOTAL	\$140,400	
Interest & Amortization ⁴		0.254
Average Annual Costs	\$35,662	

TABLE 6c
THE BENEFITS OF THE NEW MANAGEMENT ALTERNATIVE

Average Annual Savings:	\$57,145
Average Annual Costs	\$35,662
Average Annual Net Gain	\$21,483
Benefit to Cost Ratio:	$\$57,145/\$35,662 = 1.60$

⁴ Interest and Amortization for 5 Years @ 8-1/2% Interest



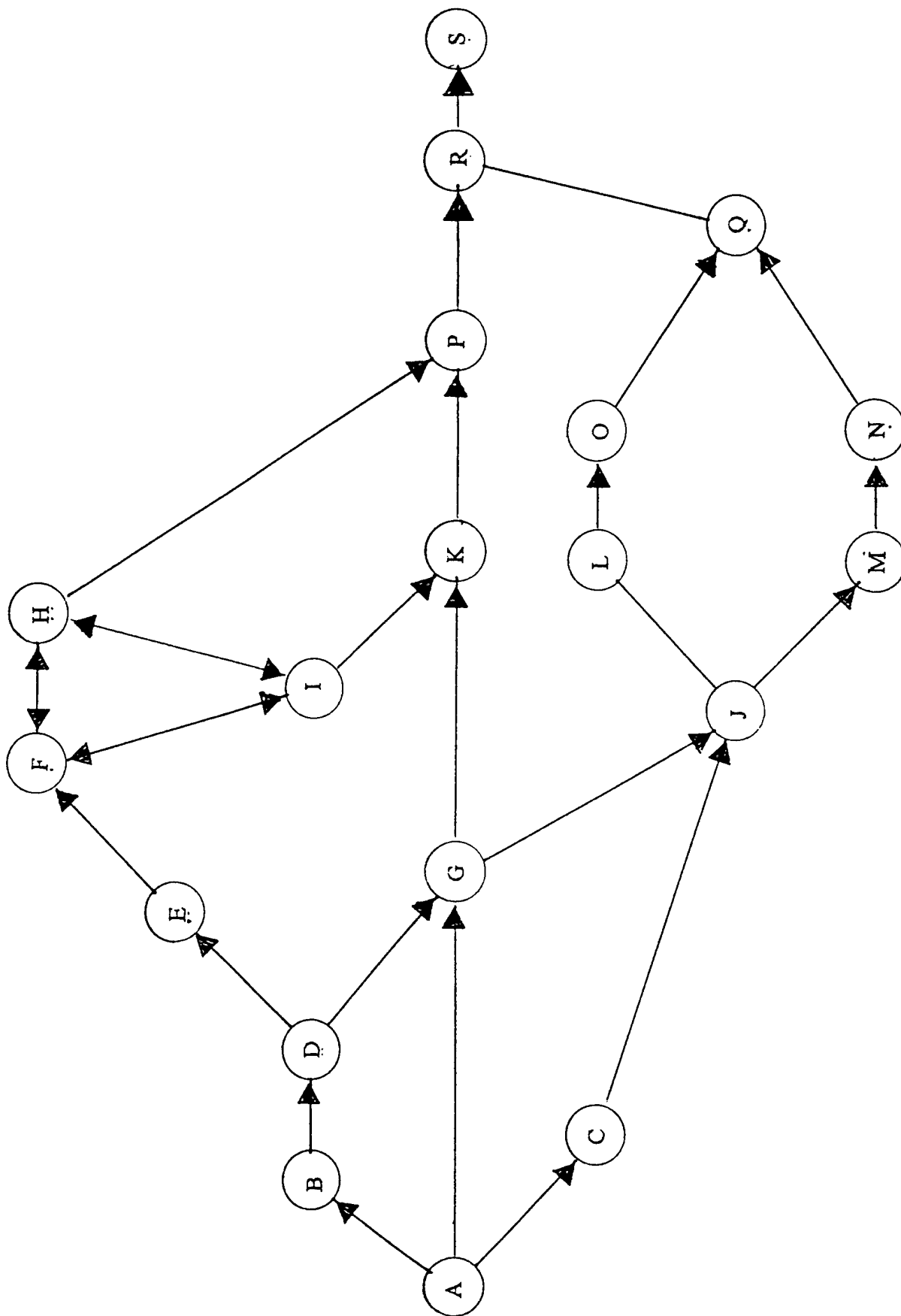


Figure 3c. - A PERT Description of a Complex Business Process or Subprocess



TABLE 7c
COMPARISON OF ALTERNATIVE SOLUTIONS

COSTS/BENEFITS	ALTERNATIVES			
	(1)	(2)	(3)	(4)
Avg Annual Savings	\$57,145	\$47,500	\$44,300	\$62,900
Avg Annual Costs	\$35,662	\$37,000	\$39,900	\$49,700
Avg Annual Net Gain	\$21,483	\$10,500	\$4,400	\$13,200
BCR	1.60	1.28	1.11	1.27

non-quantifiable attributes. PERT can be used to explore and evaluate projects, program performance, program formulation, organizational structure, communication networks, and a host of other process and systems. It is also useful in evaluating the really tough issues related to what happens when new processes cut across divisional boundaries. One of the reasons process and systems analysis is necessary lies in creating a problem when finding a solution. It sometimes happens that in removing an obstacle or "bottleneck" in one area of an organization, another bottleneck is created elsewhere. Systems analysis helps prevent this from happening by examining all the processes involved; not just the problem at hand.

The evaluation can be integrated with statistical process control to provide valuable information about process mean, variance, reliability, and correlation as used to examine the incremental approach to process improvement found in total quality management; or restructuring initiatives, de-layering, down sizing, and the more draconian process of re-engineering. This process can also be used to examine functional, cross-functional, and vertical and horizontal flow movement in the organizational structure. Best of all there are commercially available PERT computer programs which can be used with the office PC to perform the analyses mentioned above.





C.3 CONTROL CHART TECHNIQUES [Rodakowski, 1994]

Shewhart Control Charts

An excellent discussion of process variation and statistical quality control can be found in an AT&T publication [AT&T, 1956] from which much of the following information is based. When data are collected relating to the measurement properties for any problem, production, situation or process (products and services), these data usually display random variation. Instead of the same datum measurement being observed each time, the measurement (of the same thing) varies. When these data are plotted one can observe an up and down or nonuniform saw tooth character. Similarly, any series of numbers from a process will produce a zig-zag or fluctuating pattern. There is no known product, service, item or process which does not produce or show measurement variation over time. This seemingly trivial observation is extraordinarily important.

Measured random variations are caused by a large number of reasons: differences in materials, equipment, the local environment, human skills, management practices, etc. Many of these differences are small but are the chief driving force behind fluctuations which are natural or normal. On occasion, however, there will be a significant or unusual difference more profound than all other differences combined. These are not random process variations. Such significant differences may be observed when equipment breaks down, employees receive new training, management changes hands, an experienced

worker takes over where an inexperienced worker left off, etc. These large signatures or causes produce a fluctuation pattern which is unusually large or aberrant; they are abnormal, but they are not random.

Evidence indicates that there is a clear cut and measurable difference between the natural and the unnatural fluctuations. These differences can be detected and subsequently analyzed by existing statistical tools such as the frequency distribution, discussed earlier. Once it is determined that a fluctuation is unnatural, its cause can be determined. Thus, causes can be isolated and studied for any process, whether it be a production process, a service output process, or a manufacturing process.

Fluctuations were observed long ago in the manufacturing of carriage wheels, metal parts, and banking services. When engineers measured the differences between the same part manufactured in the same way within the same process, they found that the measurements tended to cluster around a central value with some degree of scatter on either side of the central value. This is the typical pattern of a frequency distribution; a subject discussed earlier. If the cause system is constant, the frequency distribution approaches some distribution function; a mathematically predictable behavior. A consistent or repeated pattern is formed and is made up of a large number of fluctuations - some larger or smaller than others - shifting within the bounds of the fluctuation pattern itself (bell shaped curve) when there are no



unusual, significant, or abnormal causes at work.

The fluctuation patterns in normal production and service operations have statistical limits. If that pattern is normal or natural, its fluctuations will fit within the confines of these limits as stated earlier. If a pattern is, however, unnatural, its fluctuations will exceed these limits. When statistical limits are added to a fluctuating pattern the results are referred to as a control chart. These statistical limits are usually 3 standard deviations from the mean. Any pattern of data in a control chart which fluctuates outside of these 3 standard deviations from the mean or which show non random (unnatural) points, it is said to be indicative of a process which is "out-of-control". Three standard deviations is a generally accepted criteria but more will be said about this later in the text.

The control chart, in sum, is a group of fluctuating, random patterns representing a process bounded within statistical limits. The control chart is the back bone of statistical process control and capability analysis mentioned earlier. There are two types of control charts. One for analyzing **variable** characteristics (anything which can be measured) and one for **attributes** (where something is produced or serviced which either passes a test or fails it). In this text we will be dealing chiefly with variable control charts because they fit in the COE process better than attributes charts and provide considerably more information.

The notion of control involved taking action with the intent of achieving a desired end; a means - ends relationship. The prime purpose in statistical process control is to detect and eliminate the unnatural fluctuations and reduce the variation in natural, normal fluctuations to foster uniformity of quality. In

other words, product or service quality needs to be reproducible within limits. Note that when a significant cause is discovered and removed, this changes the control limits by narrowing them. Leaving behind more typical cause variation fluctuating in a narrower range. The process of detecting, identifying and eliminating causes may be a long run process. Initial rapid elimination may occur, but the longer term or more complex causes may take time. The idea of a state of statistical control serves as a basis for describing and reaching the goal of uniformity and achieving the functional capability of a process capable of reaching this goal. In the following paragraphs, data for permit reports will be used for a step-by-step control chart construction. More will be said later with regard to the concepts of special and common causes of variation.

The objective of statistical process control is to eliminate special causes of variation and to monitor the process for shifts in process averages and variances over time. This goes a long way toward improvement in product and service quality.

As discussed earlier, every item, service or process varies in some characteristic. These variations may be due to human resource capabilities, environmental factors, management practices, etc. There are two major types of variation that are important and distinct to process capability analysis. They are: common cause *variation* and *special* cause variation.

Common cause variation is the collective effect of many or all individual causes of variation that are indigenous to the process of producing a good or service that cannot be removed without management action. Studies have shown that common cause variation is 85% management related



[Deming, 1982]. Each of the many causes of variation that compose the total may exhibit vastly different distributions, but in combination, they are approximately normal. Consequently, whenever we have common cause variation we can assume that the process population distribution of the variable being measured is nearly normal. Table 8c lists a few attributes of common cause variation in the COE. This list should be studied as a means of building a sensitivity to the characteristics of common cause variation. In order to correct common cause variation, that is the heart of a nonuniform production system, corrective action is required. Common cause variations are the process errors over which employees have no control, i.e., for the COE this could represent changes in regulations, priority changes, equipment breakdown, congressional requests, among others.

Special cause variation emanates from individual sources of variation that may be statistically identified and removed from the production and service process. When adequate statistical evidence is presented, employees are best at identifying a special cause of variation and are paramount in eliminating the cause. Such causes include incomplete or improper training of a new employee, a piece of equipment not properly functioning, an incorrect procedure or technique, etc. These problems represent approximately 15% of process variation [Deming, 1982]. Tables 9c and 10c list a few items of potential common or special variation.

The keys to determining whether a cause is special or common is to first detect it, isolate it, then eliminate it. These factors fall under the topic of control charts which are closely allied to common and special cause analysis.

When variable data are evaluated, the data are graphed over time on a mean chart and a range chart. For each sample data, the mean and standard deviation are most often used for plotting. However, the range may substitute for the standard deviation because of the ease of its determination without much loss in the validity of the final results.

The initial step in developing a control chart is the assembling of a sample size. Sample sizes or subgroups may be as low as 2 but more typically are 5 or any number between. A sample may be collected weekly, monthly, or annually depending upon the circumstances. At least 20 samples are deemed a viable size. For each sample, the mean $\bar{x}$ and the range R are calculated, then the mean of the individual sample means are calculated as a good proxy of the process mean. The expression for this is:

Equation (1)

$$\bar{\bar{x}} = \Sigma \bar{x}_j / k$$

where k is the number of subgroups or samples ($\bar{\bar{x}} = X$ -double bar or the average of the averages).



TABLE 8c
COMMON AND SPECIAL CAUSE ATTRIBUTES⁵

Special Causes Associated with things which are:	Common Causes Associated with things which are:
Unnatural Disturbed Unstable Non-homogeneous Mixed Erratic Abnormal Shifting Unpredictable Inconsistent Out-of-the-ordinary Different Important Significant	Normal Natural Stable Unisturbed Homogeneous Coming from a single distributon Not changing Steady Predictable Same Consistent Statistically constant Non-significant

⁵ AT&T, Statistical Quality Control Handbook (Indiana: AT&T Technologies, Inc. Sec. Ed. 1958)



TABLE 9c
HOW WOULD YOU RATE EACH:
SPECIAL VS. COMMON

- | |
|---|
| ☐ Plan formulation changes |
| ☐ Changes in regulations |
| ☐ Equipment breakdown |
| ☐ Lack of training |
| ☐ Too many meetings |
| ☐ Meetings too long |
| ☐ Non-acceptance of new ideas |
| ☐ Too many jobs/tasks per person |
| ☐ Lack of secretarial assistance |
| ☐ Communication problems |
| ☐ Quantitative errors |
| ☐ Grammatical errors |
| ☐ Lack of data or information |
| ☐ General office disturbance |
| ☐ Policy or operational differences between Division, Branches, etc. |
| ☐ Unfunded tasks |
| ☐ Micro management approaches |
| ☐ Other |



TABLE 10c
HOW WOULD YOU RATE EACH:
SPECIAL VS. COMMON

- | |
|---|
| ☐ Major unscheduled tasks |
| ☐ Flash fires, crisis events |
| ☐ Employment freezes |
| ☐ Priority changes |
| ☐ Hurricanes |
| ☐ Loss of funding/budget cuts |
| ☐ Reorganization |
| ☐ TQM |
| ☐ Long term illness of key employees/supervisors |
| ☐ Changes in management, supervision or leadership |
| ☐ Major policy directions |
| ☐ Congressional requests |
| ☐ People leaving (promotions, other jobs, etc.) |
| ☐ Other |



Following this, the average range of the subgroups are calculated:

Equation (2)

$$\bar{R} = \Sigma R_j/k$$

where k is the number of subgroups or samples as before.

From these equations, a control chart can be constructed which yields a significant amount of information about the process under investigation. Given earlier discussions, we can expect the process to be normally distributed, or nearly so, if the driving causes of variation are common. The distribution of samples sizes themselves are also expected to be normal even if small samples sizes (2 through 5) are used. One of the functions of using the mean chart is to detect a change in the production or services process mean. The use of a chart for this purpose is basically a hypothesis test. Meek, Taylor, Dunning and Klafehn [1987] describe in clear terms the purpose of variable control charts which is summarized in the following paragraphs. If a sample value is drawn from a process operation such that its mean is larger or smaller than the overall process mean, then it is likely that the process mean has changed position. When we conclude that the process mean has shifted, when actually it has not, we are making what is called a Type I error. Alternatively, when we conclude that the process mean has not shifted, when in fact it has, we are making what is called a Type II error. Usually, the calculated control limits

are set at plus or minus three standard deviations (3s) from the mean to limit the chance of making a Type I error. From a table of standard normal distribution Z-scores, we can ascertain that the probability that the process mean has shifted, when in actuality it has not, is 0.003 (3 standard deviations). Figure 4c illustrates these principles. Three standard deviations are used because studies have shown that this criteria is the most economically efficient standard to use when testing Type I and Type II errors [Shewhart, 1986].

It is the conclusion of hypothesis testing that determines the three standard deviation control limits (3s). Studies conducted in the past have demonstrated that these limits are the most economically efficient criteria when balancing the cost and benefits of detection and problem identification against the consequences of eliminating a special cause.

1. Basic Equations for Control Chart Construction

We can look at quality control from the confidence interval for $\bar{X}$. The upper and lower control limits are positioned at a distance of three standard deviations from the average sample mean by the expression [Meek, et al, 1986]:

Equation (3)

$$UCL_{\bar{x}} = \bar{\bar{X}} + A_2\bar{R}$$

Averages ($\bar{X}$ bar chart)



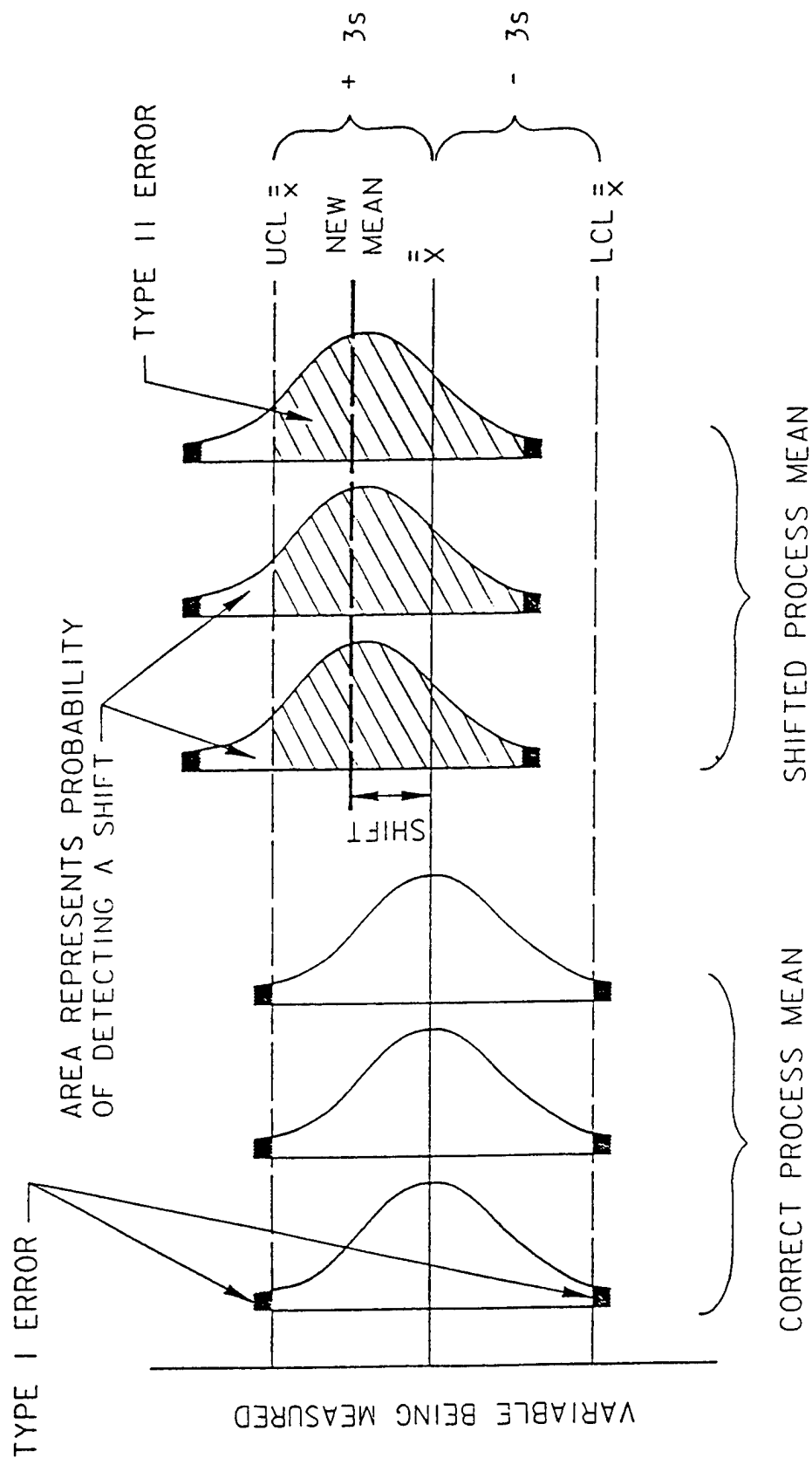


Figure 4c. - Example of Shift in Process Mean

Equation (4)

$$LCT_{\bar{x}} = \bar{\bar{X}} - A_2 R$$

where UCL_x and LCL_x are the upper and lower control chart limits, $\bar{X}$ is the process mean, A_2 is a sample size adjustment factor, and R is the mean process range, and:

Equation (5)

$$UCL_{\bar{x}} = \bar{\bar{X}} + D_4 R$$

Ranges (for R charts)

Equation (6)

$$LCL_{\bar{x}} = \bar{\bar{X}} - D_3 R$$

where UCL_R and LCL_R are the upper and lower control chart limits, R is the mean process range, and D_3 and D_4 are sample size adjustment factors. Table 11c shows the value needed for samples size adjustment multipliers.

The range chart R is used in conjunction with an $\bar{X}$ chart to audit the variability process. Variability changes are just as undesirable as changes in the process mean. The range chart is not only used to audit process fluctuation but aids in identifying ways to decrease process variability. One of the functions of statistical process control is to reduce the

variation around the desired or target process mean.

An interesting spinoff use for control charts, aside from monitoring shifts in process mean and in process fluctuations, is the diagnosis of cause and effect. Charting aids in detecting a problem and, along with other business monitoring tools, can go a long way in specifying cause and effect relationships. Simply put, more is learned about the process.

Figure 5c illustrates the setup needed to analyze the behavior of the process mean and examine range activity.

2. Rational Subgroup Selection

A subgroup is a small sample size. The choice as to how many values make up a subgroup is as much an art as a science. Generally this choice is dependent upon the behavior of the phenomenon being chartered [AT&T, 1958]. If the raw data appears to fluctuate widely, one would want to choose a subgroup size around 4 or 5 to help moderate the fluctuations. If the fluctuations appear dampened already, then a subgroup size of 2 or 3 may be more suitable. You do not want too large a subgroup size as this would tend to disguise the magnitude of fluctuations to the point of hiding special causes. Alternatively, a sample size too small may lead to many things looking like special causes. Rational subgroups are usually chosen to make the variation within each subgroup as small as possible for the process (representing the variation from common causes) and so that any shifts in the process performance (i.e., special causes) can emerge as differences between subgroups [Shewhart, 1986]. There are rules of thumb for selecting subgroups.



TABLE 11c
ADJUSTMENT FACTORS⁶

Subgroup Size	A ₂	D ₂	D ₃	D ₄
2	1.88	1.13	*	3.27
3	1.02	1.69	*	2.57
4	0.73	2.06	*	2.28
5	0.58	2.33	*	2.11
6	0.48	2.53	*	2.00
7	0.42	2.20	0.08	1.92
8	0.37	2.85	0.14	1.86
9	0.34	2.97	0.18	1.82
10	0.31	3.08	0.22	1.78

They include:

- ☐ A subgroup should be selected in such a way as to allow for opportunities in variations to show up. Consequently, subgroup size should be small (2 to 5 measurements is suitable).
- ☐ Subgroup size must remain constant for all subgroups.
- ☐ Data should be taken (sampled) frequently enough to show

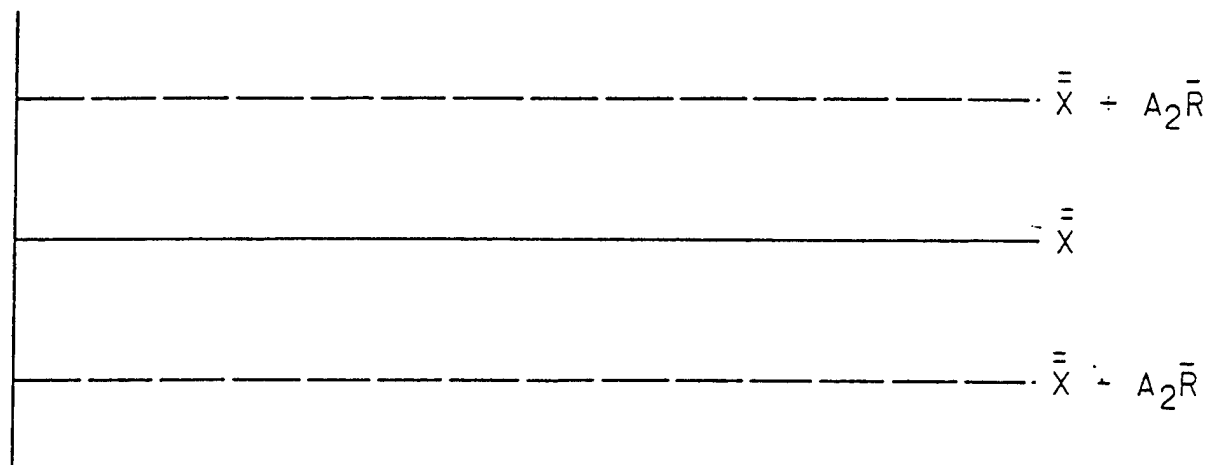
variations in the process under investigation - give the process time to show change - fluctuations.

- ☐ The number of subgroups must be sufficient to allow process variation to show up. From a statistical point, 25 or more subgroups containing about 100 or more measurements give a good test for stability and show variance.

⁶ Wayne W. Daniel and James C. Terrell., Business Statistics For Management and Economics, 5th ed. Boston: Houghton and Mifflin. 1989



MEAN CHART



RANGE CHART

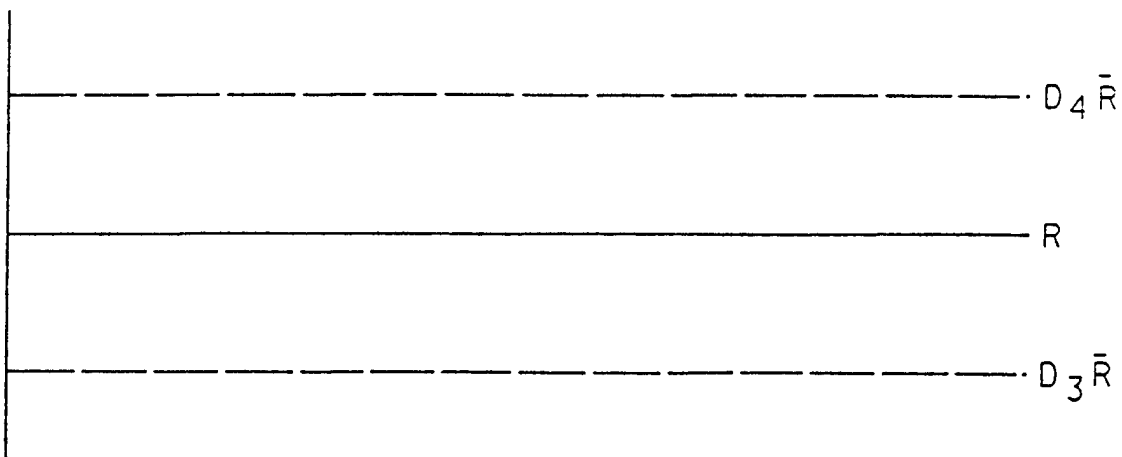


Figure 5c. - Means and Limits for Control Charts



Recall what was discussed earlier in the text; that the samples of 2-5 are used to find a mean ($\bar{X}$). These subgroup means are then used to find the mean of the means ($\bar{x}$). The mean of the sampling distribution of means is equal to the population mean. We also find the mean of the ranges R (which is our substitute for the standard deviation) approximates the mean of the population range distribution.

An example of how to develop a control chart will aid considerably in understanding what has been introduced earlier.

To explain the process, we will develop some data on the length of time needed to complete 39 Permit Reports during an FY in a Permit Branch, Construction and Operations Division. The report number and length of time it took to complete each permit are listed in Table 12c. As the data show, each report took different lengths of time to complete ranging from a low of 60 days to a high of 120 days with a mean of 95.5 days. This data was then broken into eight class intervals in order to construct a frequency distribution of the data. This process is illustrated in Table 13c. By looking at the tallies in the table, it is readily apparent that a "bell shaped" curve is formed by the variation within the data. The number of reports falling into each class interval are presented in the third column and support the tally distribution. This information is then used to construct a frequency distribution as shown in Figure 6c. The frequency distribution takes the expected form of the standard bell shaped curve with a range of values, standard deviation, mean, mode, and median. The distribution shows that the data do in fact vary as would be expected. This is the type of variation discussed earlier.

Table 14c shows the same data as in Table 12c but grouped into subgroups (randomly selected) of three. Column (1) shows a subgroup number. Each subgroup number consists of three sequential numbers. The numbers in Column (2) represent the values used to form that particular subgroup. In this case the subgroup size is three numbers. Remember a subgroup can consist of between 2 and 5 numbers. Remember also a subgroup serves two purposes; one is to dampen oscillation and the other is to serve as a "sample" of a larger set of data. Column (3) represents the sum of the values in each group. The values in parenthesis in Column (4) are rounded numbers. As can be seen at the bottom of Column (4), $\bar{x}$ (see equation 1) is calculated as 95.9 days; this is the mean of the means. Column (5) shows the range R of each subgroup. As before, the range is the difference between the highest and lowest value in a group. The mean of the ranges ($\bar{R}$) is calculated as 17.9.

The data in Table 14c is transferred to Figure 7c. Figure 7c is a standard form constructed for the purpose of graphing a control chart and showing all the information pertinent to the development of the chart. It is a complete record in and of itself. Note that the data is located in the bottom left of the chart. The raw data are shown, the mean $\bar{X}$ of each subgroup is presented and the range R within each subgroup is also shown.

Figure 8c shows the placement of process mean report completion time ($\bar{x}$) and mean range fluctuation ($\bar{R}$). It is now possible to compare movement, variances, or fluctuations on the basis of a frame of reference. Figures 9c and 10c add to Figure 8c to show the graphing process.



TABLE 12c
DATA FOR CONSTRUCTING A FREQUENCY
DISTRIBUTION AND HISTOGRAM

Permit Number	(1) Number of Days
1	60
2	71
3	81
4	130
5	81
6	77
7	81
8	90
9	101
10	90
11	103
12	110
13	107
14	103
15	78
16	100
17	90
18	90
19	109
20	110
21	120
22	108



TABLE 12c (Continued)
DATA FOR CONSTRUCTING A FREQUENCY
DISTRIBUTION AND HISTOGRAM

Permit Number	(1) Number of Days
23	90
24	111
25	118
26	91
27	91
28	93
29	94
30	95
31	99
32	99
33	98
34	97
35	92
36	100
37	100
38	91
39	92
Total	3741



TABLE 13c
DEVELOPMENT OF A FREQUENCY DISTRIBUTION

Class Intervals of the Number of Days Needed to Complete a Class Interval of Report Permit Application	Tallies		Number of Times Each Completion Was Observed (Days) (Source Table 12c)
51 - 60	1	1	2.6
61 - 70	1	1	2.6
71 - 80	11	2	5.1
81 - 90	1111 111	8	20.5
91 - 100	1111 1111 1111	15	38.5
101 - 110	1111 111	8	20.5
111 - 120	111	3	7.7
121 - 130	1	1	2.6
		39	100.1 ⁷

Mean = 95.9
Median = 95.0
Mode = 90.0
Standard Deviation = 13.61

⁷ Does not total to 100% due to rounding.



TABLE 14c
ANALYSIS OF SUBGROUP DATA

(1) Subgroup Number	(2) Values Used In Subgroup (No. Of Days)	(3) Sum of Subgroup (Number of Days) x	(4) Mean of Subgroup	(5) Range of Subgroup (R)
1	60+70+81	212	70.7 (71)	21
2	130+81+77	288	96.0 (96)	53
3	81+90+101	272	90.7 (91)	20
4	90+103+110	303	101.0 (101)	13
5	107+103+78	288	96.0 (96)	29
6	100+90+90	280	93.3 (93)	10
7	109+110+120	339	113.0 (113)	11
8	108+90+111	309	103.0 (103)	21
9	118+90+111	300	70.7 (71)	28
10	93+94+95	282	96.0 (96)	2
11	99+99+98	296	98.7 (99)	1
12	97+92+100	289	96.3 (96)	8
13	100+91+92	283	94.3 (94)	9
			13 1247.2	233
			X = 95.9	R = 17.9



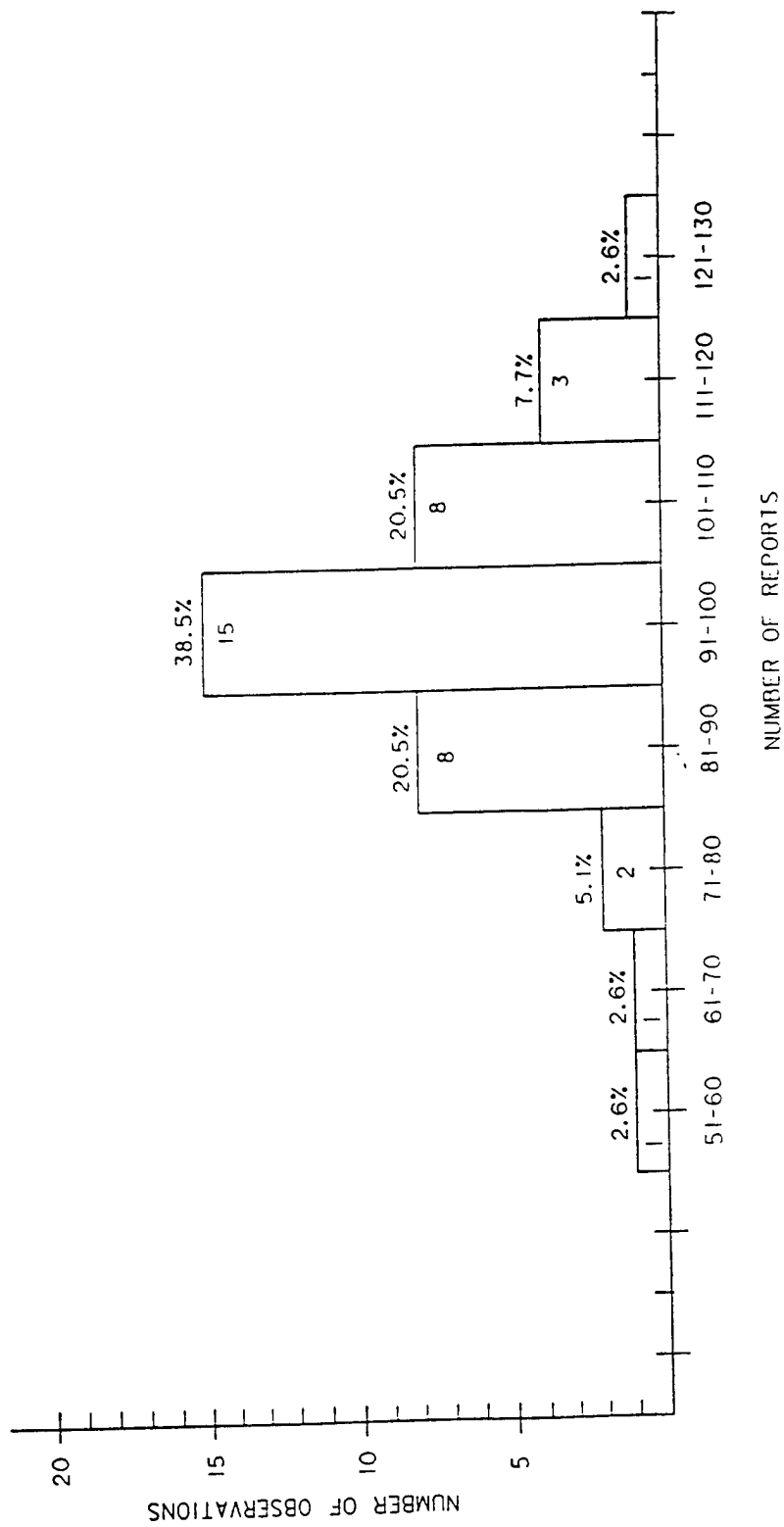
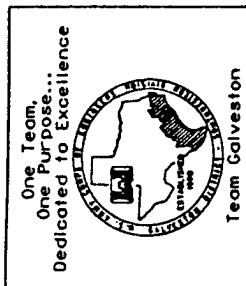


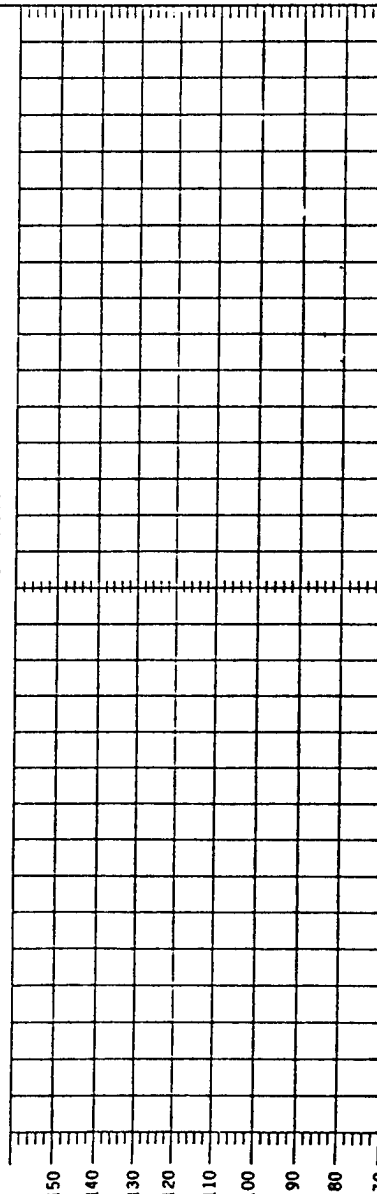
Figure 6c. - Construction of Class Intervals for the Development of a Frequency Distribution



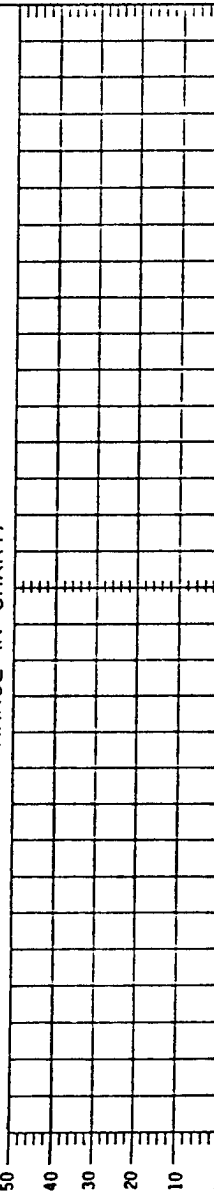
PROJECT NAME: ANALYSIS OF PERMIT REPORT
 DIVISION: CONSTRUCTION/OPERATIONS
 BRANCH: CO-R
 SECTION: CO-RR
 DATE: 10 JUNE 1993
 COMMENTS: USE $\bar{X}$ AND R CHARTS TO EVALUATE PROCESS CAPABILITY
 SUBGROUP SIZE = 3

RECORDING RAW DATA

AVERAGE (X-BAR CHART)



RANGE (R CHART)



DATE	1	2	3	4	5	6	7	8	9	10	11	12	13
DAY	1	2	3	4	5	6	7	8	9	10	11	12	13
1	60	130	81	90	107	100	109	108	118	93	99	97	100
2	71	81	90	103	103	90	110	90	91	94	99	92	91
3	81	77	101	110	78	90	120	111	91	93	98	100	92
4	--	--	--	--	--	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--	--	--	--
SUM	212	286	272	303	268	280	339	309	300	282	296	269	263
X-BAR	71	96	91	101	96	93	113	103	100	94	99	96	94
RANGE	21	23	20	20	29	10	11	21	27	2	1	8	9

STEPS 1 AND 2

$$\sum \bar{X}/N = 1247/13 = 95.9$$

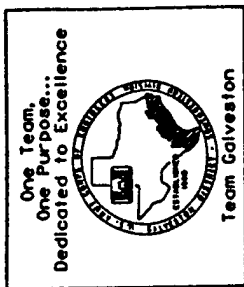
$$\sum R/N = 232/13 = 17.9$$

TABLE OF X AND R CONTROL FACTORS

SUBGROUP SIZE (n)	X CHART FACTORS FOR CONTROL LIMITS (A ₂)	R CHART FACTORS FOR CONTROL LIMITS (D ₃) (D ₄)
2	1.88	0 3.27
3	1.02	0 2.57
4	.73	0 2.28
5	.58	0 2.11
6	.48	0 2.00
7	.42	.08 1.92
8	.37	.14 1.86
9	.34	.18 1.82
10	.31	.22 1.78

NOTES

Figure 7c. - Shewhart Control Chart



PROJECT NAME: ANALYSIS OF PERMIT REPORT _____ DATE: 10 JUNE 1993
 DIVISION: CONSTRUCTION/OPERATIONS
 BRANCH: CO-R
 SECTION: CO-RR

COMMENTS: USE $\bar{X}$ AND R CHARTS TO EVALUATE
 PROCESS CAPABILITY (SUBGROUP SIZE = 3)

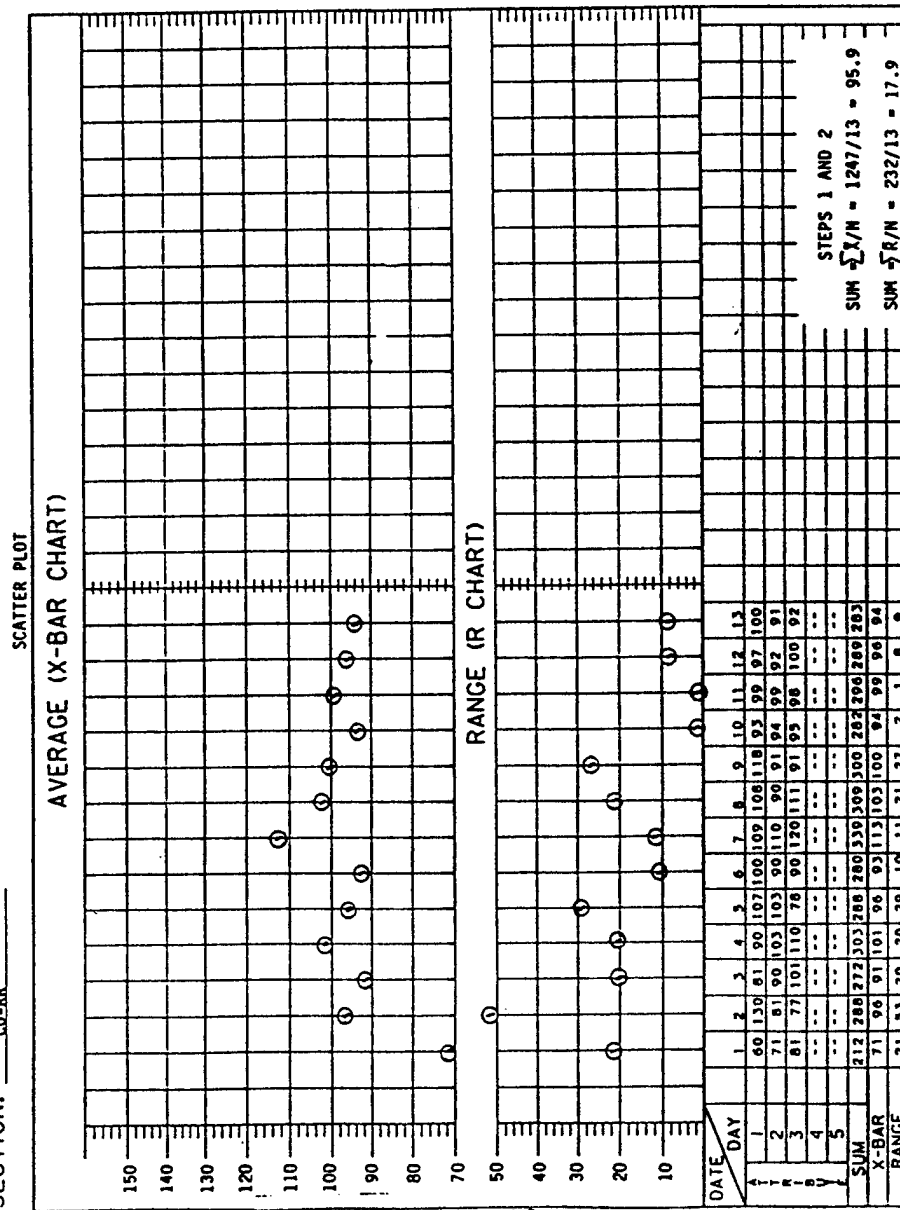


TABLE OF X AND R CONTROL FACTORS

SUBGROUP SAMPLE SIZE (n)	X CHART FACTORS FOR CONTROL LIMITS (A ₂)	R CHART FACTORS FOR CONTROL LIMITS (D ₃) (D ₄)
2	1.88	0 3.27
3	1.02	0 2.57
4	.73	0 2.28
5	.58	0 2.11
6	.48	0 2.00
7	.42	.08 1.92
8	.37	.14 1.86
9	.34	.18 1.82
10	.31	.22 1.78

NOTES

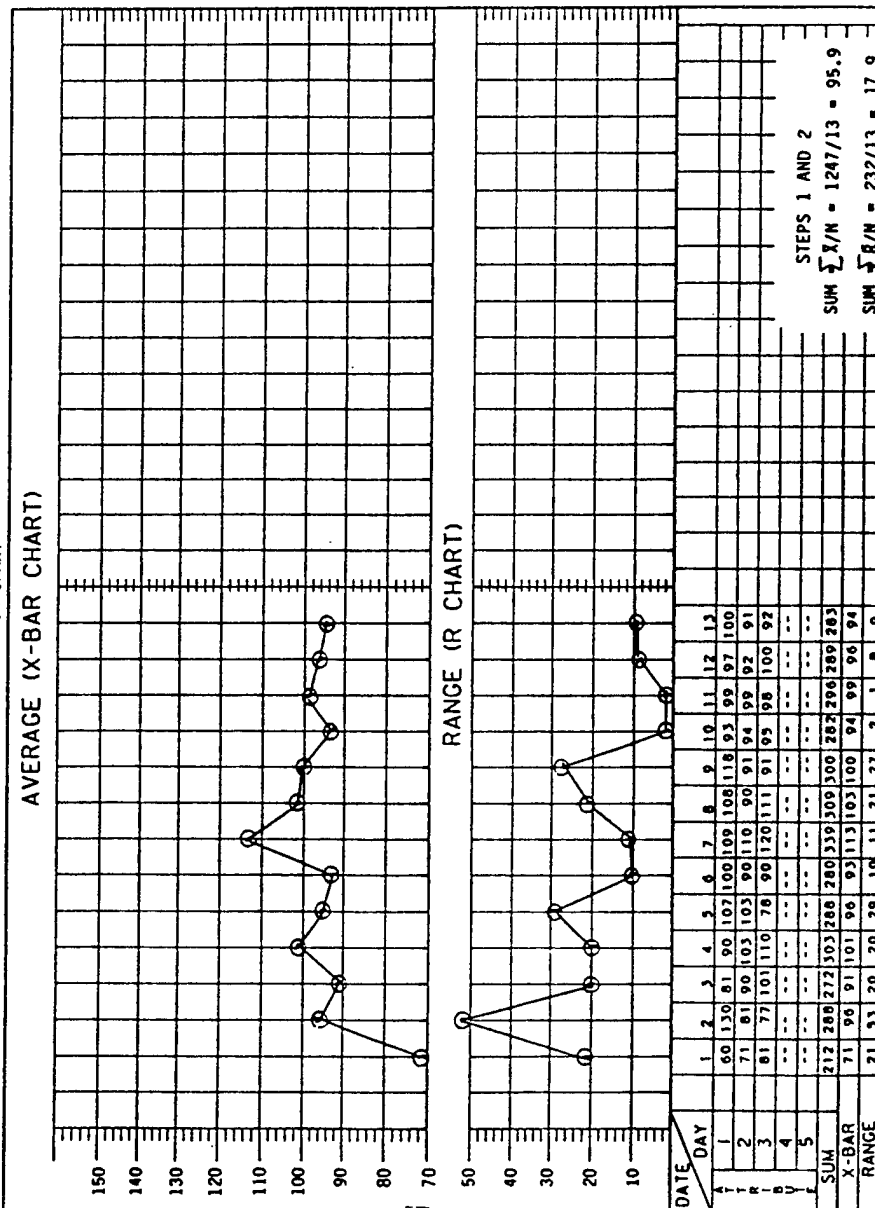
Figure 8c. - Shewhart Control Chart



PROJECT NAME: ANALYSIS OF PERMIT REPORT
 DIVISION: CONSTRUCTION/OPERATIONS
 BRANCH: CO-R
 SECTION: CO-RR

DATE: 10 JUNE 1993
 COMMENTS: USE $\bar{X}$ AND R CHARTS TO EVALUATE
 PROCESS CAPABILITY (SUBGROUP SIZE = 3)

RUN CHART



STEPS 1 AND 2

$$\sum \bar{X}/N = 1247/13 = 95.9$$

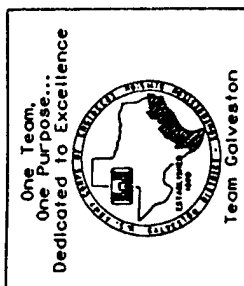
$$\sum R/N = 232/13 = 17.9$$

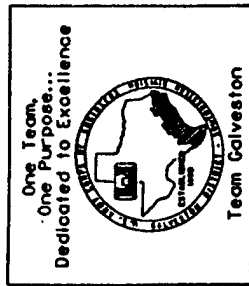
SUBGROUP SAMPLE SIZE (n)	X CHART FACTORS FOR CONTROL LIMITS (A ₂)	R CHART FACTORS FOR CONTROL LIMITS (D ₃) (D ₄)
2	1.88	0 3.27
3	1.02	0 2.57
4	.73	0 2.28
5	.58	0 2.11
6	.48	0 2.00
7	.42	.08 1.92
8	.37	.14 1.86
9	.34	.18 1.82
10	.31	.22 1.78

NOTES

Blank lines for notes.

Figure 9c. - Shewhart Control Chart

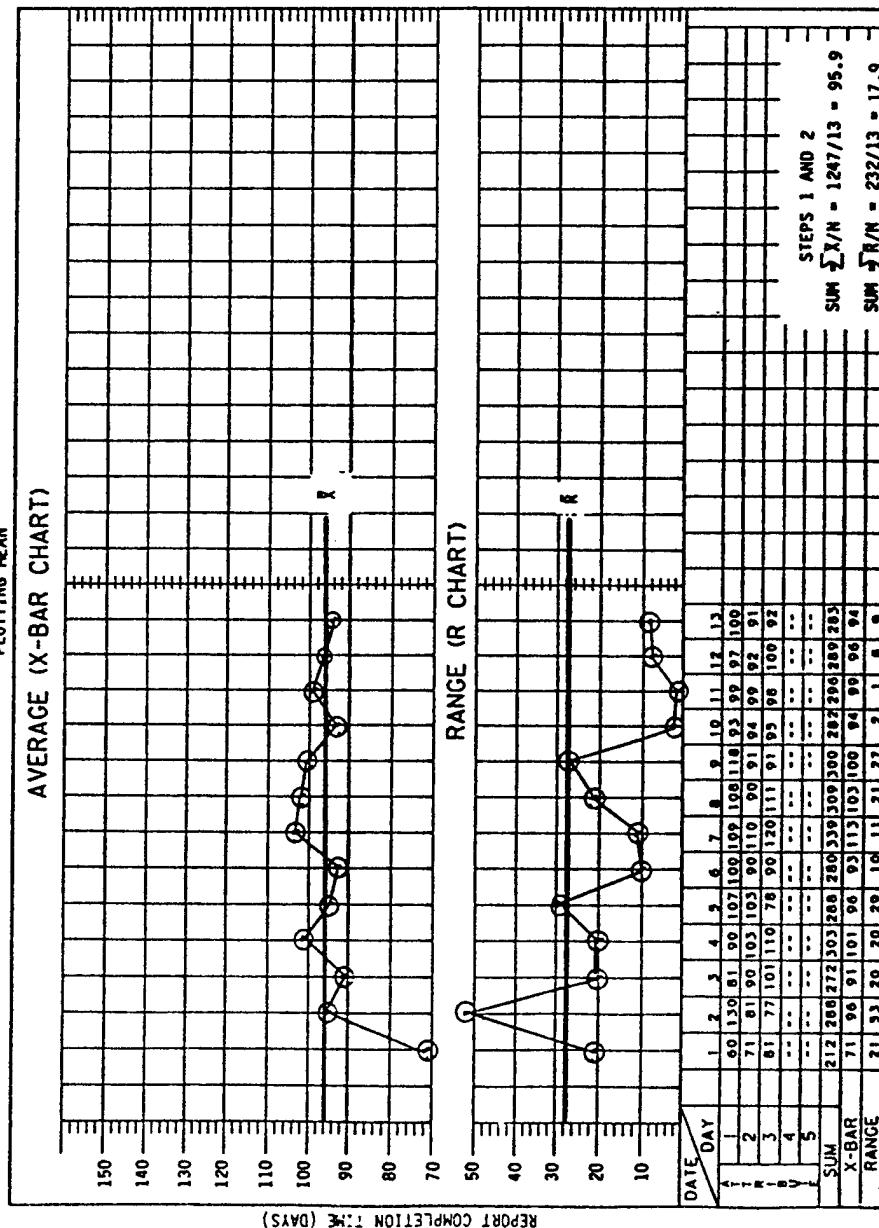




PROJECT NAME: ANALYSIS OF PERMIT REPORT DATE: 10 JUNE 1993
 DIVISION: CONSTRUCTION/OPERATIONS
 BRANCH: CO-R
 SECTION: CO-RR

COMMENTS: USE $\bar{X}$ AND R CHARTS TO EVALUATE
 PROCESS CAPABILITY. SUBGROUP SIZE = 3

PLOTTING MEAN



SUBGROUP SIZE (n)	X CHART FACTORS FOR CONTROL LIMITS		R CHART FACTORS FOR CONTROL LIMITS	
	(A ₁)	(D ₂)	(D ₃)	(D ₄)
2	1.88	0	0	3.27
3	1.02	0	0	2.57
4	.73	0	0	2.28
5	.58	0	0	2.11
6	.48	0	0	2.00
7	.42	.08	.08	1.92
8	.37	.14	.14	1.86
9	.34	.18	.18	1.82
10	.31	.22	.22	1.78

NOTES

Figure 10c. - Shewhart Control Chart

Figure 11c is the grand finale. Using Equations 3 through 6 we have calculated the lower and upper control limits for the process mean $\bar{x}$, and the mean process range R . The equations are repeated below with values inserted so that the reader can trace how the graphed data were calculated. The equations are:

The location of the Process Mean $\bar{x}$:

$$\begin{aligned} UCL &= \bar{\bar{x}} + A_2 \bar{R} & LCL &= \bar{\bar{x}} - A_2 \bar{R} \\ &= 95.9 + (1.02)(17.9) & &= 95.9 - (1.02)(17.9) \\ &= 114.2 & &= 77.6 \end{aligned}$$

The location of the Process Range R :

$$\begin{aligned} UCL &= D_4 \bar{R} & LCL &= D_3 \bar{R} \\ &= (2.57)(17.9) & &= 0(17.9) \\ &= 46 & &= 0 \end{aligned}$$

Note the sample size adjustment factors are on the figures in the small box located in the upper right hand side of the graphs.

Observe that the points located outside the 3 standard deviation limits are denoted by the darkened arrows. These points represent an out-of-control event or process; they are special cause induced. The special causes are two independent events as indicated by their different subset spawning. Something caused the mean value to fluctuate so widely that the process mean at that point shifted by more than 3 standard deviations from the process mean $\bar{\bar{x}}$. Similarly, something in the range detection indicated that a special force caused the range to widen well beyond the normal process range; i.e., past 3 standard deviations. All other fluctuations stayed within a 3 standard deviation criteria.

It should be noted that the shift in the $\bar{\bar{x}}$ for the special cause is a desirable one; the causer should be found because this point

indicates a movement in the direction of decreasing report time completion. If the point had moved in the other direction, say to 130, the cause would need to be determined because this has the tendency to move completion times upward --an undesirable effect.

Process Analysis

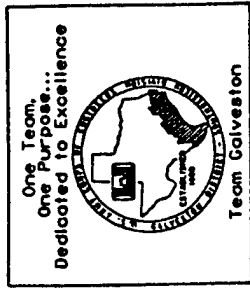
The shift noted in the R chart is undesirable because whatever caused it may happen again resulting in adverse fluctuation (a wider spread) in the range of the production process.

1. Deciphering The Magic Behind The $\bar{X}$ and R Charts

In essence, there are two out-of-control, special cause related conditions. One is when $\bar{X}$ and R data fall outside their respective statistical limits of 3 standard deviations. The second occurs when a pattern emerges with data points within the 3 standard deviation limits, but data within the common cause range form a non-random scatter configuration. The basic Figure 12c illustrates what each special cause might look like if plotted on a graph. Note that these patterns detect a problem; it takes other tools (Pareto charts, cause-and-effect charts, etc.) to isolate and identify the problem. Each graph applies to both the $\bar{X}$ and R charts.

Figure 12c-1 has been the major topic of concern covered in previous sections. Extreme events occurring during a production process (products or services) have resulted in special cause events, meaning the process is out of control. Two out of 17 points have





PROJECT NAME: ANALYSIS OF PERMIT REPORT DATE: 10 JUNE 1993
 DIVISION: CONSTRUCTION/OPERATIONS
 BRANCH: CO-R
 SECTION: CO-RR

COMMENTS: USE $\bar{X}$ AND R CHARTS TO EVALUATE
 PROCESS CAPABILITY (SUBGROUP SIZE = 3)

COMPLETED SHEWHART CONTROL CHART

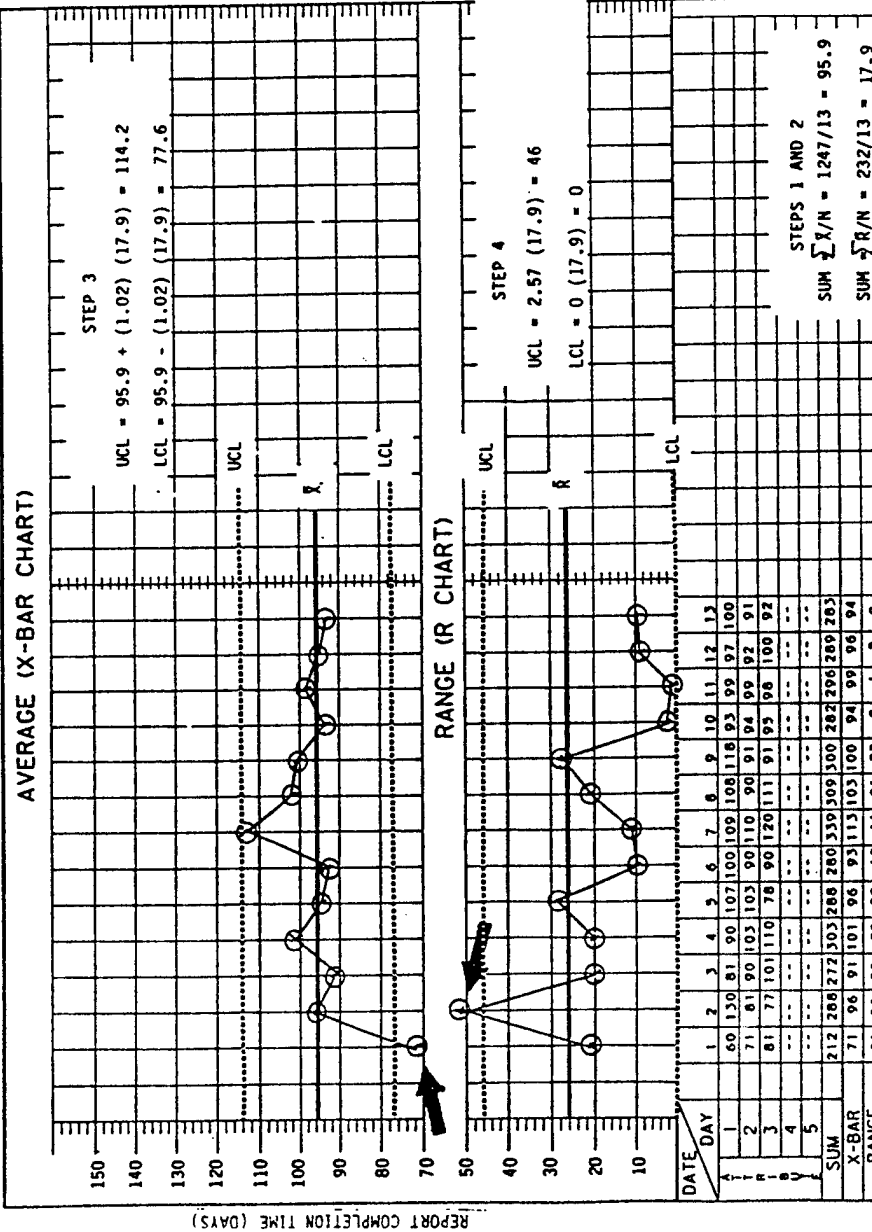
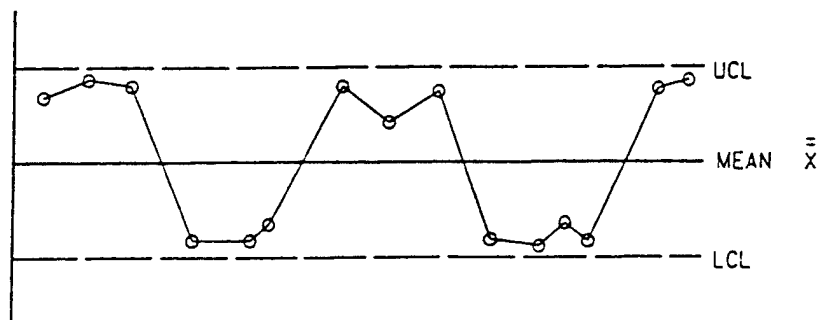


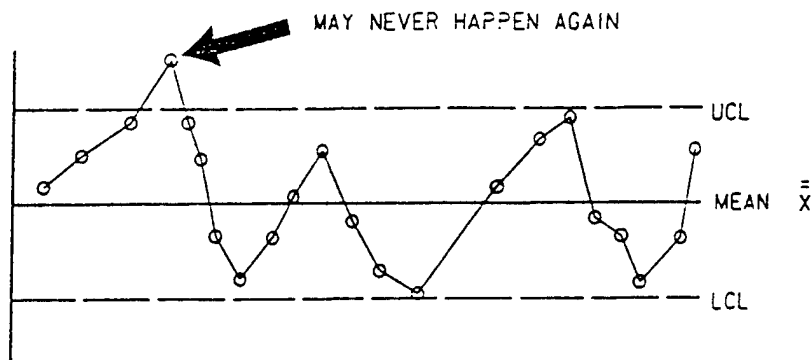
TABLE OF X AND R CONTROL FACTORS			
SUBGROUP SAMPLE SIZE (n)	X CHART FACTORS FOR CONTROL LIMITS (A ₂)	R CHART FACTORS FOR CONTROL LIMITS (D ₃)	R CHART FACTORS FOR CONTROL LIMITS (D ₄)
2	1.88	0	3.27
3	1.02	0	2.57
4	.73	0	2.28
5	.58	0	2.11
6	.48	0	2.00
7	.42	.08	1.92
8	.37	.14	1.86
9	.34	.18	1.82
10	.31	.22	1.78

NOTES

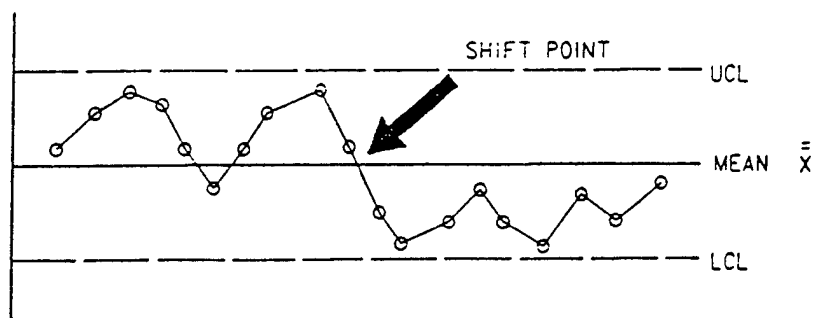
Figure 11c. - Shewhart Control Chart



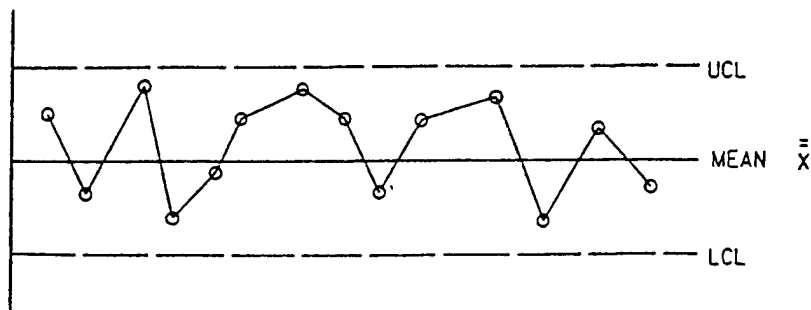
12c-5
"STRATIFICATION"



12c-6
"FREAKS"



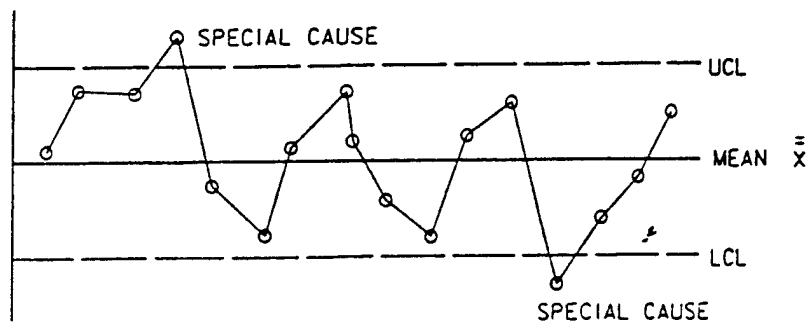
12c-7
"SUDDEN SHIFTS"



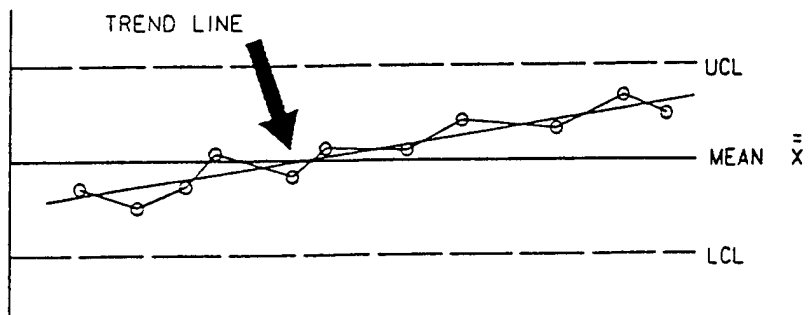
12c-8
"NORMAL"

Figure 12c. - Out of Control Patterns for X and R Charts

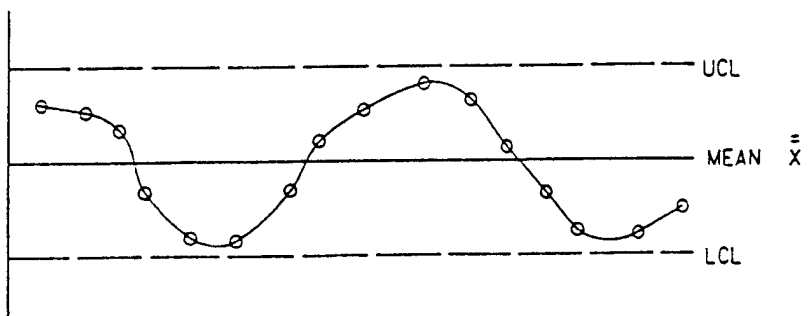




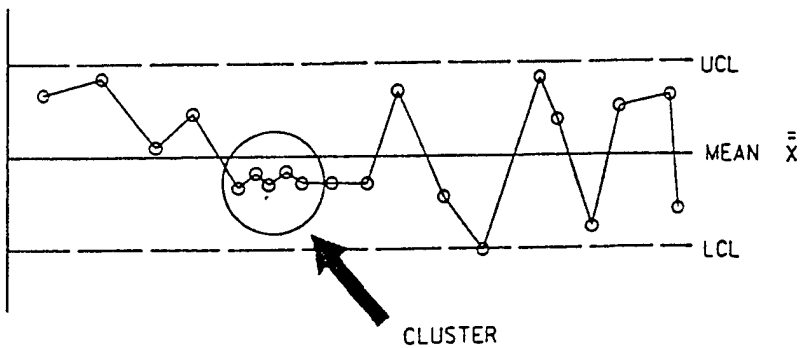
12c-1
"INSTABILITY"



12c-2
"TREND LINE"



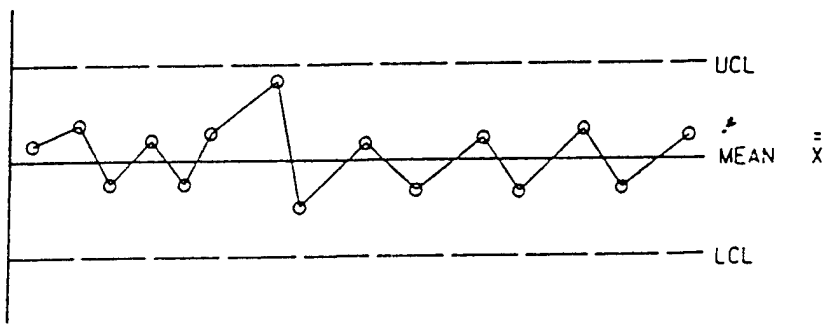
12c-3
"CYCLE"



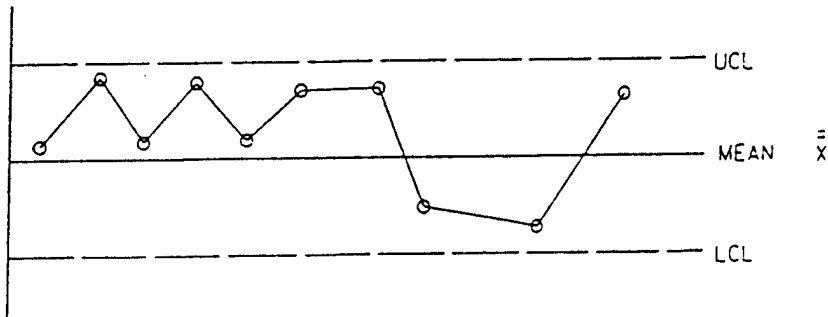
12c-4
"GROUPING"

Figure 12c. - Out of Control Patterns for X and R Charts (continued)

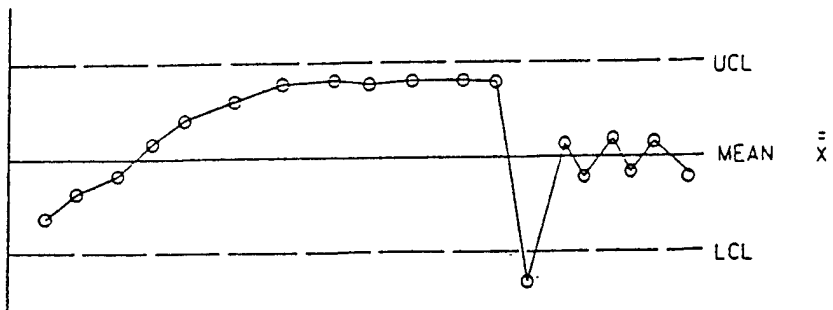




12c-9
"HUGGING"



12c-10
"RUN ABOVE AVERAGE"



12c-11
"TREND, STRATIFICATION,
SUDDEN SHIFT,
INSTABILITY"

Figure 12c. - Out of Control Patterns for X and R Charts (continued)



exceeded the 3 standard deviation limit; one above the threshold and one below. This is an unstable process. The causes need to be determined and eliminated to bring the process into balance or into stability. The cause of such an event could be one or multiple and would depend upon what specific process is being investigated. There is a strong chance that it is a localized or work-environment related problem and not a common cause.

Figure 12c-2 represents an out-of-control condition which forms a trend line. This is an out-of-control process because the data points form a trend which is a pattern that is not random. By definition, a pattern is not random. Since the line is sloped upward, something in the process is getting worse over time. This could be due to a piece of equipment gradually wearing out, resulting in the production of a poorer quality product. It could also represent poorer quality reports being produced by an employee whose work load has substantially increased or who has been given assignments which frequently change priority, both resulting in less time to do quality work. Again, the cause will be dependent upon what is being produced and what is being measured. There is no cookbook answer. A scatter plot, Pareto chart, flow chart or cause-and-effect diagram is needed to isolate the exact cause and effect relationship. Downward sloping trends also represent a condition of special causes. Note the trends in the $\bar{X}$ and R charts in Figure 11c. We have identified another out-of-control problem.

Figure 12c-3 shows an out-of-control process called a cycle. Again, a pattern is formed which is not indicative of randomness. A situation like this could be caused by a budget cycle or simultaneous scheduling. Both of these occur when, for example, a host of new project starts are all funded during the

same time frame and are expected to follow the same processes of intermediate reviews (IRC's, IPR's, etc.) and be completed at approximately the same time. This causes the "boom" and "bust" cycles illustrated in the graph. It could also be caused by contracting or inventory cycles. Despite the fact that all plotted points are within control limits, observation of such a pattern depict non-random situations which are deleterious to the production process via the non-uniformity and low quality which is often the byproduct.

Grouping is illustrated in Figure 12c-4. It too constitutes an out-of-control production process. Once again, the random criteria is broken. Grouping can be caused by temporary over control by an individual with specific criteria. It may also emanate from over-control by influential groups who have a specific target in mind such as in management by objective (MBO). The result is classified as a special cause. Micro management is often a culprit as well.

Stratification is shown in Figure 12c-5. It is exemplified by product and service outputs that take place at extremes; as shown, they cling to the upper and lower control limits. Stratification can occur due to rapidly changing priorities, changes in guidance, and as part of a moral issue, among others. Whatever the cause, there is a pattern not in line with common cause variation.

"Freaks" are nothing more than highly unusual events which have an extremely rare event occurrence. Such a case is shown in Figure 12c-6. This type of event is typified by a "bad day" or a "Peter Principle" happening. For example, ninety percent of an offices' computers are stricken by a virus on a day when a congressman needs some report, coupled with an office flu taking out a third of the staff, garnished with five new flash fires



and a discovery that some vital information needed that day was incorrect. There are plenty of reasons for a setback in schedules. This is a "Freak". It is random or highly unusual and may never happen again but is nonetheless an out of control situation by any definition.

Sudden shifts in the process are depicted in Figure 12c-7. A sudden shift is also not in line with randomness because the process mean or range has dramatically shifted from normal to abnormal or from one form of abnormal to another. These shifts can be explained by changes in training, shifting work from an inexperienced to an experienced worker or vice versa. Also, changes in guidance, management, and "flash fires" may also result in sudden shifts in process performance.

Figure 12c-8 shows no abnormalities. There are no trends, freaks, stratifications, etc. It is a normal process governed by the randomness of common cause forces. It was placed here to contrast previous special cause patterns. This is what we want to observe in a production or service process. All causes are common causes. It shows all special causes have been eliminated leaving only common causes to tend with.

Hugging is a pattern depicted when the points "hug" the centerline or one of the control limits. This pattern is typical of micro management techniques where fear and tight control govern the process. It stems from perceived or real threats if production standards exceed the upper or lower control limits. This is not a random process.

Runs are patterns where plot points stay in one position or another for periods of time as in Figure 12c-9. Such a pattern usually underscores an attempt by someone to follow a service or production process which is not in line with an average system process. Other

reasons exist for this pattern, but, as before, it is not typical of a common cause circumstance.

Finally, the reader needs to be cognizant of multiple, out-of-control processes as shown in Figure 12c-10. This figure shows the simultaneous problems of trends, runs, hugging, instability and sudden shifts. Many forces are at work producing an out-of-control process. Some of these forces blend, and subsequently even disguise others. They must be separated and eliminated from the process.

Figure 12c-11 contains a variety of anomalies; a trend, stratification, a sudden shift, and signs of instability. It is possible that several factors may show up on a control chart resembling this figure.

Table 15c summarizes the various aberrations which are indicative of adverse process patterns.

Process Stability

Previous material detailed a considerable amount of information concerning the structure and meaning of the $\bar{X}$ and R charts in monitoring product and service output quality and uniformity. There are a few simple rules and ideas which will allow for a relatively quick detection of problems as they appear in control charts. They include:

- ☐ A process is out of control if 7 points in a row fall below or above the center line ($\bar{X}$ or R).
- ☐ A process is out of control if 7 points in a row are each progressively lower or each progressively higher than the previous points.



TABLE 15c TYPES OF OUT OF CONTROL OR SPECIAL CAUSE PATTERNS ^a	
Instability	Freaks
Trends	Sudden Shifts
Cycles	Gradual Shifts
Grouping	Hugging
Stratification	Special Runs

- ☐ A process is out of control for any non-random process where it is easy to predict where the next point will be.
- ☐ A process is out of control where any non-random process is present.
- ☐ A process is out of control where any points lie outside control limits.

Figure 13c also brings to light a few concepts discussed in the text. Recall that about 68 percent of all data points must fall within one standard deviation of the mean for a process to be classified as normal. This is true for both X and R charts. Roughly translated, the middle third of a control chart frequency distribution should contain about 2/3 (67%) of all measurements and approximately 1/6 (16%) should fall into each remaining 1/3 tail of the curve. This rule of

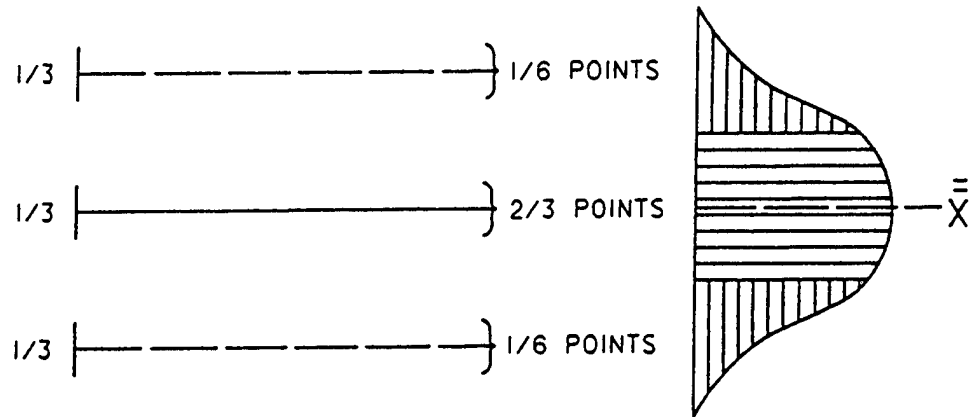
thumb helps guarantee normality and quickly identifies skewness in a process.

Figure 14c shows the pathway to continuous improvement in process capability. An explanation of the techniques starts with Period I where special causes are first discovered and then eliminated. These are identified by the arrows (instability condition and a trend; 7 points in a row) and can be assessed using Figure 12c. Period II shows that all special causes have been identified and eliminated. Note that as we progressed from Period I to Period II, the variance of the system has decreased and the mean process declined from about 4.2 percent defects to about 2.2 percent defects. As common causes continued to be eliminated through action to the system, variance continues to decrease and the mean process defects continue to fall as exemplified by Period II. The manager or employee must continue to watch for new special causes even if the old system's special causes have been

⁸ AT&T, Statistical Quality Control Handbook. (Indiana - AT&T Technologies, Inc. 2nd Ed. 1958)



$\bar{X}$ CHART



R CHART

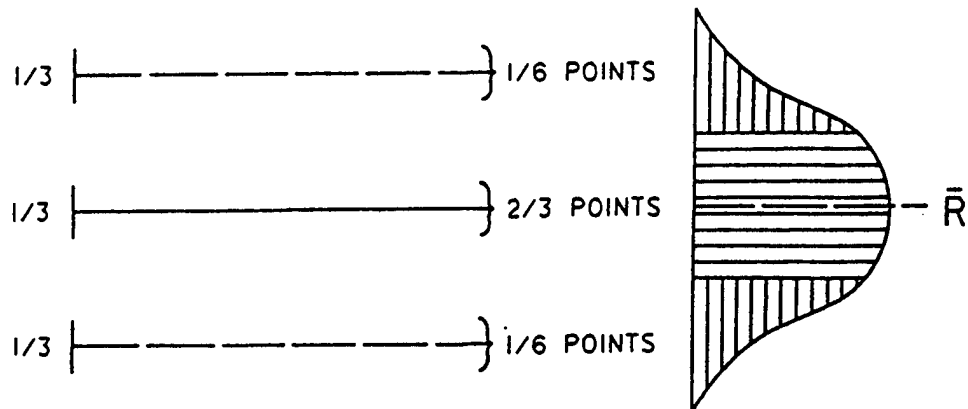


Figure 13c. - Symmetry in the Output Process

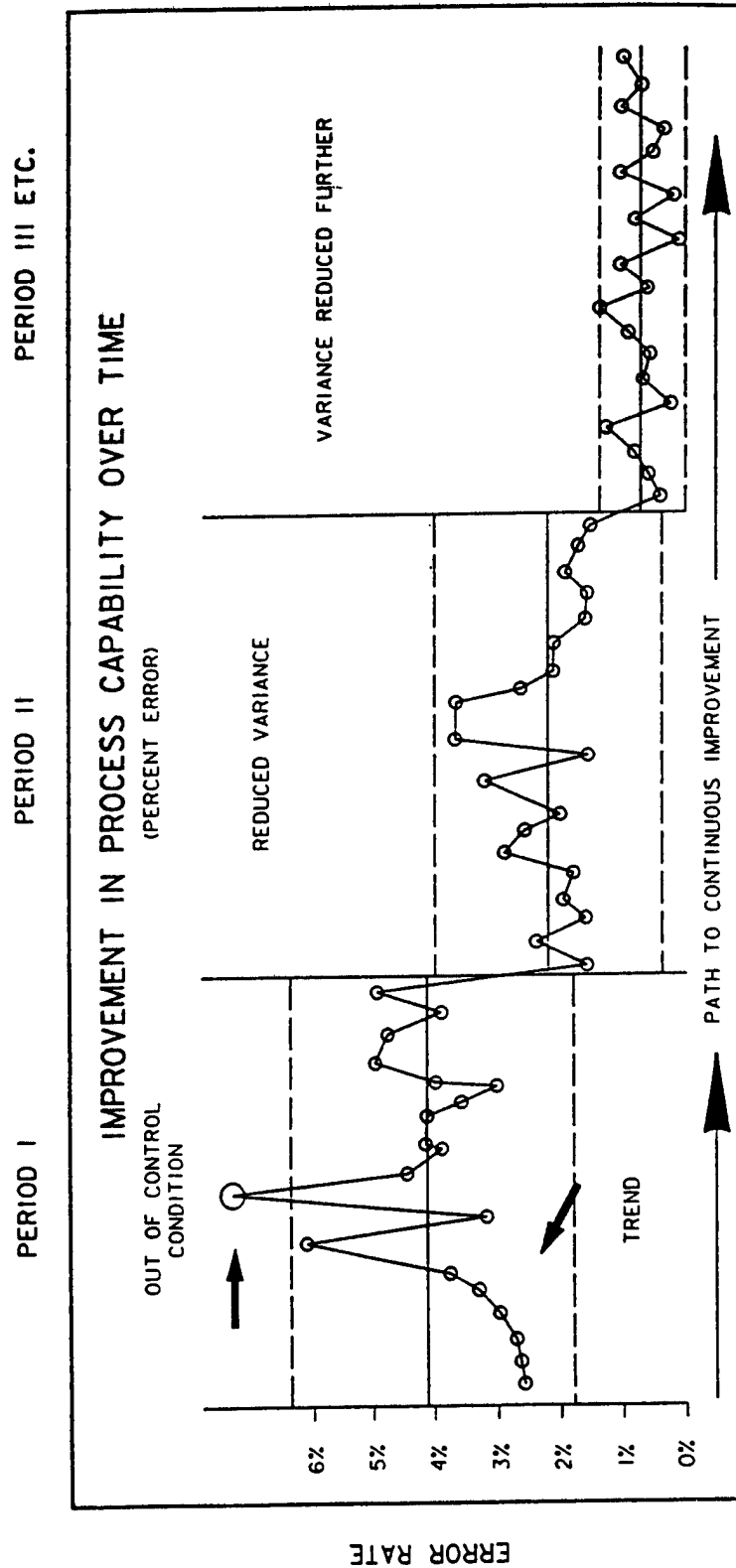


Figure 14c. - General Pattern of Progress, Demings "Constancy of Purpose"

previously eliminated. The reason is that things change over time and new special causes not previously experienced may creep into the system. When special cause factors have been eliminated (and only then), we are ready to contend with common causes. Remember, special cause is responsible for 15 percent of system process problems. The remaining 85 percent are common causes which are chiefly in the realm of management.

Demos Control Charts

Shewhart control charts can be employed to measure the performance of groups of items, as shown above, and entire processes and systems. In the previous example, we examined the processes of writing a report. The report can be viewed as either a single task or a process composed of specific groups of employees and activities. In the next example, we will explore the use of *Demos control charts in following the progress of multiple tasks*. To do this, we will use modified Shewhart control chart techniques. The Demos control chart is another tool belonging to the family of statistical process control methods.

Figure 15c uses the Demos control chart to analyze and trace waste (transit time, review time, waiting time, rework time). These were evaluated earlier within the framework of value-added analysis and cycle time. The table shows a team of 30 workers and managers on five projects or studies which will ultimately result in the completion of five water resources reports. A district office task force has kept records on a monthly basis recording the waste and process time for these and similar reports produced during previous assignments. Such records will prove very valuable as we will soon see.

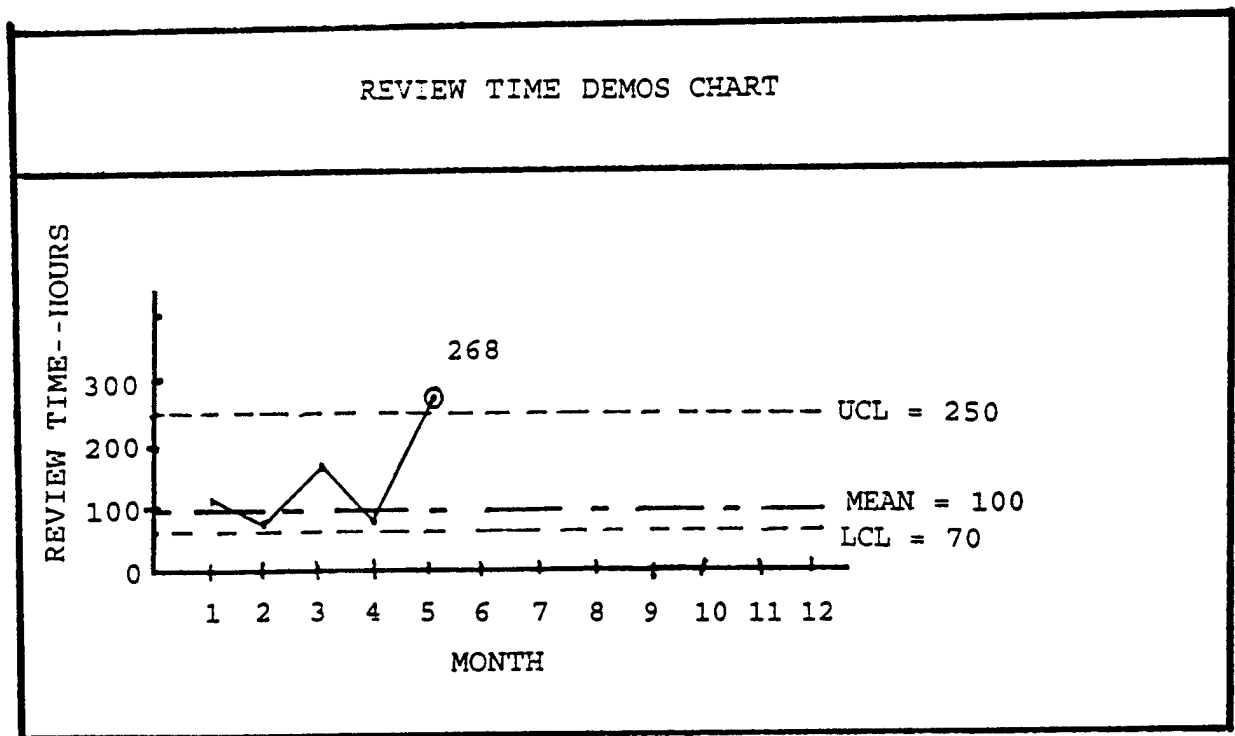
The data show, as expected, that real process time is relatively low encompassing only (1,420/7,200) 19.7 percent of the 30 day work period. The data indicate that the five reports fall within normal statistical parameters as evidenced by the historic and current average hours and waste encountered and the upper and lower control limit of 250 hours. An examination of the table for causes or low process time leads to some anomaly for project number 4 - it consumes 900 of the 1,340 hours (67.2%) alone. The Demos chart located below the data shows that something went wrong. The project 4 team leader is advised of the problem and proceeds to examine his control chart as depicted in Figure 16c. His current average for internal review time also shows a value of 180 hours which is above the upper control limit of 170 hours. It is traced to hydrology and hydraulics work with an internal review time of 600 hours! The advantage of the Demos control chart approach lies in being able to trace and record impacts along the hierarchy to measure performance, to trace cause and effect, and to observe multiple events simultaneously. This can go a long way in expediting the reduction of waste, improve cycle-time, and increase value-added.

Control charts and statistical process control fit the requirements of GPRA and the APIC criteria very effectively. They are a little more complex to understand than the use of ratio analysis but provide a quantum leap in diagnostic information and system performance measurement. Notice that this approach *measured the performance of a cross-functional activity and its team*. It could have been used to measure a single function, KRA results, program performance or a single project as well.



**-WASTE MEASURED IN HOURS-
TEAM = 30, MONTH 5**

<u>Project</u>	<u>Transit Time</u>	<u>Waiting Time</u>	<u>Review Time</u>	<u>Rework Time</u>	<u>Total Waste</u>	<u>Process Time</u>
1	100	400	240	300	1,040	400
2	250	300	0	600	1,150	100
3	10	200	0	600	810	50
4	50	500	(900)	750	2,200	300
5	<u>80</u>	<u>100</u>	<u>100</u>	<u>300</u>	<u>580</u>	<u>570</u>
Total Hrs.	490	1,500	1,340	2,550	5,780	1,470
Current Avg.	98	300	268	510	1,156	284
Hist. Avg.	90	410	100	680	915	210
UCL	500	800	250	800	3,000	510
LCL	10	50	70	40	700	40



NOTE: Basis of analysis is: 30 FTE x 30 days x 8 hrs/dAY = 7,200 possible hours.

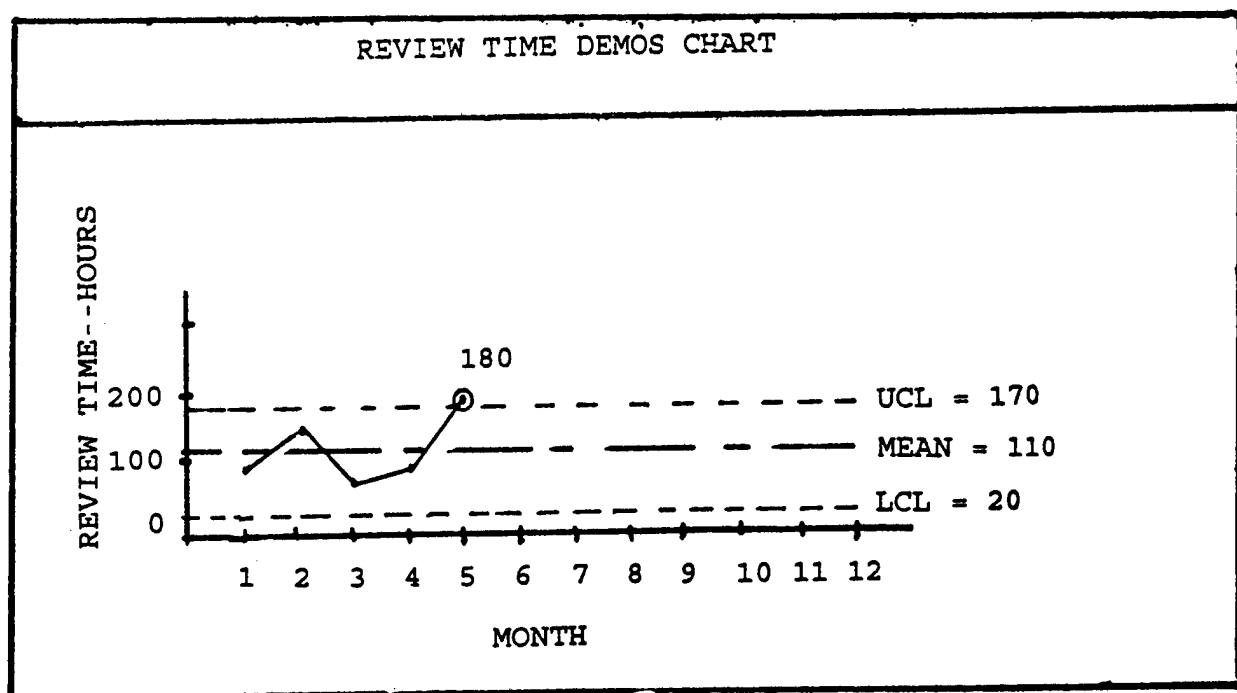
Figure 15c. - Demos Control Chart - Multi-Project Use



**-WASTE MEASURED IN HOURS-
PROJECT 4 TEAM**

	<u>Transit Time</u>	<u>Waiting Time</u>	<u>Review Time</u>	<u>Rework Time</u>	<u>Total Waste</u>	<u>Process Time</u>
Economics	2	10	40	50	102	60
Cost Est.	4	40	100	40	184	40
H & H	2	30	(600)	100	744	70
Plan Formulation	8	50	110	40	288	35
Env. Ana.	<u>2</u>	<u>10</u>	<u>50</u>	<u>30</u>	<u>92</u>	<u>35</u>
Total	18	140	900	260	1,410	240

Current Avg.	3.6	28.0	180.0	52.0	282.0	48.0
Hist. Avg.	4.4	32.0	110.0	40.0	186.4	42.0
UCL	8.0	40.6	170.0	70.8	299.0	70.0
LCL	0	2.0	20.0	10.0	50.4	22.6



NOTE: Basis of analysis is: 30 FTE x 30 days x 8 hrs/dAY = 7,200 possible hours.

Figure 16c. - Demos Control Chart - Single-Project Use



APPENDIX D

THE MEASUREMENT OF EFFECTIVENESS





D.1. THE MEASUREMENT OF EFFECTIVENESS

The Goals and Objectives Approach

Effectiveness is an assessment of the results of a program compared to its intended purpose. Intended purpose is most frequently part of an organization's strategic plan and goals and is expressed in the form of objectives. Objectives are the key to measuring effectiveness performance. Good objectives have six characteristics which include [Management Concepts, Inc., 1995]:

- ☐ They state exactly what result is wanted,
- ☐ They define how much of a result is wanted,
- ☐ They indicate the finish time for the desired results,
- ☐ They signal where the outputs are expected to occur,
- ☐ They denote who the results are desired for, and
- ☐ They describe why the outputs are needed.

The degree to which these objectives can be quantified will depend in part how they are written. There are circumstances which do not lend themselves to easy measurement or quantification at all. It is best to set objectives which can be measured to prevent bias in interpreting the results of a performance measurement program. In many cases judgement also plays a role. Measurement also tends to make clear what

the targets are. Let us set up an example of how an analyst can write objectives which are measurable. Table 1d will help explain the differences between well written and poorly written objectives.

The process starts out, as described earlier, as a sequence of planning events which begin with a vision statement, progress to a mission statement, continue through the development of goals, and end with specific objectives. All of these statements must be *aligned with the same theme and results in mind*. Objectives one through four are designed to specify the details of GOAL (3). Each goal would require its own set of objectives, but for simplicity, and because it is about the objective at hand, we will focus chiefly on fulfilling the requirements of GOAL (3).

The first objective meets all the criteria for a good objective. It states the results desired; it develops a list of five critical result areas and ten useful index measurement tools and techniques. It specifies how much is wanted; five critical result areas, and ten tools and techniques. It also identifies the required completion time as the end of FY 1997. The results are to occur for each division. The "who for" question points to district use and GAO auditing, and the reason for the effort is to improve cost efficiency. All six criteria have been satisfied. Notice that in fulfilling all criteria there is no doubt what is to be accomplished, for whom, when, why and the



TABLE 1d
PLANNING AND EFFECTIVE OBJECTIVES

Vision:	To be the most efficient and effective district in the U. S. Army Corps of Engineers
Mission:	To meet or exceed our customer expectations in all mission-related water resource projects and programs.
Goals:	(1) To complete our activities and programs on or before scheduled completion times and on or below budget.
	(2) To adopt a continuous process improvement culture district-wide.
	(3) To institute performance measurement of our business activities and processes.
	(4) To increase staff training to meet anticipated future organizational needs.
	(5) To implement benchmarking practices to increase our product and service efficiency and effectiveness.
	(6) Other goals as needed.....
Objectives to Meet Goal Number (3):	(1) The purpose of this objective is to quantify performance from an efficiency perspective for use by the district and GAO auditors to evaluate district cost control. Each division in the district will develop a list of the five most critical cost areas (called cost drivers) impacting their specific operations using Pareto analysis, and institute ten index measurement tools and techniques that quantify process operational cost efficiency by the end of FY 1997.
	(2) With the same purpose specified in number (1) above, each division will construct a business process map down to the branch level detailing cycle time and dollars expended for each activity node in the process map. Use a five year data base, PERT techniques, and SPC (statistical process control) to arrive at a mean, median, mode , and variance for each activity node. This effort will be completed by the end of FY 1997.



TABLE 1d

PLANNING AND EFFECTIVE OBJECTIVES
continued

Objectives to Meet Goal Number (3):	(3) Using the purpose, tools, and techniques described in objective number (1) above, each division will reduce process cost per employee-year 5 percent below 1997 inflation adjusted levels by the end of FY 1997.
	(4) Improve the quality of our products and services through increased cross-functional coordination thereby reducing operational costs in the long run.

targets to be met. This is not a "fuzzy" statement. Can the results be measured?

Suppose that the five critical result areas listed are completed but only eight of the ten index tools have performed as hoped by the end of FY 1997. When the situation is stated in this fashion, it is possible to measure success with numbers. The case cited above would indicate that performance on the five critical result areas was 100 percent, but that of the ten tools and techniques only 80 percent have been satisfied ($8/10=80\%$). If the 1995-1997 deadline was missed by four months, this could be quantified by: $24+4/24=1.167$ or 16.7 percent over schedule. A performance effectiveness table for the objective might then look as follows:

Objective Criteria	Target	Actual	Performance Effectiveness
Critical cost areas	5	5	100%
Performance indexes	10	8	80%
Scheduled Months	24	28	83.3%

The above process demonstrates that effectiveness can be quantified if the objectives are written in the appropriate way. This does not mean that the process is not

without problems. The difference between the target and actual objectives do not, for example, measure the relative importance of the two performance indexes not developed. They may have much more importance than the eight that were developed. This type of argument is, however, true with any performance measure. There are no perfect indicators; absolutes are rare, and numbers are not absolutely deterministic. A situation such as this does not diminish the need to quantify nor is it an excuse to back off and resort to pure judgement, guesstimates, or "shooting from the hip" management reactions. Behavior such as this is often a favorite tactic for those who are concerned with results and accountability.

The reader can examine the merits of objectives (2) and (3). Test them against the six criteria to see if they are complete or need revision. Also test them for measurability. These objectives were written for internal district performance evaluation. Objectives can be written for all the KRA's listed earlier in this document and for external feedback from the customer.



Objective number (4) is clearly not well written. It reeks of transitory verbs, vagueness, fuzziness, and breaks just about every rule of a good objective. A recent review by OMB of early GPRA pilot performance plans by numerous agencies indicated a surprising number of objectives written similar to objective (4). Such objectives constituted about 80% of early "first shot" efforts on the part of participating agencies [Management Concepts, Inc., 1995]. Objectives must fulfill the criteria listed or will be returned to the agency unapproved and for further work.

The Quality Function Deployment Approach (QFD)

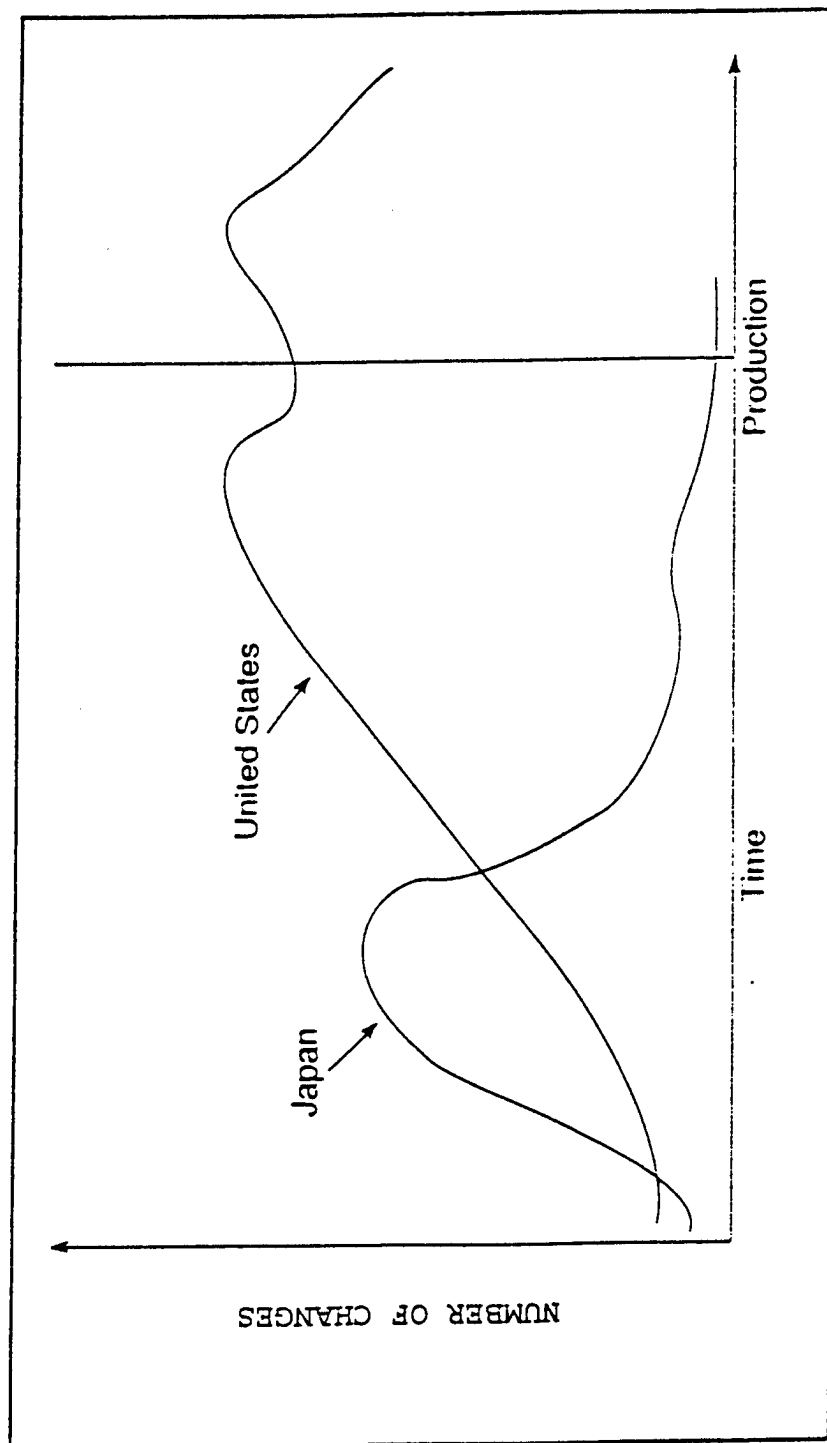
The Quality Function Deployment (QFD) is a newly developed TQM method that allows planners and managers to include customer's wants, needs, and expectations in the decision process [Berk, 1993]. It is a graphical tool for making decisions where there are multiple goals and objectives and resulting conflicts. It also is a tremendous aid in blending customer expectations with the engineering and planning process of the COE to form the desired outputs and outcomes. In this respect it is an effectiveness process tool and an effectiveness measurement tool. It employs the "voice of the customer" in what we do. It began as an engineering tool used to match customer needs and wants with the design and engineering process in the private sector but it became valuable as a "marketing" tool for public organizations. This is novel because in times past public institutions have not had a market tool other than the public meeting. It incorporates cross-functional team efforts to help eliminate

"surprises" when products and services cross from the planning-engineering phase of work to the public review phase of planning where customers examine the plans for themselves. This is often a difficult and expensive event as customers find out that what they wanted is not what is on paper. Considerable re-formulation becomes necessary. This situation is depicted in Figure 1d. With QFD this is avoided, product and service quality improves, waste (as described earlier) is reduced, and tax dollars are saved.

For this to be an effective tool, the decision-makers must be cognizant of the importance of systems-related operations. That is, most production and service problems are not caused by employee activities but by systems problems. The organization must be willing to adopt statistical process control as described earlier and design of statistical experiments. These are the tools which form the foundation which connects the COE management process and the customer making the organization much more effective. To be successful today we must be at least as customer driven as we are engineering driven. Also notice that *QFD is a prevention tool*; not a post problem analysis tool. It fits quite well with the Deming philosophy of building quality in the process is rather than inspecting it out--after the fact. It also a navigation aid in making decisions that require *trade-offs* between conflicting needs, wants and customer expectations. One of the more powerful aspects of QFD is its use with benchmarking to compare internal organization perceptions with those of the customer and competitors.

One of the questions QFD addresses is that of determining the WHATs of customer





(SOURCE: Department of Defense TQM Manual 5000.51G.)

Figure 1d. - Japanese and U.S. Engineering Design Changes

needs and expectations. An example of this presentation is illustrated on the right side of Figure 2d. In this example five WHATs were requested by the customer. This information was obtained through customer surveys and interviews. For a flood control project the customer needs requires five WHATs including: high project economic benefits, environmental sensitivity, a 100 year level of protection, the lowest reasonable cost, and it must be acceptable to their general constituency. The interviews used to assemble this information are used to elaborate and clarify WHATs but, just as importantly, to unmask any unspoken or unexpressed desires not listed. It is better to delight customers than to just satisfy them. This is a quality touch that incorporates unexpressed wants in the WHAT matrix. In simple terms, the WHAT matrix is a conduit for the wants of the customer.

The next step, after determining the WHATs, is to ascertain the HOW much of the WHATs can be achieved. "The HOWs are what an organization has to implement in order to satisfy the WHATs" [Berk,1993]. These are also shown in Figure 2d. Some of the HOWs may conflict with one-another; others may complement each other. The HOWs often fall under the engineers umbrella because they are design and performance oriented. In this case the most desirable HOWs from an engineering perspective must be mixed with those from the customer's perspective. The engineer must be willing to accept customer features because the customer is the one paying the bills and using the final output. This does not mean that safety is compromised but that the "best" engineering designs are not necessarily preferable to customer wants. It

is clear that any HOW can help satisfy more than one WHAT and sometimes they are in conflict; this is an expression of what happens in the real world. Also HOWs can conflict or be contrary to each other as well. This is a desirable situation because it is important to observe, document, and weed out conflicts within the HOWs now rather than find problems after time and funds have been expended. As the table shows it is convenient to list the WHATs in a column and the HOWs in a row to form a matrix which has blank areas or squares which can be filled in with more information about the relationship between the WHATs and HOWs. As alluded to above, the blank spaces in the WHAT-HOW matrix can be used to draw a strength or correlation relationship between the WHATs and HOWs. This matrix shows the manner in which the HOWs affect the WHATs. The legend shown in the upper left hand corner of the matrix shows the traditional symbols used to describe the degree of relationship between the WHATs and HOWs. A circle with a dot in the center indicates a strong relationship. A simple circle shows a moderate relationship. A triangle indicates a weak relationship. These symbols show how strongly a HOW supports the achievement of a WHAT. A blank square indicates no relationship. Such an entry suggests that a HOW has been incorporated that does not satisfy any WHATs which means it can be deleted to reduce costs; a first important step in reducing process costs. It may also mean that a customer need (a WHAT) is not being met in which case additional analysis is needed. The purpose thus far in constructing the QFD matrix is to match customer WHATs with design and



Relationship
Legend

- ⊙ Strong
- Moderate
- △ Weak

		HOW	EARTH CHANNELS	DRY DETENTIONS	LEVEES	CONCRETE CHANNELS	PROPERTY BUY-OUTS
WHAT							
High Project Benefits			Δ		○	⊙	
Environmental Sensitivity			⊙	⊙	Δ		
100 Year Protection			Δ	○		⊙	Δ
Low Cost			⊙		⊙		
Socially Acceptable			⊙	○	Δ		

Figure 2d. - Measures of Effectiveness - Quality Function Deployment (QFD) Matrix



planning concepts--to produce a product which meets or exceeds an array of customer needs. This is an effectiveness criteria.

It may be useful to elaborate on the symbols within the matrix. Let us take the WHAT of Environmental Sensitivity to show how to use this matrix. The HOW of Earth Channels shows a strong relationship with environmental sensitivity. This is understandable especially because an earth channel compared to a concrete channel solution to a flood control problem is generally regarded by environmentalist as preferable. Similarly, a dry detention is strongly related to an environmental WHAT because it creates recreation space (can be used as a park or recreation) and it would prevent urban development which may otherwise increase run-off and flooding downstream. It also maintains the integrity of open, green space and habitat. In this case the HOW of levees is only weakly tied to environmental sensitivity because any channel work at all (earth or concrete) will require that the ambient channel and right-of-way habitat conditions be disturbed. On the positive side, a levee may create a buffer between disturbing influences from activities on the urban side of the levee. In this case the HOWs of concrete channels and property buy-outs have little or no correlation with environmental sensitivity and are left blank. The responses to each of the rows and columns in the QFD matrix will likely vary for each project and what was a satisfactory answer in one case may not be in another.

There is a HOW MUCH associated with the HOW which helps determine success of the design and planning teams in meeting customer expectations. This is illustrated at the bottom of the matrix in Figure 3d. This

portion of the matrix provides a glimpse of what customers consider as satisfactory in meeting their needs and wants. For example, under the column labeled earth channels in HOW, customers would be satisfied if 80 percent of all required channel work were earth noting that in some circumstance some concrete use may be necessary to preserve channel integrity, around bridge abutments, along bends in the channel, etc. The remainder of the HOW MUCH section describes similar requirements. These requirements are also determined by customer surveys and interviews.

Figure 4d shows yet another characteristic of the QFD matrix. The triangle located on top of the matrix is what is called a CORRELATION MATRIX and has its own legend located in the upper right hand corner of the figure. This part of the matrix is important in detecting conflicts between the HOWs. A circle with a dot in the center means a strong positive correlation. A simple circle means a moderately positive conflict. A # and ## represent negative and very negative correlations respectively between the HOWs. This matrix allows us to discover not only what the conflicts are but, to determine the degree of conflicts that may exist in the process. Resolving these conflicts will often require trade-offs and prioritizing of wants and needs--compromise. Many of the conflicts do not necessarily require that a HOW be dropped in the trade-off process but may be dealt with by modifying the HOW MUCH portion of the matrix. The trade-offs are customer driven but are done in consultation with the engineers and planners from the COE. Notice that the use of earth channels and concrete channels are in conflict



Relationship
Legend

- ⊙ Strong
○ Moderate
△ Weak

WHAT		HOW	EARTH CHANNELS	DRY DETENTIONS	LEVEES	CONCRETE CHANNELS	PROPERTY BUY-OUTS
High Project Benefits			△		○	⊙	
Environmental Sensitivity			⊙	⊙	△		
100 Year Protection			△	○		⊙	△
Low Cost			⊙		⊙		
Socially Acceptable			⊙	○	△		
		HOW MUCH	80% Earth Channels	3,500 Ac-Ft. Available	Not To Exceed 1.5 Mi.; Less Than 3 Ft. High	No More Than 20% Concrete Work	< 50 Res. Prop.'s

Figure 3d. - Measures of Effectiveness - Quality Function Deployment (QFD) Matrix



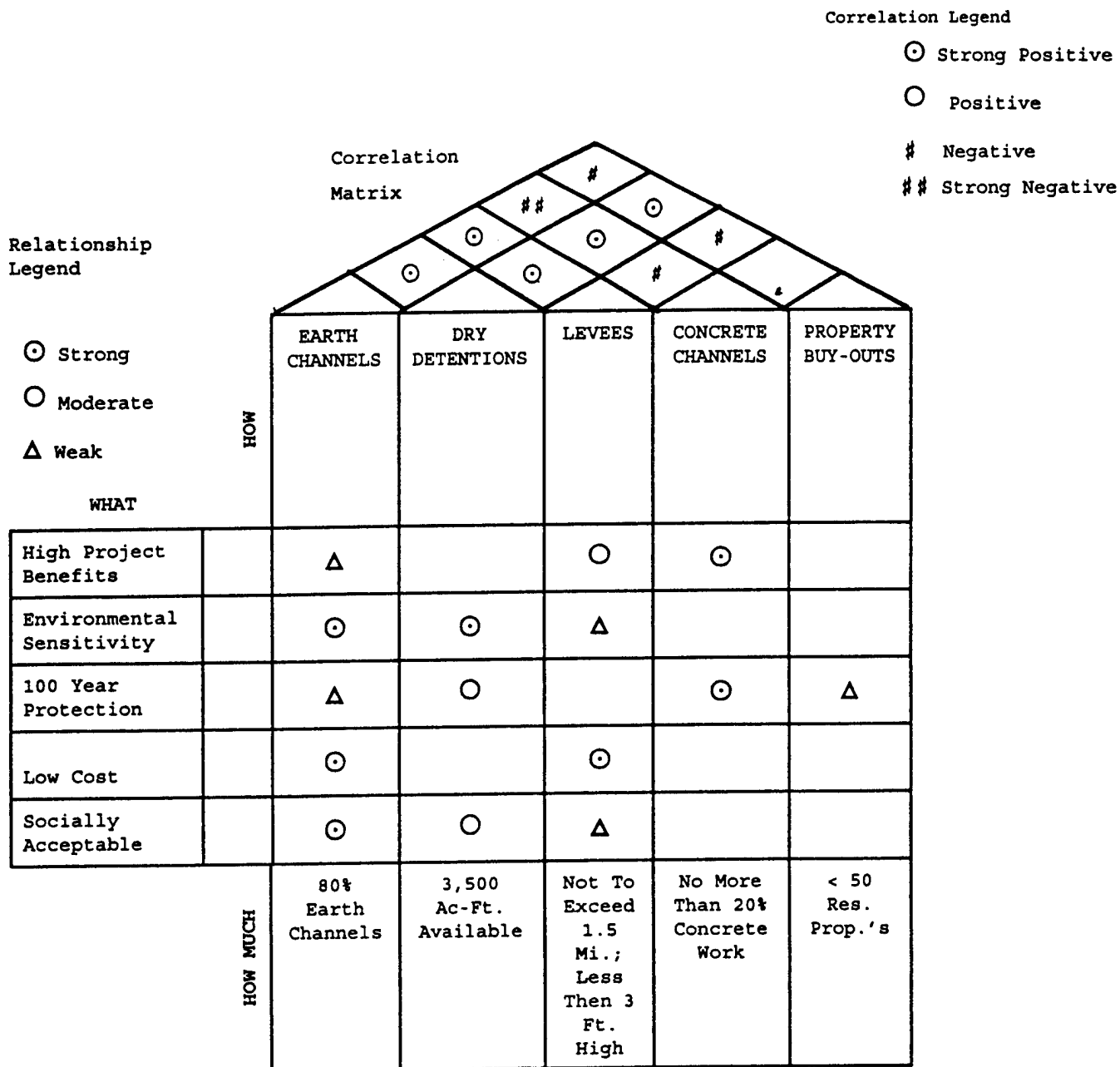


Figure 4d. - Measures of Effectiveness - Quality Function Deployment (QFD) Matrix



(strong negative correlation) in the CORRELATION MATRIX within the HOW and with the WHAT. The reason for this was discussed earlier; the locals want earth channel solutions and not concrete channels due to the environmental aspects of earth channels. This is a point of trade-off that needs to take place. The solution may lie in HOW MUCH in terms of the percent of earth channels and the percent of concrete channels used.

Figure 5d completes the matrix by the inclusion of two benchmarking components; internal benchmarking and external benchmarking. The purpose of these benchmarking analyses are to compare customer perceptions of what we perceive as good and bad project attributes and what the customer perceives as good and bad attributes. This serves as a reality check on plans and designs and helps assure that the systems is customer driven rather than engineer driven. These ratings can be obtained with customer surveys and through interviews.

The external benchmarking process uses a CUSTOMER BENCHMARKING process and is located to the right of the matrix in Figure 5d. Notice the area which is labeled "BAD" and "GOOD". This is filled in by the customer after consultation with the COE on engineering and planning characteristics. The "U" represents the COE effort, the "A" and "B" are competitor designs as viewed by the customer. The lines connecting the "U" rankings represent the graph of COE performance. Notice that the customer's perception of our plans are good for the WHATs in project benefits, and level of protection but are bad on the cost of construction side. In essence this shows how well the customers feel the designs and plans satisfy

their needs; it represents feedback to the COE.

Internal benchmarking can be observed at the bottom of the matrix just below the HOW MUCH portion of the matrix. It is entitled PLANNING AND ENGINEERING BENCHMARKING. The symbols are the same as with external benchmarking. This benchmarking effort is done internally and includes an analysis of competitor ideas and plans compared to the ones developed by the COE. Notice that the COE's impression of its plans and designs are perceived to be better than the customer's perceptions of our plans and designs. This acid test is needed to satisfy the domain of customer wants and needs.

The QFD matrix has one more valuable characteristic to contribute. This is the IMPORTANCE RATING located at the very bottom of the table. It is developed in the following manner. The customer is asked to rank each WHAT based upon how important that WHAT is to them. This is now shown next to the WHAT characteristics; to the right of the matrix with the numbers--4,4,3,5,2.

Each rating is assigned an importance number as shown in the legend below the WHAT portion of the matrix. Each row and column entry in the WHAT-HOW matrix is multiplied by the importance scale number to arrive at an IMPORTANCE RATING located at the very bottom of the figure. For example:

- the 4 next to the High Project Benefits under WHAT is multiplied by the value in the triangle of 1 (in the legend) to arrive at a value of 4;



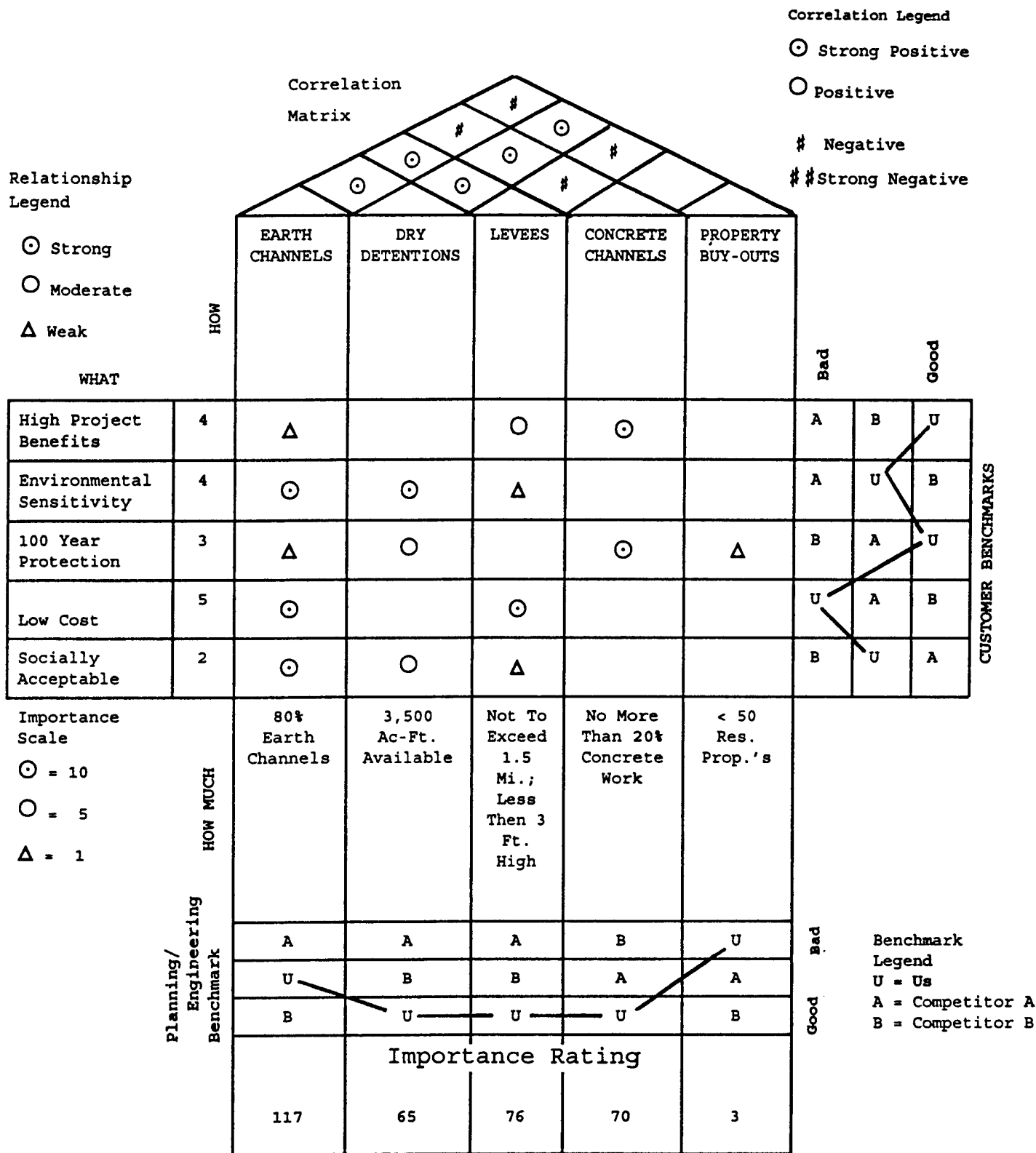


Figure 5d. - Measures of Effectiveness - Quality Function Deployment (QFD) Matrix



- ☐ the 4 next to Environmental Sensitivity under WHAT is multiplied by a value of 10 to arrive at a value of 40;
- ☐ the 3 next to 100 Year Protection under WHAT is multiplied by a value of 1 to arrive at 3;
- ☐ the 5 next to Low Cost under WHAT is multiplied by 10 to arrive at 50, and;
- ☐ the 2 next to Socially Acceptable under WHAT is multiplied by 10 to get 20.

The values are summed by column to arrive at an Importance Rating of 117 ($4 + 40 + 3 + 50 + 20 = 117$). The same process is done for each of the five columns. The resultant values are used to measure the importance of items in the relationship between WHAT and HOW. The numbers

have no particular meaning in-and-of themselves but convey relative importance for quality assessment and in making trade-offs, if needed.

The QFD matrix helps identify customer needs and expectations, determines how to meet them, establishes goals and objectives, leads to improved quality and quantifies effectiveness. This is precisely the tool needed to satisfy NPRA and the APIC criteria. It focuses work efforts on the customer, provides good project analysis opportunity, improves program performance, guides organizational management, and prevents team members from going astray of what is important. It allows for the development of plans with customer input well before large sums of money are expended and prevents much of the waste of re-work (reformulation), and reduces the cycle time (doing it right the first time) often accompanying the traditional COE approach to planning and engineering.



APPENDIX E

SURVEYS & PARETO CHARTS





E.1. SURVEYS & PARETO CHARTS

Surveys

This part of the text will not cover the subject of customer surveys in any comprehensive format. The subject is so vast that it would require an entire book to do it. Rather, the following material will focus on surveys which are quantifiable in character rather than narrative. It will further zero-in on those types of survey questions which will yield a Pareto chart or a probability frequency distribution. These are very powerful tools and satisfy the subject of this text--performance measurement. It is recognized that narrative responses to survey questions are very important and should be a part of any comprehensive survey taken to determine values, aesthetics and customer's feelings and attitudes about what impacts them. The subjects of internal and external customers will be covered, although the quantification of the survey of either of the two is virtually the same. The subject is highly topical in terms of GPRA and APIC. Both documents strongly suggest that surveys are an integral part of performance measurement and analysis and will go a long way in helping to win the new Baldrige (APIC) criteria in the ACOE award.

An internal customer is anyone in your organization for whom you provide a service or product. To illustrate, assume you are part of the transformation process and add value to the services you provide or the products you make. Someone else receives

this output service or product from you within the organization and adds further value in what they do, and so on. If what you pass on to the next person in the production process is of poor quality, they must contend with this situation, either by returning it to you or by correcting it themselves. The alternative is simply to pass the error on to the customer. By the time this error is caught somewhere along the transformation chain, we either have to rework the problem (time is wasted, costs are incurred), or an unhappy customer returns the flawed item. Any scenario under these circumstances results in a costly situation. This means that any person who receives a faulty item or service you provided, represents an unhappy customer; this is your internal customer.

An external customer is the recipient of the final product or service. It is the person or persons who pay for the output or item with certain performance expectations, particular wants and needs. If errors are present or the product or service flawed in some way, an unhappy customer is the outcome. The consequence may be the loss of a customer, returned merchandise, rework, wasted time, increased costs, etc.

There are tools which can be used to measure either internal or external customer satisfaction. Surveys are one vital tool for this purpose and Pareto charts are another. They are both critical forms of two-way communication with feedback. One tactic in utilizing surveys is to have the customer



construct the questions for you--of the questions they want to be asked about your performance. Another is to have an uninterested third party such as a consultant or university produce a scientific, unbiased questionnaire.

Surveys take various forms including written questionnaires from one-on-one interviews, written questionnaires from mailed surveys and telephone questionnaires. There are closed-ended questions and open-ended questions. Whatever method is chosen the one growing preference lies in quantifying results so that they can be used to draw conclusions and improve organizational performance. The days of making decisions from "intuition" and "judgement" are rapidly disappearing. There is still a surprising amount of this going on today. The most significant aspects of using surveys for obtaining information are threefold; to obtain data or feedback, to use this feedback to make system improvements, and to construct the survey in an unbiased manner. Though you may wish to construct the survey questions yourself, it is advisable to have a contractor review them to prevent leading questions, directional wording, and add clarity if needed. This is an insurance policy to prevent bias from entering the survey and tainting the results. It is also a factor APIC-reviewers will look for.

Surveys can serve a variety of functions: to gather opinions, probe attitudes, gauge climate and identify opportunities. They are also a cost-effective way to gather information and measure progress. The best way to illustrate the use of surveys is to provide an example of the use of a questionnaire. Table 1e contains a list of quoted comments [Heaphy & Gruska, 1995]

of critical potential customer responses. The questionnaire or survey is directed toward internal customers for management purposes. It is a questionnaire designed to obtain "employee perceptions" about a TQM/APIC effort going on within their organization. The questions themselves can be re-worded for different effects. They can also be modified for external customer responses. Notice that some questions allow five responses and others six. It is a generally believed notion that too few choices (say 3 or 4) to question responses may not cover the range of potential answers leaving the respondent a little frustrated. In like manner, too many choices in many cases require a level of discrimination not easily dealt with by respondents. For example, a ten gradation response requires a very fine-tuned thought process on the part of the respondent. This may be frustrating as well. It is a good idea to allow a response range of between 5 and 7 choices although, in some cases, this rule of thumb can be broken.

Let us take question one from Table 1e regarding "customer driven quality" as an example of application. Table 2e and the accompanying figure (Figure 2e) located below represents an analysis of responses to the hypothetical survey. Column one represents the coded response circled by the respondent. Column two is the response. Column four is the percent breakout and column five shows how the mean response is calculated. Forty nine respondents addressed the questions with a resulting mean of 2.89 (2.9, rounded). The largest interval of responses resided with number three, "moderate", which is supported by the mean response. The figure below depicts the frequency distribution of the data above.



TABLE 1e
CULTURAL CHANGE SURVEY PERCEPTIONS²

1. *“Customer-driven quality:* The ultimate goal of quality efforts is to delight the customer. This is a strategic concept that requires a company to pleasantly surprise and delight the customer, not just prevent defects.” *Are we accomplishing this goal?*

Very <u>Poor</u>	<u>Poor</u>	<u>Moderate</u>	<u>Good</u>	<u>Excellent</u>
1	2	3	4	5

2. *“Leadership involvement:* The senior executives of a company establish the company culture by their words and actions. Personal involvement in the performance initiative is required to demonstrate commitment, understanding, and the company’s values.” *Is leadership really involved?*

Very <u>Poor</u>	<u>Poor</u>	<u>Moderate</u>	<u>Good</u>	<u>Excellent</u>
1	2	3	4	5

3. *“Continual improvement and learning:* Throughout the Criteria, the last area to address is often “How do you evaluate and improve (the process just described)?”
“Ongoing improvement of key processes is essential to achieve or maintain a leading position in the market.” *Is this a real ongoing effort to improve processes?*

Very <u>Poor</u>	<u>Poor</u>	<u>Moderate</u>	<u>Good</u>	<u>Excellent</u>
1	2	3	4	5



TABLE 1e
CULTURAL CHANGE SURVEY PERCEPTIONS²

4. *“Employee participation and development: Customer delight is the goal defined by the Baldrige Criteria. One of the ways to achieve this is to develop the full potential of the workforce. This includes employee involvement, training, recognition, safety, and satisfaction.” Is employee development, along these lines, progressing?*

<u>Very</u> <u>Poor</u>	<u>Poor</u>	<u>Moderate</u>	<u>Very</u> <u>Good</u>	<u>Excellent</u>
1	2	3	4	5

5. *“Fast response: Success in the competitive marketplace requires efficient and effective processes. Reducing the time it takes to bring a new product or service to the marketplace is now a recognized objective. Likewise, time to respond to a customer inquiry or complaint or time to respond to an employee suggestion often differentiates the high-performance organizations from the bureaucratic ones.” How well do we respond to customer requirements in terms of response time?*

<u>Very</u> <u>Poor</u>	<u>Poor</u>	<u>Moderate</u>	<u>Very</u> <u>Good</u>	<u>Excellent</u>
1	2	3	4	5

6. *“Design quality: Products and services that are designed to be insensitive to expected variation (robust) give a company an advantage. Success will be achieved even when conditions are not optimal. Moving the focus of quality from manufacturing or delivery to the design stage allows the biggest quality impact on the overall product or service.” What is your impression of the design quality in the district?*

<u>Very</u> <u>Poor</u>	<u>Poor</u>	<u>Moderate</u>	<u>Very</u> <u>Good</u>	<u>Excellent</u>
1	2	3	4	5



TABLE 1e
CULTURAL CHANGE SURVEY PERCEPTIONS²

7. *“Prevention: Intuitively, it is accepted that prevention is more effective than fire fighting. But it is hard to talk to someone about fire prevention when their house is on fire. If we don’t make time for prevention activities, the fires will continue.” Are we too fire-fight oriented or can improvements be made?*

Very <u>Poor</u> 1	<u>Poor</u> 2	<u>Moderate</u> 3	Very <u>Good</u> 4	<u>Excellent</u> 5
--------------------------	------------------	----------------------	--------------------------	-----------------------

8. *“Partnership development: Partnerships between labor and management, between suppliers and the company, and between the company and customers offer win-win opportunities. Partnerships with educational institutions to develop the workforce and partnership with other companies for joint developments are examples of other win-win opportunities.” Is this a management attitude about partnership development?*

Very <u>Poor</u> 1	<u>Poor</u> 2	<u>Moderate</u> 3	Very <u>Good</u> 4	<u>Excellent</u> 5
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9. *“Long-range outlook: Developing partnerships with suppliers, developing the full potential of the workforce, and creating the future for our customers require a long-range outlook. At least 3-5 years and, in some industries 10-15 years, should be the planning horizon.” Are we actually developing long-range plans and partnership programs with external suppliers?*

Very <u>Poor</u> 1	<u>Poor</u> 2	<u>Moderate</u> 3	Very <u>Good</u> 4	<u>Excellent</u> 5
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TABLE 1e
CULTURAL CHANGE SURVEY PERCEPTIONS²

10. *“Management by fact: Facts combined with product or process knowledge are very powerful. Trends, projects, and cause-and-effect relationships should be studied with an understanding of variation.” Is there a positive ongoing effort to collect and use data and information for decision making?*

Very <u>Poor</u>	<u>Poor</u>	<u>Moderate</u>	<u>Good</u>	<u>Excellent</u>
1	2	3	4	5

11. *“Good corporate citizen: A company’s quality goals and objectives should address corporate responsibility and citizenship such as public health, public safety, and the environment. Giving back to the community by working with educational institutions or local government are included in the Criteria.” Does your organization present a positive image in this area?*

Very <u>Poor</u>	<u>Poor</u>	<u>Moderate</u>	<u>Good</u>	<u>Excellent</u>
1	2	3	4	5

12. *“Results orientation: Internal results should be correlated with field results and financial indicators. Performance indicators are a means of communicating and monitoring progress. These include customer satisfaction and retention, market share, product and service quality, human resource performance and development, financial indicators, and public responsibility.” Does your organization have a “results orientation”?*

Very <u>Poor</u>	<u>Poor</u>	<u>Moderate</u>	<u>Good</u>	<u>Excellent</u>
1	2	3	4	5



TABLE 1e
CULTURAL CHANGE SURVEY PERCEPTIONS²

13. The Baldrige Award is a very prestigious achievement placing an organization among "the best". *What level of effort do you believe your organization is generating to actually attempt to win this award?*

<u>0-20%</u>	<u>20-40%</u>	<u>40-60%</u>	<u>60-80%</u>	<u>80-100%</u>
1	2	3	4	5

14. Self-empowered teams have a reputation for being the best environments to work in and the most productive. *Where does your organization stand in this regard?*

Very <u>Poor</u>	<u>Poor</u>	<u>Moderate</u>	Very <u>Good</u>	<u>Excellent</u>
1	2	3	4	5



TABLE 2e
DEVELOPMENT OF FREQUENCY DISTRIBUTION OF PERCEPTIONS

(1) #	(2) Response	(3) Frequencies	(4) %	(5) Calc. Or Mean
1	Not at all	5	10.2	5
2	Very little	11	22.4	22
3	To some degree	20	40.8	60
4	Very positive strides	10	20.4	40
5	Being given full support	3	6.1	15
	Total Sample	49	99.9	142

Mean Score 142/49 = 2.89
Mode Score = 3.00
Median = 3.00

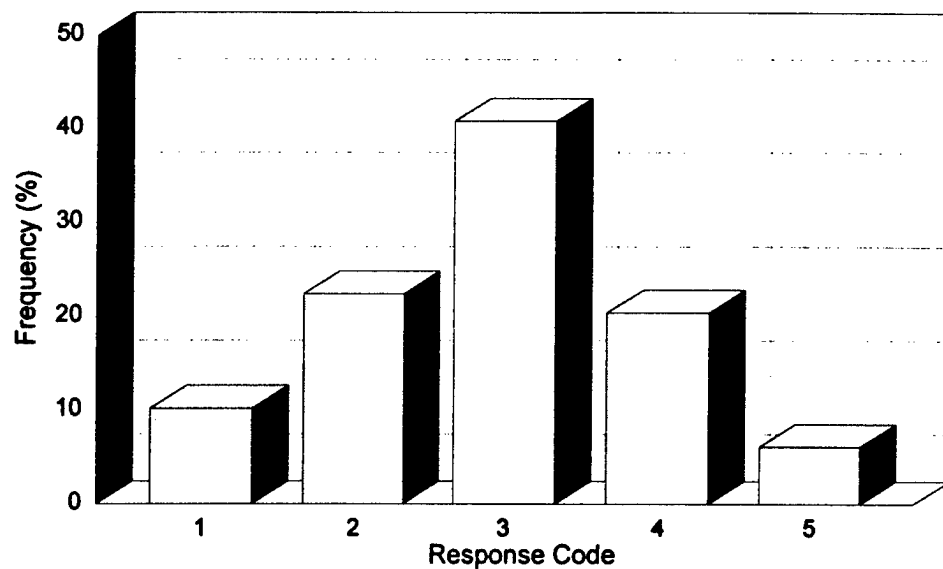


Figure 2e.



The reader can observe that indeed response three is the most popular but that there is a spread of responses around this central value. Previous discussions concerning frequency distributions can be used to further statistically describe the significance of this distribution. In this case it is not necessary to grind through the statistical calculations to determine the variance or standard deviations, etc. This type of distribution analysis does not warrant a great deal of statistical analysis. The shape of the distribution, mean, mode and median is sufficient to tell the analysts what is happening and what the perceptions of the customers are.

Figure 1e will aid in deciphering the significance of the various shapes this distribution could have taken. It will aid the user in the event that different shapes do arise with other questions and other surveys taken in the future.

The shape of curve #2 tells us that the responses are fairly normal, with a centered peak and symmetrical in shape. This is a normal shape in that responses show a spread but the normal "bell shaped" geometry is present. Curve #1 is normal in symmetry but note that it is far more peaked than curve #2. This means there is less spread among the respondents--they tend to agree more strongly than those indicated by curve #2. Curve three is also normal in shape and holds the "bell" shape but is indicative of a wider disagreement among the respondents as noted by the lower, flatter appearance. Curve #4 lost its ell configuration and is skewed to the right. This implies that the respondents are leaning toward an answer to the right of the curve and have decidedly shied away from whatever the response to the right of the

curve indicated. Curve #5 is similar to curve #4 but is asymmetrical to the right. This means that whatever responses were to the right of the question are more highly favored than those to the left. Curve #6 says that the respondents are polarized--about half favoring a response to the left of the question and half to the right. This entails a split of an organization in outlook or views concerning the question. Curve #7 is an extreme of curve #6. Here, there is extreme disagreement and, one would go so far as to say, a major split, rift or high degree of difference in views on this issue. This degree of separation between peaks probably borders on hostility--a hot issue is at stake. Curve #8 is a little like curve #6 but there is a polarization between a minority view and a majority view on the question at hand, as depicted by the different peak sizes. Finally, curve #9 shows an even spread of views and responses throughout the organization. Employees or customers are perhaps "indifferent" or the issue is irrelevant.

As the reader can see, the shape of the curve developed or formed from plotting a frequency curve can tell a good deal about the population surveyed. It becomes clear that the questions in the survey must be unbiased and very clear because interpretation can be distorted by a misunderstood question. It is also wise to pre-test a questionnaire or survey using a small population in order to weed out potential problems with question language.

There are variations in the construction of frequency distribution curves. Notice that question 13 in Table 1e uses a range of values for answers. Some questions will require this approach. Notice the above example illustrates the application of a



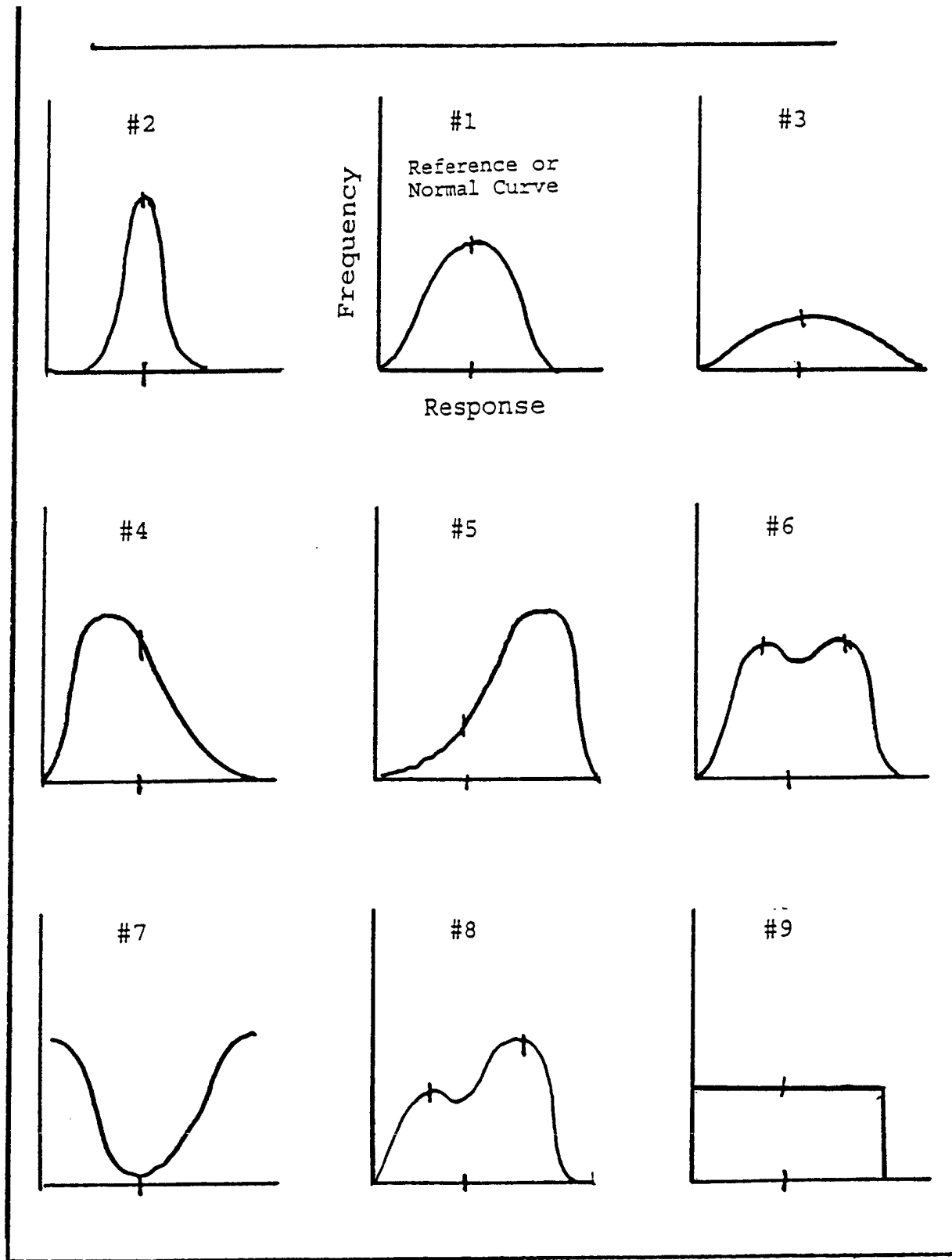


Figure 1e. - Interpretation of Frequency Distribution Shapes



process which has widespread acceptance and a good deal of utility. There are questions which require yes/no, true/false, fill in the blank, short answers, multiple choice answers, etc., and all of them are valuable. This approach provides a good deal of information. There is an alternative way to design a questionnaire. Ask the customer to construct a list of survey questions that he/she would want you to ask them about your performance at the end of some performance period; say a year. The advantages of this are obvious.

Pareto Charts

A Pareto chart shows the relative frequency of importance of collected information or data. Although it is a relatively simple tool and among the seven key tools of TQM [Rodakowski, 1994], it is valuable enough to include in a discussion of performance measurement. The approach and deployment of this tool is straightforward. Whenever a problem arises and solutions are sought, the forum is asked

to prioritize solutions to the problem. The actual ranking of priorities can be achieved through focus groups, brainstorming, consensus resolution, win-win bargaining, majority vote, Delphi method, or some other satisfactory method. Figure 3e illustrates the process. There are variations of the ranking process itself; ranking by vote, ranking by use of actual data, the ranking of solutions, the ranking of the "core" or root problems, et al. The ranking is in order of importance to the situation being addressed, be it a problem or a solution. It requires agreement and discussion of difficult issues, it demands systems thinking, requires planning and coordination, represents doing more with less, it forces prioritization, and, most of all, it compels action. It also ranks performance, if designed to do so. As Figure 3e shows, a group (PAT team, ESC, etc.) has determined that 50% of wasted time in cycle time analysis came from waiting time, another 30% came from rework, 15% came from review time, and the remainder (5%) came from a variety of sources. It is clear what must be done and where to start.



PARETO CURVE

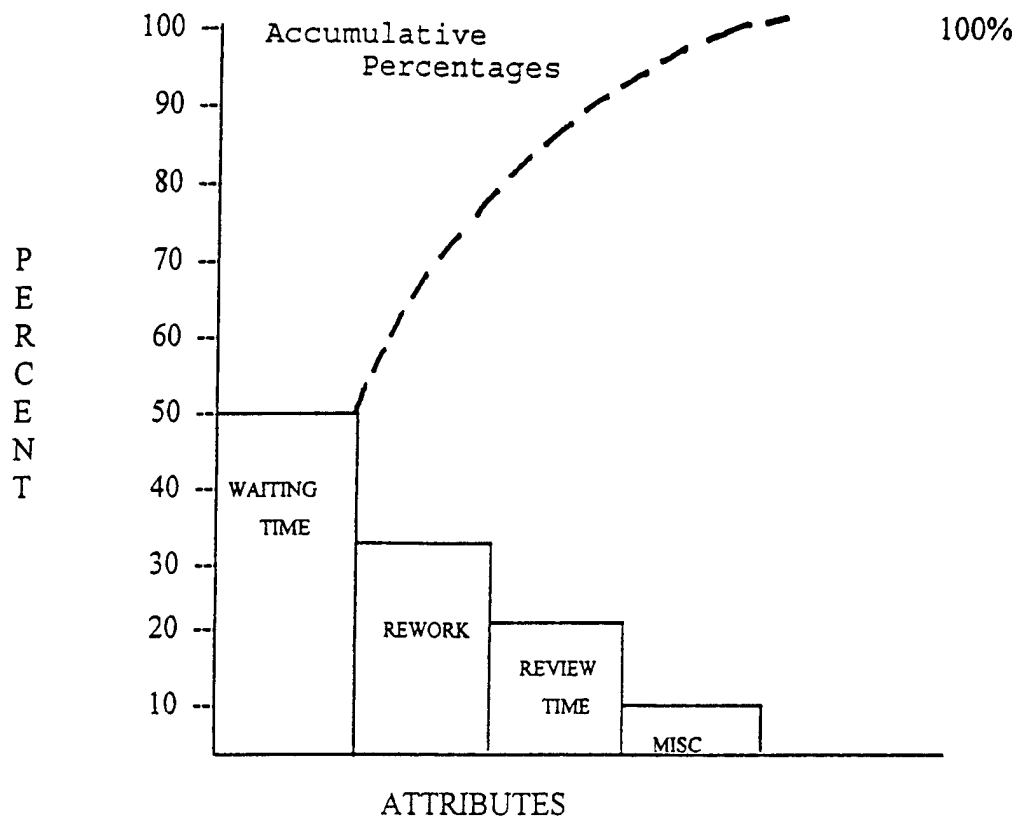


Figure 3e. - Pareto Curve





E.2. SUMMARY

This book has concerned itself with the measurement and improvement of performance. It is applicable to local, state and federal governments as well as other non-profit and commercial organizations. It contains state-of-the-art quantitative methodologies in support of continuous improvement initiatives, TQM, and the APIC tradition. It not only explains "how" to measure organizational performance but, in a macro context, "what" to measure as well.

It began with a brief discussion of the new laws and executive orders now permeating the Federal government such as NPR, GPRA, CSS, APIC, and Labor-Management Partnership Agreements—all part of a growing national performance movement. It then detailed such timely topics as waste evaluation, cycle-time analysis, value-added, business planning, benchmarking, productivity measurement, efficiency measurement, statistical process control, process and systems mapping, Shewhart and Demos control charts, quality function deployment and a host of additional up-to-date techniques and methods. The text also included outlines of such organizational attributes as structure, the need and development of a vision and mission statement, goals and objectives, operating characteristics, key, core or critical processes among others.

The text's strength lies in applied examples covering such areas as resource inputs, processes or resource transformation, product and service outputs, outcomes, program effectiveness, etc. The performance measures are explained using detailed examples mimicking real world situations. The material is comprehensive and technical but necessary if metrics are to become part of the cultural process change needed to overcome effectiveness, efficiency and productivity problems. Unusual but important areas are also covered. The world is rapidly becoming more competitive with increased needs and importance in areas of change adaptation, knowledge acquisition and capability, and information processing and infusion. Performance measurement for these new business characteristics is also embraced.

There are many tools not covered which are of a more traditional vein but still very valid. They can be found in the material listed in the bibliography. Important tools and methods such as simple and multi variate regression analysis, Monte Carlo simulations, correlations analysis, "t" test of significance, analysis of variance, Chi Square, etc. are also part of the new analyst's tool chest. These are no longer tools reserved for the statistician; but their application is now a requirement among "world class" organizations.



GLOSSARY

Activities. The steps of a process. [James H. Saylor].

Activity-based cost accounting (or management). A form of managerial accounting in which indirect costs, normally thought of as overhead, are assigned to projects or activities rather than to aggregations of type of costs (travel, supplies, consultants) and are apportioned by an appropriate "driver" rather than just becoming "labor burden" as in standard accounting. [Thor, 1994]

Adaptability. The flexibility of the process to handle future, changing customer expectations and today's individual, special customer requests. It is managing the process to meet today's special needs and future requirements. Adaptability is an area largely ignored, but it is critical for gaining a competitive edge in the marketplace. Customers always remember how you handled, or didn't handle, their special needs. [Harrington, 1991]

Benchmarking. Systematic comparison of elements for the performance of an organization against that of other organizations, usually with the aim of mutual improvement. [Thor, 1994]

Best of class. One of a group of similar organizations whose overall performance, effectiveness, efficiency, and adaptability is superior to all others. [James H. Saylor, 1992]

Capital productivity. The output of a process divided by the quantity of capital associated with the creation or modification of that output, thus a measure of the efficiency or effectiveness of the use of capital. [Thor, 1994]

Common Cause. The source of random, or natural, variation in a process. Common causes--or "assignable causes," as they are sometimes called--are inherent in the production process itself. [Hart, Bogan, 1992]

Continuous improvement system. A disciplined methodology to achieve the goal of commitment to excellence by continually improving all processes. [James H. Saylor, 1992]

Control chart. In quality analysis, a charting technique that allows determination of whether the variation being observed in a process is within "normal" bounds or a symptom of a changed process. [Thor, 1994]

Cycle time. The elapsed time it takes to do a defined piece of work, from the receipt of all needed supplies and information to the delivery of the finished work. [Thor, 1994]



Deming, W. Edwards. (1900-1994) A pioneer of the modern quality movement who emphasized the use of statistical techniques and disciplined striving for zero defects. [Thor, 1994]

Downtime. The cost to redo rather than to go on to the next, new task. [Roseland, 1989]

Effect. A problem or defect that occurs on the specific job to which a group or team is assigned. [James H. Saylor, 1992]

Effectiveness. (1) The extent to which the outputs of the process or subprocess meet the needs and expectations of its customers. A synonym for effectiveness is quality. Effectiveness is having the right output at the right place, at the right time, at the right price. Effectiveness impacts the customer. [Harrington, 1991] (2) A characteristic used to describe a process in which output conforms to requirements. [James H. Saylor, 1992]

Efficiency. (1) The extent to which resources are minimized and waste is eliminated in the pursuit of effectiveness. Productivity is a measure of efficiency. [Harrington, 1991]. (2) A characteristic used to describe a process that produces the required output at a perceived minimum cost. [James H. Saylor, 1992]

Empowerment. The power of people to do whatever is necessary to do the job and improve the system. [James H. Saylor, 1992]

Energy productivity. The relationship between the output of a process and the amount of energy required to create or modify that output. [Thor, 1994]

Facilitator. One who assists the group or team in applying the TQM tools and techniques. [James H. Saylor, 1992]

Family of measures. A balanced collection of four to six performance measures (usually including productivity, quality, and customer satisfaction) that together provide a comprehensive view of organizational results but individually also provide diagnostic value. [Thor, 1994]

Feedback. A process in which the producers of a result receive modifying information from that result. In this case, individuals and work groups of all types receive direct information about their outputs. [Thor, 1994]

Flowchart. A step-by-step display of how a process functions using a series of coded figures to represent different kinds of activities and interventions, used in business process reengineering and benchmarking data development. [Thor, 1994]

Functional organization. An organization responsible for a major organizational function, such as marketing, sales, design, manufacturing, or distribution. [James H. Saylor, 1992]



Goal. The specific desired outcome. [James H. Saylor, 1992]

Hierarchical nature of a process. The various levels of a process. [James H. Saylor, 1992]

Histogram. A set of vertical bar graphs that demonstrates the distribution of a variable in a population. [Thor, 1994]

Index. A set of numbers showing percentage variation from an arbitrary standard, usually 100, representing the status at some earlier time. [Thor, 1994]

Inflation(deflation). The degree to which general or specific prices have increased (or decreased) from one time period to another. [Thor, 1994]

Input. That which is used to make an output; in productivity measurement an expression of the physical amount (or dollar value) of one or more elements utilized in the production process. [Thor, 1994]

Kaizen. A Japanese expression referring to continuous improvement in all phases of a business. [Hart, Bogan, 1992]

Key process. A series of activities so critical that value added work cannot be accomplished without them.

Key result area. An area of resource input, processing activities, output, outcome, or results which, when measured, serve to diagnose an entire process or system.

Labor productivity. The relationship between the output of a process or entity and the labor inputs used in creation or modification of that output. [Thor, 1994]

Malcolm Baldrige National Quality Award. A quality award first presented by the President of the United States in 1988 that recognizes approach, deployment, and results of a manufacturing or service organization's quality initiative. Its basic criteria have become the standard for self-assessment of quality in the United States. [Thor, 1994]

Materials productivity. The relationship between the output of a process and the materials inputs used in creation or modification of that output. [Thor, 1994]

Measurement. The act or process of measuring in order to compare results with requirements. A quantitative estimate of performance. (James H. Saylor, 1992]

Multifunctional team. A team consisting of representatives from more than one function. [James H. Saylor, 1992]



Outcome. Downstream from output, an outcome is the ultimate result of a productive process. If the output is a high school diploma, the outcome is a job offer. If the output is a patient diagnosed, the outcome is a patient cured. [Thor, 1994]

Pareto analysis. A system of analysis based on the principle that, in any phenomenon, relatively few factors account for the majority of effects. Juran uses the phrase “vital few” to suggest that it is more efficient and less costly to concentrate on the most important sources or types of failures, customers, and so on. [Hart, Bogan, 1992]

Pareto chart. A chart that connects frequency of process difficulties with potential cause classifications. Pareto’s law suggests that a large percentage of the difficulties are typically caused by a small percentage of the causes. [Thor, 1994]

Performance measurement. A means of evaluating efficiency, effectiveness, and results. A balanced performance measurement scorecard includes financial and nonfinancial measures focusing on quality, cycle time, and cost. Performance measurement should include program accomplishments in terms of outputs (quantity of products or services provided, e.g., how many items efficiently produced?) And outcomes (results of producing outputs, e.g., are outputs effectively meeting intended agency mission objectives?). [Management Concepts Inc., 1995]

Process. (1) A systematic series of actions directed to the achievement of a goal. [J.M. Juran, 1992]
(2) A series of activities that takes an input, modifies the input (work takes place/value is added), and produces an output. [James H. Saylor, 1992]

Process analysis. Tool used to improve a process and reduce process time by eliminating non-value-added activities and/or simplifying the process. [James H. Saylor, 1992]

Process capability. The ability of a process to meet operating goals or internal--or external-customer requirements. “Capability” may differ from actual performance due to “special causes”--conditions or events due purely to chance and not to the production system itself. [Hart, Bogan, 1992]

Process control. The systematic evaluation of performance of a process, and the taking of corrective action in the event of nonconformance. [J.M. Juran, 1992]

Process improvement. The set of activities used to detect and remove common causes of variation in order to improve process capability. Process improvement leads to quality improvement. [James H. Saylor, 1992]

Process management. A management approach comprising quality management and process optimization. [James H. Saylor, 1992]



Process performance. A measure of the effectiveness and efficiency with which a process satisfies customer requirements. [James H. Saylor, 1992]

Productivity. The relationship between the output of a process or entity and one or more of the inputs used to create that output. [Thor, 1994]

QC, Quality Circle. A group of workers who have undergone training for the purpose of solving work-related problems. [J.M. Juran, 1992]

Quality. (1) "Quality is meeting customer needs and expectations consistently and efficiently." [Turner, 1993] (2) Product features that respond to customer needs; (3) freedom from deficiencies. [J.M. Juran, 1992]

Re-analysis. The cost of correcting defects. [Roseland, 1989]

Replacement cost. What it would cost to replace a specified amount of old productive capacity using current design and technology. [Thor, 1994]

Review. The cost of another review cycle. [Roseland, 1989]

Robust design. The design of a product for minimal quality losses. [James H. Saylor, 1992]

Root cause. Underlying reason for nonconformance within a process. When it is removed or corrected, the nonconformance is eliminated. [James H. Saylor, 1992]

Simulation. Techniques of observing and manipulating an artificial mechanism (model) that represents a real-world process that, for technical or economical reasons, is not suitable or available for direct experimentation. [James H. Saylor, 1992]

Special cause. An "abnormal" source of variation that does not arise from the production process itself, but which is extraneous and unpredictable. [Hart, Bogan, 1992]

Standard deviation. A parameter describing the spread of the process output. The positive square root of the variance. [James H. Saylor, 1992]

Statistical control. Term used to describe a process from which all special causes of variation have been removed, leaving only common causes. Such a process is also said to be stable. [James H. Saylor, 1992]

Statistical Process Control (SPC). Based on the principle that no two units of output of a process are likely to have the exact same specifications. SPC involves the mathematical determination



of acceptable limits of variation. Graphs are used by workers to plot output variable and visually determine when a process is “in” or “out of” control. [Hart, Bogan, 1992]

Strategy. A broad course of action, chosen from a number of alternatives, to accomplish a stated goal in the face of uncertainty. [James H. Saylor, 1992]

Stretch goal. An ambitious, usually long-term quality goal that requires extraordinary effort, innovation, and planning to achieve. [Hart, Bogan, 1992]

Subprocesses. The internal processes that make up a process. [James H. Saylor, 1992]

System. A configuration of things or processes so inter-connected as to behave as one. [Rodakowski, 1994]

Total factor productivity. Sometimes used interchangeably with *total productivity*, but more precisely the relationship of a value-added output to its labor and capital inputs with price effects removed. [Thor, 1994]

Total productivity. The relationship between the output of a process and all of the inputs to that process (typically labor, capital, energy, and materials) with price effects removed. [Thor, 1994]

Total Quality Management (TQM). A philosophy and a set of guiding principles that represent the foundation of a continuously improving organization. TQM is the application of quantitative methods and human resources to improve the material services supplied to an organization, all the processes within the organization, and the degree to which the needs of the customer are met, now and in the future. TQM integrates fundamental management techniques, existing improvement efforts, and technical tools under a disciplined approach focused on continuous improvement. [James H. Saylor, 1992]

Value added. Sales less purchased goods and services, or viewed from the other direction, labor plus capital plus profit. [Thor, 1994]

Variance. In quality management phraseology, any deviation from specifications; in statistics, the square of the standard deviation.

Waste. The net loss in labor and material. [Roseland, 198]

Weighting. The systematic combining of unlikes, in this case (1) the combining of process outputs that have different inherent degrees of input usage and (2) the combining of the results of the family of measures members based on predetermined relative importance. [Thor, 1994]



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ANNOTATED BIBLIOGRAPHY

The following have been abstracted from the main bibliography as outstanding reading for those wishing to better understand the concepts and ideas incorporated in this book. All are applicable to COE performance measurement.

Berk, Joseph & Susan. Total Quality Management. Sterling Publishers. 1993. A good all around treatment of the principles of TQM. Strong on Systems Failure Analysis, Taguchi Analysis, and ANOVA. Quality Function Deployment is also covered in operational detail. These are important to COE implementation of GPRA and APIC.

Deming, W. Edwards. Out of the Crisis. MA: Massachusetts Institute of Technology, Center for Advanced Engineering Study, 1982. The original works which started the TQM movement. Very good on Shewhart Control Charts, Deming's 14 points, and many other elements such as continuous improvement, constancy of purpose, process capability, common and special causes of process variation, et al.

Harrington, H. J. Business Process Improvement: The Breakthrough Strategy for Total Quality, Productivity, and Competitiveness. New York: McGraw-Hill, 1991. Outstanding coverage of PROCESS CYCLE TIME, COST ANALYSIS, REAL VALUE-ADDED ANALYSIS, BUSINESS VALUE-ADDED, AND NO VALUE-ADDED. Good coverage of process SIMPLIFICATION. Very applicable to COE business operations. Also covers effectiveness, efficiency, and productivity very well. The only book I have found which discusses the measurement of organizational adaptability.



Maskell, Brian H. Performance Measurement for World Class Manufacturing: A Model for American Companies MA: Productivity Press, Inc. 1991. Excellent on COST ANALYSIS, CYCLE TIME ANALYSIS, STATISTICAL PROCESS CONTROL such as the use of the SHEWHART CONTROL CHART and the DEMOS CONTROL CHART. Also covers such timely subjects as VALUE-ADDED ANALYSIS, DIRECT LABOR PRODUCTIVITY, BENCHMARKING, OVERHEAD ANALYSIS, and ACTIVITY BASED COSTING.

Thor, Carl G. The Measure of Success, Operating High Performance Organizations. VT: Oliver Wight Publishing Co., 1994. Covers PERFORMANCE MEASUREMENT, FAMILIES OF MEASURES, PARTIAL AND TOTAL PRODUCTIVITY MEASUREMENT, THE COST OF POOR QUALITY, the relationship between BENCHMARKING AND PERFORMANCE MEASUREMENT---and much more. Plenty of examples.



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