SECTION 9
MEASUREMENT, INFORMATION, AND DECISION MAKING

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INTRODUCTION

Managers Need Information. The general business leader and quality manager share an eternal lament first voiced by Alexander the Great: "Data, data, data! I'm surrounded by data. Can't anyone get me the information I really need?" Alexander needed answers to some rather basic questions. "Where is the enemy? How large are his forces? How well will they fight? When will our supplies arrive?" His spies, lieutenants, and others gathered data. But they could not always satisfy Alexander's need for information.

Today's business manager also has a voracious appetite for information (see also Drucker 1995). Obtaining needed information is time-consuming, expensive, and fraught with difficulty. And in the end, the manager is often less informed than Alexander the Great. Basic questions like "What do customers really want? How well are we meeting their needs? What is the competitor going to do next?" are not easier to answer. This, despite an amazing proliferation of measuring devices, customer surveys, statistical methods, and database and networking technology. Just as quality management is a never-ending journey, so too is the task of learning of, obtaining, sorting through, synthesizing, and understanding all the data and information that could productively be used. It seems that the manager's appetite for information will never be satisfied.

Systems of Measurement. We usually consider information in light of decisions that managers must make and the actions they take. Information plays a similar role in science. The scientific method is essentially a process by which hypotheses are proposed, experiments designed to test aspects of those hypotheses, data collected and analyzed, and the hypotheses either advanced, discarded, or modified. Time-tested and rigid standards apply. Most businesses cannot afford the required rigor. The system of measurement advanced here parallels the scientific method, but the standards are different. "Caution" is the watchword in science. "Success" is the watchword in business. (See Section 47 for further reference to the scientific method and experimental design.)

In some cases, the manager is presented with well-defined choices. A simple example is the question: "Is this process in a state of control?" The manager can either decide that the process is in control and take no action, or decide that the process is not in control and take action to find and eliminate a special cause. (See Section 4: The Quality Control Process.) In other situations, the range of options is ill-defined and/or unbounded. In many cases (perhaps too many), the manager may even choose to gather more data. In almost all cases, it appears axiomatic that the better the information, the better the decision. Here *better information* may have any number of attributes, including more complete, more accurate, more relevant, more current, from a more reliable source, more precise, organized in a more convincing fashion, presented in a more appealing format, and so forth.

A critical step in obtaining needed information is measurement. To measure is "to compute, estimate, or ascertain the extent, dimensions, or capacity of, especially by a certain rule or standard" (Webster 1979). Measurement, then, involves the collection of raw data. For many types of measurements, specialized fields have grown up and there is a considerable body of expertise in making measurements. Chemical assays and consumer preference testing are two such areas. Data collection may involve less formal means—searching a library, obtaining data originally gathered for other purposes, talking to customers, and the like. For our purposes, all such data collection shall be considered measurement.

Of course there is more to developing the information the manager needs then simply collecting data (indeed, therein lies Alexander's lament). For examples we cited "more relevant" and "presented in a more appealing format" as attributes of better information. It is evident that the choice of what to measure and the analysis, synthesis, and presentation of the resultant information are just as important as the act of measurement itself. High-quality information results only from high-caliber and integrated design, data collection, and analysis/synthesis/presentation. Thus we distinguish between the *act of measurement,* or data collection, and the *measurement process,* which includes design, data collection, and analysis/synthesis/presentation. This process is presented in Figure 9.1 and described throughout this section.

But good information is not a decision. So Figure 9.1 goes further. The measurement process is preceded by a step "Understand framework" and followed by a step "Make decision/take action." These steps put the measurement process in its proper context and represent the suppliers to and customers of the measurement process. Finally, Figure 9.1 features one further important subtlety. Decision makers in most organizations are often too busy to carefully consider all the data and evaluate alternatives. What they require are recommendations, not just clearly presented information. So the analysis/synthesis/presentation step is better described as analysis/synthesis/recommendations/presentation of results and recommendations. It could be

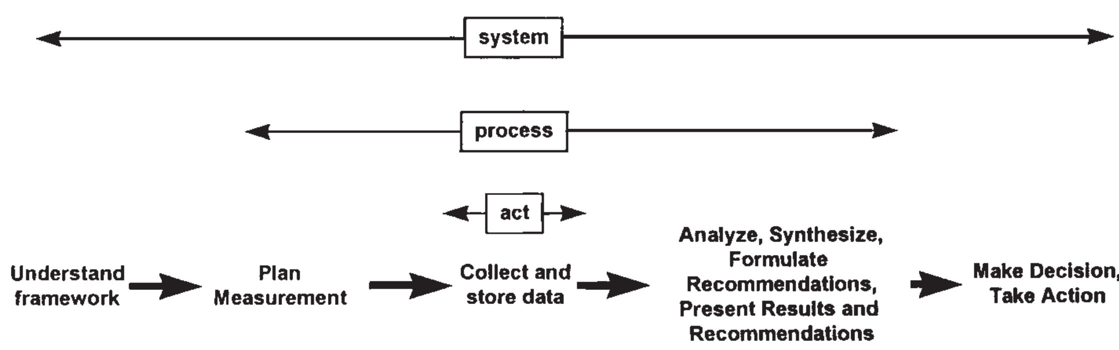

FIGURE 9.1 The act of measurement is but one step in a larger measurement system. Herein we consider the measurement process as consisting of steps needed to collect data and present results. The larger measurement system also embraces the decisions that are made and the framework in which the process operates.

argued that formulation of results is better thought of as a part of decision making. But it is more often the case that those analyzing data also are expected to make recommendations. Indeed, they may be petitioning decision makers to adopt their recommendations.

As will be discussed, decision making is often a complex political process, in and of itself. Thus the framework in which information is produced is critical. At a high level, the framework defines the overall context in which decisions are to be made, including such diverse considerations as the organization's business goals, its competitive position, and its available resources; customer requirements; the goals and biases of decision makers; and any relevant constraints on the measurement process or decision making. For any particular decision, the framework includes the specific issues to be addressed. Taken together, these five elements (framework, design, data collection, analysis/synthesis/recommendations/presentation, and decision/action) compose a "measurement system".

Ultimately, the goal is to help the organization make consistently better decisions and take better actions. Here, *better decisions* are defined in terms of results in achieving organizational objectives. Good measurement systems support a number organizational goals, not just a few (Kaplan and Norton 1992, 1993; Meyer 1994). It is usually true that "what gets measured, gets managed." Most organizations intend to pursue a variety of goals, satisfying customers, providing a healthy and fulfilling workplace, meeting financial objectives, and so forth. In many organizations financial measurements are the most fully developed and deployed. It is little wonder that financial considerations dominate decision making in such organizations (Eccles 1991).

The most important point of this section is that those who define and operate a measurement process (i.e., those who gather or analyze data or who recommend what the organization should do) must consider the system as a whole, including the environment in which it operates. It is not sufficient to be technically excellent or for one or two elements to be outstanding (see Futrell 1994 for a review of the failures of customer satisfaction surveys). Overall effectiveness is as much determined by how well the elements relate to one another and to other systems in the enterprise as by excellence in any area. The following personal anecdote illustrates this point.

Very early in my career, I was asked to recommend which color graphics terminal our department should buy. I spent a lot of time and effort on the measurement process. I talked to several users about their needs, called a number of vendors, arranged several demonstrations, and read the relevant literature. At the time (early 1980s) the underlying technology was in its infancy—it had many problems with it and a terminal cost about $15,000. Further, many people anticipated dramatic and near-term improvements to the technology and substantial price reductions. So I recommended that we wait a year and then reconsider the purchase. I was proud of my work and recommendation and presented it to my manager. He promptly informed me I had misunderstood his question. The question was not "Should we buy a terminal?" but "Which terminal should we buy?" (and none was not a permitted answer). In retrospect, I could have: explicitly defined the possible decisions in advance, or thought through the framework. My manager was a forward thinker. He had seen the potential for personal computing and clearly wanted to experiment. Even casual consideration of his objectives would have made it clear that "wait a year" was an unacceptable recommendation.

About This Section. The primary audiences for this section are persons interested in helping their organizations make better decisions. I have already noted that obtaining relevant information can be time-consuming, expensive, and fraught with difficulty. On the other hand, there are many cost-effective practices that everybody can take to reduce the gap between the information they desire and the information they have at their disposal.

Readers may have several interests:

- Those whose measurement and decision processes are well defined may be especially interested in comparing their processes to the "ideals" described here.
- Those who make measurements and/or decisions routinely, but whose processes are ad hoc, may be especially interested in applying the techniques of process management to improve their measurements and decisions.

- Those whose interests involve only a single "project" may be especially interested in learning about the steps their project should involve.

This section does not consider many technical details. Entire volumes have been written on technical details of measurement making (see Finkelstein and Leaning 1984 and Roberts 1979, for example), statistical analysis (see Sections 4, 44, 45, and 47 of this Handbook, for example), graphical data presentation, and the like.

In the next section, we consider measurement systems in greater detail. Outputs of each step are defined and the activities needed to produce those outputs are described. Then, we consider more complex measurement systems, involving hierarchies of measurements. The fourth section provides practical advice for starting and evolving a measurement system. The final section summarizes good practice in a list of the "Top 10 Measurement System Principles."

Three examples, of escalating complexity, are used to illustrate the main points. At the so-called "operational level," we consider the measurement system for a single step for the billing process summarized in Figure 9.2. At the tactical level, we consider the measurement system needed to support changes to the feature set associated with the invoice (the result of the billing process). We also consider measurement systems needed to support strategic decisions. Virtually everyone is involved in some way or another at all three levels of decision making.

A middle manager may find himself or herself playing the following roles:

- A designer of the measurement system used at the operational level
- A decision maker at the tactical level
- A supplier of data to strategic decisions

MEASUREMENT SYSTEMS AND THEIR ELEMENTS

Figure 9.3 expands on Figure 9.1 in two ways: It lists the work products produced at each step and describes the work activities in more detail. The first two steps (understand framework and plan measurement) are planning steps. There is no substitute for careful planning, so most of the discussion is on planning. The most important work products of the system are decisions and actions. Other work products aim to produce better decisions and actions. So we begin the discussion with the final step: Make decision/take action.

Make Decisions/Take Action. The first step in defining a measurement system is to understand who will make the decisions and how. Many decisions, and virtually all decisions of consequence, are not made by an individual, but by a committee or other group. In some cases, this helps build support for implementation. In others, it is more a vehicle for diffusing accountability. Some groups decide by majority rule, others by consensus. Most groups have a few key individuals. Some are thoughtful leaders, others are self-centered, domineering bullies. Few decision makers are completely unbiased. Most are concerned, at least to some degree, with their careers. Individuals intuitively make decisions based on different criteria. Some are risk takers, others are risk-averse. Some are concerned only with the near-

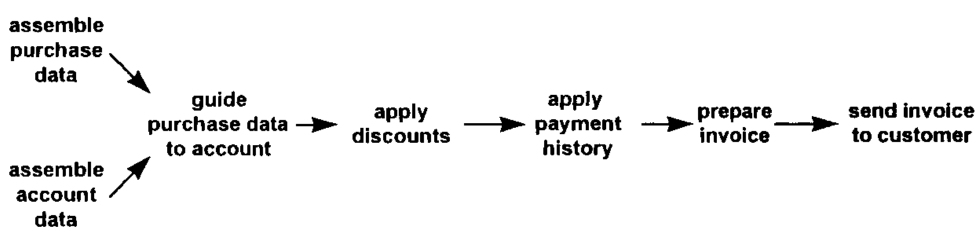

FIGURE 9.2 A hypothetical billing process.

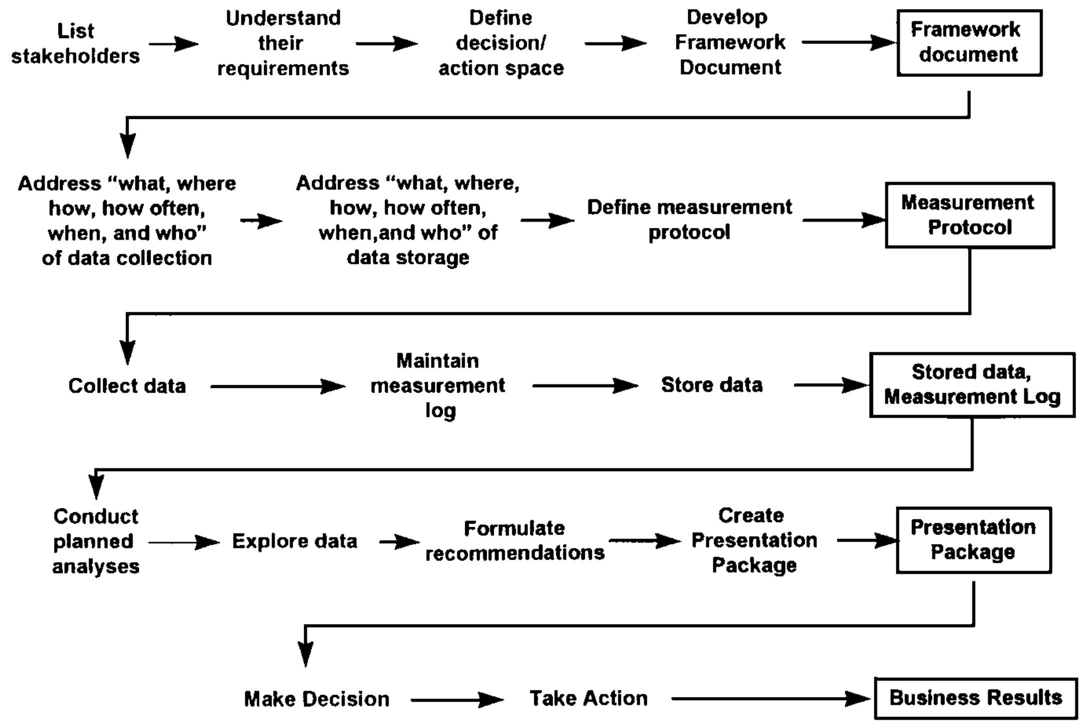

FIGURE 9.3 Further detail about subprocesses of the measurement system. For each subprocess, the principal work product and several steps are given.

term financial impacts, others consider the long-term. And those who may be saddled with responsibility for implementation have other perspectives. Decision making is thus also a political process that the designer of the measurement system is well advised to understand.

Understand Framework. Prior to determining what to measure and how to measure it, it is important to understand the overall framework in which the measurement system operates. We've already noted the political nature of decision making. Those who make decisions and take actions are members of organizations, and all organizations have their own politics and cultures that define acceptable directions, risks, behaviors, and policies that must be followed. These features of the organization form much of the context or framework for the measurement system. Good measurement systems usually work in concert with the organizational culture. But they are also capable of signaling need for fundamental changes in the culture.

Defining the framework is somewhat akin to stakeholder analysis in strategic planning. Stakeholders include at least three groups: customers, owners (and perhaps society), and employees. Each has valid, and sometimes conflicting, goals for the organization. These impact the organization's business model and in turn, the measurement system. We consider each in turn. See Figure 9.4.

1. *Customers:* One goal of most organizations is to maintain and improve customer satisfaction, retention, and loyalty. Customer needs are usually stated in subjective terms. At the operational level, a consumer may simply want "the bill to be correct." At the tactical level, an important requirement may be that the invoice feed the customer's invoice payment system. Finally, at the strategic level, business customers may want to establish single sources of supply with companies they trust. It is important to recognize that there is an element of subjectivity in each customer requirement. Technicians are often dismayed by customers' lack of ability to give clear, objective requirements. But customers and their communications abilities are explicitly part of the overall framework.

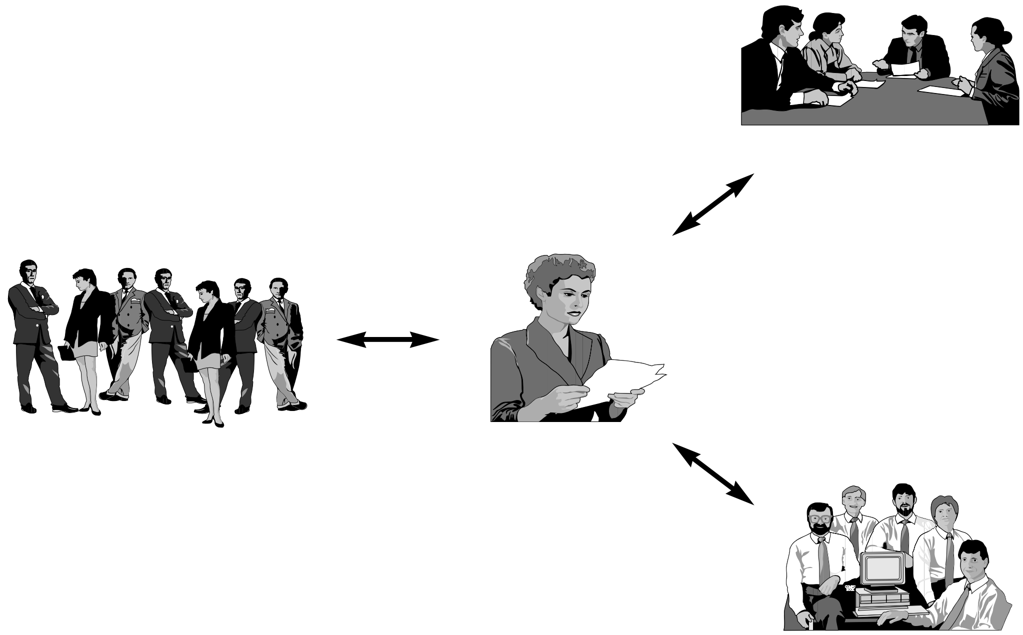

FIGURE 9.4 The measurement system is impacted by and impacts virtually all systems within an organization.

2. *Owners:* Owners of the business are usually less concerned about day-to-day considerations and more concerned about the economic viability, both long- and short-term, of the business. Their interests are reflected in corporate direction, competitive position, and financial performance. They usually wish, implicitly at least, to see costs kept to the lowest levels.

The impact of their interests on the measurement system is that certain things are more important to measure than others. Consider a company that wishes to pursue a strategy of price leadership. It wishes to be perceived as "just as good" as a major competitor, but wants to keeps costs as low as possible. Such a company will design its measurement system around competitive intelligence. It will not, for example, invest to learn of customers' preferred bill formats. In contrast, a company pursuing customer value and intimacy will design its measurement system to learn more about customers, how they use the organization's products and services, and how to use these measurements in defect prevention. It will invest to learn how to make its invoices a source of advantage.

3. *Employees:* Insofar as measurements systems are concerned, employees are stakeholders because they depend on the organization for their livelihood. Many are also stakeholders because they make decisions and take actions, others because they collect data, and so forth. Employees may view the measurement system as a device of management control, but good measurement systems are also empowering. In our operational example, the day-to-day decision maker could be owner of the guiding function, the billing process owner, or even a product manager. There may be good reasons for the process owner—local custom, required skill, union rules—to be the decision maker. But it is usually preferable that decisions be made as close to the action as possible. So unless there is a compelling reason otherwise, the owner of the guiding function is the preferred decision maker. In contrast, poor measurement systems require much additional time and are of dubious value.

A second aspect of understanding the framework involves the range of possible decisions and actions. A list of such decisions and actions is called the "decision/action space." In some cases creating this list is a straightforward exercise and in others it is nearly impossible. At the lowest, or operational, level it is usually possible to describe the decision space completely. Thus, in our first example, there are only a few possible decisions:

- The process is in control and performing at an acceptable level and should be left alone,
- The process is out of control and must be brought under control.
- The process is in control but not performing at an acceptable level. It must be improved.

At the tactical and strategic levels, the exercise of defining the decision/action space becomes more difficult. The range of possible decisions may be enormous, many possible decisions may be difficult to specify beforehand, and some decisions may be enormously complex. In our second (tactical) example, one possible decision is to leave the invoice alone. But the invoice can also be improved, possibly in a virtually unlimited number of ways. There are any number of incremental improvements to the formatting and accounting codes. Or the invoice can be wholly redesigned. A paper invoice may be replaced with an electronic one, for example. Finally the invoice may even be replaced with a superior invoice based on electronic commerce on the Internet.

Experience suggests that the more carefully the decision/action space is defined, the better the resultant decisions. This is just as true at the strategic level as it is at the operational level.

Unfortunately there are no complete templates for defining the framework. Any number of other considerations may be pertinent. For examples, legal obligations, safety rules, or technical limitations may be very important.

Framework Document. The end result should be a framework document that captures the major points of the work conducted here. It should describe major business goals and strategies and customer requirements, define the decision/action space and decision makers (by name in some cases, by job classification in others), note important constraints (financial and other), and reference more detailed business plans and customer requirements. And, as the business grows and changes, so too should the framework document.

Plan Measurements. Once the planner understands decision space and the framework in which the measurement system operates, plans for the remaining steps of the process are made. The output of this step is a "measurement protocol", a document that describes the "whats, whens, wheres, hows, and how often" of data collection, storage, and planned analyses. Perhaps most importantly, the protocol should also describe the "whos"—who is responsible for each step. Figure 9.5 portrays the landscape to be covered. The most important issues to be addressed are discussed below.

Data Collection: What to Measure. Above, we noted that most customer requirements are stated in subjective terms. These requirements have to be translated into a set of objective measurements. A good example involves the early days of telephony. Customers' most basic requirement was "to hear and be heard." An almost unlimited number of problems can thwart this basic requirement. And, except for the actual speech into the mouthpiece and sound emanating from the earpiece, a phone call is carried electrically. A remarkable series of experiments helped determine that three parameters, loss, noise, and echo, each measurable on any telephone circuit or portion thereof,

	Data collection	Data storage	Analysis, synthesis, recommendations presentation
What			
Where			
When			
How			
How often			
Who			

FIGURE 9.5 The landscape to be covered by a measurement protocol.

largely determined whether the customer could hear and be heard (Cavanaugh, Hatch, and Sullivan 1976; AT&T 1982).

In recent years, Quality Function Deployment (Hauser and Clausing 1988) has proven to be an invaluable tool in helping map subjective user requirements into objective criteria for process performance. Figure 9.6 illustrates an ideal scenario in which the user requirement for a "correct bill" is first translated into a small number of objective parameters that are further translated into requirements on steps in the billing process (and, in particular, on guiding).

Naturally, many requirements will never lend themselves to objective measurement. Our second example, involving changes to a feature set, is such an example. Here the primary sources of data will be customer satisfaction surveys, customer feedback, observation of competitors' features, and views of likely technological innovations.

In some cases, it is pretty clear what you would like to measure, but you simply can't measure it. A famous story involves the vulnerability to enemy fire in World War II planes. The goal was to have more aircraft complete their missions and return safely. And, ideally, one would like to determine where aircraft that didn't return were hit. But these aircraft were not available. Good surrogate measurements are needed in such cases. The problem with World War II aircraft was addressed by examining where planes that did return were hit and assuming that those that didn't return were hit elsewhere.

In almost all cases, literally dozens of possible measurements are possible. The planner is usually well advised to select "a critical few" measurements. There are decreasing returns as measurements are added, and too many measurements can overwhelm the measurement system. The planner should list possible measurements and rank-order them. There will be an essential few that he/she must select. Other measurements should only grudgingly be admitted. Reference to the framework is usually most helpful in making the necessary selections.

Many planners fall into a trap by concentrating on getting a few good measures for each step of a process and giving insufficient attention to overall measurement. There is a compelling logic that, in billing for example, if each step performs correctly, then the overall process will perform correctly. Unfortunately this logic is often incorrect. Too many problems can arise between steps, where accountability is not clear. An overall measure of bill correctness and measures of correctness at each step are needed. The principles of business process management are covered in Section 6.

Precise definitions of what is measured are essential, as slight changes in definition can produce very different results, a fact that advertisers may exploit (see Schlesinger 1988 for one example).

Data Collection: Where. The planner must simultaneously determine where to make measurements. In quality management, the usual evolution is from inspection at the end of a production process to measurement of in-process performance. Immature systems place greater weight on inspection, more mature ones on in-process measurement (see Ishiakawa 1990).

Data Collection: When, How, How Often. In some cases, no new data are collected, but rather existing data from "customer accounts" or other databases are used. The planner is still advised

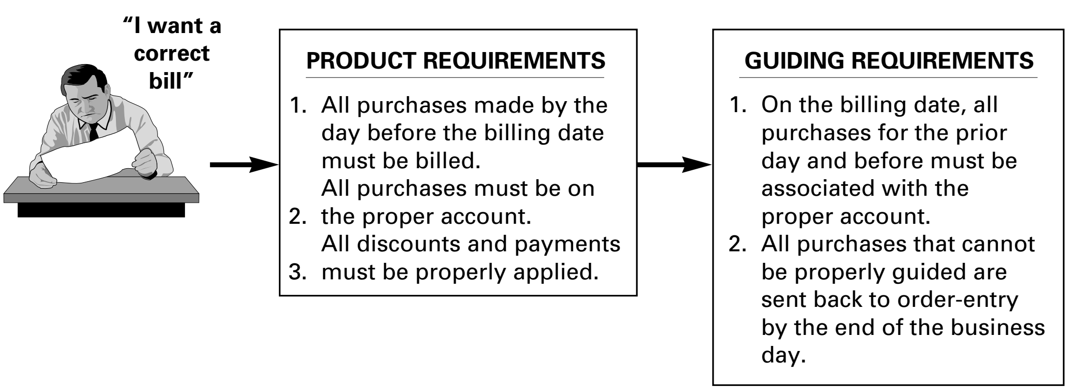

FIGURE 9.6 Customer requirements are usually subjective. They need to be translated into objective measurable parameters. Here it is done for the requirement "I want a correct bill" and the guiding step of the billing process.

to learn about the intricacies of data collection, as data collected for one purpose may not suit another.

The planner next specifies how, when, and how often measurements are to be made. Each should be spelled out in full detail. "How" involves not only how a particular measurement is to be made, but also how the measurement equipment is to be calibrated and maintained and how accurate data are to be obtained. "When" and "how often" must be addressed to ensure that ample data are available. The interested reader is referred to Sections 44, 45, and 47.

Data Storage and Access. Perhaps nothing is more frustrating than knowing "the data are in the computer" but being unable to get them. Planners too often give insufficient attention to this activity, and data storage and retrieval becomes the Achilles' heel of the system. Suffice it to note that, despite an explosion in database technology, especially in ease of use, data storage and retrieval are not easy subjects and should be carefully planned.

Data Analysis, Synthesis, Recommendations, and Presentation. Finally, the planner must consider the analysis, synthesis, formulation of recommendations, and presentation step. While all the analyses that will be carried out cannot be planned, certain basic ones should be. Thus, in our operational example, the addition of a point to a control chart at specified intervals should be planned in advance.

Who. Just as important as what, where, when, and how is who. Who collects data, who stores them, who plots points on control charts, who looks at data in other ways. All should be specified.

Measurement Protocol. The output of this step is a measurement protocol that documents plans for data collection and storage, analysis/synthesis and presentation. In effect, the measurement protocol defines the sub-processes to be followed in subsequent steps. Written protocols appear to be common in many manufacturing, service, and health-care settings. In many other areas, particularly service areas, written protocols are less common. This is poor and dangerous practice. Protocols should be written and widely circulated with those who must follow them. There are simply too many ways to interpret and/or bypass verbal instructions. The protocol should be carefully maintained. Like many useful documents it will be in constant revision.

Collect Data. When all goes well, data collection involves nothing more than following the measurement protocol. All going well seems to be the exception rather than the rule, however. For this reason, those making measurements should maintain careful logs. Good discipline in maintaining logs is important. Logs should be kept even when calibration and measurement procedures go as planned. It is most important that any exceptions be carefully documented. One topic, data quality, deserves special attention (see also Redman 1996 and Section 34). Unfortunately, measuring devices do not always work as planned. Operators may repeat measurements when, for example, values are out of range. Or data analysts may delete suspect values. Detecting and correcting erred data goes by many names: data scrubbing, data cleanup, data editing, and so forth. It is better to detect and correct readings as they are made, rather than later on. And naturally it is best to control data collection so that errors are prevented in the first place. But wherever errors are caught, changes in data must be carefully logged.

Protocols for tactical and strategic systems often call for literature scans, attendance at professional conferences, discussion with consultants, and so forth. When data are gathered in this manner, it is important that sources be documented. It is best to determine original sources.

Analyze, Synthesize, Formulate Results, and Present Results and Recommendations. Once data are collected, they must be summarized and presented in a form that is understandable to decision makers. This step is often called "data analysis". But that term is a misnomer. "Analysis" is defined as "separating or breaking up of any whole into its parts so as to find out their nature, proportion, function, relationship, etc." Analysis is absolutely essential, but it is only one-fourth of the required activity. The other three-fourths are "synthesis", "formulation of results", and "presentation". Synthesis is "composition; the putting of two or more things together so as to form a whole: opposed to analysis." Alexander's henchmen (and many others) seem not to have heard of synthesis. Next, specific "recommendations" for decision/action are developed. Finally, presentation involves putting the most important results and recommendations into an easily understood format.

That said, we use "analysis" as a shorthand for analysis, synthesis, formulation of results, and presentation. There are four steps:

- Completing planned analysis
- Exploratory data analysis (when appropriate)
- Formulation of results and recommendations
- Presentation of results and recommendations

For the operations example, the planned data analysis and presentation involves nothing more than computing an average and control limits and plotting them and requirements lines on a chart. Such a chart is presented in Figure 9.7. Simple as it is, the control chart is ideal:

1. It prescribes the proper decision for the manager.
2. It is graphical (and most people more readily interpret graphs) and visually appealing.
3. It is easy to create, as it does not require extensive calculation (indeed, much of its utility on the factory floor stems from this point).
4. It empowers those who create or use it.
5. Perhaps most important, the control chart provides a basis for predicting the future, not just explaining the past. And the whole point of decision making is to make a positive impact on the future.

Unfortunately, in tactical and strategic situations, this step is not so simple. We have already noted that many analyses should be planned in advance. Time should also be allotted for data exploration (also called data analysis, exploratory data analysis, data visualization, etc.). There are often "hidden treasures" data, waiting to be discovered. Indeed explosions in database and graphical exploration technologies can increase any organization's ability to explore data. More and more, all data, including details of all customer transactions and operations, are available. The most critical element, though, is not tools, but inquisitive people who enjoy the detective work needed to uncover the treasures.

The output of this step is a "presentation package." It may be nothing more than the control chart. The new tools also make it possible for every organization to present results in a clear,

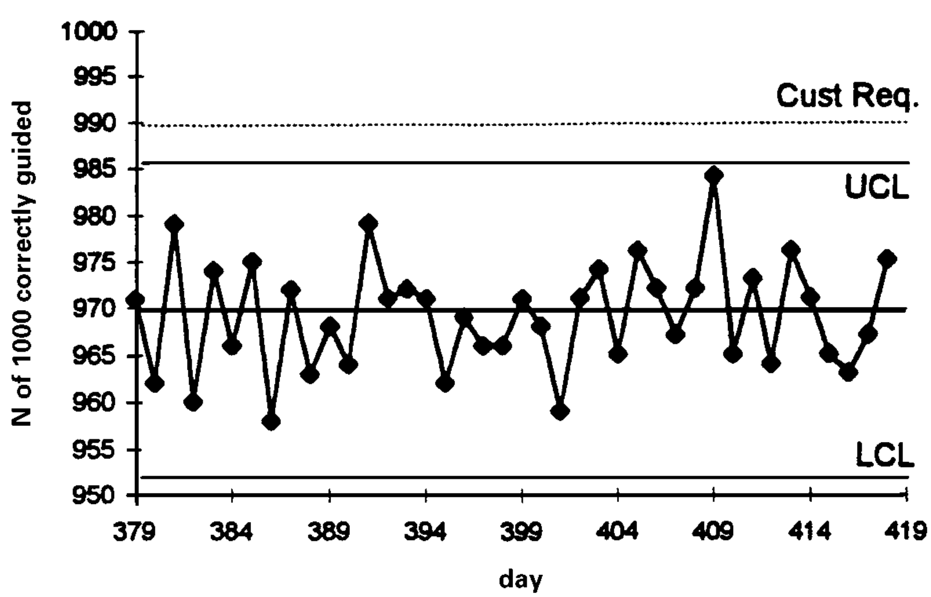

FIGURE 9.7 The control chart, quite possibly the best presentation vehicle in quality management.

understandable, and engaging manner to every organization. Experience suggests that good presentation is

- *Comprehensive:* The presentation covers the points of view of all pertinent stakeholders. It is, in effect, a "balanced scorecard" (Kaplan and Norton 1992; Eccles 1991).
- *Presented in layers:* High-level summaries that cover the landscape are presented in overview and layers of additional detail are available, as needed.
- *Graphical:* Almost everyone prefers well-conceived graphical summaries to other forms of presentation. See Tukey (1976), Tufte (1983), and Chambers et al. (1983) for good examples and practice.
- *Fair and unbiased.*
- *To the point:* Recommendations should be specific and clear.

We conclude with a quotation: "We also find that common data displays, when applied carefully, are often sufficient for even complex analyses…" (Hoaglin and Velleman 1995).

Data Quality and Measurement Assurance. Clearly, decisions are no better than the data on which they are based. And a data quality program can help ensure that data are of the highest possible quality. One component of a data quality program is measurement assurance. The National Institute of Standards and Technology (NIST) defines a measurement assurance program as "a quality assurance program for a measurement process that quantifies the total uncertainty of measurements (both random and systematic components of error) with respect to national or other standards and demonstrates that the total uncertainty is sufficiently small to meet the user's requirements." (Carey 1994, quoting Belanger 1984). Other definitions (Eisenhart 1969; Speitel 1982) expanded, contracted, or refocused this definition slightly. All definitions explicitly recognize that "data collection," as used here, is generally itself a repeatable process. So the full range of quality methods is applicable. Clearly measurement assurance is a component of a good measurement system.

But the data quality program should be extended to the entire system, not just data collection. The measurement system can be corrupted at any point, not just at data collection. Consider how easy it is for a manager to make an inappropriate decision. Figure 9.8 illustrates a simple yet classic situation. Note that the control chart clearly indicates a stable process that is meeting customer needs. However, an inexperienced manager, at the point in time indicated on the chart, notes "deteriorated performance in the previous three periods." The manager may decide that corrective action is needed and take one, even though none is indicated. Such a manager is "tampering." Unless saved by dumb luck, the best he or she can accomplish is to waste time and money. At worst, he or she causes the process to go out of control with deteriorated performance.

In many organizations it is common to "manage the measurements, not the process." Departmental managers urged to reduce their travel costs may be facile at moving such costs to their training budgets, for example. In good measurement systems, the measurement assurance program helps all components function as planned.

Checklist. Figure 9.9 summarizes the elements of a good measurement system for the billing example. The planner, moving from left to right on the figure, first defines the desired decision/action space. Next, the overall context is defined. It consists of three components: the customer's overall requirements and specific requirements on this step, the choice of operator as the decision maker and his/her understanding of control charts, and the budget allotted for quality control on this assembly line. The measurement protocol specifies the data collection plan, and raw data is collected accordingly. The control chart is the presentation vehicle.

To conclude this section, Figure 9.10 presents a measurement system checklist. It may be used to plan, evaluate, or improve a system. Not all items on the list are of equal importance in all systems.

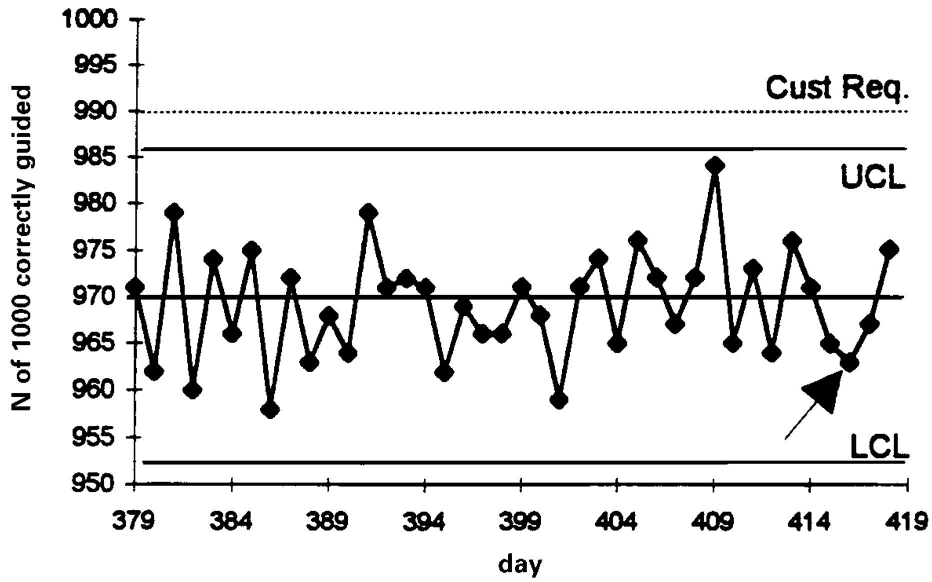

FIGURE 9.8 The control chart misinterpreted. At point 417, the overzealous manager sees evidence of degraded performance.

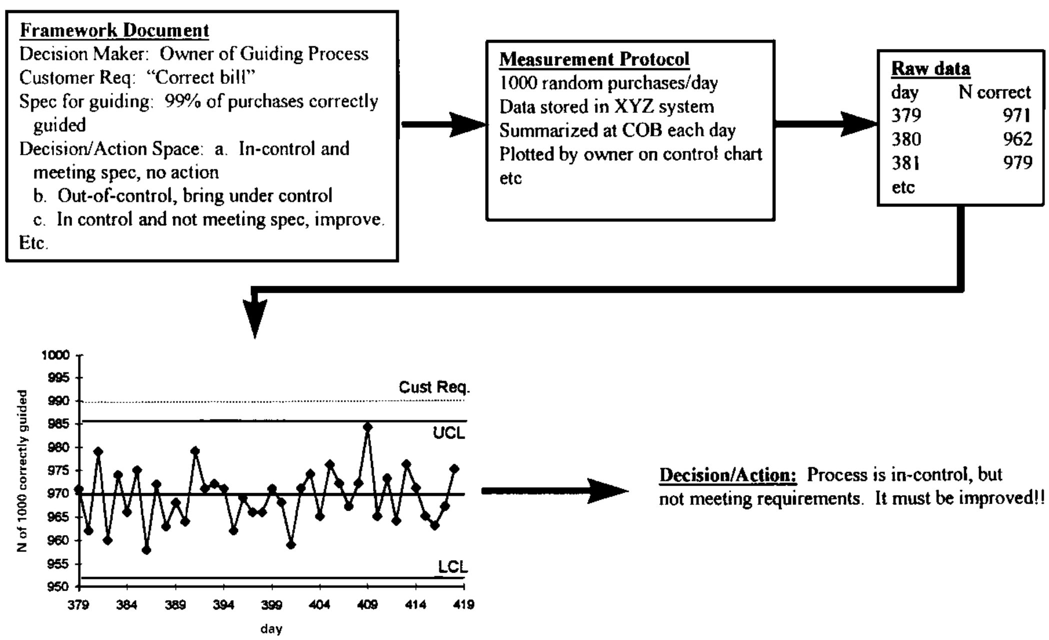

FIGURE 9.9 The major elements of a measurement system for the guiding step are summarized.

HIERARCHIES OF MEASUREMENTS

Objective Measurement versus Subjective Measurement. Texts on science, management, and statistics often extol the virtues of objective measurement, made on a nominal scale, over subjective "opinions," especially those of the "Yes/No" variety. The reasons are simple: Opinions are imprecise and subject to change.

These disadvantages aside, subjective measurements have certain advantages that should not be dismissed. First and foremost, customer opinion is the final arbiter in quality management. Second,

PLANNER'S CHECKLIST

Make decision/take action
- Is the decision/action space specified as clearly as possible?
- Are the planned actions consistent with the decision and the data that lead to them?

Define framework
- Are customer requirements clearly defined?
- Are the requirements of owners clearly defined?
- Are employee requirements clearly defined?
- Are any other major stakeholders identified? Are their requirements clearly defined?
- Are decision makers named?
- Is the framework documented?

Plan measurements
- Are plans for making measurement clearly laid out, including:
    - What is to be measured?
    - When are measurements to be made?
    - Where are measurements made?
    - How are measurements to be made, including calibration routines, data editing, and how a measurement log is to be used?
    - How often are measurements to be made?
    - Who is responsible for measurement, including calibration?
- Are plans for data storage clearly laid out, including:
    - What data are to be stored?
    - When are they to be stored?
    - Where are they to be stored?
    - How is storage to be accomplished?
    - How often are data stored? How often are data backed up?
    - Who is responsible for data storage and data management?
- Are planned analyses and data presentations clearly defined, including:
    - What analyses are planned?
    - When are planned analyses conducted?
    - Where are analyses conducted (i.e., which analytic environment)?
    - How are planned analyses carried out?
    - How often are routine analyses made?
    - Who conducts the planned analyses?
- Is the measurement protocol written?
- Are those who make measurements familiar with the protocol?
- Is the protocol under change management?

Collect and store data
- Is the measurement protocol followed?
- Do data collection plans provide high-quality data?
- Is a measurement log of exceptions maintained?

Analysis, synthesis, present results
- Is the measurement protocol followed?
- Are presentation packages clear and understandable?
- Are results presented in a comprehensive and fair manner?
- Is sufficient time allotted for data exploration?

Data quality program
- Is the data quality program comprehensive? Does it cover all aspects of the measurement system?
- Is the data quality program documented?

FIGURE 9.10 A measurement system designer's checklist.

there are always requirements that customers are not able to state in objective terms. A fairly typical customer requirement is: "I want to trust my suppliers." "Trust" simply does not translate well into objective terms. Of course, the customer may be able to give examples that illustrate how a supplier can gain trust, but these examples do not form a solid basis for a measurement system. Finally, there is a richness of emotion in customer opinion that does not translate well into objective parameters. If the customer discussing trust above adds: "If this critical component fails, our product will fail. We'll lose customers and jobs if that happens," there can be no mistaking this customer's priorities and the sense of urgency associated with such components.

While it will still be necessary to make objective measurements, the designer of the measurement system should also work to ensure that everyone hears the "voice of the customer" (Davis 1987).

Systems of Systems. So far, we have treated our operational, tactical, and strategic examples as if they were independent of one another. Obviously this is not the case. Ideally, measurements made at a lower level can be integrated into higher-level measurements, and higher-level measurements provide context (framework) to help interpret lower-level measurements. We call this property "integrability." The customer requirement for a "correct bill" should lead to overall measures of billing process performance and of the performance of each step. It is possible to achieve a certain amount of integrability. But as a practical matter, integrability is harder than one might expect, even with financial measurements.

Manager's Intuition. Measurement systems can take a manager only so far. Even the best measurement systems cannot eliminate all risk in decision making. And Lloyd Nelson has noted that "the most important figures are unknown and unknowable" (Deming 1986). Corporate traditions are made of the fiercely independent leader who defied the numbers to take the organization into new and successful directions (although I suspect that many organizations are also long gone because of similar decisions). Morita's decision to invest in the Walkman is a famous example of such a tradition. So clearly, there are times when the decision maker's intuition must take over. Managers and organizations must recognize this situation. Certainly decisions supported by data are preferred, but organizations must not require that all decisions be fully supported. The danger that an opportunity will pass or a potential crisis will escalate while diligent managers seek data to support a clear direction is simply too great. Organizations must support individual managers who take prudent risks. And individual managers should train their intuition.

STARTING AND EVOLVING MEASUREMENT SYSTEMS

Just as organizations are adaptive, so too are their systems. Measurement systems must be among the most adaptive. Day-to-day, they are integral to the functioning of the organization at all levels. It is not enough for measurement systems to keep pace with change. They also must signal the needs for more fundamental change. In this section we provide some practical advice for starting and evolving measurement systems.

1. It is usually better to build on the existing system than to try to start from scratch. All existing organizations have embedded measurement systems. Even start-ups have rudimentary financial systems. So one almost never begins with a "clean sheet of paper." Fundamental business changes will require new types of measurements (indeed the quality revolution forced many organizations to expand their focus to include customers) but they will only rarely eliminate all established measurements or measurement practices. In addition, in times of great change, the measurement system is an old friend that can be counted on to provide a certain amount of security.

2. Experiment with new measurements, analyses, and presentations. Learn what others are doing and incorporate the best ideas into your system.

3. Prototype. It is difficult to introduce new measures. Prototyping helps separate good ideas from bad, provides an environment in which technical details can safely be worked out, and gives people needed time to learn how to use them.

4. Actively eliminate measures that are no longer useful. This can be very difficult in some organizations. But we have already noted that good measurement systems are not oppressive. Similarly, we have noted the need to create new measures. So those that have outlived their usefulness must be eliminated.

5. Expect conflicts. We noted in the previous section that it is not usually possible to fully integrate measurements. Conflicts will arise. Properly embraced, they are a source of good ideas for adapting a measurement system.

6. Actively train people about new measures, their meaning, and how to use them.

SUMMARY OF PRINCIPLES

We conclude this section with the Top 10 Measurement System Principles:

1. Manage measurement as an overall system, including its relationships with other systems of the organization.
2. Understand who makes decisions and how they make them.
3. Make decisions and measurements as close to the activities they impact as possible.
4. Select a parsimonious set of measurements and ensure it covers what goes on "between functions."
5. Define plans for data storage and analyses/syntheses/recommendations/presentations in advance.
6. Seek simplicity in measurement, recommendation, and presentation.
7. Define and document the measurement protocol and the data quality program.
8. Continually evolve and improve the measurement system.
9. Help decision makers learn to manage their processes and areas of responsibility instead of the measurement system.
10. Recognize that all measurement systems have limitations.

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