

Using Statistics and Statistical Thinking to Improve Organisational Performance¹

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Summary

A systematic approach to measuring organisational performance is fundamental to the pursuit of business excellence. As such, the area of organisational performance measurement, and its use of data and analysis to inform business decisions, affords statisticians a potentially high value-adding opportunity. To be effective in this area, statisticians need to appreciate the differing requirements for statistical information in various management zones of an enterprise.

This paper describes a strategy that seeks to link measurement to all facets of organisational performance, particularly to desired business outcomes, and also to mesh measurement with process improvement in a natural way. The use of statistics and statistical thinking is then discussed in this context, with particular focus on the opportunity for statisticians to have a key role at the top decision-making level of the organisation. We argue that the role requires skills in both advanced technical statistical modelling and analysis, and in statistical thinking. It also requires a preparedness to form an appreciation of the business and management imperatives faced by the leaders of an enterprise, and a willingness to work from this basis.

Key words: Performance measurement, Quality improvement, Value Added, Success Measures, Comparative Value Analysis, Customer Value Analysis, Key Performance Indicators, Core Business Processes, Value Adding Areas

1 Introduction

The over-riding goal of a business is to stay in business.

For the head of any enterprise, this means:

- increasing the value of the organisation and thereby generating wealth for owners and shareholders (*i.e. establishing business performance credibility*)
- adding value to, and growing, profitable customers (*i.e. creating market potential*)
- achieving the above through the utilisation of the knowledge and creativity of people working within a supportive system. (*i.e. establishing organisational capability*)

Whilst these imperatives apply most readily to organisations operating in a competitive marketplace, they are increasingly applicable for government agencies and other not-for-profit groups that are under growing pressure to justify their existence as part of a competitive national infrastructure. Even though such enterprises may not operate as commercial businesses in terms of seeking to generate profit or growth, they must become more business-like, or performance-oriented, in the way they are managed.

The purpose of this paper is to discuss the need for statistics and statistical thinking in helping managers measure, monitor and improve all aspects of organisational performance.

Traditionally, the efforts of statisticians have been concerned primarily with quality control and improvement of operational processes (although there have been significant movements away from this work, as discussed later in the paper). The success of these efforts is evidenced by the fact that statistical process control, design of experiments, and related techniques are recognised as essential for effective and efficient service provision, manufacturing, production, market surveys, and so on.

However, in our view, there is also a critical need for statistics and statistical thinking at the levels of the Board and of top management, and that such an enhancement of the traditional role of a statistician is a key step in achieving and

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sustaining superior organisational performance. To explore this enhanced role, we need first to establish the environment within which such a role is played out. In a companion report (“Pursuing business excellence: the measurement imperative”, hereafter denoted DFV), we have described a general approach to selecting measures to provide such a context. A significant part of this paper is devoted to discussion of the measurement approach, because we believe it is crucial to effective deployment of Statistics and Statistical Thinking throughout an organisation.

Contemporary management approaches provide the framework for this emerging role. National programs that seek to recognise high performing organisations, such as the Malcolm Baldrige National Quality Awards and the Australian Quality Awards, identify a number of principles critical to achieving excellence. Within such a framework, these principles are put into practice through designated categories relating to *Customers, Leadership, Planning, People, Processes* and the *Use of Data for Information and Analysis*. An analysis of Quality Award evaluations over several years indicates that the last of these categories is an area of consistent weakness in the management system of organisations, undermining their ability to optimise management of performance.

This is hardly surprising, since few statisticians are employed as statisticians in the upper echelons of business: W. Edward’s Deming’s cry from the wilderness that a statistician (a so-called ‘statistical master’) should be seated on the right (or left) hand of a company’s Chief Executive Officer has gone largely unheeded. (There is one area of business that provides an interesting exception to this, namely the insurance industry, where the importance of the work of the Chief Actuary has long been recognised.) Some of the reasons why Deming might have held this view have been explored by Joiner (1985), and are reviewed later in the paper. We hope to cast further light on the subject: indeed, a major objective of the paper is to make explicit some of the high-level enterprise activities for which statistical work, including advanced technical statistical modelling and analysis, is crucial. We believe that these activities provide the means by which statisticians can engage the attention of top management on an ongoing basis, something that they have generally failed to do, to date.

The paper is laid out as follows. In Section 2, we advance some principles for the design of a measurement system and canvass some of the issues that need to be considered in devising an approach to measuring organisational performance; the framework of DFV is then described briefly in Section 3. With this context, the requirement for statistics and statistical thinking is discussed in Section 4. Section 5 considers the implications for statisticians, should they seek to take up the challenge of this enhanced role.

2 Measuring organisational performance: some preliminary issues

The approach to measurement developed in DFV has been motivated by three design principles:

Alignment: The approach supports the organisational mission, vision and goals; for example, by relating appropriately to people's areas of Accountability and Responsibility.

Systems thinking: Measurements should be linked appropriately with system and process monitoring, control and improvement.

Practicability of implementation: At any level (management / sub-system) there is a straightforward procedure for identifying the sorts of measurements which need to be collected (although not necessarily their precise nature).

These principles are linked to a number of key concepts that we explore briefly here and explore in more detail in the referenced source. The concepts are those of Value Adding Areas, Lead and Lag Indicators, Accountability and Responsibility, and Core Processes.

2.1 Value Adding Areas

Measurement of the performance of an organisation relates to the impact of its products and services on the society, or environment, in which it operates. This environment provides the essential inputs that allow the enterprise to function, and absorbs from the enterprise the outputs, both intended and unintended, that provide the reason for its existence. The extent to which the system inputs, transactions and outputs are in harmony with the environment determines the sustainability of the enterprise.

Sarasohn & Protzman (1948) ask the question: "Why does any company exist?" and then postulate the most common response to be: "The purpose of a company is to make a profit". They provide two responses, or rather ripostes, to this, of which the second is of immediate relevance to us:

"There is another fault that I would find in such a statement. It is entirely selfish and one-sided. It ignores entirely the sociologic aspects that should be a part of a company's thinking. The business enterprise must be founded upon a sense of responsibility to the public and to its employees. Service to its customers, the wellbeing of its employees, good citizenship in the communities in which it operates — these are cardinal principles fundamental to any business. They provide the platform upon which a profitable company is built." (Sarasohn & Protzman, *op. cit.*, § I.1)

Richard Normann (1984) suggests that extent of harmony of an enterprise with its environment state can be gauged by high-level enterprise measures relating to *creating* or *adding value* from a broad societal, rather than just business economic, perspective. Thus, Normann postulates that for long-term sustainability, an enterprise needs to achieve three interdependent outcomes simultaneously —

- appreciative and profitable customers and markets
- development of the enterprise's people within a supporting structure
- promotion of its own economic health

— to which we would nowadays add a fourth:

- being a 'good corporate citizen'

A strategic plan for any enterprise could be reasonably expected to recognise these relationships in some way. A 'healthy' enterprise operating in a 'healthy' economy and contributing to a 'healthy' society would seem to be a reasonable starting point for sustainability, and the fundamental strategic issue for enterprises. The environment in which an organisation functions can be represented notionally by four specific constituencies of influential stakeholders, commonly considered to be Owners, Customers, Employees and Communities. (For some enterprises, it may be appropriate to add a fifth, namely Strategic Partners, if long-term relationships with some other enterprises are of strategic importance.) These stakeholder constituencies exert influence because they are significant providers of inputs to, or users of outputs from, the organisation. They are central to the concept of 'value adding' as they are the essential arbiters of quality performance.

2.2 Lead and Lag indicators

In order to devise an approach to measurement that can be used at all levels of management of an enterprise, two different types of measures are needed: those that are indicators of current performance, and those prognostic of future performance. Business value adding, typically measured through a detailed financial analysis, provides a primary *lag* indicator of business success. However, such traditional accounting indicators do not allow a confident prediction of future success.

Typically, measurement information collected to support management decisions has tended to be suitable only for control after the event (trouble-shooting), rather than for prediction (managing improvement). For example, for many Boards of Directors, the main information used to assess how the company is going is a quarterly financial statement, the content of which was determined by decisions made and actions taken months and years before. The compelling analogy is that of endeavouring to steer a car along the road by looking in the rear-view mirror. Effective forecasting of future enterprise viability requires knowledge and understanding of more subtle *lead* indicators. Whilst such indicators have long been extant in economic areas, their use has tended to be only occasional in the other Value Adding Areas; further, attempts to quantify the *uncertainty* associated with predictions have not been common.

Significant lead indicators would relate to industry growth, customer / market strength (*e.g.* brand ownership, customer loyalty), institutional competencies (knowledge, know-how), strategic alliances, status of information technology and process technology, internal efficiencies, innovation and improvement activities, and so on.

It is appropriate to recall one of Deming's pithier aphorisms: "Management is prediction".

2.3 Accountability and Responsibility

A sub-text for our approach to measurement is the dictum: *Measurement drives behaviour*, or as Eliyahu Goldratt observes: "You tell me how you measure me, and I will tell you how I will behave" (Goldratt 1990, page 28). Because of this, appropriate measurement of people's Accountabilities and Responsibilities is crucial to the alignment of their behaviours and activities with the strategic purpose of the organisation.

The importance of the concepts of Accountability and Responsibility was recognised at least 50 years ago (*e.g.* Sarasohn & Protzman, 1948, §II). Yoshikazu Tsuda (personal communication) distinguishes them as follows: *Accountability* relates to being charged with ensuring that certain outcomes are achieved; and *Responsibility* to being charged with carrying out certain tasks. The types of measures that managers need to monitor or report relate directly to their areas of accountability and responsibility.

Top management of an organisation will have wide accountability in relation to performance. They will 'operationalise' their accountability through the designation of specific responsibilities and delegation of appropriate authority. Senior management will retain specific responsibilities that they will personally execute; in large organisations, there are significant differences between their accountabilities and their responsibilities. For people without management responsibilities working within the organisation, accountability and responsibility overlap to the point of being largely indistinguishable.

2.4 Core processes

Historically, organisations have been described by referring to their functional organisation charts that detail positions, incumbents and hierarchical relationships. This approach reflects an internally-focussed 'authority based' approach to power in traditional organisations. 'What are the functions and who works for whom?' are the key issues.

However, in contemporary performance-driven organisations that are responding to their environments rather than their own needs, this paradigm is being replaced by an externally-oriented approach centred on stakeholder needs, particularly those of customers. As a consequence, there is a requirement for management of the broad cross-functional processes that service the stakeholders, rather than of functional processes that support the hierarchy. At an organisational level, this requires the introduction of the concept of core (business) processes that underpin achievement of the organisation's mission, vision and goals.

Core processes represent the business-level activity streams that constitute the means by which products and services are produced and delivered to customers. As such, they tend to cut completely across the vertical management lines of an organisational chart. Thus, they represent the means by which the organisation pursues its mission. Because of their cross-functional nature, core processes are best managed through shared accountability at the level of the senior

executive group in an organisation. (See Kearns & Nadler (1992, page 206) for comment on the key role of the concept of core processes in the current context.)

We give examples of sets of core processes for two very different organisations, to emphasize the general applicability of the approach.

Example 1: EnergyAustralia

CP1: Securing the customer. This process involves many groups such as marketing, legal, communication, installation, and so on, who have to work together to provide the most efficient means of locating potential customers and securing their business.

CP2: Supplying the customer with power. This process involves groups such as the installation team, accounts department (to invoice the customer) and again communications.

CP3: Supplying the customer with other services. This process involves several of the groups from CP1 and CP2, as well as groups related to the other services.

CP4: Support services. This involves many key processes (finance, human resource management, asset management *etc.*) as well as some other processes concerned with development of the organisation (as distinct from mere maintenance).

Example 2: Royal Melbourne Institute of Technology

CP1: Teaching and Learning. This would include pre- and post-university activities such as attracting prospective students and subsequent association with alumni.

CP2: Research and Development. This is a core process of a world class university but the nature of the R&D undertaken (*e.g.* pure or applied, consulting, contract *etc.*) should reflect the mission of the university and will include the research work of postgraduate students. At the very least this concept includes the advancement of knowledge, and its application in the mission of the university.

CP3: Contributions to Society. This is based on a view that a world class university is a major contributor to the well-being of society, both locally and globally, through contributions to debate, acting as a custodian of intellectual outputs, provision of community services and building relationships with industry, government, schools and the wider community.

CP4: Support services. (see previous example)

As the elaboration indicates, a core process will be composed of several key processes, each of which is itself a combination of sub-processes. Since quality improvement is achieved by process improvement, the measurement system used to monitor, control and improve organisational performance will be inextricably bound up with the description of the processes comprising the overall system. (In this paper, the term ‘improvement’ will be taken to include both small-step and large-step, or *incremental* and *breakthrough*, improvements.)

3 A general approach to measurement for prediction and improvement

3.1 Introduction

This section provides a brief description of the approach to measuring organisational performance described by DFV, to which paper the reader is referred for fuller discussion and examples of its application. At the end of the section, comparisons are made with some other approaches to measurement.

The Strategic, Tactical and Operational ‘Zones of Measurement’ described below correspond to a simplified version of Sarasohn and Protzman’s ‘Zones of Management’ (Sarasohn & Protzman, §II). (Our ‘Strategic’ zone corresponds to the Sarasohn–Protzman ‘Trusteeship’ Zone, our ‘Tactical’ zone to their ‘Departmental Administration’ zone, and our ‘Operational’ zone to their ‘Lower, or Supervisory Management’ zone). See also Snee (1986, 1990) and Hare *et al.* (1995). In essence, the strategic zone corresponds to the Board or Governing Council of an enterprise; the tactical zone to the top level of executive management; and the operational zone to the level of management relating to real work processes (*i.e.* to the actual mission of the enterprise).

3.2 Strategic, tactical and operational measures

From the outset, we draw what we regard as a fundamental distinction, between the *external* and *internal* views of the enterprise: see Figure 1. The importance with this dichotomy relates to the fact that the starting point for developing a measurement system is with the external view of the enterprise.

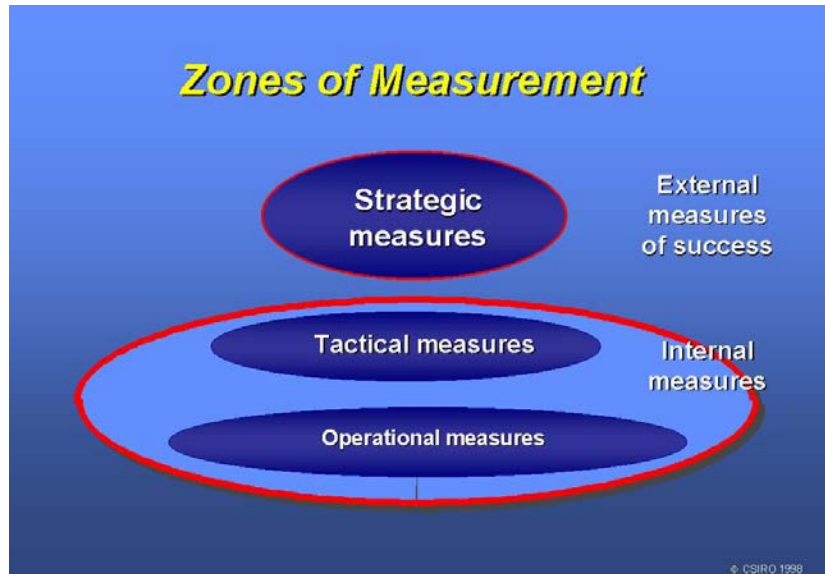


Figure 1. The dichotomy between external and internal measures associated with an enterprise.

Strategic measures.

According to the approach described in DFV, the outside world will judge the success of an enterprise by how well it performs in the four or five Value Adding Areas described in Section 2.1. Accordingly, we seek to attach to each of these areas some *Measures of Success* that are chosen to capture *an external view of good long-term performance*, that is, of desirable *outcomes* for the various stakeholder groups. Schematically, we can depict this as in Figure 2.

A crucial characteristic of Success Measures is that they are, for the most part, *measures relative to an alternative 'investment'*. (Sarason & Protzman, 1948, § I.3(c)) note, in the context of collection and summarisation of data relating to products, that:

“The emphasis here is on making market and sales studies not only of your own company’s products but also of your competitors’ products, analysing such things as customer preference, sales reaction, etc.

In DFV, it is argued that whereas companies were able to survive during the 1980s through a combination of sound financial management and meeting customers’ needs, in the late 1990’s this is no longer sufficient: in each of the Value Adding Areas, organisational performance can only be judged *relative to the competition*. Viewed in this context, we can interpret these measures informally, as follows:

For Owners: measures of the comparative status of the organisation as a desirable place to invest. For a profit-making enterprise, several measures are available. One such measure which originated in banking in the 1950’s as ‘residual capital growth’ and is now known as EVA (for ‘Economic value added’), can be defined as

$$EVA = net\ profit - (equity \times \% \text{ cost of equity})$$

For Customers: measures of the ‘preferred supplier’ status of the organisation. Measures of CVA (Customer Value Added) have been used for several years. They derive from Customer Value Analysis (which also employs the CVA acronym) which is based on surveys of both one’s own customers and also those of one’s competitors and the methodology, and which provides, in addition to long-term success measures, a powerful tool for prioritising improvement efforts. Further discussion of such measures will be given in §4.

For Employees: measures of the comparative status of the organisation as a preferred place to work. Measures of Value Added for People working for the organisation can be developed along the lines of CVA.

For the Community: measures of public support for the continued presence of the organisation in a particular locality, or peer support for the continued membership in a professional community. Again, these measures can be devised using analogous methodology to CVA.

Success Measures will typically be reported quarterly, biannually or annually, with (say) 5-year target values appearing in the Strategic Plan.

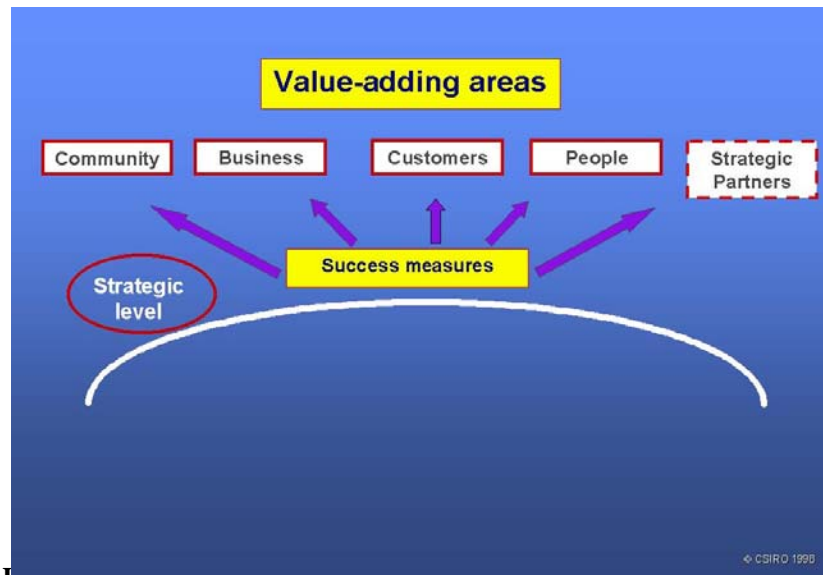


Figure 2. How the outside world judges the enterprise. External to the organisation's system, and associated with each Value Adding Area, are Measures of Success. Some measures are currently extant in some form (Economic Value Added, or *EVA*; and Customer Value Added, or *CVA*), and others need to be developed (People Value Added, or *PVA*; Community Value Added or *ComVA*).

While each of the Success Measures will be a lag indicator in its own right, a strength of this approach is that it provides for the existence of lead-lag relationships between the measures from different Value Adding Areas. From a business perspective, the Value Adding Areas incorporating customers/markets, people/systems and communities, represent *strategic lead indicators* of future economic success. However, most of the useful lead indicators will be found inside the enterprise, in the *Tactical* zone which we now discuss.

Tactical measures

In this context, 'tactical' relates to how the strategic direction and goals of the organisation are to be implemented. Tactical management is essentially enacted through the management system of the enterprise. What leadership characteristics do we need? What long- and short-term plans are to be resourced and implemented? How are the outcomes of these plans going to contribute towards the broad strategic goals? Are these tactical plans consistent with the explicit policies of the organisation? What should we be measuring to assess our performance? How should we control our products and services? Have we got the right people? Are our people competent?

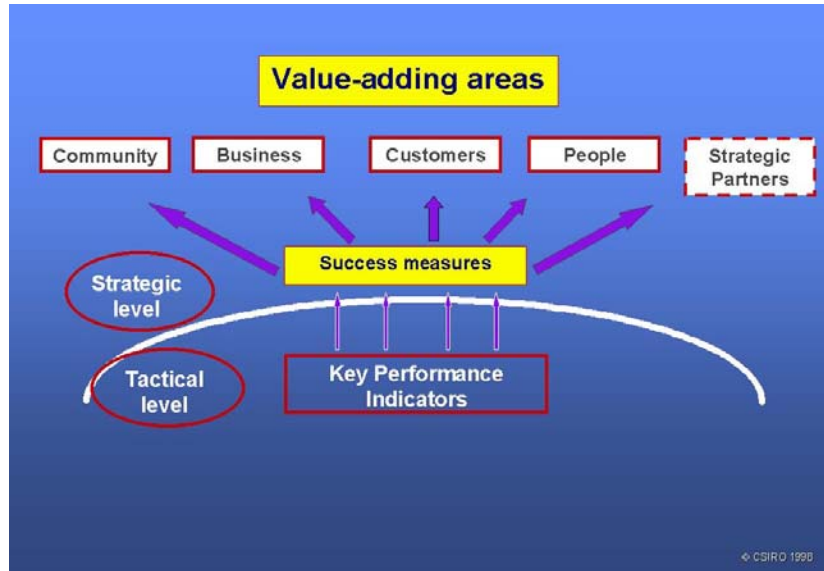
'Tactical' managers have two types of accountability —

- accountability to develop and implement an efficient management system for operating the enterprise. That is, that 'tactical' managers ensure that the management system promotes integration of the strategic intents with the products, services and processes of the enterprise.
- accountability for the performance of aggregated operational measures relating to their areas of authority and responsibility.

— implying two classes of tactical measures:

- measures of status of the management system
- aggregated measures of operational performance

The aim in this zone is to determine a minimal set of Key Performance Indicators (KPIs), or *explanatory variables*, that collectively predict the subsequent performance of the strategic Success Measures, constituting a *multivariate response*. These KPIs can be considered to represent the full scope of accountability of the General Manager of the enterprise (and also of the executive, in the case of core processes). See Figure 3.



Some of the KPIs can be determined by careful consideration of so-called Critical Success Factors, that is, the organisational performance factors likely to have significant influence on Success Measures; others will derive from efficiency, waste and productivity considerations for the core business processes. These measures, whether aggregated or related to organisational efficiency (Porter 1996), are the ones that General Managers should have in their monthly reports in formats appropriate to their requirements for making decisions. Examples of KPIs include:

Owner-related: profitability, revenue, costs, market share, efficiency measures such as cycle time

Customer-related: On time delivery, complaints, response times

Employee-related: absenteeism, safety, labour turnover, competencies

Community-related : safety, public relations, publicity, promotions, overall outcome of an environmental audit.

Other forms of organisational measures may be available on a less frequent basis; for example, those derived from assessments against Quality award criteria or from audits against management system standards. They still have an important role to play in planning and in prioritisation of improvement efforts, if not in prediction.

Whilst there is no direct emphasis on Key Performance Indicators being comparative in nature (whereas this is an important characteristic for Measures of Success), it is common practice for high-performing enterprises to use so-called 'benchmarking' against industry standards to calibrate their KPIs. Appropriate benchmarking may generate reasonable tactical measures that can, to a significant degree, act as surrogates for Success Measures.

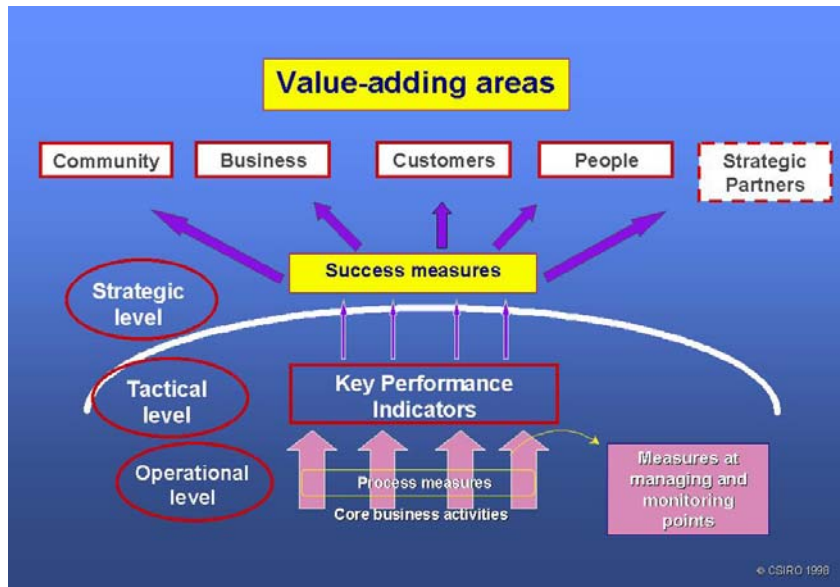
Operational measures

In this context, 'Operational' relates to the processes in which the people of the organisation interact to create its value-added products and services. Therefore, operational measures relate to process, product and service performance, and form the basis for quality improvement. Operational measures have time frames from instantaneous to short term aggregations, typically covering the period of a working shift or a day, exceptionally up to a month. Real-time process control is included in this group.

Operational measures are determined from the specific characteristics of the products and services, typically through specifications, and from process procedures and standards. Hence, these measures relate to direct control and are specific to the product or service process. Measures in this zone provide a basis for assessing stability and capability. See Figure 4.

In aggregated formats, these measures provide the basis for tactical KPIs. In manufacturing environments, typical aggregated measures will relate to product waste and yield, cycle times, product characteristics *etc.* In service environments, typical aggregated measures will relate to complaints, responses to enquiries, cycle times, error rates *etc.*

Snee (1986, 1990) has discussed the role of statistical thinking in the context of three ‘levels of activity’ in an organisation, that he labels ‘Strategic’, ‘Managerial’ and ‘Operational’; the first two of these correspond to the Tactical and Operational levels of management, in the language of this paper, with Snee’s Operational level being, in effect,



people without management responsibilities.

Figure 4. Operational measures are the basis for process control, monitoring and improvement, and the basis for improving tactical measures.

3.2 Comparison with Balanced Scorecard and Six Sigma

The Balanced Scorecard and Six Sigma, are two important approaches to measurement in current use.

The Six Sigma approach

The term ‘Six Sigma’ refers to a methodology developed initially by Motorola. It is based on the more general approach of identifying one or two vital quantities and using measures based on these to drive improvements at all levels of the enterprise. The vital quantities identified were the *cycle time* and *capability* of each process. Cycle time was to be reduced as much as possible. Process capability was to be improved to the point where the chance of the process outputs failing to meet specification was less than the probability that a Gaussian variate lies more than six standard deviations (*‘six sigma’*) from its mean value. A great strength of the approach is that it is simple to communicate the key drivers to all levels of the enterprise.

In our context, this would imply, in the Tactical zone, that the most important Key Performance Indicators would be the cycle time and capability of each of the core processes; and similarly in the Operational zone. Thus a Six Sigma approach might provide some guidance in selecting measures in various zones, and as such, fits into our framework. However, there is no explicit recognition of the need to simultaneously add value for several stakeholder groups, nor to quantify what this might mean (in the form of measures of success).

More recent Six Sigma-based methodologies for improvement, for example the Six Sigma quality program used at General Electric Company, are similar in many ways to the approach to adopting Quality advocated by Conway (1992). Conway's driver is 'waste', which he interprets very generally: 'waste' is

"... the difference between the way things are now and the way they would be if everything were perfect. ... When we speak of WASTE, we do not mean just scrap and rework in a plant. We mean scrap in every form: wasted material, wasted capital, wasted opportunities, wasted time and talent. ... Organisations waste human talent when they do not use the brains, time and energy of all the people involved in a process."

It is beyond the scope of this article to explain either the Conway or the Six Sigma approach to Quality. Detailed information about Six Sigma and pointers to the literature can be found in Hoerl (1998). However, we note here that key element in the GE Six Sigma approach to selecting improvement projects is financial. Hoerl (*op. cit.*, page 36) notes:

"Performance metrics are established that directly measure the improvement in cost, quality, yield, and capacity. Contrary to some TQM initiatives, financial figures are required both to select projects and evaluate success, and performance metrics are tracked rigorously."

This fiscally-driven approach would appear to have some important ramifications, not necessarily all beneficial. It is not clear that all processes are directly susceptible to such drivers, particularly human resources processes. Also, there is no guarantee that all KPIs vital to prediction of success in the Value Adding Areas relating to People and Communities will be identified.

The Balanced Scorecard approach

The Balanced Scorecard (*e.g.* Kaplan & Norton 1992, 1996) approach uses a specific set of measures to provide a picture of organisational performance. The measures employed incorporate financial, customer, internal business processes and learning and growth. It is a matter of conjecture as to whether these are sufficient to provide a comprehensive picture of organisational performance. A recent paper by Heredia (1998) that compared Balanced Scorecard approaches against a national Quality Awards framework concluded that there might be some significant gaps.

The Balanced Scorecard approach seeks to provide a balanced picture of current operating performance and drivers of future performance by focussing measurement in four general areas: financial, customer, internal business processes, and learning and growth. A detailed discussion of the relationship of Balanced Scorecard to our approach is given in DFV. In the context of the present paper, the important point to make is that our approach to measurement can add significant value to an implementation of the Balanced Scorecard in a number of ways, including

- the clear identification of the four or five Value Adding Areas in which the enterprise has to be simultaneously successful;
- how success is to be measured; and
- the stratification of measures into Strategic, Tactical and Operational zones, with their lead or lag indicator interpretation and their links to people's jobs through accountabilities and responsibilities.

4 The role of statistics and statistical thinking in improving organisational performance

4.1 Statistical thinking and related issues

Generally, the need for, and opportunities for, statisticians arise at all levels in the organisation. In practice, the only information available to us about the strategic, tactical and operational measures we define is uncertain, as it has to be based on collection, modelling and analysis of data. This brings us into the realm of understanding and managing uncertainty. Statistics is the science for doing this.

Mallows (1998) reviewed a number of definitions of ‘statistical thinking’, such as that used by the American Society for Quality (ASQ (1996) — Statistical Thinking as a philosophy of learning and action based on three fundamental principles:

- All work occurs in a system of interconnected processes
- Variation exists in all processes
- Understanding and reducing variation are keys to success

and found most of them inadequate, because

“... they do not emphasize the need for thinking about what data might be relevant, and they do not admit that such thinking is necessary even when variability is so small (or data are so abundant) that variability is not the central issue” (*op. cit.*, page 3).

Mallows’ proposed definition is:

“Statistical thinking concerns the relation of quantitative data to a real-world problem, often in the presence of variability and uncertainty. It attempts to make precise and explicit what the data has to say about the problem of interest.”

It might be argued by proponents of other definitions that this proposal is itself deficient in not explicitly identifying process and system thinking as intrinsic to the means by which “precise and explicit” information is extracted from data. For the purposes of the present discussion, we shall take ‘statistical thinking’ to include both the ASQ and Mallows’ definitions, rather than advancing yet another attempt at specification.

Snee (1990) identified the three points of the ASQ definition as key concepts to be understood by top management.

Through their specialist knowledge, statisticians can make recommendations about

- how (including when and where) to measure
- what to measure
- how to report the results of measurement
- how to react to the reports
- how to interpret statistical information in business terms

at all levels in the organisation. Joiner (1985), in responding to a comment made to him by W. Edwards Deming that

“... Nothing less is required than the transformation of the American style of management — and you [statisticians] must show management how to create that climate ...”

canvassed a number of general areas in which statisticians have particular expertise, including

- teaching managers to focus on process rather than on blaming individuals
- demonstrating, using data, that the great majority of problems (“85%”) are due to the system in which people are working, rather than to the people themselves, so that managers will start to seek solutions to problems through process understanding and improvement (leading to greater trust of management). (In

this context, Snee (1990) specifically emphasizes the need for management to understand the crucial distinction between common and special causes of variation.)

- quantifying current process capability, as a means of improving communication of expectations between departments; and, more generally, basing decisions on facts and data
- coaching others in the use of good scientific method

Hare *et al.* (1995) and Britz *et al.* (1997) have discussed these and related issues; in particular, Hare *et al.* explore the practical matters of helping managers to develop appropriate skills in application of statistical methods and in statistical thinking, and seeking to ensure that these skills are used.

In the context of the present paper, a lot of statistical work *has* been done on processes at the Operational level, using design of experiments to support industrial experimentation, capability studies and various forms of process control to monitor, control and improve processes. The real gaps appear at the Tactical and Strategic levels, a point stressed by Snee (1990).

4.2 Statistics and statistical thinking: Strategic zone

The role of statisticians

At the Strategic level, statisticians have an important role to play in

- (i) devising Measures of Success in Value Adding Areas
- (ii) advising on feasible target values
- (iii) survey design, data collection, modelling and analysis
- (iv) developing appropriate formats for presenting reports on Key Performance Indicators to the Board

So, given a way of measuring ‘*Value Added for the Owner / Customer / People / Community*’, many issues arise in connection with (i)–(iii) What are realistic strategic target values? What data are needed to forecast them? What degree of precision is possible in the forecasts? What relationships might exist between the Success Measures, what are their key internal predictor variables and can all this be modelled for effective prediction?

Item (iv) means that information is to be provided in a way that makes explicit any significant pattern (such as a real trend), *or lack of pattern*, and conveys the information in language accessible to the Board, thus providing the basis for appropriate action, *or for no action*. An obvious example of an opportunity for improvement in this respect relates to the widespread practice of simply reporting monthly financial indicators in comparison with the previous month, or with the corresponding figure 12 months before. There appears to be no obstacle (apart from limitations of some databases) to providing the information in the form of time series extending back as far as is historically sensible, and so providing an appropriate backdrop of variability for the current set of indicators.

Skills required by management

To be able to cope with these issues, Board members need an appropriate level of understanding of statistical concepts including, at a minimum, an understanding of variability sufficient to interpret control charts, dot plots and scatterplots, familiarity with Pareto diagrams and the concepts of lead and lag indicators, and a general appreciation of process and system thinking and its role in improvement. In larger enterprises, where more complex surveys are carried out to determine stakeholder perceptions, rather more sophistication may be called for, such as the ability to understand simple trellis display; see the article by Clark *et al.* cited in the discussion of CVA below. A good starting point for helping the Board to develop these skills would be to present them with a monthly report revised so that it contains, at least as an Executive Summary, each Key Performance Indicator in an appropriate format (a trend chart, a dot chart, or maybe simply an exception report).

Such heightened understanding can then lead to a new level of skill: that of asking the right sorts of questions. For example, a CEO might be asked “What are you monitoring that makes you confident of hitting a target capability for a delivery process?”, or “What are your two highest priorities for improvement, and on what basis did you select them?”

Applications of statistical methods for control and improvement

In §3.1, the concepts of Economic Value Added (EVA) and Customer Value Added (CVA) were introduced. Here, we elaborate briefly on EVA, and in more detail on CVA, which has been rather more extensively developed in statistical terms.

As noted earlier, there are a number of measures of comparative business success like *EVA* in use by the business community. The article “A star to sail by?” in *The Economist* (August 2nd, 1997, pp. 57-59) provides an assessment of EVA and other possible measures of business performance. However, such measures are typically derived from deterministic accountancy models and reported as a single numbers, with no accompanying statement as to their precision. *EVA* would certainly appear to be susceptible to statistical modelling, as a function of estimates of value from the other Value Adding Areas and of appropriate tactical measures.

There has been rather more statistical progress in the area of adding value for Customers. An excellent example of a powerful approach to developing a wide class of Success Measures, and of the concomitant need for expert statisticians, is provided by the methodology of Customer Value Analysis. An introductory account of this subject is given by Gale (1994), and Clark *et al.* (1997) report on a major statistical study of data arising from an analysis of customer value data for Lucent Technologies.

Customer Value Analysis is an approach to measuring the effectiveness of an enterprise in meeting its customers’ needs, compared with the effectiveness of its competitors. It is based on estimating the market’s perception of the *relative value* (in terms of product or service quality, features, pricing *etc.*). In its simplest version, there are a few basic steps:

- Step 1. Ascertain the most important attributes of the products or services, from the perspective of the market for such products or services. (This may well include careful segmentation of the market into subgroups with quite different requirements.)
- Step 2. Determine the market’s priorities on these attributes.
- Step 3. Survey one’s own customers and those of one’s competitors, to determine the relative performance of the enterprise, in other words, the relative *Value Added for Customers of the enterprise*.
- Step 4. Present the results appropriately (*e.g.* graphical form).

(The idea of surveying not only one’s own customers but also those of one’s competitors goes back many more years, *e.g.* Sarasohn & Protzman (1948).)

The contention is that market share is linked to customers’ perceptions of the company’s performance. Ray Kordupleski, who led the introduction and exploitation of Customer Value Analysis in AT&T some years ago (see *e.g.* Gale, *op. cit.*) has shown how statistical modelling of a measure of *Customer Value Added (CVA)* in terms of appropriate tactical quantities can both identify and drive improvement of crucial lead indicators, and also act as a lead indicator for improved business performance.

Kordupleski defines *CVA* as the ratio of *Perceived worth of your offer* to *Perceived worth of competitor offers*. A simple illustration of his statistical approach (as presented in courses by his company, Customer Value Management™ Inc.) is provided in Figure 5. Survey data, comprising importance weightings of the factors, and ratings of company performance, are available for each box in the tree, for one’s own enterprise and for the chosen competitors; a tree diagram can then be constructed for the ratios of any competitor’s ratings to one’s own. Then a series of hierarchical models can be constructed, starting with the left-most box (*CVA*) and modelling each box value in terms of the set of immediate inputs to it. Kordupleski uses linear models at each step. The weightings and the regression coefficients provide guidance about which factors to improve, in order to obtain the greatest leverage on *CVA*.

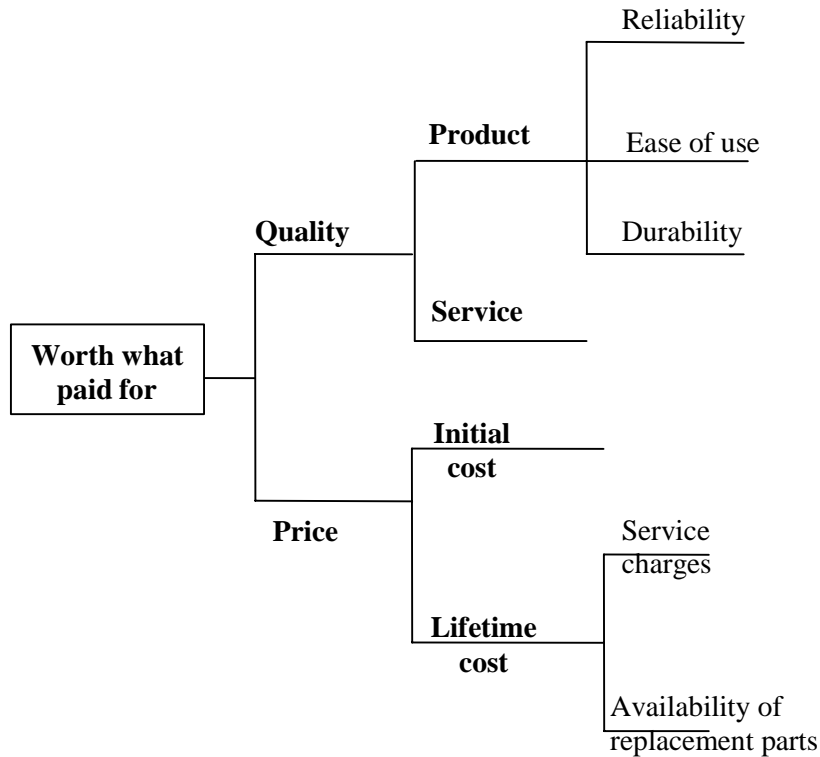


Figure 5. Prototypical representation of the type of survey data used as input to a Customer Value Analysis. Each label represents a question asked of an interviewee about their rating of the organisation, usually on a 10-point scale. Similar data are collected about the market’s perceptions of the competition.

As is not uncommon, even this a “first order” approach to statistical modelling can produce significant gains. However, the study by Clark *et al.* shows what can really be achieved when the full panoply of modern statistical display, modelling and analysis techniques is brought to bear on data of this type. The (ongoing) study involves a quarterly sample survey, polling about 800 customers on 47 attributes. Each respondent rates either one or two companies on most of the attributes, using a scale of 1 to 10. When a respondent rates two companies, one is always Lucent. Some respondents appear in the survey in different quarters. The analysis calls for development of a Bayesian model (of the ratings themselves, rather than the ratios) to account for complex sources of variation, and a range of modelling elements:

- partly hierarchical, with a time series component
- random location effects of respondents modelled as t-distributions
- random scale effects of respondents
- company-attribute quarterly effects modelled as first order autoregressive time series
- repeated measures
- effects due to respondent job classification, geography (Europe and North America), business unit effects
- error terms modelled as multivariate t-distributions

In principle, the approach to Customer Value Analysis is directly applicable to the other Value Adding Areas, thereby providing both a comprehensive suite of Success Measures and an important tool to identify and prioritise improvement activities. We shall use the term *Comparative Value Analysis*²(CoVA™): to refer to the general application of the Customer Value Analysis approach to any of the Value Adding Areas.

4.3 Statistics and statistical thinking: Tactical zone.

The role of statisticians

Here, statisticians have a key role to play in

- devising Key Performance Indicators that will act as predictors of the Success Measures, without having deleterious effects in terms of the behaviours they induce in people. An example of how a measure could force undesirable behaviour would be the use of cycle time reduction as a KPI, without any countervailing force, such as a six-sigma KPI, to control process variability. The problem of devising Key Performance Indicators for the research *outputs* of a research organisation or group has proved a long-standing challenge to managers and researchers alike.
- developing good predictive models for the Success Measures (responses) based on the KPIs. The set of Success Measures constitutes a multivariate response, which is to be predicted from the set of KPIs. Complicating factors include time series dependencies of the KPI data, and also the fact that some Success Measures (*e.g.* in the *Customer* and *People* areas) are themselves lead indicators for those in the *Owner* area, and conversely.
- Ensuring effective presentation of management information to senior managers and the Board, and educating Board and top management about *what* information they should receive, *how* it should be interpreted, *when* to act, and (on occasion) *what action* to take.

Skills required by management

The senior management themselves might be expected to have broader understanding of matters statistical than do Board members. In particular, they need a good understanding of the use of Comparative Value Analyses to drive improvements. Additional requirements would include familiarity with display of distributions (histograms and boxplots), the ability to interpret more complex graphical displays (*e.g.* trellis), more complex time series displays (run charts, times series of boxplots), process flowcharting, and a general appreciation of the role of designed experiments in process improvement. Britz *et al.* (1997) note that "... strategic statistical thinking can motivate executives to

- Flowchart the overall system and its core processes [*see below*]
- Create a strategy and communicate it throughout the organization
- Use data from various sources to assess the organization
- Develop and implement measurement systems to assess progress
- Encourage employees to experiment to find better ways to do their work"

Identifying *what* should be measured, and the concomitant statistical issues, lie at the heart of much of this.

Returning to the first of these points, a powerful aid to developing measures is available for use at both Tactical and Operational levels: the Deployment Flowchart. A standard flowchart shows the sequence or sequences of activities relating to a process, and is used to understand workflows, highlight areas of waste and complexity (*e.g.* loops in the process), and to identify opportunities for measurement. A *deployment* flowchart adds an extra dimension – the people/department axis – that allows the interaction between people and process to be displayed explicitly, and provides greatly enhanced opportunity to focus on measurement. Deployment flowcharts have been around for a number of years (*e.g.* Scholtes 1988 and Tribus 1992) but it is only recently that their real power over more traditional flowcharts has begun to be recognised. Figure 6 shows a Deployment Flowchart for an important process for a health care provider. As part of their *Treating the Patient* core process, one key process relates to evaluation of the overall service. The flowchart in Figure 6 shows how the data relating to day-care patients are captured by the Research Unit, in order to evaluate and improve their services.

²™ application pending

Each action (meeting, decision, production of report, ...) is exhibited under the person or group involved in it. Each horizontal line in the chart represents a Customer–Supplier relationship, and hence the opportunity to measure whether customer requirements are being met at each stage in the process. Measures can be noted in a column at the right of the chart. The drop-shadow on the task to *Provide clinical service* indicates that this is actually a whole sub-process charted elsewhere. Quite apart from its power as a method for revealing explicitly the interactions between people and process, it provides a systematic way of developing appropriate in-process measures.

Last, but not least, senior managers need the ability to be able to communicate quantitative information to the Board in an understandable fashion and, as with Board members, the ability to ask process- and improvement-oriented questions of their direct reports.

Applications of statistical methods for control and improvement

A significant amount of the statistical work required to carry out Comparative Value Analyses (*e.g.* to display, model, analyse and interpret EVA and CVA) takes place at the Tactical level, particularly with a view to identifying major improvement activities. Also at this level, the Shewhart–Deming *Plan–Do–Study–Act* (PDSA) improvement cycle leads directly to the methodology of experimental design, at least in its simpler versions, in order to improve values of Key Performance Indicators.

With more and more enterprises capturing and storing massive volumes of data in electronic form, we can expect to see opportunistic action on the part of senior management seeking to identify major improvements or new business initiatives by studying these archives. This will require the emerging methodologies of ‘data mining’ combined, as always, with effective graphical presentation of the results.

4.4 Statistics and statistical thinking: Operational zone.

The role of statisticians

As noted in the Introduction, this is traditionally where statisticians have contributed most, and with commensurate success. If Mathematics is the language of Science, Statistics is the language of Scientific Method: the quantification of uncertainty, the disciplined and efficient pursuit of process control and improvement, and the timely and effective communication of information are areas in which statisticians should play a vital, even essential, role. However, past success should not cloud the view of what still needs to be done. Instilling, indeed institutionalising, the practice of statistical thinking in managers and the general workforce is a never-ending task. Also, there is the (usually) unstated requirement to stay abreast of current best statistical practice, particularly in effective presentation of information in working with complex processes.

Skills required by management

Accompanying the more technical role of a statistician at this level is an increase in the requirement for technical understanding by operational management: for example, managers would be expected to have a deeper appreciation of the role of experimental design in process improvement, a broad understanding of both statistical and engineering process control. They would be actively deploying the PDSA cycle to obtain improvements. And, as was the case with senior management, there is a crucial need to be able to report quantitative information in an understandable fashion.

Applications of statistical methods for control and improvement

Examples of application of statistics and statistical thinking include all facets of process monitoring, control and improvement, particularly design and analysis of experiments, process control (statistical and engineering), process and systems thinking; regression and correlation, all the usual display and measurement issues; and teaching people to carry out experiments, to think in terms of processes and systems, and to focus improvement efforts upstream of major value-adding process steps. See Britz *et al.* (1997) for further comment.

4.5 General comments

In *all* zones of measurement, a host of statistical issues arise:

- gathering data only if they are both *necessary* and *sufficient* to support sound decisions. Related issues to do with with collection, recording and use of data are captured nicely by Price's Three Rules of Quality Control, now known as Price's Dictum:
No inspection or measurement without proper recording.
No recording without analysis.
No analysis without action.
(Price 1984).
- providing information in a timely and appropriate form (where "appropriate" might include graphical, image and tabular methods; and in 'hard copy' or using some form of electronic medium) to support management activities.
- for any system used for capturing data and disseminating management information, emphasis on 'simplicity' (in terms of the system's ease of implementation at any level of an organisation).
- an appreciation of 'levels of measurement' — nominal, ordinal, interval, ratio — and the limitations of each.

5 Discussion

Statistics and statistical thinking are key factors in seeking to ensure long-term prosperity of an enterprise. The problems arising in measuring, monitoring and improving organisational performance offer the opportunity to do interesting and challenging work in many areas of Statistics, including measurement, sampling, statistical graphics, modelling, analysis and teaching. And no-one else has the requisite quantitative skills and knowledge to help organisations improve in this area.

Blanton Godfrey, in discussing the paper by Joiner (1985), noted that

“It is a mistake to think that the language of managers is just money. The good managers today speak many languages: engineering, economics, computer science, physics, even statistics. We do, however, need to know how to get their attention better.” (Godfrey 1995)

We suggest that a measurement-based approach to improving organisational performance along the lines outlined in this paper offers a potentially fruitful way of addressing the issue raised in Godfrey’s last sentence.

Gunter, in offering “an unvarnished opinion on the state of the quality profession” in his final regular feature **Statistics Corner** in *Quality Progress*, lamented that

“... ISO-mania is symptomatic of an even more pervasive decline in the quality profession, I believe: the retreat from quantitative methodology to soft quality. By soft quality, I mean that aspect of quality management that emphasizes human relations, personnel organization, communications procedures, meeting conduct, and the like. I do not wish to dismiss this stuff as useless; some is both necessary and important. However, without the core quantitative disciplines that actually measure and effect real improvement, it ends up being mere fluff and distraction — all form and no substance.

I know that many of you are nodding your heads in bemusement saying that this sort of blather is exactly what one would expect of a nerdy statistician. But I would like to remind you all that ASQ's roots are in the work of George Edwards, Walter Shewhart, Eugene Grant, W. Edwards Deming, Ellis Ott, Harold Dodge, and the other founding giants of both the Society and the profession. While these folks were certainly concerned with quality management, they primarily emphasized — and indeed, invented — the quantitative statistical methodology needed to get better products and services out the door.

...

I believe that the flight from quantitative methodology in general — and statistical methodology in particular — is basically a capitulation. This stuff is hard. It is hard to learn, hard to implement, hard to teach others. It's a lot easier to send everyone through a class on how to hold better meetings or improve interdepartment communication than it is to learn SPC or experimental design. So by dismissing quantitative methods as inadequate and ineffective, one avoids having to expend that effort. This represents, I am sorry to say, a dilution of the skills of the quality professional.” (Gunter 1998)

Why, in particular, haven't statisticians had significant involvement at the top level of management in the past. Three answers suggest themselves immediately.

Firstly, they haven't known what to carry in the door that will capture the CEO's attention. Secondly, there is a widespread perception that the only important statistical work to be done at the top level of management is to communicate an understanding of the vital importance of understanding variability, and process thinking, and that there is no requirement for 'interesting' (= hard, challenging) statistical modelling and analysis. Thirdly, few 'success stories' published in the non-statistical literature highlight the central role of statistics and statistical thinking in achieving success.

Taking the third issue first, there are very encouraging signs of change. Some of the current Six Sigma initiatives have clearly led to impressive 'bottom-line' improvements (e.g. Hoerl 1998, Snee 1998). We hope we have responded to the first two issues. The measurement framework carries with it an imperative to address very directly the sorts of things that should be of ongoing concern for top management. And there are significant technical skills required to carry out Comparative Value Analyses. Whilst the ability to communicate the importance of understanding variability and of process and systems thinking is vital, *it is not an end in itself*; rather, it is a means to producing better-informed business decisions. CEOs don't care about variability *per se*; however they do care about things like risk, waste and inefficiency, all of which link directly to business outcomes.

A significant question remains unaddressed, however. What is required of statisticians, and of managers, to make it all work?

This is not a new question. In fact, Shewhart was addressing a related issue (admittedly in a rather more limited context) in 1939, when he wrote:

“The future contribution of statistics in mass production lies not so much in solving the problems that are usual to the statistician today as in taking a hand to coordinate the steps of specification, production and inspection. The long-range contribution of statistics depends not so much upon getting lots of highly trained statisticians

into industry as it does on creating a statistically minded generation of physicists, chemists, engineers, and others who will in any way have a hand in developing and directing the production processes of tomorrow.” (Shewhart 1939; final paragraph of Chapter I)

More recently, Snee (1991) addressed the question directly, arguing that:

“We must help create synergy between management philosophy and procedures and quality technology — including statistical thinking ... Statisticians must know their role in total quality and quality improvement efforts and understand the behavioral aspects of statistics.”

Implicit in this statement is the contention that statisticians must have a broader understanding of business and management issues in order to realise the totality of their potential contribution to improving how an organisation performs. This is hardly a startling requirement. Statisticians consulting to biologists, geologists, or physicists are well aware of the need to learn enough of the relevant science to be able to address their clients’ problems in their proper context. We surmise that the difference between those situations and the one under discussion is that whereas Biology, Geology and Physics are generally recognised (by statisticians) as substantial areas of learning, Management has yet to achieve this status. Snee (1991, 1998) discusses some of the broader skills and knowledge required of statisticians to fulfill what is, in effect, a new role: consulting to the highest levels of management in an enterprise. He goes on to comment (Snee 1991, in a section entitled *Statisticians must change their culture*):

“Achieving total quality involves a top-down process that must have the active participation of top management. If statisticians want to help their organizations pursue total quality, they must influence management. There is no other way to make the necessary changes. Good technical work is important, but real progress comes from influencing how an organization operates and makes decisions.”

and (Snee 1998, in a section entitled *Changing our minds, our world*):

“I have argued that there are two root causes for the lack of broad statistical thinking and methods: a narrow focus on problem solving in manufacturing, research and development, and an emphasis on technical uses of statistics to the exclusion of managerial applications.

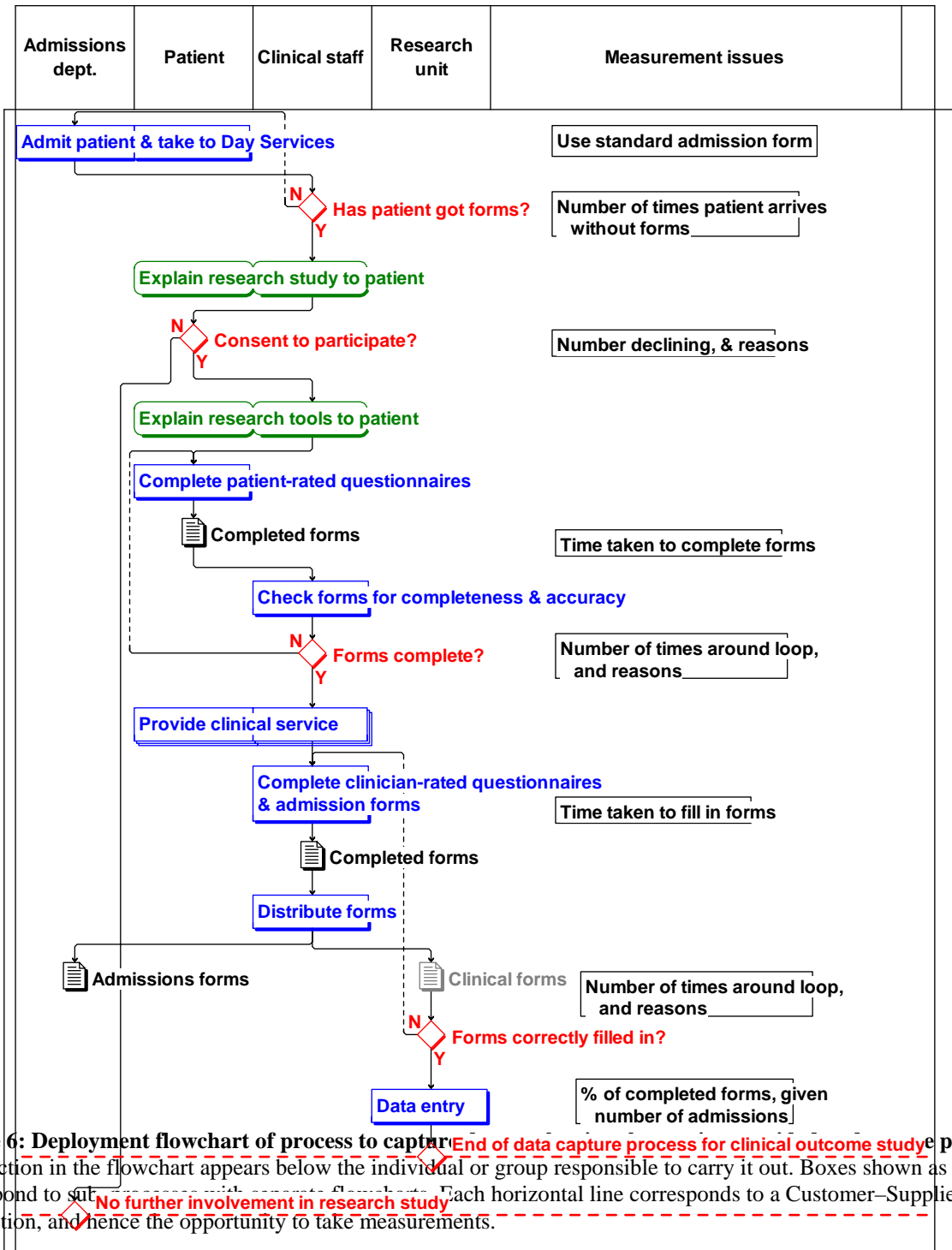
I have suggested two key strategies for attaining better business results: focusing on process improvement projects to reduce costs, increase revenue, and improve customer satisfaction, and building statistical thinking and methods into the very processes that we use to run our business.”

Viewed in the light of the Zones of Measurement model, even this last paragraph is too limiting. As has been noted above, Gunter, Normann, Sarasohn and others have stressed the importance of adding value for People and for the Community, in order to sustain long-term prosperity. The CEO’s focus, and consequently the statistician’s focus and language, should be directed initially to the Strategic zone, and work back from there. How else can alignment with the Mission of the enterprise be achieved, and how else can statisticians maximise the impact of their value-adding activities?

6 Conclusions

1. The structured approach to measurement provides statisticians with an opportunity to add value at all levels of an enterprise.
2. Statisticians need to wear top management’s ‘perspecticles’, to use Myron Tribus’ term, when talking to top management.
3. There is a pressing need for more compelling case studies published in the literature that CEOs read.

If statisticians can prove to be effective in their new role, the benefits both to organisations and to the statistical profession are likely be very substantial. The benefits for organisations will come from significantly increased effectiveness and efficiency in pursuing their missions. The benefits for statisticians will come through recognition by top management of the vital, indeed essential, contribution made by statisticians, statistics and statistical thinking to business excellence of their enterprise.



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Résumé

Une approche systématique pour la mesure de performance des entreprises est fondamentale à la poursuite de l'excellence au sein des activités commerciales de l'entreprise. De ce fait, le domaine des mesures des performances de l'entreprise ainsi que son utilisation des études et données pour informer les décisions commerciales, donne aux statisticiens les moyens d'apporter une valeur ajoutée potentiellement élevée. Les statisticiens, pour être efficaces dans ce domaine, ont besoin d'apprécier et comprendre, les différents besoins de l'information statistique, et ce dans diverses zones d'activité commerciale de l'entreprise.

Cet article décrit une stratégie qui requiert la liaison des mesures à toutes les facettes des performances de l'entreprise, en particulier aux résultats escomptés des activités commerciales. Cette stratégie relie d'une manière naturelle les mesures au processus d'amélioration de l'entreprise. L'utilisation des statistiques et de la pensée/reflection statistique est présentée dans ce contexte avec une attention particulière donnée à l'occasion pour les statisticiens de jouer un rôle primordial au niveau le plus élevé de management de l'entreprise. A notre avis, ce rôle requiert des compétences en techniques avancées pour la modélisation et l'analyse statistique, ainsi qu'en réflexion statistique. Ce rôle requiert également une aptitude à former une appréciation de l'activité commerciale de l'entreprise, ainsi que des impératifs de management des dirigeants de cette dernière; et la bonne volonté de travailler à partir de cette base.