Maintenance Performance Management
in Capital Intensive Organizations

by

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A thesis submitted in conformity with the requirements
for the degree of PhD
Graduate Department of Mechanical & Industrial Engineering
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Abstract

Given the significance of maintenance in today's operating environment, excellence in maintenance performance becomes a strategic issue of capital intensive organizations. Managing for excellence needs effective measurement of performance. Whilst organizational performance measurement in general has been discussed extensively in the literature, few of these discussions focus specifically on the maintenance function. The overall objective of this research project is to study the role measurement can play in managing maintenance performance. In the initial phase of the inquiry, eight maintenance organizations in Hong Kong and Canada were visited and interviews were conducted during these visits. Findings from such field work indicate that maintenance organizations seldom measure their performance using a balanced set of indicators, or regard performance measurement as a strategic management tool. An approach that involves the use of strategy driven balanced scorecards has been proposed to enhance effectiveness of maintenance performance management.

Given its novelty, the proposed approach had to be put into practice to validate its efficacy.
Two maintenance organizations were involved as collaborating parties in an action research to study the application of balanced scorecards as the tool for managing maintenance performance. Observations from the action research indicate that the initial balanced scorecards developed by maintenance organizations are typically machine-centric, rich in outcome measures but poor in performance drivers, with weak linkage between scorecard measures and the espoused strategy of the maintenance organization. The tools for the design and deployment of the maintenance scorecards, and those for the presentation and analysis of scorecard results were identified and field tested. Conditions conducive to successful applications of balanced scorecards in maintenance organizations are found to include: existence of a participative and social process, widespread understanding of the balanced scorecard concept, the maintenance strategy is widely communicated, the momentum of change is sustained, and the support infrastructure is in tune with the espoused strategy. Two propositions are derived from the results of the action research viz:

Proposition 1 — *Maintenance performance management is emphasized in organizations where maintenance is regarded as an investment, an integral part of asset management, and where managers have a holistic but not machine-centric mind-set.*

Proposition 2 — *Managers with a good understanding of the balanced scorecard concept will be able to use the balanced scorecard to inform people of the key result areas and show them how exemplary maintenance performance in these areas can be achieved.*

The five-step framework proposed in this study provides the road-map for applying balanced scorecards in managing maintenance performance. The design of the maintenance system that will fit in the specific operating environment can be guided by the soci-technical system-based framework suggested in this thesis.
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1. Introduction

1.1 Challenges of Maintenance

Intense competition on the supply side and heightened volatility in customer requirements on the demand side are the characteristics of the current business environment. Confronted with such reality, organizations are under great pressure to enhance their capability to create value to customers and improve the cost effectiveness of their operations on a continuous basis. Maintenance, being an important support function in businesses with significant investments in plants and machinery, plays an important role in meeting this tall order. It has been found that in the UK manufacturing industry, maintenance spending is between 12 to 23 per cent of the total factory operating costs (Cross 1988). In refineries, the maintenance and operations departments are often the largest and each may comprise about 30% of total staffing (Dekker 1996). Acquiring the right mix of physical assets and making the best use of those already in place to meet business needs are the ways maintenance can contribute to improve competitiveness of capital intensive organizations.

The performance demanded of maintenance has been made much more challenging by the following developments in the contemporary business environment:

(1) Emerging trends of operation strategies.

The conventional wisdom embracing the concept of “economy of scale” is losing followers. An increasing number of organizations have switched to “lean manufacturing”, “just-in-time production” and “six-sigma programs”. These trends highlight a shift of emphasis from volume to quick response, elimination of waste, and defect prevention. With the elimination of buffers in such demanding environments, breakdowns, speed loss and erratic process yields will create immediate problem to the timely supply of products and services to customers. Obviously, installing the right equipment and facilities, optimising the maintenance of these
assets, and effective deployment of manpower to perform the maintenance activities are crucial factors to support these emerging trends of operation strategies.

(2) Toughening societal expectations

There is widespread acceptance of the need to protect the environment and safeguard people's safety and health, especially in the developed countries. As a result, a wide range of regulations have been enacted in these countries to control industrial pollution and prevent accidents in the workplace. Scrap, defects, and inefficient use of materials and energy are sources of pollution. They are often the result of operating plant and facilities under less than optimal conditions. Machine breakdowns interrupt production. In chemical production processes, a common cause of pollution is the waste material produced during the start-up period after production interruptions. Apart from producing waste material, catastrophic failures of operating plant and machinery are also the major cause of industrial accidents and health hazards. Keeping facilities in optimal condition and preventing failures are an effective means to meet the ever more demanding societal challenge of pollution control and accident prevention. These are the core functions of maintenance.

(3) Technological changes

Technology has always been a major driver of change in diverse fields. It has also changed at a breathtaking rate in recent decades, with no signs of slowing down in the foreseeable future. Maintenance is no exception in being under the influence of rapid technological changes. Non-destructive testing, transducers, vibration measurement, thermography, ferrography, and spectroscopy make it possible to perform non-intrusive inspection. By applying these technologies, the condition of an equipment can be monitored continuously or intermittently while it is in operation. This gave birth to condition-based maintenance, an alternative to the classical time driven approach to preventive maintenance (Tsang 1995).
Power electronics, programmable logic controllers (PLCs), computer controls, transponders, and telecommunications systems are increasingly being introduced to substitute electromechanical systems. They offer the benefits of improved reliability, flexibility, compactness, light weight, or low cost. Fly-by-wire technology, utilizing software controlled electronic systems, has become a design standard for the current generation of aircraft. Flexible manufacturing cells and computer integrated manufacturing systems are gaining acceptance in the manufacturing industry. Contactless smartcards (CSC) are being introduced in public transport services as a convenient means of fare collection. The CSC project involves the creation of a network of computer systems, specialized CSC devices, control processors and communications processes, for a consortium of transport service providers. In the electric utility industry, automation systems are being installed to enable faults in the transmission and distribution network to be identified and dealt with remotely.

The deployment of these new technologies is instrumental to enhancing system availability, improving cost effectiveness of operations, and delivering better or innovative services to customers. At the same time, the move also presents new challenges to maintenance. New knowledge has to be acquired to specify and design the new systems taking advantage of these emerging technologies. New capability has to be developed to commission, operate and maintain such new systems. During the phase-in period, interfacing old and new plant and equipment is another challenge to be handled by maintenance.

(4) Changes in the people and organizational systems

The doctrine that focuses primarily on efficiency in industrial management worked well to produce exemplary performance in past eras when the business environment was highly stable. Companies were busy producing standard goods and services to satisfy the insatiable demand of their customers, and these companies were protected from the onslaught of outside
competition through regulation or imposition of trade barriers in their home market. Product life cycle was long due to slow technological change and tolerance of accepting customers who would take whatever was available on the market. On the human dimension, people perceived work merely as a means to earning a living. All these have changed in today’s turbulent environment. People at work — the individuals who make things happen in organizations — have undergone significant transformation.

There is a growing body of knowledge about people at work, about organizations, and about management with new attitudes towards work. In an affluent society, people have a desire to improve the quality of life at work. Furthermore, the social and demographic changes that have taken place in the current era affect how we regard and define work. Some examples of these changes are:

- Pressures for equal treatment of women and minorities.
- Improvements in education.
- More faith in the ability of individuals to manage themselves.
- Challenges to authority and a growing psychology of entitlement.
- With rampant downsizings and restructurings, people have reduced loyalties to single organizations and increased loyalties to professions.

In face of the new reality, progressive organizations are exploring new directions in their labour-management agreements. This leads to the appearance of a variety of innovative and highly successful organizational forms, such as horizontal structures, network organizations, self-managing work teams, virtual organizations, strategic alliances. Some of these could be the appropriate options for meeting today’s challenge of providing excellent maintenance services to organizations.
1.2 Management of Maintenance Performance

Given the significance of maintenance in today’s operating environment, excellence in maintenance performance becomes a strategic issue of capital intensive organizations. Managing for excellence needs effective measurement of performance, which forms the basis of evaluation and decision making. Organizational performance measurement in general has been discussed extensively in the literature. However, few of these discussions focus specifically on the maintenance function. Among those few that have such focus, performance measurement is regarded only as a tool to support operational control of maintenance operations. The extent to which the role of measurement can be expanded in managing maintenance performance is a research topic yet to be explored. The overall objective of this research project is to study this issue and develop a framework for maintenance performance management in capital intensive organizations. It attempts to address the following specific problems in the domain of this study:

(a) Application of the balanced scorecard as a measurement tool for managing maintenance performance.

(b) Identifying tools for planning and review of maintenance performance.

(c) The critical success factors and barriers to successful implementation of effective maintenance performance management systems.

(c) Using the socio-technical systems (STS) approach to identify the type of performance management system for maintenance organizations.

(d) Formulation of a framework for managing performance of world class maintenance organizations. Issues essential for achieving alignment in the organization, such as strategy formulation and deployment, linking the performance measurement system to the espoused strategy, providing communication channels, reviewing achievements, and establishing regulatory mechanisms will be addressed in the framework.
Managing maintenance performance with a strategic perspective is a pioneering endeavour. At the time when this research project commenced, no maintenance organization was known to have adopted this innovative approach to managing its performance. There was a need then, and it still exists today, to promote the new concept and its underlying theory to managers and maintenance professionals in industry. Executive development programs and conference presentations delivered by the researcher were used as vehicles to raise the awareness of the unorthodox concept. Subsequently, two major organizations in Hong Kong were sufficiently convinced of the theoretical merits of the ideas and agreed to be collaborating partners in this research project. Being an exploratory study into possibly an emerging management phenomenon, the action research methodology was adopted in that part of the inquiry that focused on the implementation of the new performance management system. The researcher played the dual roles of adviser and observer in the transformation process in these organizations.

The claims of originality in this research are:

- Investigation into an innovative approach to managing maintenance performance.
- Being instrumental in transforming the maintenance performance management systems in the collaborating organizations.
- Applying the action research methodology in industrial settings to study an embryonic management phenomenon.

1.3 Structure of the Thesis

In Chapter 1, the characteristics of contemporary business environment producing significant impacts on maintenance are discussed. They highlight the strategic importance of the function in organizations with significant investment in capital facilities, and establish the need to review the traditional approach to maintenance performance management. The overall objective and specific
focus of the research project, as well as the originality elements of the inquiry are delineated.

Chapter 2 is a comprehensive review of the relevant literature. First, the maintenance function is defined. This is followed by an examination of the theory of measuring organizational performance in general and maintenance performance in particular. The pitfalls of utilizing commonly used maintenance performance indicators are also reviewed. Various approaches to establishing maintenance performance measures required for effective decisions in today’s turbulent business environment are then discussed. A holistic approach to performance measurement featuring strategic perspectives is identified to have much potential for application in managing the maintenance function. It is the theory underpinning the Balanced Scorecard (BSC), which can form the centrepiece of a performance management system. At the end of the chapter, recommendations for a research agenda are made for applying the BSC in managing maintenance performance. Some of these agenda items are being addressed in this research.

The Balanced Scorecard for maintenance performance is driven by the organization’s maintenance strategy, which may vary from one organization to another. The various dimensions of maintenance strategy are therefore discussed in Chapter 3. These include: service delivery options, organization and work structure, maintenance methodology, and support systems. The key elements involved in organizational transformation processes are also examined.

The three-phase research methodology adopted in this project is described in Chapter 4. It features the case study approach because maintenance organizations that have taken the pioneering step of using Balanced Scorecards to manage their performance were non-existent at the beginning of the study. Two collaborating organizations were subsequently recruited as test sites for introducing such change. Field visits, interviews, analysis of company documents, and the action research method were employed for data collection.

Analysis of data is presented in Chapters 5 to 7. This includes findings from field visits to eight
maintenance organizations in Hong Kong and Canada conducted in the first phase of the study (Chapter 5). They provide information about common practices of maintenance performance management. The results obtained from a questionnaire survey on the typical profile of performance measures currently used in Hong Kong based companies, and other characteristics of the current performance management practices in these companies are reported in Chapter 6. Next, observations obtained from the action research in the two collaborating organizations are discussed in Chapter 7. While the two host organizations are at different stages of the change process, the findings obtained from these two organizations are complementary — one provides data for the front end of the change process, the other provides data for the back end.

Generalization from findings of this study is the subject of Chapter 8. Finally, major contributions of the research, limitations of the inquiry, and suggestions for further studies are addressed in the concluding chapter (Chapter 9).
2. Literature Review

2.1. Introduction

Maintenance is typically regarded as a necessary evil, an expense account which is a popular target for cost reduction programs. Hence, the measurement of maintenance performance tends to focus on tracking direct costs or its surrogates, such as the head count of the maintenance unit, total duration of forced outages during a specified period, etc. As organizations are increasing their investment in capital intensive equipment, the performance of maintenance operations has become a major management issue.

The first part of this Chapter will define the maintenance function. It is followed by a review of the theory and practice of measuring organizational performance in general and maintenance performance in particular. The pitfalls of utilizing the commonly used maintenance performance indicators are also examined. In the subsequent section, various approaches to establishing maintenance performance measures that would lead to effective decisions in today’s turbulent and highly competitive environment are discussed. These approaches include the usage of a single measure, multiple measures and system audits for performance evaluation. Also presented is a method for comparing the operational efficiencies of multiple maintenance organizations. In the concluding section, recommendations for a research agenda are made for applying a holistic approach to maintenance performance measurement.

2.2. The Maintenance Function

Before something can be measured, it must be defined. The traditional perception of maintenance’s role is to fix broken items. Taking such a narrow view, maintenance activities will be confined to the reactive tasks of repair actions or item replacement. Thus, this approach is known
as reactive maintenance, breakdown maintenance, or corrective maintenance. A more recent view of maintenance is defined by Geraerds (1985) as: "All activities aimed at keeping an item in, or restoring it to, the physical state considered necessary for the fulfilment of its production function."

A similar definition of maintenance is given in BS3811 (BSI 1993). Obviously, the scope of this enlarged view also includes the proactive tasks such as routine servicing and periodic inspection, preventive replacement, and condition-monitoring. Depending on the deployment of responsibilities within the organization, these maintenance tasks may be shared by several departments. For instance, in an organization practising Total Productive Maintenance (TPM) (Nakajima 1988), the routine servicing and periodic inspection of equipment are handled by the operating personnel, whereas overhauls and major repairs are done by the maintenance department. If the strategic dimension of maintenance is also taken into account, it should cover those decisions taken to shape the future maintenance requirements of the organization. Equipment replacement decisions and design modifications to enhance equipment reliability and maintainability are examples of these activities.

The Maintenance Engineering Society of Australia (MESA) recognizes this broader perspective of maintenance and defines the function as: "The engineering decisions and associated actions necessary and sufficient for the optimization of specified capability." 'Capability' in this definition is the ability to perform a specific action within a range of performance levels. The characteristics of capability include function, capacity, rate, quality, responsiveness and degradation. The scope of maintenance management, therefore, should cover every stage in the life cycle of technical systems (plant, machinery, equipment and facilities): specification, acquisition, planning, operation, performance evaluation, improvement, and disposal (Murray et al. 1996). When perceived in this wider context, the maintenance function is also known as physical asset management.
Fig. 2.1 shows the EUT-maintenance model developed at Eindhoven University of Technology, the Netherlands (Geraerds 1990) which provides a conceptualisation of the processes involved in the maintenance function. Its main focus is on meeting the maintenance needs of *technical systems* already in place. This is achieved by utilising internal maintenance capacity and external services, with the support of spare parts inventory management and performance measurement. There are two cycles of management processes embedded in the maintenance function. The first cycle consists of the managerial processes of formulating maintenance policies, establishing objectives, planning, auditing, and measuring performance that apply to the entire function. The issues addressed in the planning process include organizational structure, staffing, resource allocation, action plans, etc. The second cycle is concerned with technical planning and operation of maintenance activities for individual *technical systems*. These involve the selection of maintenance regimes (reactive, preventive, condition-based, TPM, etc.), planning and optimization of maintenance decisions, scheduling and execution of work. The cycle is closed by providing feedback through capturing and analysis of performance data (see Fig. 2.2, Coetzee 1997).

2.3. The Theory of Performance Measurement

Neely, Gregory and Platts (1995) provide a comprehensive literature review of performance measurement that addresses two distinct aspects, namely levels and concepts. They examine performance measurement at three different levels: (a) the individual performance measures, (b) the performance measurement system (PMS), and (c) the relationship between the PMS and its environment. Three of the key concepts identified in the review are:

(1) Performance measures can be classified in a number of ways according to their perspective, namely financial and non-financial measures, outcome measures and performance drivers, internal and external measures. Another classification, suggested subsequently by Kaplan and
Norton (1996b), is linked to the level of focus of the measures: *diagnostic measures* are used to monitor and control day-to-day operations and *strategic measures*, on the other hand, are selected to inform the stakeholders of the organization's strategic intent and the progress that has been made in achieving it.

(2) Performance measures need to be positioned in a strategic context, as they influence what people do. Peters and Waterman (1982) explain this succinctly — "*What gets measured gets done.*" The pattern of decisions and action within an organization defines the strategy in practice. Thus, performance measurement should not be considered purely as a means to provide information for management control and decision making; it can also serve as a powerful motivational tool driving decisions and action that are consistent with the espoused strategy.

(3) The PMS does not exist in isolation. The effectiveness of the PMS in shaping behaviour depends on the support of a matching organizational infrastructure relating to issues such as resource allocation, work structuring, management information, reward and recognition in addition to technical or operational activities such as maintenance operations. For example, there is a need to link performance measurement to reward systems because, as Hammer and Stanton (1995) state, "*The way to people's hearts and minds is not through their ears but through their wallets.*" As such, work in the organization should be structured to achieve joint optimization of the social and technical subsystems, or at least a good fit between them, and there is choice in developing such organizational designs (Gerwin and Kolodny 1992). The organization in which the PMS is embedded must also be understood as an open system that is in continuous interaction with its environment. When that environment is turbulent, organization designs must repeatedly change to best adapt to the uncertainty of the environment. This perspective is referred to as a *Sociotechnical Systems* (STS) approach.
If performance measures are to trigger effective beneficial change, they have to fulfill two conditions. First, they should relate to what is controllable by the unit to be evaluated. Second, favourable results on these measures will contribute to specific Business Success Factors. The level of analysis (for instance, organization versus the maintenance department), and the agreed sphere of influence of the function being measured, will significantly influence the measures used. If average equipment life is used as a measure of performance, maintenance must have an input in equipment purchase decisions. When the lost time for repair is monitored, the organization being measured should have jurisdiction over staffing decisions and stocking of spare parts (Dwight 1994).

The widely used performance measures were developed on the premises of the scientific management movement pioneered by Frederick Taylor about a century ago, a period when demand far exceeded supply, the operating environment was very stable, and labour intensive operations were the norm. The conventional wisdom of management evolved from such a background is characterised by a preoccupation with maximizing the utilization of resources. Thus, in assessing maintenance performance, various efficiency indicators (equipment availability and labour utilization, etc.) and financial measures (such as repair and preventive maintenance costs) are routinely tracked.

Assessments in terms of financial measures are typically performed through variance analysis, which breaks a variance down into its constituent parts such as price variance and usage variance to determine the causes of the discrepancy. It has been shown that variance analysis is dysfunctional to global optimization because it focuses on minimization of within-department costs (Kaplan 1990). Here are two likely scenarios in an industrial organization:

(1) The Purchasing Department, which is evaluated on price variance, makes purchase decisions on the basis of price. Parts and services carrying the lowest price tag are selected even though the parts may have an inferior quality (a higher failure rate) or the services are seldom
completed on schedule. The consequence of such decisions will show up as unfavourable usage variance in departments such as Maintenance and Production where these items or services are consumed.

(2) The Maintenance unit is reluctant to introduce condition based maintenance even though it will prevent unplanned outages due to machine breakdowns, a major benefit manifested in the Production Department. The resistance exists because when compared to the "do nothing" option embodied in the standard cost, it will give rise to unfavourable usage variance in the cost of planned maintenance, an indicator commonly used to measure maintenance performance.

Furthermore, the notion of comparing the actual cost to a 'static' standard cost in variance analysis is incompatible with the philosophy of continuous improvement. Trends as well as deviations from the 'standard' should be tracked to motivate favourable change as an on-going process. If a 'standard' is to be established, it should be based on the best-in-class benchmark instead of the organization's historical performance level.

Apart from the above problems relating to variance analysis, Kaplan (1989) also points out that the 'numbers' produced by traditional management accounting systems are:

(a) too aggregate to provide relevant information for operational control,

(b) available too late for corrective action to be taken, and

(c) too distorted by the standard overhead absorption method.

Whilst these traditional accounting systems are at best adequate for tracking costs associated with the consumption of raw materials and labour that go into a product, the overhead absorption procedure allocates costs to all items produced during a reporting period so that these expenses can be split between products sold and products still on hand. Product unit costs are established by recovering total periodic expenses from the total output of the period. With this orientation, all
expenses associated with support functions such as engineering, logistics, and maintenance are classified under the category of overhead costs, which are subsequently allocated to a product according to the direct labour content or machine hours used in its production. This way, the overhead cost of products can be seriously distorted. Consider two different processes that have been used to manufacture a given product: Process I uses a flexible manufacturing cell (FMC) which requires frequent preventive maintenance, and Process II uses general purpose machines requiring minimal maintenance. Under the absorption method, most of the maintenance expenses will be allocated to the output of Process II even though the lion's share of these expenses are actually consumed by the output of Process I. A decision to phase out Process II by installing another FMC will not reduce unit maintenance cost as expected from the costing information. To the contrary, the unit maintenance cost will have a significant increase after the change! This should not be interpreted as a deterioration of maintenance performance. The accounting system is at fault.

Recognizing the flaws of the standard management accounting systems in today's business environment, Kaplan (1988) proposes that activity-based costing (ABC) systems should be adopted. He also advocates the use of frequent non-financial measurements for more effective shop-floor control. The ABC approach does not differentiate between direct and overhead costs. It is a resource consumption model in which cost objects, such as machines requiring maintenance services, consume activities that in turn consume resources. This model is more adequate for monitoring the costs of those activities that lead to delivery of a product or service. Take the maintenance operation as an example, ABC can track the costs of the various activities in the service chain which is triggered on receipt of a work order. These activities include processing of the work order, job scheduling, provisioning of spare parts, and delivery of the maintenance service.

The ABC method considers that in the long run, all activity costs are variable. Information on the expected level of specific activities that consume a resource will highlight mismatch between loading
and available capacity. The prime factors that determine the activity level are known as the cost drivers of that activity. In the case of maintenance activities, the cost drivers may include preventive maintenance policy, degree of machine standardization, training of operators, spare parts inventory policy, etc. By analysing the cost drivers, managers can identify design faults that create wastes in the activity. Also, the process of mapping activities to cost objects can single out non-value added work, which offers potentials for business improvement (Tsang 1995).

Equipment maintenance is a key process in industries such as transportation, utilities, mining, and manufacturing. It represents a significant component of the operating cost in these industries. Much of these expenses are consumed by non-value adding management control or logistics related activities. Through the application of business process reengineering (BPR) pioneered by Hammer and Champy (1993), maintenance processes can be streamlined to eliminate waste and produce breakthrough performance in areas valued by customers. Activity-based costing (Kaplan 1988), being an effective tool for capturing all the end-to-end expenses associated with a process, will provide the financial measures for determining the outcome of such changes.

Various aspects of performance measurement have been extensively discussed in the literature. Atkinson, et al. (1997) identify that there are three roles in performance measurement, namely coordinating, monitoring, and diagnostic. Poirier and Tokarz (1996), Neely et al. (1997) offer suggestions on the design of good performance measures. Cameron (1986), Keegan et al. (1989), Maskell (1991), Bevan and Thompson (1991), Lockamy and Cox (1995), Kaplan and Norton (1996b) provide their sets of guidelines for design of performance measurement systems that would lead to excellent performance in today’s highly turbulent and competitive business environment. The principles shared by most of these prescriptions are:

(a) Measures are organization-specific — they are linked to the organization’s strategy.

(b) Multiple measures — internal and external, financial and non-financial measures, performance
drivers and outcome measures — should be used to achieve balance in perspective, and to communicate the causal relationships for achieving business success.

(c) Measures should be user-friendly — simple, easy to use, available promptly.

(d) Measures at different levels of the hierarchy are aligned and they are integrated across an organization's functions.

(e) Involve employees in formulating strategies and identifying the related performance measures.

(f) The organization's infrastructure encourages desired behaviour and supports operation of the measurement system.

(g) Effectiveness of the system and its contribution to overall organizational performance are reviewed periodically to allow changes and improvements to be made.

2.4. The Practice of Performance Measurement

In a review of the performance literature, Cameron (1986) finds that measures of organizational performance are often selected on the basis of convenience. Typically, the measures used are either too narrowly or too broadly defined. This is a problem related to level of analysis; measures of individual, group, and organizational performance are not necessarily the same. In fact, focusing on a biased set of lower level measures may encourage sub-optimization. Other common features of performance measures identified in the review are:

- proxies of measures selected on the basis of convenience are often unrelated to organizational performance;
- a single measure is commonly used to assess performance which is a multidimensional construct;
- *Outcome measures* are the dominant type of indicators for evaluating performance, whereas *effects* are most frequently used in policy decisions and by the public. *Outcome measures*
reflect short-term results, but sustainable performance depends on the long-term effects of strategies pursued by the organization.

Results of a KPMG survey (1990) of 150 of The Time 1,000 companies, excluding the top 200, found that the information used to monitor performance was rated poor or average by close to half of the respondents in terms of relevance, accuracy, timeliness, completeness, cost effectiveness and presentation. Internal information and past financial performance appeared to dominate the information set. External information was not reported as being widely used in strategy formulation or monitoring. In fact, information available to formulate and review strategy was rated poor or average by the majority of respondents.

A large scale postal survey of almost 12,800 organizations both in the private and public sectors in the UK was conducted in 1991 to determine the state of practice of performance management in industry (Bevan and Thompson 1991). With a response representing a fifth of the total UK workforce, the survey results indicated that just under 20 percent of respondents claimed to be operating a formal PMS, but that a further two-thirds did have policies for managing employee performance generally. Evidently, there was a patchy and incomplete uptake of performance management techniques in the UK. The main reasons employers gave for introducing performance management included improving organizational effectiveness and increasing employee motivation. It was also found that organizations with a formal PMS were more likely to have a performance-related reward system.

In 1995, another survey on performance measurement was conducted in the US, covering over 200 organizations. (APQC 1996) It can be observed from the results that “Overall, the majority of management systems are designed around short-term, control-oriented financial frameworks that are fundamentally tactical.” The characteristics of performance measurement in participating organizations are as follows:
• dominated by financial or other backward-looking indicators
• failure to measure all the factors that create value
• little account taken of asset creation and growth
• poor measurement of innovation, learning and change
• a concentration on immediate rather than long-term goals.

In its conclusion, the survey report states: "Despite reasonably high level use, non-financial measures and targets are frequently treated in isolation from strategic objectives. They are not reviewed regularly, nor are they linked to short-term or action plans — they are largely ignored or 'for interest' only."

Maintenance practices of small and medium sized enterprises (SME) is the focus of a recent survey conducted in Australia (De Jong 1997). It is found that the main measure of maintenance performance used in the responding companies is the ratio of the total cost of the maintenance system to estimated equipment replacement value (ERV). Other measures are chosen according to the priorities of the company and they may include number of accidents, value of spare parts to ERV, maintenance cost to production cost. Two other significant observations made from the study are:

1. Companies which have equipment performance goals and maintenance performance goals in place show both lower maintenance cost and lower proportions of reactive maintenance.

2. As the practice moves more towards proactive and relies less on reactive maintenance, the direct cost of maintenance will tend to reduce.

2.5. Classifying Maintenance Performance Measures

Arts and Mann (1994) use the time horizon to classify maintenance decisions into three categories, namely strategic, tactical, and operational. Strategic maintenance decisions are made in the selection of design options for management systems or products to be developed, or plant and machinery to
be acquired that will be compatible with the organization's business strategy. Tactical maintenance decisions relate to the formulation of policies for effective and efficient use of available resources. Operational decisions are made to achieve a high level of effectiveness and efficiency in maintenance activities.

Maintenance plans are often established with a view to achieving a quantified objective. However, the objective is usually chosen by 'gut feel' rather than by careful analysis. In a study done during the Second World War it was discovered that aircraft of the U.K.'s Coastal Command was prevented from maximizing their flying time since a wrong objective (maximizing serviceability) was used (Crowther and Whiddington 1963). Serviceability, defined as the ratio of the number of aircraft on the ground available to fly plus those flying to the total number of aircraft, was initially used as the measure of performance for these aircraft. With the technology in those days, for every hour spent flying, two hours would be required for maintenance. Thus, aiming for a high level of serviceability would be in conflict with Coastal Command's wartime requirement of maximizing the flying time of aircraft. On the other hand, in situations where aircraft are called upon only on emergencies, a high serviceability objective may be appropriate.

Many indicators of maintenance performance discussed in the literature are developed to support operational decisions. Armitage and Jardine (1968) note that these indicators are, at best, descriptive signalling that some action needs to be taken. To be more useful, decision rules which are compatible with organizational objectives should also be in place such that the preferred course of action can be determined on the basis of the indicators' values.

To facilitate detection of trends when the level of activities may vary over time, or comparisons are made between organizations of differing scales of operation, indices are often used as measures of maintenance performance. Campbell (1995a) classifies these commonly used performance measures into three categories on the basis of their focus:
(1) Measures of equipment performance — e.g. availability, reliability, overall equipment effectiveness

(2) Measures of cost performance — e.g. Operation & maintenance (O&M) labour and material costs

(3) Measures of process performance — e.g. ratio of planned and unplanned work, schedule compliance

However, the underlying assumptions of these measures are often not considered when the results are interpreted.

<table>
<thead>
<tr>
<th>Level</th>
<th>Assumptions</th>
<th>Typical Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Overt Bottom-Line impact</td>
<td>• Impacts of maintenance actions on down-time, quality, yield and future maintenance costs are negligible.</td>
<td>• Direct Maintenance Cost</td>
</tr>
<tr>
<td></td>
<td>• Causes of maintenance costs arise and are controllable within the accounting period.</td>
<td></td>
</tr>
<tr>
<td>2. Profit-Loss and Overt Cost Impact Performance</td>
<td>• Impacts of maintenance actions on quality, yield and future maintenance costs are negligible.</td>
<td>• Direct Maintenance Cost</td>
</tr>
<tr>
<td></td>
<td>• Causes of maintenance costs and down-time arise and are controllable within the accounting period.</td>
<td>• (Delay Time) × $/hr.</td>
</tr>
<tr>
<td>3. Instantaneous Effectiveness Measures</td>
<td>• Causes of maintenance impacts on the business arise and are controllable within the accounting period.</td>
<td>• Overt Maintenance Action Cost</td>
</tr>
<tr>
<td></td>
<td>• Only the events occurring now will occur in the future</td>
<td>• Utilization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Availability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reliability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Overall equipment effectiveness</td>
</tr>
<tr>
<td>4. System Audit Approach</td>
<td>• System excellence implies the best possible performance.</td>
<td>• Planned/Unplanned work ratio</td>
</tr>
<tr>
<td></td>
<td>• Strategies and current techniques are effective.</td>
<td>• Actions carried out compared with strategy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Backlog trends</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• % maintenance induced failures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• System Audit</td>
</tr>
<tr>
<td>5. Time Related Performance Measurement</td>
<td>• Projections for future demand and obsolescence are accurate.</td>
<td>• Value-based measurement</td>
</tr>
</tbody>
</table>

**Fig. 2.3** Levels of Performance Measures
Dwight (1994) proposes to classify performance measures into a hierarchy according to their implicit assumptions regarding the impact of the maintenance system on the business. There are five levels in the hierarchy, indicating a progression in awareness of the Business Success Factors that are controllable or influenced by maintenance. Some details of the classification are shown in Fig. 2.3.

The measures in the fifth level recognize that expenses include depletion of the fixed asset resource, the value of which depends on future demand, technological changes, and the appropriateness of the various maintenance actions. They also allow maintenance actions to be judged against factors like the remaining life of the equipment, process or product.

Maintenance is an essential support function in an organization’s value chain. Dwight states that its contribution to the organization’s business success can be analysed as a function of four variables:

- the cost of the action,
- the effect of disruption caused by the required maintenance actions,
- the effect on equipment performance between maintenance actions, and
- the ability of the action to affect the life of the asset.

An assessment of the situation with respect to these dimensions determines the appropriate maintenance actions that will affect the bottom line. This analysis, in turn, will determine the relevant measures of performance that should be used. For example, when a company has surplus productive capacity, disruption may have a low correlation with success. In such a case, any measure that relates to disruption will not be appropriate.

Whilst these four variables relate to the impact of maintenance at the equipment level, other indicators that measure performance of the maintenance system should also be in place. These measures of system performance are typically designed to detect if planned work had been done and
completed on time, or to track resources consumed by the system. Again, these measures are appropriate only if they have a cause-and-effect relationship with business performance.

2.6. Approaches to Measuring Maintenance Performance

A Value-Based Performance Measure

Maintenance activities determine the future options available to meet demand. The readiness to deal with uncertain events, such as equipment breakdown, is also influenced by maintenance management decisions. In the light of these characteristics, Dwight (1995) identifies the following shortcomings of performance measures currently used in industry:

(a) The concept of accumulation of risk is not captured.
(b) The focus is on the immediate rather than the overall requirement.
(c) The measures are not related to business requirements.

A performance measure that takes into account the impact of maintenance activities on the future value of the organization has been proposed by Dwight (1994) as follows:

\[
\text{Performance} = \frac{V_r - V_I}{V_r^*}
\]

where \(V_r\) is the value realized in the period, which is equivalent to \(CF(t - 1, t)\), the cash-flow during the interval \((t - 1, t)\). \(V_I\) is the future value lost compared with the known best value, \(V_r^*\), which, in turn, is given by: \(V_r^* = V^*(t - 1) - V^*(t)\) where \(V^*(t)\) is the estimated best attainable sum of future real cash flows, or 'residual value' in the system at time \(t\). \(V^*(t)\) and \(V_I\) must be calculated \textit{ex post}e by considering the circumstances prevailing during that period. In this calculation of value, it is assumed that the best available option will be taken up in the next period.

An alternative definition of performance, which deals with 'residual value' in the system, is:
Performance \[= \frac{CF(t-1,t) + V^*(t)}{V^*(t-1)}\]

The data required in determining the above performance measure can be collected from an existing system using a conceptual model known as the "Incident Evaluation Approach" (see Fig. 2.4, Dwight 1995). This approach involves the compilation of a library of possible primal incidents and their associated actions, leading to secondary incidents. An incident is a failure mode of the system which will reduce the potential output of the system. The expected residual value of an action policy is determined by the expression:

\[
\sum_{i=1}^{N} (p(C_i)CF_i)|A
\]

where \( p(C_i) \) is the probability of occurrence of incident \( C_i \) as a function of time. \( CF_i \) is the expected cash flow as a result of \( C_i \) occurring at its expected time, given the available resources implied by action set \( A \). The optimal action policy and \( V^*(t-1) \) are determined \textit{ex poste} by taking into account the involuntary incidents that actually occurred during the interval \((t-1,t)\).

![Diagram](Fig. 2.4 The Incident Evaluation Approach to collecting data for performance measurement)

This is a laborious procedure which only focuses on the financial impact of decisions associated with system failures. If other dimensions of performance measures, such as customer perception and contribution to meeting the future business needs of the organization, are to be assessed, a more comprehensive approach to performance measurement has to be used.
The Balanced Scorecard

Organizations typically use financial measures as performance indicators. Some of the drawbacks of these measures have been discussed in the section on “The Theory of Performance Measurement”. Even if those flaws can be eliminated, financial measures still have the drawback that they tend to shape managers’ mind-set that focuses on short-term results. The short-term thinking is driven by the investment community’s short-term perspective. As a result, very few managers will choose to make capital investments or pursue long-term strategic objectives that will jeopardize quarterly earnings targets.

Income-based financial figures are lag indicators. They are better at measuring the consequences of yesterday’s decisions than at indicating tomorrow’s performance. Managers are willing to play the earnings game. For instance, investment in maintenance can be cut back to boost the quarterly earnings. The detrimental effect of the cut back will only show up as increased operating cost in some future periods, by which time the manager making the cut back decision may have already been promoted because of the excellent earnings performance. In view of these deficiencies, customer oriented measures such as response time, service commitments, and customer satisfaction have been proposed to serve as lead indicators of business success (Eccles 1995).

To assure future success, organizations nowadays must be financially sound and customer oriented. This is possible only if their internal processes can provide a set of distinctive core competencies that will enable them to achieve their business objectives. Furthermore, they also need to have the capability to improve and create value continuously, through development of their most precious assets — the employees. An organization which excels in only some of these dimensions can, at best, be a mediocre performer. Improvements in operational capabilities such as faster response, better quality of service, reduced waste, etc. will not lead to better financial performance unless the spare capacity created by the operational improvement is utilized or the operation is
downsized. Also, maintenance organizations that are efficient in delivering high quality services will not remain viable for long if they are slow in developing new expertise that will meet the emerging needs of the user departments. For example, electro-mechanical systems are being phased out by electronic and software systems in many automatic facilities. In the face of the new demand, the maintenance service provider has to transform the profile of its expertise from one that is primarily in the electrical and mechanical trades to one that is more focused on electronics and information technology.

Obviously, relying on a single measure will not be able to capture all these requirements. A balanced presentation is therefore the preferred approach to measuring maintenance performance. The Balanced Scorecard (BSC) proposed by Kaplan and Norton (1992) offers the template for the balanced presentation. It is a vehicle that translates a business unit’s mission and strategy into a set of objectives and quantifiable measures built around four perspectives: Financial (shareholder’s views), Customer (performance attributes valued by customers), Internal Processes (the long- and short-term means to achieve the financial & customer objectives), and Learning & Growth (capability to improve and create value). It directs managers to focus on a handful of measures that are most critical for the continual success of the organization.

The Balanced Scorecard had been implemented in a number of major corporations in the engineering, construction, microelectronic and computer industries (Kaplan and Norton 1993). Experience in these pioneering organizations indicates that the Scorecard will get its greatest impact on business performance, only if it is used to drive a change process. The development of a Balanced Scorecard also engenders the emergence of a strategic management system that links long-term strategic objectives to short-term actions (see Fig. 2.5, Kaplan and Norton 1996a, 1996b)
A strategic management system that builds around a Balanced Scorecard is characterised by three keywords — focus, balance and integration. Ashton (1997) explains these three attributes as follows:

"Focus has both strategic and operational dimensions in defining direction, capability and what the business or its activities are all about, while balance seeks an equilibrium for making sense of the business and to strengthen focus. Integration is critical, ensuring that organizational effort knits into some form of sustainable response to strategic priority and change."

The BSC approach provides a holistic framework for establishing performance management systems at the corporate or business unit level. When the approach is applied to managing the performance of maintenance operations, a process involving the following steps can be followed (see Fig. 2.6, Tsang 1998a):

(1) Formulate strategy for the maintenance operation — Strategic options such as developing in-house capability, outsourcing maintenance, empowering frontline operators, introducing teamworking, enhancing flexibility of workforce, and adopting relevant new technology are considered and decisions made through a participative process.
(2) Operationalize the strategy — The maintenance strategy is translated into long-term objectives. The relevant Key Performance Indicators (KPIs) to be included in the BSC are then identified and performance targets established. Suppose outsourcing the maintenance and repair of generic and common equipment and vehicle fleets has been chosen as a strategy to allow an electric utility company to focus on its core competencies of managing its transmission and distribution system. The KPIs and performance targets that relate to this strategic objective are "outsource 20% of maintenance work" and "reduce maintenance costs by 30%" in two years. The former indicator belongs to the "Internal Processes" perspective and the latter the "Financial" perspective. To achieve vertical alignment, these objectives, KPIs and targets are cascaded into goals for teams and individuals.

(3) Develop action plans — These are means to the ends stipulated in the targets established in step (2). To achieve the targets relating to outsourcing of non-core maintenance works given in the above example, the company may have decided to develop capabilities in the following three areas which are needed in the outsourcing process: contract negotiation, contract management, and the ability to capitalize on emerging opportunities arising from changing technology and the changing competitive environment in the maintenance field. These action plans should also encompass any necessary changes in the organization’s support infrastructure, such as structuring of maintenance work, management information systems, reward and recognition, resource allocation mechanisms, etc.

(4) Periodic review of performance and strategy — Progress made in meeting strategic objectives is tracked and the causal relationships between measures are validated at defined intervals. The outcome of the review may necessitate the formulation of new strategic objectives, modification of action plans and revision of the scorecard.
Some of the KPIs featured in the Scorecard for measuring the maintenance performance of an electricity transmission and distribution company may include the following items (Tsang & Brown 1998):

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Strategic Objectives</th>
<th>Key Performance Indicators (KPIs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial</td>
<td>Reduce operation &amp; maintenance (O&amp;M) costs</td>
<td>O&amp;M costs per customer</td>
</tr>
<tr>
<td>Customer</td>
<td>Increase customer satisfaction</td>
<td>Customer-minute loss</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Customer satisfaction rating</td>
</tr>
<tr>
<td>Internal Processes</td>
<td>Enhance system integrity</td>
<td>% of time voltage exceeds limits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Number of contingency plans reviewed</td>
</tr>
<tr>
<td>Learning &amp; Growth</td>
<td>Develop a multi-skilled &amp; empowered workforce</td>
<td>% of cross-trained staff</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hours of training per employee</td>
</tr>
</tbody>
</table>

Since these measures are derived from the organization's strategic objectives, the Balanced Scorecard is specific to the business unit for which it is developed.

By directing managers to consider all the important measures together, the Balanced Scorecard guards against sub-optimization. Unlike conventional measures which are control oriented, the Balanced Scorecard puts strategy and vision at the centre and its emphasis is on achieving
performance targets. The measures are designed to pull people toward the overall vision. They are identified and their stretch targets established through a participative process which involves the consultation of internal and external stakeholders — senior management, key personnel in the operating units of the maintenance function, and the users of the maintenance service. This way, the performance measures for the maintenance operation are linked to the business success of the whole organization.

The theoretical underpinning of the Balanced Scorecard approach to measuring performance is built on two assertions:

(1) Strategic planning has a strong and positive effect on a firm's performance.

(2) Group goals influence group performance.

The link between strategic planning and a firm's performance has been the subject of numerous research studies. By applying the meta-analytic technique to analyse the empirical data drawn from planning-performance studies published in the last two decades, Miller and Cardinal (1994) are able to establish a strong and positive correlation between strategic planning and growth. They also show that a similar link between planning and profitability exists when the firm is operating in turbulent environments.

The existence of group goal effect is also established in a similar study on previously published research findings relating to goal setting in groups (O'Leary-Kelly et al. 1994).

Although it is a common belief in industry that strategic planning is important for ensuring an organization's future success, very often the performance measures and the actual company improvement programs are inconsistent with the declared strategy. Such a discrepancy between strategic intent and operational objectives and measures is reported in a recent survey conducted in the Belgian manufacturing industry (Gelders et al. 1994). This unsatisfactory situation can indeed be avoided by introducing the Balanced Scorecard.
System Audits

An organization's maintenance capability can be inferred from an audit of its maintenance system. The audit is a thorough and comprehensive review of the various dimensions in the maintenance system, such as organization, personnel training, planning and scheduling, data collection and analysis, control mechanisms, measurement and reward systems, etc. To get unbiased findings, the reviewer should have no direct responsibility or accountability for performance of the system under review. The audit is usually conducted by using a questionnaire designed to provide a profile of the maintenance system. Typically, the questionnaire is structured to address specific key areas in the system to be audited. Responses to these questionnaires may take one of these forms:

(a) either “yes” or “no”;

(b) choose one or more of the available options;

(c) on a Likert-type scale of, say, 1 to 5, to indicate different degrees of agreement or lack of it.

Different weights may also be assigned to different questions to reflect their relative contributions to system performance. Even though they may use sophisticated assessment schemes, the underlying theory of system audits is obscure.

Dwight (1994) suggests a procedure that relates the state of a system element, such as “feedback from operations”, to its contribution to the system’s overall performance.

<table>
<thead>
<tr>
<th>Ad hoc system</th>
<th>is the state of</th>
<th>System Element</th>
<th>influences on</th>
<th>Failure Attribute</th>
<th>contributes to</th>
<th>Business Success</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feedback from operations</td>
<td></td>
<td>Frequency of delays</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10%</td>
<td>×</td>
<td>100/350</td>
<td>×</td>
<td>0.5</td>
<td>=</td>
<td>0.015</td>
</tr>
</tbody>
</table>

Fig. 2.7 Determining the contribution of an observed system state to business success

In the example given in Fig. 2.7, an organization’s maintenance function only obtains feedback
from operations on an ad hoc basis. Suppose the *standard* state (the best practice) for this system element is to empower the operator to be the maintainer. When compared to the *standard*, the observed state scores 10% of the maximum rating. *Feedback from operations* is recognized as one of the system elements that have an influence on the failure attribute *Frequency of delays* (scoring 100 points out of a total of 350). With *Frequency of delays* contributing to 50% of business success, the overall performance contribution of the observed state of *Feedback from operation* is computed as:

\[
10\% \times \frac{100}{350} \times 50\% = 0.015
\]

The overall performance of the maintenance system can be determined by aggregating the contributions to business success of the observed states of all the system elements that have an influence on a relevant failure attribute.

In this procedure, mutually exclusive and collectively exhaustive *Failure attributes* that contribute to business success have to be identified. The same requirements also apply to the *System elements* that have an influence on a *Failure attribute*.

The more typical system audit tends to focus on the issue of conformance to a *standard* model both in system design and execution. It is assumed that the *standard* can be universally applied to achieve superior performance. The maintenance system audit questionnaires in Westerchamp (1993) and Wireman (1990) are developed on the basis of this concept. This approach to system audits fails to recognize that different organizations operate in different environments. Product, technology, organizational culture and the external environment are some of the key variables in an organization’s operating environment and they may be in a state of constant change. Superior performance will be achieved only if the internal states and processes of the organization fit perfectly in the specific operating environment. Sociotechnical System (STS) analysis provides a methodology
to design a system that will achieve this fit (Taylor and Felten 1993). Thus, the basic assumption of a *standard* reference model implicit in the design of the typical audit questionnaire is problematic.

An effective system audit that focuses on the organization’s social systems can be designed on the basis of the Parsonian paradigm, which postulates that people are organized into groups to fulfill these four (GAIL) functions (Parsons and Smeler 1956):

- attaining goals that legitimize the group’s existence (G);
- adapting to external circumstances (A);
- integrating activities for survival (I);
- maintaining the possibility to function in the longer term (L);

In the context of maintenance management, these functions relate to four roles, namely user, designer, manager, and maintainer, respectively. Running through these roles are three macro processes that collectively contribute to achieving the goals of the organization:

- Producing (products).
- Maintaining (equipment).
- Modifying and building (new facilities)

The equipment can be in the *start-up*, *stabilising*, or *stable* phase. The interface between the roles and processes must be managed and controlled in ways which are appropriate to the equipment’s phase of existence. For example, when the equipment is in the *start-up* phase, Engineering (the designer) and Production (the user) should play a leading role in maintenance. However, when the equipment is in the *stable* phase, Maintenance and Operations Management should become the driving force.

Organizational culture, the *softer* aspect of the organization, is an important element that can also be assessed by a culture audit. Scores relating to various dimensions of the organization’s culture can be plotted on a multifactor chart developed from the competing values model (Quinn and
Rohrbaugh 1983). The four quadrants in the chart defines four orientations of cultural dimensions: innovative, supportive, rule-oriented, and goal-oriented, which correspond to the adaptive, pattern maintenance, integrating, and goal-attainment functions, respectively in the Parsonian paradigm. A culture audit can bring out the cultural differences, if any, between various parties in the organization. It can also detect mis-matches between an organization’s culture and its approach to maintenance management, such as introducing self-directing teams in a Production Department which has a very low level of innovative and goal orientations (Rensen 1995).

The alignment between strategy, actions and performance measures, a basic principle in the design of performance measurement systems, can be audited using the Performance Management Questionnaire (PMQ) developed by Dixon et al. (1990). The tool can also be applied to perform a reality check on the performance measurement in practice rather than the one on paper. Any deficiencies identified from these processes will become the driver for realigning perceptions, or changing the measurement system.

2.7. Performance Analysis

Performance analysis is the measurement and comparison of levels of achievement of specific objectives. To evaluate the overall performance of maintenance operations across organizations in a specific industry, the measures of achievement must not be influenced by matters unrelated to non-operational issues, such as accounting and taxation rules, or financing arrangements. In single-input, single-output cases, productivity defined as the ratio of output to input is an adequate measure of operational performance. However, the analysis becomes more complex when multiple inputs and multiple outputs are involved. These multiple inputs could have different units of measures and the same situation may also apply to the multiple output measures. Consider the case of comparing the maintenance performance of railway systems. The inputs can include available kilometres, passenger...
trips per day, rolling stock and station facilities, etc. O&M costs per car operating kilometre, and car operating kilometre per total staff plus contract hours are examples of the multiple outputs.

*Data Envelopment Analysis* (DEA), developed by Charnes, Cooper and Rhodes (1978), is a non-parametric approach that can be used to compute multiple-input, multiple-output productivities. It does not require preassigned weights for inputs and outputs; these are implicit in the data set. Performing DEA requires the solution of a linear programming (LP) model for each decision-making unit (DMU) in the peer group. The set of solutions of the LP models in the data set will define the *data envelopment surface*, a piecewise empirical extremal surface, in a hyperspace with \( m + s \) dimensions where \( m \) is the number of inputs and \( s \) is the number of outputs. DMUs which are on the data envelopment surface, also known as the *efficient frontier*, are considered top performers amongst their peers.

Fig. 2.8 shows the envelopment surface of 8 DMUs each consumes a single input \((x)\) to produce a single output \((y)\). The piecewise linear efficient frontier is defined by DMU\(_1\), DMU\(_3\), DMU\(_5\), and DMU\(_6\). The other 4 DMUs which lie below the surface are considered inefficient.

![Fig. 2.8 Data Envelopment Surface for the Additive Model](image-url)
A number of basic DEA models have been developed. The choices for the basic models depend on the type of envelopment surface employed and the measure selected to quantify the degrees of inefficiency associated with those DMUs that do not lie on the efficient frontier. Essentially there are two types of surface, namely constant returns-to-scale surface and variable returns-to-scale surface. The efficient frontier shown in Fig. 2.8 is an example of variable returns-to-scale surface.

In the case of constant returns-to-scale surfaces, they must pass through the origin of the hyperspace that defines the data set. The dotted line radiating from the origin and touching DMU\textsubscript{j} in Fig. 2.8 is an example a constant returns-to-scale surface.

Consider the case in which there are \( n \) DMUs, each of which consumes varying amounts of \( m \) different inputs to produce \( s \) different outputs. The amounts of inputs consumed by DMU\textsubscript{j} are \( X\textsubscript{j} = \{ x\textsubscript{ij} \} \) (for \( i = 1, \ldots, m \)) to produce the amounts of outputs at values \( Y\textsubscript{j} = \{ y\textsubscript{rj} \} \) (for \( r = 1, \ldots, s \)). It is assumed that \( x\textsubscript{ij} \geq 0 \) (less is better) and \( y\textsubscript{rj} \geq 0 \) (more is better). Furthermore, all the inputs and outputs are discretionary, i.e., the amounts can be varied at management’s discretion. Let \( X \) denotes the \( m \times n \) matrix of input measures, and \( Y \) denotes the \( s \times n \) matrix of output measures. The additive DEA model, which prescribes a variable returns-to-scale and piecewise linear envelopment surface, takes the following form:

\[
\min_{\lambda, s^+, s^-} z_0 = -\mathbf{1}s^+ - \mathbf{1}s^- \\
\text{s.t.} \quad Y\lambda - s^+ = Y_0 \\
\quad -X\lambda - s^- = -X_0 \\
\quad \mathbf{1}\lambda = 1 \\
\quad \lambda, s^+, s^- \geq 0
\]

The constraint for \( \lambda \) specifies the convexity of the efficient frontier. This LP problem is solved for \((X_0, Y_0) = (X_j, Y_j)\) where \( j = 1, \ldots, n \). Each \((X_0, Y_0)\) represents a specific DMU to be rated. A DMU is on the efficient frontier if the corresponding LP model yields \( z_0^* = 0 \) (an optimal
value is denoted by "\textit{\textbullet}". When any component of the slack variables \(s^{*}\) or \(s^{-}\) is not zero, the corresponding DMU is not on the frontier, i.e., it is inefficient. In the latter case, \(z_{0}^{*}\), \(s^{**}\), and \(s^{-}\) provide respectively an overall measure of inefficiency, as well as the amounts of inefficiency in the various outputs and inputs.

A review of the various basic DEA models and their extensions to deal with complications such as inputs and outputs that are non-discretionary, or have categorical values can be found in Charnes \textit{et al.} (1994).

DEA is often supplemented with multiple regression analysis to identify the significant factors contributing to superior performance of the DMUs on the frontier.

The procedure has been used to compare the operational performance amongst airlines (Schefczyk 1995), hospitals (Ozcan and McCue 1996), schools (Thanassoulis 1996), and special economic zones in China (Zhu 1996). An example illustrating the use of DEA to study the performance of a number of aircraft maintenance operations over multiple time periods can be found in Charnes \textit{et al.} (1985).

\textbf{2.8. Concluding Remarks}

Performance measures will only provide useful information for guiding management decisions and shaping desirable employee behaviour if they are appropriately selected to fit the operating environment peculiar to the organization. The indiscriminate use of commonly employed performance measures without regard to their underlying assumptions and their adequacy in reflecting the organization's strategic focus may lead management astray by providing misleading information for management decisions or giving incoherent signals to employees on what factors are important to the organization's success.

Maintenance performance measurement is a complex task since multiple inputs and multiple outputs are involved in the process. Various approaches to measuring maintenance performance have
been reviewed. The value-based performance measure attempts to assess the impact of maintenance activities on the future value of the associated assets. However, the procedure involved is laborious and it has a limited focus — the measure is a financial indicator expressed in terms of future cash flows. The Balanced Scorecard provides an alternate and holistic approach to measurement which is developed on the notion that no single measure is sufficient to indicate the total performance of a system. It translates the organization's strategy on maintenance into operational measures in multiple dimensions that collectively are critical indicators of current achievements and powerful predictors of future maintenance performance. While some of the indicators featured in the Balanced Scorecard are easily quantifiable (these are known as hard measures), some others are soft measures which lend themselves to evaluation by using the system audit approach. Examples of soft measures include the fit between organizational culture and the structuring of maintenance work, the vertical alignment of objectives at different levels of the hierarchy, and horizontal integration across multiple functions that interact with maintenance. System audits designed on the basis of STS analysis provide an approach to predicting future maintenance performance with particular focus on interactions between the social system in the organization and its operating environment. The extent of alignment within the organization can be surveyed by using instruments such as PMQ.

Value-based measures, the Balanced Scorecard, and system audits are approaches to measuring the maintenance performance of an organization. When the operational efficiencies of multiple maintenance organizations are to be compared quantitatively, however, the DEA approach will be appropriate.

**Recommendations for Future Research**

The Balanced Scorecard has received increasing acceptance in industry as the model for measuring overall performance of business units. Despite such interest in industry, the feasibility of applying the BSC model for managing performance of a specific function, maintenance for instance, is still
an uncharted area which needs researching. In this context, the specific issues are:

(a) What processes should be in place to:
   - implement a BSC-based performance management system for maintenance operations?
   - match the strategy, as manifested in the measures of the BSC, with the culture and the prevailing operating environment of maintenance operations?
   - ensure vertical alignment and horizontal integration?

(b) A typical BSC for a business unit has measures representing four perspectives: financial, customer, internal processes, learning and growth. Are these perspectives still appropriate for the BSC of maintenance operations?

(c) What is the optimum number of performance measures to be included in the maintenance BSC?

(d) How to validate that the BSC reflects the declared strategy of the maintenance operation? The following questions are relevant:
   - How to ensure that the various performance measures used are associated with each other and linked to the strategy?
   - How to ascertain the completeness of the measures in the BSC?

(e) When problems are identified in the periodic reviews, how to ensure that the system will regulate itself, such as modifying the strategy, fine-tuning the action plans, or replacing inadequate performance measures with better ones?

(f) Are there generic measures for evaluating maintenance performance?

(g) How to analyse the costs and benefits of a maintenance performance management system?

(h) In measuring maintenance performance, what are the measures that relate to:
   - the learning and growth perspective?
   - the performance drivers that can be used as lead indicators (predictors of performance)?
(i) What elements of organizational infrastructure are mandatory to support the BSC-based maintenance performance measurement system?

(j) What are the success factors and common pitfalls in implementing the BSC-based performance measurement system?

The performance of maintenance operations can be enhanced only to the extent that the stakeholders concerned behave in an orchestrated manner that will ensure availability of productive assets to meet demands at minimum life cycle cost to the organization. The framework built around a Balanced Scorecard as outlined in Fig. 2.6 provides a model for achieving this goal. Investigation into the issues listed above will surely shed light on the contributing factors to ensure success of the maintenance performance measurement system.

Some of the agenda items listed above fall in the focus of this study.
3. Strategic Dimensions of Maintenance Management

3.1. Introduction

A holistic approach to measuring maintenance performance that captures the strategic perspectives has been presented in the previous chapter. The centre-piece of the approach is the balanced scorecard, the design of which is driven by the organization’s maintenance strategy. The various dimensions of maintenance strategy are examined in this chapter.

The functions of maintenance have been discussed extensively in the literature. The EUT maintenance model (Geraerds 1992) identifies the processes involved in meeting the maintenance needs of technical systems already in place and the interrelationships of these processes. The management processes embedded in the maintenance function are modelled by Cortes (1997). The MESA model (Murray, et. al. 1996), on the other hand, shows the links between different types of maintenance decisions. At a higher level of abstraction, Visser models maintenance as a transformation process encapsulated in an enterprise system (Visser 1998). In Visser’s input-output model, the resources deployed to maintenance include labour, materials, spares, tools, information and money. The way maintenance is performed will influence the availability of production facilities, the volume, quality and cost of production, as well as safety of the operation. These, in turn will determine the profitability of the enterprise. Since the use of external service providers has always been an option in maintenance decisions, the inputs to the maintenance process should also include these external resources, see Fig. 3.1.
From the above input-output model, four strategic dimensions of maintenance as listed below can be identified. The first relates to the inputs, the next two are concerned with the design of the maintenance process itself, and the fourth one is about the support systems.

(1) Service delivery options — the choice between in-house capability and outsourced service.
(2) Organization of the maintenance function and the way maintenance tasks are structured.
(3) Maintenance methodology — the selection of maintenance policies.
(4) Elements in the infrastructure that support maintenance.

3.2. Service Delivery Options

In the past, when the merits of vertical integration were emphasized in management thinking, maintenance activities in organizations were typically performed by internal suppliers. External suppliers were used only under the following situations:

- The available in-house maintenance capability was insufficient to meet peak demand. In such cases, short-term outsourcing would be used to fill the shortfall.
- The expected volume of maintenance work was too small and the variety of maintenance related specialist skills too wide to justify at least one specialist on standby.
- The organization did not have the expertise and specialized facilities to perform the maintenance work; the cost of developing such capabilities and assets in-house would be prohibitive while there were established suppliers in the market to provide the required services.

In recent years, a trend has emerged that subscribe to the concept that unprecedented business performance can be achieved if the skills and resources, limited commodities in an organization, are better leveraged to focus on a set of core competencies. Core competencies, a key concept in this approach, is defined as a bundle of skills and technologies that enables an organization to provide
a particular benefit to customers (Hamel and Prahalad 1994). Thus, maintenance activities for which the company has neither a strategic need nor a special capability are prime candidates to be outsourced. The maintenance services typically outsourced include the maintenance and repair of generic and common equipment, electronics, environmental equipment, mobile fleets, buildings and grounds, projects and improvements, as well as plant overhauls (Campbell 1995b).

The selection of maintenance service delivery options should not be regarded as a purely tactical matter. The decision should be made in the context of the company's overall business strategy. When companies consider outsourcing of their maintenance activities as a strategic option, they need to answer three key questions: What should not be outsourced? What type of contractual relationship with the external service supplier should be adopted? How to manage the risks of outsourcing?

What Should Not be Outsourced

There are two key strategic issues that determine the option between outsourced and internally provided services (Quinn and Hilmer 1994). The first factor is the potential for achieving a sustainable competitive edge by performing the work internally. If management perceives that achieving preeminence in performing certain maintenance services — done cheaper, better, or in a more timely manner — will enhance the company's competitiveness, such services should be done internally. The second factor is the degree of strategic vulnerability if the work is outsourced. If there is insufficient depth in the market, an overly powerful supplier can hold the company ransom. On the other hand, if the individual suppliers are too weak, they may not be able to supply quality and innovative services as good as the buyer could by performing the work internally. Knowledge is another important dimension that affects vulnerability. It is extremely risky to outsource work when the company does not have the competence to either assess or monitor suppliers, or when it lacks the expertise to negotiate a sound contract.

Obviously, companies should not outsource those activities that are crucial elements of their core
competencies. However, this caveat is often not heeded when outsourcing decisions are driven by cost-cutting and headcount-reduction criteria. As a result, control of activities critical to establishing the company’s competitive advantage can be unwittingly ceded to suppliers.

Interpreting “core competencies” as “things that we do best” is fallacious. This misconception is damaging as it encourages management to outsource activities with which it is having problems. If the company has difficulty in managing an internal supplier, it probably cannot communicate its requirements adequately to the external supplier. Thus, internal problems are traded with more sticky problems of dealing with external suppliers. It will be even more devastating if the problematic activity over which the company relinquishes control is a critical link in its current or future value-creation process.

When an external supplier offers a significant cost-saving deal on the company’s core activities, management should refrain from outsourcing them. Instead, the internal service provider should be challenged to improve its cost-effectiveness, using the supplier’s offer as a benchmark of performance. Furthermore, one should not rule out the possibility that the supplier may be using a “loss-leader” tactic in making the favourable offer to the client — the price differential could well be the supplier’s investment in controlling and developing such strategic capabilities (Lonsdale and Cox 1997).

Not all the “things that we do best” would qualify as the organization’s core competencies. Venkatesan (1992) points out that these capabilities are core to the organization only if they:

- have a high impact on what customers perceive as the most important service attributes;
- require highly specialized knowledge and skills and specialized assets, all of which are in short supply;
- involve technology that is still fluid, and a clear technological lead is the likely prize of being the successful pioneer in applying that technology.
Obviously, these core capabilities should be kept within the organization. When a maintenance service, which can be one of the "things that we do best", has been classified as a non-core activity, it can be considered to be outsourced. However, the decision depends on the relative costs of in-house and external provision of that service. Apart from the direct costs involved, the relevant transaction costs in the two options are:

(a) Internal provision — continuing R&D, personnel development, and infrastructure investment that at least match those of the best supplier to maintain a competitive edge; overhead for managing the insourced activities.

(b) Out-sourcing — the costs of searching, contracting and controlling the outsourced activities.

If it is found to be more cost-effective to keep an exemplary but non-core capability, the company should explore the possibility of commercializing the expertise to serve the needs of non-competitors. For example, a railway company may have developed a high speed in-process inspection system to monitor the wear on brake plates while the train car is being cleaned in the car-wash. Since the automated system is not a key element of the company's competitive edge, it can be made available to other railway companies or maintenance service providers to generate extra revenue.

**Choosing the Type of Contractual Relationships**

The potential benefits of outsourcing maintenance activities include less hassle, reduced total system costs, better and faster work done, exposure to outside specialists, greater flexibility to adopt new technologies, and more focus on strategic asset management issues (Watson 1998, Campbell 1995). However, these are seldom realized because the contracts tend to be task oriented rather than performance focused, the relationships between the outsourcing company and the contractors are adversarial rather than partnering. This phenomenon is caused by the problem that the profit motives of the parties involved in the relationship are not shared — the contractor wishes to maximize
returns, whilst the client’s major goals are to minimize costs. As a result, competitive bidding is the preferred mechanism for selecting contractors. In response to the lack of long-term commitment from the client, the supplier makes minimal investment in staff development, plant, equipment, and new technologies. This short-term tactic adopted by the contractor, in turn, often causes the client to replace one adversary with another, thereby setting a vicious circle in motion.

The type of maintenance contract in use is an important factor that determines the relationship between the outsourcing company and its service suppliers. Martin (1997) classifies maintenance contracts into three types, namely work package contracts, performance contracts, and facilitator contracts, see Fig. 2. Brief discussions of these contracts follow.

<table>
<thead>
<tr>
<th>Type of contract</th>
<th>Type of service</th>
<th>Contract complexity</th>
<th>Client-contractor relationship</th>
<th>Client maintenance knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work package contract</td>
<td>Fixed number of activities, lump sum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance contract</td>
<td>Availability, budget constraint</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facilitator contract</td>
<td>Maximizing asset utilization, cost/output</td>
<td></td>
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<td></td>
</tr>
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</table>

Fig. 3.2 Types of Maintenance Contract (Source: Martin 1997)

*Work package contracts* are the most basic form of maintenance contracts. Design of the maintenance concepts, planning and control logic, as well as spare parts management are performed by the client, who tells the contractors when they are needed to do what maintenance activities. Evidently, this mode of contracting is task oriented, and the contractors are engaged as mere providers of skilled manpower and tools to execute well defined work specified by the client.

*Performance contracts* are also known as *performance specified maintenance contracts* (PSMC).
This mode of contracting applies to cases where a comprehensive range of maintenance services are awarded to a single contractor. Instead of specifying what and when maintenance activities are to be performed, the contract stipulates the desired performance on key outputs, such as failure rates, availability, response time, and time for restoration of system interruption. It requires the contractor to inspect, measure, decide on priorities, design and implement the work. Furthermore, the supplier also has to monitor and make adjustments to the implementation to meet the required outputs. By allowing flexibility in achieving the desired outputs and providing performance-linked incentive, this approach encourages the supplier to invest in new technology and innovation to seek continuous improvement (Watson 1998).

*Facilitator contracts are also known as term lease contracts.* In this mode of contracting, the client is only the user of the physical assets owned and maintained by contractors. A long-term partnership relationship needs to be in place if the contractor has to provide assets constructed to meet the specific operational needs of the client.

A fourth type of maintenance contract is management consultancy, in which a consultant is hired to provide management only services — specifying the ‘what’, ‘how’ and ‘when’ of a wide range of maintenance services. These services are delivered by independent service providers sourced and managed by the consultant on behalf of the client (Rafter 1998).

The arms-length relationship of work package contracting is appropriate for short-term outsourcing, designed as a supplement of the client’s in-house capability during periods of peak demand. If it is applied as a policy for long-term outsourcing, the practice is prone to wastage, inefficiency and duplicated effort. On the other hand, the approach of engaging a management contractor under a fixed management fee, while absorbing all other costs associated with service delivery does not motivate the external service providers to apply innovative practices and make
continuous improvement.

PSMC is the preferred contracting policy for strategic outsourcing because of its potential of leveraging the contractor’s knowledge and creativity to deliver optimal maintenance service. The experience of government agencies and state owned organizations in Australia which had outsourced their maintenance activities showed that more value can be obtained from this type of contract by incorporating the following features (Pyman 1998 and Watson 1998):

- specify performance measures linked to the client’s business plan and regulatory requirements;
- the supplier’s management staff and field technicians dedicated to the contract are located at the client’s premises; the integration provides the benefits of an in-house workforce such as instant communication, minimal disputes, ownership of work, and system knowledge;
- contractor and client use the same maintenance management system for processing of both job and financial transactions;
- reward performance with contract extension; penalise persistent non-performance with termination of contract.

The cooperative relationship engendered in this approach can significantly reduce the transaction costs of receiving maintenance services and information. This is because contracts focusing on demand side requirements (the desired maintenance performance), joint rewards, and information sharing are more flexible, less complex and less expensive to execute.

Term lease contracting offers the benefits of PSMC at a higher cost by taking the burden of capital investment off the outsourcing company. For assets already owned by the company, transferring the ownership of these items to the maintenance contractor provides a source of cash infusion to the company.

Frey and Schlosser (1993) specify the proper focus of strategic outsourcing. In the case of outsourcing maintenance services, companies should focus more on enhancing business critical
performance parameters rather than on reducing headcount, more on minimizing total cost than on minimizing elemental costs, more on capturing asset management knowledge than on buying maintenance services, more on developing meaningful relationships with a few suppliers than on enlarging the supplier base.

**Managing the Risks of Outsourcing**

While outsourcing a whole range of maintenance services has the potential for significant benefits, it also exposes the company to the following risks (Quinn and Hilmer 1994 and Campbell 1995):

- **Loss of critical skills** — The company can quickly lose its critical maintenance skills after the related services have been outsourced. It will be devastating if subsequently the contractor is found to lack the capability or commitment to performing up to expectations and a promising replacement cannot be identified promptly.

- **Loss of cross-functional communication** — When complete or partial maintenance activities are outsourced, contacts between maintenance and other functions that interact with it tend to reduce, especially when the contractor is operating away from the company's site. The contractor's staff are seldom as prepared as in-house colleagues to go beyond their immediate remit and take the time to work out innovative solutions to problems encountered.

- **Loss of control over a supplier** — A contractor, after building up its expertise with the outsourcing company's support, may decide to offer the acquired knowledge to competitors. Apart from the above risks, there are other factors which render the expected benefits of outsourcing unattainable. These include:

  - **Shifts in the balance of power during the contract period** — While managers are alert to the risks of outsourcing into a supply market with only one, or very few, feasible suppliers, they often overlook the possibility that the balance of power may change during the period of a contract even in broader supply markets. Companies that have lost their maintenance skills will
be at the mercy of their service suppliers when the contractual relationships are adversarial. Signals that demonstrate a contractor’s dominance over the relationship include a decline in responsiveness to requests, a decline in the quality of the work provided, and the replacement of the original contract team with one of an inferior grade.

- *Employee morale* — Most employees perceive outsourcing as a negative development. They have to face the uncertainties of radical changes such as new roles, new skills or, if they also consider the option of moving to an external service supplier, new organizations. Employee morale will suffer if these anxieties are not addressed by management in the early stage of the move (Lonsdale and Cox 1997).

- *Hidden costs* — Companies often underestimate the setup costs of outsourcing, including staff redeployment costs and longer-than-expected hand-off or parallel running costs, as well as the costs of contract management (Earl 1996). Excess charges are another form of hidden costs. They arise due to incomplete coverage of a contract — certain aspects of maintenance work are mistakenly believed to have been covered in the scope of the contract.

- *Access to external talents* — Contrary to common belief, access to external talents can be limited. First, the outsourced work is often supported by the company’s previous technical staff. Second, contractors often siphon talented employees to woo other accounts, and they prefer specific directions and rarely initiate new strategies (Lacity et al. 1993).

To avoid these risks, companies are advised to adopt measures listed below:

1. **Take care of the affected employees.** The company should inform its maintenance staff of the outsourcing decision as soon as possible, and provide them with outplacement service if necessary. Typically, the contractor will hire some of the displaced employees on a trial basis to ensure continuity of service and knowledge in the transition period.

2. **Avoid outsourcing contracts that are set in concrete.** Incorporating variation clauses in the
contract and specifying annual contract reviews are not foolproof and optimal approaches to dealing with uncertainties. A more effective way to hedge against uncertainty and change in outsourcing arrangements is to create a process of conflict resolution and problem solution for the inevitable uncertainties (Earl 1996).

(3) Split maintenance requirements between two or more suppliers to establish a threat of competition (Lacity et al. 1995). The competition will be aggressive when the multiple contractors are roughly equally efficient. In case only one supplier seeks a contract, the company can still encourage competition by maintaining an option to perform some or all of the maintenance activities in-house (McMillan 1990). The potential contract covering those activities currently withheld from being outsourced serves as a carrot for good performance.

(4) Insist the supplier to use a stable team for service delivery. If the company knows a trusted candidate, specify that person as the supplier’s account manager in the contract. In addition, the suggested features of a performance specified maintenance contract (PSMC) mentioned earlier, as well as frequent and close contact with contract employees all help to build partnering relationships with suppliers.

(5) Use three specialist teams in the contracting process. First is a contract negotiation team consisting of in-house technical experts with a deep understanding of the company’s maintenance requirements. Second is a contract management team established to get the most out of maintenance contracts. The specialists on this team should be knowledgeable in the hired service providers, the users, and the contracts. They challenge suppliers when they are not meeting the terms of the contract, deal with disputes over the contract’s interpretation, and determine penalties. The team also decides when users are asking too much or too little of suppliers. The third team consists of technical experts whose job is to monitor changing technology, changing business needs, and the changing capabilities of available maintenance
3.3. **Organization and Work Structuring**

The strategic decisions involved in the organizational design and structuring of maintenance work include: plant specialization, workforce location, composition and flexibility of workforce. These decisions are made by taking into consideration factors such as workload characteristics, plant location, cost of unavailability, skills and knowledge required, production policy and human resource policy.

In traditional organizations, the structure is hierarchical and highly functionalised: engineering is responsible for the design and procurement of new plant as well as modification of existing ones, production is responsible for operating the plant, and maintenance for maintaining it. Furthermore, the maintenance tradeforce is organized into highly specialised trades. This type of organizational design has the following problems which can result in poor operational efficiency:

- Low utilization of resources, because of the many small single-trade or single-shift maintenance and production groups — often manned up to the peak of a variable workload.
- The vertical and horizontal polarization within the structure is not conducive to organizational learning. For example, it becomes difficult to feedback maintenance information to aid the specification of new plant.
- It does not foster a sense of ownership of assets.
- The fine-grained demarcation of trades and skill levels creates an inflexibility which causes inefficiency in the planning and execution of those maintenance works that involve multi-trade tasks;
- High management cost due to an excess of hierarchical layers and functional positions.

The type of maintenance work to be performed is an important factor affecting the design of
maintenance organizations. Maintenance work can be classified by its planning and scheduling characteristics as follows (Kelly 1997):

(1) **First line work** — This type of work is performed on a daily basis. It consists mainly the emergency corrective work, jobs that have to be carried out immediately or with minimum delay due to safety or economic imperatives. Since these jobs occur randomly, they cannot be scheduled in advance. Simple deferred corrective jobs and frequent preventive routines, such as minor replacements, inspection and lubrication, are also included as first line work to smooth out the fluctuating emergency workload.

(2) **Second line work** — It consists of deferred corrective work involving jobs that usually take less than two days to complete and require relatively few tradesmen. Also included are minor reconditioning work as well as short or medium periodicity services and preventive work. This type of work can be prioritized, planned and scheduled in the long term.

(3) **Third line work** — It comprises major shutdown, plant overhaul, capital projects and modifications. It creates peak loads at medium to long-term intervals.

Clamp (1996) proposes an alternative way to categorise maintenance work:

(1) **Level 1 maintenance** is performed to keep the plant running. It covers activities such as minor repairs, process testing, production scheduling and environmental control — the immediate support required by the production plant. These are first line work in Kelly’s classification.

(2) **Level 2 maintenance** covers those activities which produce significant changes to the condition of the plant, such as major component replacement and detailed inspection. It is in-situ work executed intermittently.

(3) **Level 3 maintenance** requires very special skills and facilities. It covers activities such as overhauls, reconditioning and plant modifications. These are third line work in Kelly’s categorization.
The pertinent organizational design issues for maintenance are discussed below:

**Plant Specialization**

This can range from a plant-flexible tradesman who is responsible to work on all plant to a plant-specialized one who only works in a specified area or on a particular type of plant. The advantages of plant specialization include improved work quality and faster response due to greater plant knowledge and sense of ownership. A stronger spirit of team-working with the plant operators can also be developed. However, this mode of organization will face a major problem when the workload varies considerably from one plant-specialized group to another. In such case, labour utilization will be lower because the workload cannot be balanced by exploiting labour mobility.

**Workforce Location**

Should the maintenance workshop be centralized or dispersed? Plant-flexible trade groups are usually located centrally or close to their designated area. When a particular type of equipment is used in widely scattered locations, such as compressors in a large oil field, roving trade groups may be employed to maintain such plant. The plant-specialized trade groups will obviously be located close to the plant they maintain. The main problem with decentralized plant-specialized groups is that it is difficult to achieve flexible labour movement between trade groups.

Location of the tradesforce also depends on the type of maintenance work it performs. If fast response and deep knowledge of the plant are imperative, the responsibilities for first line (level 1) work, and for the necessary resources, are best shoudered locally, within each plant. Due to its specialist nature, third line (level 3) work is usually performed by a centralised unit located away from the plant.

The knowledge and skills involved is another factor that determines how the maintenance function is organized. If the work requires a new capability to be developed by the service provider, as in the case when power electronics is first introduced to replace electro-mechanical controls in a railway
system, it is best done by a centralised unit. Apart from simplifying the management of the learning process, the requisite expertise can be built up more quickly when all such work is channelled to the central unit. After ample experience and deep knowledge of the work have been acquired, deploying decentralized units to provide the maintenance service becomes a feasible option.

The degree of centralization of the maintenance function can also be a function of asset life cycle. Consider a railway system, during the initial stage, most of the activities are project oriented. Accordingly, only a small and centralized maintenance team would be required. When the system gradually entered into full operation, both the level of activities and the tradeforce of the maintenance function would increase, thereby driving the need for decentralization. As the system matures and the organization becomes more decentralized, effective communication and synergy will suffer. Through automation, some dispersed activities can be performed centrally to improve performance.

**Workforce Specialization**

Trade specialization is a characteristic of traditional maintenance organizations, the drawbacks of which have been highlighted earlier. Where the work requires special skills and where the workload can be made relatively smooth, it is appropriate to adopt trade specialization. This situation can exist in the second line reconditioning workshop. However, it is more often to find maintenance work that requires a range of skills, although one skill is usually predominant. In such case, inter-trade flexibility is of paramount importance. This can be achieved by developing a multi-skilled tradeforce. However, making the transition from a highly specialized structure to a flexible one is often a lengthy and expensive process because of the investment in training and the installation of the new structure.

Apart from introducing inter-trade flexibility within the maintenance tradeforce, there is another emerging trend in maintenance management — amalgamating the roles of plant operator and first
line maintainer. The operator-maintainer is trained to both operate the plant and do first line maintenance across all the traditional trades. An advanced form of this approach is autonomous maintenance, a key element of total productive maintenance (TPM) pioneered by the Japanese (Nakajima 1988). The concept, to be discussed further in the next section, fosters the sense of plant ownership by developing the operator-maintainer to be involved in continuous improvement.

**Structuring of Maintenance Work**

Clamp (1996) advocates that level 2 and level 3 work (defined earlier) should be organized around whole tasks. These could be significant fabrication work or overhauls of a particular type of plant items such as motors, pumps, or compressors. Workgroups with the resources to plan, do and evaluate these whole tasks in as self sufficient a way as possible need to be established. Each workgroup will have the responsibility of satisfying the customers of its particular service.

When the quantity of work does not justify setting up a separate workgroup for each of the identified whole tasks, it is necessary to aggregate the whole tasks into clusters which offer mutual benefit to the tasks and the assigned workgroup. The clustering can be determined by assessing strength of the relationships between tasks based on four factors: technology (skills, knowledge, and common equipment required), information (for planning, scheduling or modification), the interaction between one task and the other, and the degree to which the output of one task becomes the input to the other. For example, maintenance work on motors, gearboxes, and pumps can form a cluster. Each workgroup thus formed is a group of technicians with aggregate skills to tackle its whole tasks.

The practice of work structuring tends to move organizations from rigid functionalism towards task based structures. This makes it more important to have functional centres of responsibility to maintain plant standards. Each functional centre of responsibility needs to determine the mandatory plant standard and ensure the long term training and career paths of the respective engineers and technicians.
Yet another approach to solving the common maintenance problems is to make the engineering staff responsible for the plant and locating them, to the extent practicable, next to the corresponding production staff. The engineering staff become the plant owners, taking on the responsibilities of asset management. In some organizations, the asset management unit also embodies the functional centres of responsibility mentioned above.

**Interface with Operations**

This issue is particularly relevant to level 2 work because it is done in-situ. The appropriate degree of integration between operation and the maintenance support service can be determined by using a methodology called technology profiling which is based on the concepts of hard technology and soft technology. Hard technology is reliable and stable. When the level 2 maintenance work involves predominantly hard technology, such as the annual maintenance of a toll bridge, the related support engineering can be organized separately from operation and the work handled by a separate maintenance unit.

Soft technology, on the other hand, is insecure and evolving, as in the case of grand prix car racing. In such environment, engineering needs to be closely integrated with operation, and there is a strong case for professional, broadly skilled engineering to support the more complex, varied, flexible and changing process technology because the frequent interactions (Clamp 1996).

**Teamworking**

Hierarchy and fractionated tasks (a result of specialisation) are the design logic of traditional organizations. In this approach to organizational design, people are not expected to respond to unpredictable events. It works fine for stable environments, but is ill suited in work situations with inherent uncertainties, as the case with maintenance work: the multiple possible locations of a fault, the variability in the extent of damage caused by a failure, and the differing windows of opportunities available for disruptive work to be performed on the plant. Self-managing teams (SMTs), which aim
at leveraging and enhancing employees' capabilities, and commonly used in agriculture, in mining, and in construction, are better suited for such turbulent environments. Members in a self-managing team are responsible for both executing the task as well as monitoring and controlling their own performance. Each SMT needs to contain sufficient variety to match the range of its work tasks. It also needs the autonomy to adjust and reorganize its internal resources, skills and competencies in response to the changed needs of its work. With these design features, SMTs are immensely flexible and responsive, and members are highly satisfied in doing their work.

Sociotechnical systems (STS) concepts (Taylor and Felten 1993) provide the theoretical basis for SMTs. The design principles for establishing SMTs as proposed by Kolodny and Stjernberg (1993) are summarised as follows:

- Team activities are task-oriented and designed with a strong performance focus.
- The team is organized to perform whole and integrated tasks.
- The team should have some autonomy (that is, control over many of its own administrative functions such as self planning, self evaluation, and self regulation.) Furthermore, members should participate in the selection of new team members.
- Detailed specifications of tasks, procedures and methods are kept to minimum. Only those essential for information sharing with outside parties, for scheduling, or for coordination are established. Within the team, standards are arrived at through agreement on group norms. The flexibility allows the team to evolve and change as members grow and develop, and increase their competencies through multi-skilling.
- Multiple skills are valued. This encourages people to adapt to planned changes or occurrence of unanticipated events.

Examples of successful SMTs and their critical success factors are reported by Hackman (1986b), Kolodny and Stjernberg (1993), Gephart and VanBuren (1996). Workgroups consisting of operator-
maintainers introduced earlier, who are also empowered to manage their day-to-day activities with minimum direct supervision are SMTs with first line maintenance work in the portfolio of their responsibilities (Kelly 1997).

Introducing self-managing teams in an existing maintenance organization is a major undertaking with its pitfalls. A four-stage process for making the transformation is shown in Fig. 3.3.

Self-managing teams do not exist in isolation. A support system must be in place to make them successful, as highlighted in some of the managerial work in the transformation process. The required support system for various strategic initiatives of maintenance management will be discussed in a subsequent section.

<table>
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<td>Creating performance condition</td>
<td>Forming &amp; building the team</td>
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- Establishing and analysing the work to be done
- Determining the authority the team will have
- Assessing the costs, benefits, and feasibility of using a team to do the work
- Designing the team task
- Selecting team members
- Providing contextual support
- Arranging for needed material resources
- Helping the team establish its boundaries
- Legitimizing and assisting with the task-redefinition process
- Assisting in the development of group norms and member roles
- Providing opportunities for the team to learn from its experiences
- Providing opportunities for the team to renegotiate aspects of its performance situation
- Providing process assistance as needed to promote positive team synergy
- Providing opportunities for the team to learn from its experiences

Fig. 3.3 Stages of Managerial Work for Creating SMTs (Source: Hackman 1986a)

3.4. Maintenance Methodology

To keep a plant in running condition, it needs to receive primary care which includes routine servicing such as cleaning, fueling, lubricating, as well as periodic inspection and calibration. On top of these essential activities, policies have to be established to maintain plant availability. There are three basic approaches to maintenance: run-to-failure, preventive maintenance, and design
improvement.

(1) Run-to-failure (RTF) — Only routine servicing is performed on the item until it fails. This can be justified when the impact of failure is inconsequential or the investment in preventive measures exceeds the expected benefits of improved reliability or higher availability.

(2) Preventive maintenance (PM) — Items are replaced or returned to good condition before failure occurs. The most common forms of this policy are scheduled PM and condition-based maintenance (CBM), respectively. In the former approach, PM action is performed on the item at the scheduled time regardless of its actual condition. The schedule can be usage based or time driven. Since the schedule is often drawn up on the supplier’s recommendation made with limited, if any, local knowledge of actual use conditions, or from past experience, it is seldom optimal. PM schedules that minimize resource consumption or maximize availability can be determined through the use of quantitative decision models. Parameters featured in these models are factual information such as time-to-failure distributions, costs of intervention (inspection, repair, or replacement), and the consequence of failure. Jardine (1973) provides a wide range of decision models for PM policies. A survey of more recent work on PM models can be found in Tsang (1995).

It is obvious that under the regime of scheduled PM some items may be over maintained, that is, replaced prematurely. However, if the condition of the item can be monitored continuously or intermittently it will be possible to carry out PM actions only when failure is judged to be imminent. This is the concept of CBM. Performance parameter analysis, vibration monitoring, thermography, oil analysis, and ferrography are some of the condition monitoring techniques that support CBM. Each of these methods is designed to detect a specific category of faults. For example, vibration monitoring can be deployed to detect wear, imbalance, misalignment, loosened assemblies, or turbulence in a plant with rotational or reciprocating
parts. An OR model for optimizing replacement decisions which takes into account the information obtained from condition monitoring is provided by Makis and Jardine (1992).

(3) **Design improvement** — The design is modified to achieve one or more of these objectives: improve reliability, enhance maintainability, minimize maintenance resource requirements, and eliminate the need for routine servicing.

**Reliability Centred Maintenance**

The maintenance approach best suited to an item can be determined using the Reliability Centred Maintenance (RCM) methodology. It provides a structure for determining the maintenance requirement of any physical asset in its operating context, with the primary objective of preserving system function cost effectively (Moubray 1997 and Smith 1993). Identification of system functions and functional failures, as well as failure mode and effects analysis are important elements in RCM. Performing these analyses on assets for the first time is labour intensive and time consuming. It requires the involvement of the operators and the maintainers. There are two reasons for such requirement. First, it draws on the operators’ intimate knowledge about the asset concerned. The involvement motivates the operators to use their resourcefulness to develop innovative ways of performing the PM tasks. Second, the collaboration nurtures a teamworking spirit between operations and maintenance, replacing the adversarial relationship commonly exists between the two parties. It is also part of the buy-in process — being an active collaborating party of the decision process, operations will be more ready to implement the PM tasks they have to perform as determined from the RCM exercise. Furthermore, the learning outcomes and communications outcomes of RCM studies will enhance the organization’s intellectual assets. The knowledge and experience thus acquired are firmly locked up in the organization and they can be put to good use in creating value for future projects.

Being a costly and lengthy process, RCM should be implemented selectively. Only complex and
high risk systems, or those being grossly over maintained are likely to get benefits that justify the investment. One further caveat: RCM can create anxiety in the workforce. The existing maintenance practices are challenged — some of the current practices will be abandoned and new ones introduced. With elimination of non-value adding work on previously over-maintained assets, the workforce engaged in maintenance activities will be downsized. The prospect of job displacement is commonly perceived by employees as a threat to their job security. The challenge for them to learn new skills required by their new job requirements may also be threatening. Taking steps to allay these fears are key to successful implementation of RCM.

**Total Productive Maintenance**

RCM is an asset centred methodology with a primary focus on making decisions on the type of maintenance tasks to be used. Total Productive Maintenance (TPM), on the other hand, is a methodology with a very different orientation — it focuses on people and is an integral part of Total Quality Management (TQM). The methodology was developed in Japan’s manufacturing industries, initially with the aim to eliminate production losses due to machine breakdowns in Just-in-Time (JIT) production systems. TPM redefines the organization of maintenance work by applying the following principles:

- Cultivate a sense of ownership in the operator by introducing autonomous operator maintenance — the operator takes responsibility for the primary care of his plant. The tasks involved include cleaning, routine inspection, lubrication, adjustments, minor repairs, as well as cleanliness and tidiness of the operator’s work space.

- Optimize the operator’s skills and knowledge of his plant to maximize operating effectiveness. The operator is thus mobilized to detect early signs of wear, misadjustment, note oil leaks, errant chips, or loose parts. He is also involved in making improvement suggestions to eliminate the losses due to breakdowns or sub-optimal performance of the
plant.

- Use cross-functional teams consisting of operators, maintainers, engineers and managers to improve people and equipment performance.
- Establish a schedule of clean-up and preventive maintenance to extend the plant's life span and maximize its uptime.

Being relieved of the primary care activities, the expertise of the maintenance department can be redeployed to focus on more specialised work such as major repairs, overhauls, tracking and improvement of plant performance, creation, replacement and modification of physical assets. Instead of having to attend to numerous chores, it can devote its resources to address strategic issues like formulating maintenance policies, implementing maintenance information systems, scanning and introducing new maintenance technologies, training and development of the workforce in operations and maintenance.

TPM is not a quick solution. It requires a change in employees' attitude and their values, which takes time to accomplish. Therefore, it demands long-term thinking and planning. Quick and company-wide performance gains should not be stressed in the initial stage. Senior managers must demonstrate their commitment to TPM by devoting time and allocating resources to create and sustain the cultural change and to provide necessary training to employees to achieve autonomous maintenance. Experience shows that planning and correct timing of moves are important. Full-scale implementation will be short-lived if it is not done after a corresponding change in work culture. To limit uncertainty and enhance the chances of success in the initial stage, small-scale pilot projects should be conducted where quick and visible benefits can be expected. The experience gained from these pilot projects can also be used to fine-tune the subsequent full-scale implementation (Tsang and Chan 2000).
3.5. Support Systems

The strategic initiatives discussed above such as multi-skilling, inter-trade flexibility, outsourcing, RCM, TPM, redesign of work processes and structures often fail to deliver the expected benefits. The main reason for such failures is that new values, management behaviours, and new support systems, including information, training, performance management, and reward systems, that align with these initiatives were not in place when the change programs were implemented.

Participation and Autonomy

Employee empowerment is a core concept shared by the change programs, with the expectation of creating internal commitment in employees. To get internal commitment, management must involve employees in defining work objectives, specifying how to achieve them, and setting stretch targets. If employees have little control over their destinies, the organization only gets external commitment which is akin to contractual compliance. Many organizations believe that they have embraced empowerment in their change programs. However, in more cases than not, employees receive mixed messages in these programs. For example, in many change programs, all the steps involved have been precisely prescribed by the change agent (management). The mixed message employees get in these initiatives is “do your own thing — the way we tell you.” With all actions and requirements defined externally, the resulting behaviour cannot be empowering and liberating. While autonomy should be a core concept of empowerment, management retains control through information systems, processes, and tools (Argyris 1998). Thus, employee participation and autonomy must be in place for empowerment to take root.

Hierarchy and Communication

Evolutionary psychology, the science which asserts that human beings retain the mentality of their Stone Age forebears, provides insights into human behaviour at work. Some of its findings that relate to hierarchy and communication in organizational settings are (Nicholson 1998):
- People tend to classify others into in-groups and out-groups. It explains why some groups, such as operations and maintenance, within organizations are so difficult to mix, an impediment to communication and organizational learning.

- Bad news is heard first and loudest.

- People tend to be risk averse when stay in the comfort zone. They are more willing to take risks when dissatisfied with the status quo.

- Informal communication networks exist throughout the organization and information passes through them rapidly. Having managers who wander around and ask questions can be an effective way to communicate, as long as it is done in a climate of trust and openness. Such informal practices also have the benefits of sending out positive signals and reinforcing official messages.

Managers will do well to recognize the above innate tendencies of human beings when communicating with employees. This is particularly important on sensitive issues such as outsourcing, de-layering, restructuring of work. Framing the situation as a crisis looming on the horizon (losing competitiveness due to high maintenance costs) and taking steps to address the expected anxieties of employees (no-layoff policy) are useful moves to get buy-in for change programs.

In a culture that stresses participation and autonomy, the function of hierarchy is not control but support. Decisions on broad-based issues, such as implementation of RCM or introduction of a new reward system, are made after management has entered into a dialogue with the affected employees. In their new roles, managers provide overall direction for the work that is clear and engaging. They also offer hands-on coaching and consultation to help employees avoid unnecessary losses of effort, to increase taskrelevant knowledge and skills, and to formulate uniquely appropriate performance strategies that generate synergistic process gains. They should also be responsive to requests from
employees to ensure that the resources required for performance are available when needed (Hackman 1986b). Every complaint should be considered an opportunity for improvement, and people are encouraged to turn their complaints into improvement ideas, as managers at Toyota do (Maccoby 1997). Employee empowerment can degenerate into exploitation if changes at the first level of management are not continuously reinforced by changes throughout the management hierarchy. Strong employee voice is needed to ensure that shopfloor concerns are heard at all levels of management (Adler 1993).

**Education and Training**

Empowerment will degenerate into abandonment if employees fail to get the right tools, training on their use, and support in their implementation. Educational resources, which can include technical consultation as well as training, must be available and accessible to employees with identified needs. For instance, the specialists of maintenance department are called upon to upgrade operators to operator-maintainers in TPM, or external consultants are hired to train members of the contract negotiation team and the contract management team for outsourcing of maintenance work. However, the training should not be limited to transfer of technical skills and knowledge needed for optimal task performance. It should also cover generic matters like the business imperatives peculiar to the organization (what determines the value of its product and services to customers), problem solving techniques, team dynamics and facilitation skills. The additional training managers receive addresses issues such as the new roles (leader, communicator, coach, resource providers) they perform in the change programs, and the new management behaviours that will align efforts and engender commitment towards organizational goals.

**Reward and Recognition**

According to evolutionary psychologists, the desire to obtain status in organizational settings is human nature. Attempts to eliminate status through de-layering, or removal of status markers such
as assigned parking space, will find new variations spring up in their place. Instead of working against such human instincts, managers are advised to recognize and reward employees through status recognition (Nicholson 1998) in flexible ways. At NUMMI, a GM joint venture with Toyota in Fremont, California, teamworking is the norm for getting work done. The culture is reinforced by promoting employees who teach and help others to team leadership roles (Maccoby 1997). It should be realised that promotion cannot be used liberally to reward exemplary performance, especially in flat organizations. Therefore, fluid forms of recognition may need to be adopted. These include bonuses, performance awards, certificate of appreciation, and one-shot responsibilities such as leadership in a system commissioning task or a plant refurbishment project.

A wide variety of remuneration programs that take into account factors other than rank, experience and length of service are being used in some progressive organizations. In the pay-for-skill program at Mass Transit Railway Corp., Hong Kong, maintenance trades persons are paid for acquiring and applying new skills and knowledge required by their jobs. Corning and Eastman Chemical have similar reward programs to develop their multi-skilled employees. Pay-for-performance and goal sharing programs award bonuses that are linked to group performance. For example, “Work-group Excellence” is a pay-for-performance program at Xerox which rewards the performance of a work team as a whole. Then, within each team, rewards are distributed on the basis of such factors as experience. In Corning’s goal sharing program, 75% of each bonus dollar award is based on how well a business unit meets its objectives. The remaining 25% is based on Corning’s return on equity. All employees in the unit receive the same percent of base pay as a goal-sharing bonus (Gephart and VanBuren 1996).

If an organization stresses teamworking, the remuneration structure should promote teamwork rather than undermine it. From a study on two best practice organizations (Fel-Pro and Steelcase), Meimoun (1995) identifies the following critical success factors for a reward and recognition system
that encourages teamworking:

- Top management commitment to teamworking and the concept of team-based rewards and recognition.
- Management is available and visible.
- Employees are regarded as the organization's most valuable assets.
- Employees value empowerment and involvement as a form of reward and recognition.
- The organization relies on structured processes, policies, and documentation.
- A strong network is in place for vertical, horizontal, diagonal, intra-team, and inter-team communication.
- A performance measurement is in place.
- Employees participate in training.

Argyris (1998) cautions that offering employees the “right” rewards alone is unlikely to produce sustained empowerment. The power of such methods wears off with use, creating dependency to maintain commitment. Trust, involvement and autonomy are the lasting ingredients that drive human energy and activate the human mind.

**Performance Measurement**

Performance is measured with reference to clearly defined objectives. Measuring maintenance performance in its totality is complicated because multiple interacting objectives are involved. Some of these aims affect each other in an inverse relationship. For example, if prompter service and faster response to service calls are desired, it may be necessary to employ more people in maintenance, have more strategically located sub-stores, and better communication and transportation methods. Such decisions will probably increase the cost per maintenance hour (Priel 1974). One may argue that better service and lower maintenance costs can be achieved by reengineering the process of delivering maintenance services. However, major process innovations in a specific function such as
maintenance do not occur continuously. In view of the complications, it becomes a common practice to measure individual aspects of maintenance performance: equipment (availability, reliability), cost (O&M costs), process (scheduled compliance).

The shortcomings of the maintenance performance measurement systems typically found in industry have been discussed at length in the previous Chapter. The generic performance indicators in common use are useful mainly to support operational control and benchmarking purposes. Given their retrospective and introspective perspectives, they are inappropriate to provide a holistic assessment of maintenance’s performance. Furthermore, it does not provide information for predicting the unit’s ability to create future value needed to support business success of the organization. To achieve that purpose, performance measures that are linked to the espoused strategy of the maintenance function must be tracked. These are known as strategic measures. A process for managing maintenance performance from the strategic perspective has been presented in Chapter 2, see Fig.2.6 on page 2-23. A core feature of the process is the Balanced Scorecard (BSC) which provides a balanced presentation of strategic performance measures around four perspectives: financial, customer, internal processes, learning and growth. Managers often find the strategy too abstract to guide them in making day-to-day decisions. By using the BSC, the strategy of the maintenance function is translated into something more tangible and actionable — long-run (strategic) objectives, the related performance measures and their targets, action plans. Clearly, the BSC is a powerful communication tool for providing a sharp focus on factors that are important to maintenance in making contributions to business success of the company. It enables holistic assessment of unit performance and guards against sub-optimization because all the key measures that collectively determine the total performance of maintenance are being monitored.
**Management Information Systems**

Managers formulate strategies, make decisions, and monitor progress against plans by collecting, retrieving, and analysing data. Management information systems should allow seamless flow of information through the organization to support these managerial tasks. However, managers often find that their existing information systems do not communicate with each other and their operating practices are inconsistent. This is because these so called legacy systems were developed at different times to serve their dedicated purposes with little, if any, due consideration for integration with other systems.

The emergence of enterprise systems (ES) — software packages with fully integrated modules for the major processes in the entire organization — offers the promise to integrate all the information flows in the organization with the following benefits:

- Replacing a large number of the legacy systems with an integrated one produces significant cost savings. It eliminates the expensive tasks of maintaining redundant data, transferring data between incompatible systems, updating and debugging obsolete software code.

- Managers can make informed decisions when data on multiple aspects of operations are readily available for analysis. If the financial-reporting system cannot talk with the maintenance management system, then optimal decisions on equipment replacement cannot be made with confidence. If the work order control system is incompatible with the inventory control and purchasing systems, then maintenance jobs cannot be done efficiently when the critical spares are not available. Fragmentation of information is a cause of incoherent decisions.

The decision to install a generic, off-the-shelf ES has its pitfalls. Managers must consider the implications on their business imperatives. They should check whether the logic of the system is in conflict with the logic of the organization’s practices. The suitability of an ES should be determined
from a strategic perspective. In other words, the *enterprise* should be stressed, not the *system* (Davenport 1998).

If maintenance is a significant function in the organization, the ES should have modules supporting maintenance management. The required features in these modules include facilities for maintaining equipment history, support for preventive maintenance, work order control, inventory control and purchasing. Through integration with the other software modules that handle payroll, accounts payable, cost accounting, shop floor data collection, knowledge base diagnostics, etc., real-time decision support information can be retrieved by managers using user-friendly interfaces.

To leverage the benefits of enterprise systems that support maintenance, managers are advised to specify the following requirements in the software modules:

- To exploit the wealth of information embedded in their maintenance data, there should be functions that support modelling of life time distributions, inspection or preventive maintenance schedules, or equipment replacement decisions. Without these decision support facilities, organizations are typically “data rich, but information poor”!

- If RCM is implemented, features that support the methodology are desirable. Support for documentation of Failure Mode, Effect & Criticality Analysis (FMECA) is one such feature.

- The system can present performance results in a format specified by the user. If the balanced scorecard (BSC) approach is in use, the system should be able to support it. In such case, the design should follow the logic of the process — strategic objectives are linked to their performance measures which, in turn, have their respective targets; the top level BSC is linked to lower level ones in a cascading manner. Navigating within the process should be done through a graphical user interface (GUI). High level measures can be drilled down to reveal further details provided by the lower level measures they summarise. Trending of data is another essential capability required. Furthermore, the information should be accessible in
real-time to all employees deemed to play a direct role in affecting the performance tracked.

- If the organization has strategic partners in its logistics system, there are huge benefits in establishing direct electronic links with their software systems. If the inventory control, purchasing, and accounts payable modules can communicate seamlessly with their counterparts in the supplier, then provisioning of spares can be managed efficiently with minimal human intervention and transactions can be processed with low error rates. If part of the maintenance service is outsourced, a direct link with the external supplier’s system will shorten the elapsed time between the issue of job requests and response of the supplier. Tapping into the supplier’s system also enables the user to monitor the supplier’s performance in delivering the required maintenance services. This requirement suggests that the strategic partners need to be involved in establishing the system specifications and in system commissioning.

3.6. Conclusion

Four strategic dimensions of maintenance management — service delivery options, organizational design, maintenance methodology, and support systems — have been discussed. The critical decision areas in each of these dimensions are also examined. The two factors that permeate in these dimensions are human factors and information flow. An understanding of behaviour at work and the conditions for enhancing group effectiveness will produce better organizational designs that stimulate people’s minds and create internal commitment. Due consideration of these factors will also increase the chances of success in the change programs. These principles also apply to the design of interfaces with external partners — suppliers of equipment, spares, and maintenance services. The seamless flow of information is another enabler of exemplary performance. Information can influence people’s behaviour when a performance management system with linkage
to the espoused strategy and balanced assessment is in place. Implementing this system is a big challenge but the huge potential payoff will justify the effort.

Fig. 3.4 summarizes the key points discussed in this Chapter.
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</tbody>
</table>

Fig. 3.4 Strategic Dimensions of Maintenance Management
4. Design of the Investigation

4.1. Introduction

Research designs in organization studies can be broadly classified into qualitative research and quantitative research. A comparison between these two research methods on seven dimensions is given in Figure 4.1 (Bryman 1989).

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Qualitative Research</th>
<th>Quantitative Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aim of the research</td>
<td>Mostly used to discover patterns and linkages of theoretical importance — to build theories, such as process models.</td>
<td>Mostly used to test hypotheses; sometimes may also be used for exploratory study.</td>
</tr>
<tr>
<td>Approach to collecting data</td>
<td>Unstructured</td>
<td>Model based</td>
</tr>
<tr>
<td>Sources of data</td>
<td>Field notes from observations, interview transcripts, archival records, published documents, physical artifacts.</td>
<td>Questionnaires are most commonly used; data gleaned from archival records, published documents and artifacts that are amenable to categorization or quantitative measurement such as counting are also used.</td>
</tr>
<tr>
<td>Contextual information</td>
<td>Focus of attention</td>
<td>Usually little attention is given to context.</td>
</tr>
<tr>
<td>Linkages among parameters</td>
<td>Dynamic relationships can be explored</td>
<td>Can only identify static relationships; this limitation can be mitigated to a certain extent by the use of archival data.</td>
</tr>
<tr>
<td>Subjects’ interpretation of facts</td>
<td>Strong emphasis — respondent validation exercise</td>
<td>Less emphasis</td>
</tr>
<tr>
<td>Researcher’s involvement in the organization</td>
<td>The researcher adopts a stance of an insider to the organization.</td>
<td>The researcher may have virtually no involvement in the organization.</td>
</tr>
</tbody>
</table>

Fig. 4.1 Comparison Between Qualitative and Quantitative Research

While qualitative research is often used in exploratory studies for theory building, the typical objective of quantitative research is to test hypotheses derived from a theoretical framework. Content analysis of documents and study of artifacts can be utilized to obtain data for both types of research.
However, they are seldom used as primary sources of data in organization studies. The major source of data in quantitative research typically comes from questionnaire surveys. On the other hand, qualitative research commonly uses the case study approach which utilizes observations and interviews to generate data that are rich in contextual information. Bryman (1989:173) cautions that the aim of case studies is not to infer the findings from a sample to a population, but to engender patterns and linkages of theoretical importance. Yin (1994) argues that the case study approach is preferred when the “how’s” or “why’s” are asked, and the focus is on contemporary phenomena in which case the researcher has little control over events. The strengths and weaknesses of theory building from case studies as well as the roadmap for building theories from case study research are presented by Eisenhardt (1989).

**Phase I**

- Literature Review
- Field visits and semi-structured interviews

**Phase II**

- Formulate a framework for maintenance performance management
- Disseminate the approach to industry
- Identify collaborating organizations

**Phase III**

- Action research
- Interview representatives of major stakeholders and study company documents
- Advise collaborating organization on implementation of its performance management system
- Lessons learned and generalization from the in-depth case studies

*Fig. 4.2 The Three-Phase Research Methodology*
4.2. The Research Methodology

Fig. 4.2 outlines the three-phase methodology used in this research project.

Phase I

Phase I involved the collection of background information about maintenance performance management in the target population. Both literature review and interviews were employed to gather the relevant data. The literature review, presented in Chapter 3, surveyed the theoretical work on the issue that has been reported in the literature so far. Data on current practices of maintenance performance management were collected through semi-structured interviews conducted in the period from July 1996 to December 1997. These interviews were made during field visits to eight organizations listed below:

<table>
<thead>
<tr>
<th>Organization</th>
<th>Industry</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hong Kong Aircraft Engineering Co.</td>
<td>Aircraft maintenance</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>Motorola Semiconductors (Hong Kong)</td>
<td>Semiconductors assembly</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>Shell Hong Kong</td>
<td>Petrochemical oil terminal</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>ASM Pacific Technology</td>
<td>Precision machines manufacturing</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>Housing Department, Hong Kong Housing Authority</td>
<td>Property development &amp; real estate management</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>Dofasco</td>
<td>Steel making</td>
<td>Hamilton, Ontario</td>
</tr>
<tr>
<td>Molson Breweries</td>
<td>Beer brewing</td>
<td>Etobicoke, Ontario</td>
</tr>
<tr>
<td>Lever Pond's</td>
<td>Consumer products manufacturing</td>
<td>Toronto, Ontario</td>
</tr>
</tbody>
</table>

Fig. 4.3 Organizations Covered in the Field Visits in Phase I

These organizations represent a cross section of industries operating with significant maintenance budgets. By including organizations in Hong Kong and Canada in the sample, the commonalities and differences, if any, between maintenance performance management practices in these two places can be identified.
Interviews instead of questionnaire surveys were used to collect field data in this phase because the inquiry was at the exploratory stage, and there were no hypotheses to be tested.

**Phase II**

Building on the findings of Phase I, a framework for maintenance performance management based on a holistic approach to measurement was formulated in Phase II. The core element in the approach is the Balanced Scorecard (BSC), a performance measurement tool proposed by Kaplan and Norton in their seminal paper (Kaplan and Norton 1992). Being an innovation in maintenance management, the framework and its underlying theory had to be introduced to managers and professionals in the field. This was done by the researcher who presented the approach in a number of executive development programs on maintenance management offered by The Hong Kong Polytechnic University in 1997 and 1998. A paper on the subject was also published in an international journal (Tsang 1998a).

As suggested by the saying, “the proof of the pudding is in the eating”, the new approach has to be put into practice to gather evidence for validating its underlying logic. Introducing the change is a major undertaking. It involves a paradigm shift in recognizing the strategic role of performance measurement. Other parts of the organizational infrastructure, such as management information, resource allocation, reward and recognition systems, may also require to be overhauled to support the new measurement system. Evidently, such a transformation program needs to be driven from the top. Furthermore, the efforts invested in focusing the new measurement system on the maintenance function are more likely to be justified in capital intensive organizations.

Target organizations were identified and approached by the researcher to explore the possibility of getting them involved as collaborating parties in this inquiry. To get their collaboration, the senior management of the targeted organizations had to be convinced about the merits of the new system. Two maintenance organizations in Hong Kong agreed to take part as collaborating parties in this
research project. The first collaborator was the Asset Management Department of Power Systems Business Group (PSBG) of CLP Power, a vertically integrated utility company serving 1.76 million electricity customers in Hong Kong. W.L. Brown, Chief Engineer of Asset Management was the sponsor of the investigation in CLP Power. The second collaborator was the Operations Engineering Department (OED) of Mass Transit Railway Corporation, an urban railway system providing public transportation services to over 2 million commuters on an average weekday. Y.K. Chan, Quality & Standards Manager of OED, was the sponsor of the inquiry in MTRC. To gain the trust and support of these organizations, they were given assurance that they would have a chance to read draft papers of case studies about them before publication to check for accuracy and confidentiality. Should reference to sensitive information is absolutely necessary in a publication, the identity of the organization would be disguised.

To obtain information on the current practices of performance management in local organizations, a questionnaire survey on the issue was also conducted in early 1999. Participants of an executive development program offered by The Hong Kong Polytechnic University were polled. These participants were senior executives or professional staff representing a wide range of industries in Hong Kong. The survey instrument was designed on the basis of the preliminary findings of Phase I, and it had been tested and improved before being used in the survey.

**Phase III**

The action research methodology was adopted in this phase of the research. Action research is basically a consensual approach to inquiry and works from the assumption that cooperation and consensus making should be the primary orientation of research activity. Stringer (1996) characterizes action research as processes that:

- are rigorously empirical and reflective;
- engage people who have traditionally been called “subjects” as active participants in the
research process, and

- result in some practical outcome to the lives or work of the participants.

Stringer also defines the role of the researcher in action research as a catalyst to stimulate people to change. The essence of the work is process rather than the result achieved. The key is to enable people to develop their own analysis of their issues. The research will analyze the situation, change what they do not like, examine several courses of action and the probable results or consequences of each option. The stakeholding groups are the primary focus of attention and source of decision making. After a plan has been chosen, the researcher’s role is to assist in implementing the plan by raising issues and possible weaknesses and by helping to locate resources. The researcher does not focus only on solutions to problems but also on human development. The responsibility for a project’s success lies with the people. Thus, the working principles of action research are focused on: relationships, communication, participation, and inclusion (Stringer 1996:38).

In the first stage of the action research, company documents were studied to obtain information about the host organization’s mission, vision, its organization structure, management systems, strategies, initiatives and performance measures. Next, representatives of the major stakeholders of the maintenance function — senior management, staff units and operating units of the maintenance organization — were interviewed individually to collect their views on the performance measurement system currently in place in the organization. These semi-structured interviews typically focused on the following areas:

- Interviewee’s role in the maintenance operation.
- Existing practice of maintenance serviced by the interviewee’s unit.
- Key result areas and major initiatives of the interviewee’s unit.
- Existing practice of performance management

At the end of each interview, the researcher also took the opportunity to brief the interviewee on
the strategic approach to managing maintenance performance as outlined in a paper he authored (Tsang 1998a). Another effort made by the researcher to promote awareness and enhance understanding of the new approach in the host organizations included giving three presentations on “Measuring Maintenance Performance Using Balanced Scorecards”. The audiences of these presentations were:

- Managers and engineers of the operating units, and executives of the finance unit in the Power Systems Business Group (PSBG) of CLP Power.
- Managers, engineers and professional staff of the Operations Engineering Department (OED), MTRC.
- Members of the OED Senior Management Group, MTRC

Each of these presentations generated much interest in the audience as judged by the enthusiastic discussion and probing questions raised during the ensuing Q&A session.

For each host organization, findings of the one-on-one interviews were shared with the champion of the change initiative. Serving as the facilitator of the initiative, the researcher followed this up by a series of meetings with the champion or his deputies to exchange ideas and discuss various issues relating to the design and application of Balanced Scorecards as performance management tool in the host organization. The issues covered in these discussions included:

- Strategic issues identified by the host organization and the major initiatives developed to neutralize the perceived threats or exploit the envisaged opportunities.
- Performance measures to be featured in the Balanced Scorecards.
- Setting of stretch (5-year) targets for performance measures in the Balanced Scorecards.
- Validation of the causal relationships between action plans and their expected outcome.
- Analysis and presentation of performance data.
- Cascading higher level Balanced Scorecards to lower level ones.
The two collaborating organizations were at different stages of the change process, with MTRC at an advanced stage of implementing Balanced Scorecards in its maintenance operations. The extent to which MTRC’s Balanced Scorecard application had achieved its desired transformation was assessed by polling the managers involved through a questionnaire survey. The instrument used in this survey was a customized version of the one employed in the Phase II survey described earlier.

Finally, generalizations from the action research conducted in the two collaborating organizations are made to address the focus areas of this research project, which include:

- Lessons learned from the change initiatives at CLP Power and MTRC.
- A framework for determining a preferred approach to managing maintenance performance.
- A model for managing performance of world-class maintenance organizations.

5.1. Introduction

This chapter presents the findings of field work in Phase I of the study, shedding light on the current practices of performance management in eight maintenance organizations operating in Hong Kong and Canada. One or more visits were made to each of these organizations during the period from July 1996 to December 1997. The representatives of the host organizations who were the principal informants of the case studies as well as the dates of these visits are listed in Fig. 5.1 below:

<table>
<thead>
<tr>
<th>Organization</th>
<th>Principal Informant(s)</th>
<th>Date(s) of Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorola Semiconductors</td>
<td>C.L. Ko (Equipment Engineer), Ray Fung (Senior Process/Equipment Engineer)</td>
<td>July 1996</td>
</tr>
<tr>
<td>Shell Hong Kong</td>
<td>Gary Chan (Senior Engineer, Instrumentation &amp; Maintenance)</td>
<td>July 1996</td>
</tr>
<tr>
<td>ASM Pacific Technology</td>
<td>P.K. Chan (Maintenance Manager, Sha Tau Kok Plant)</td>
<td>September 1996</td>
</tr>
<tr>
<td>Housing Department</td>
<td>Galvin E. Kitson (Senior Quality Coordinator)</td>
<td>December 1997</td>
</tr>
<tr>
<td>Molson Breweries</td>
<td>Sukumar Roy (Maintenance Systems Manager), Alan Gordon (former Senior Manager)</td>
<td>August 1996 &amp; June 1997</td>
</tr>
<tr>
<td>Lever Pond's</td>
<td>Stan Reid (Production Manager)</td>
<td>June 1997</td>
</tr>
</tbody>
</table>

Fig. 5.1 Field Work in Phase I — Principal Informants and Dates of Visits
The current practice of each sampled organization will be explained individually. Generalizations that can be derived from the findings in the sampled organizations are discussed at the end of this chapter.

5.2. Hong Kong Aircraft Engineering (HAECO)

HAECO provides aircraft maintenance services in Hong Kong’s International Airport. These services can be broadly classified into base maintenance and line maintenance activities. Base maintenance services are work performed on equipment that has been removed from service, such as repair, overhaul, and refurbishment of aircraft or its subsystems (airframe, engines, cabin interior). These are jobs carried out in the hangar or in the workshop. Line maintenance, on the other hand, refers to engineering services rendered to prepare aircraft for the next flight, and to support ground services equipment on the airfield.

The researcher visited the Equipment Maintenance Section in July 1996. The Section is in the Ground Services Department of the Line Maintenance Division. It offers maintenance services to Ground Support Equipment (GSE), which are specialized vehicles such as those that provide aircraft with electricity and air conditioning while it is on the ground. The Section also manages the maintenance and servicing of transportation vehicles, which are known as general vehicles at HAECO. The company has a fleet of about 310 vehicles, about 50% of which are general vehicles and the rest are GSE. Maintenance and overhaul of general vehicles are outsourced. The management of such outsourced work is handled by the Planning Unit of the Section.

Routine servicing of vehicles is performed by user departments, using check sheets developed by Facilities & Development, the Department that provides engineering support to the rest of the company. For hoists and heavy material handling equipment, starters, and haul trucks, routine monitoring and overhaul are performed by centralized crews in the Facilities & Development
Department. The Maintenance Section has a garage to provide preventive maintenance services on GSE, such as minor check, major check, annual inspection, refurbishment and overhaul. Major checks and refurbishment include load tests when the equipment is safety or production critical. Examples of these critical items are Ground Power Unit, Air Start Unit, and Aircraft Towing Tractor. Breakdown of these equipment while in service may damage the aircraft engine, or it may block the runway. Furthermore, removing such heavy and immobilized equipment is a serious problem.

The Maintenance Section also conducts random patrol inspection on vehicle/equipment which is in service. Readings taken from the equipment’s instrumentation, noise, evidence of leakage, and exhaust from the engine are sources of information to judge condition of the equipment.

Apart from monitoring the commonly used financial and productivity indicators that relate to its operations, the Maintenance Section also tracks the following performance indicators by vehicle type:

- Serviceability, which is defined as the ratio of available time to elapsed clock time. Available time is clock time less downtime. The latter can be caused by planned maintenance, breakdown maintenance, modifications, non-routine (damage) repairs, or unavailability of spares.
- Number of breakdowns.

The common problems of the Maintenance Section include:

- Heavy utilization of GSE. Thus, sometimes the user department is reluctant to release them for preventive maintenance.
- Some spares are expensive and HAECO is the only user in Hong Kong. Economic consideration and space constraints limit the quantity of spares that can be kept by the company. The equipment suppliers also do not keep local stock of infrequently used and expensive spares. If needed, such items will have to be shipped by air freight and the lead
time can be as long as 45 days. The Service Exchange Program has been established to improve the situation. Under this program, items that can be repaired by the supplier will trade for a refurbished one kept locally by the vendor.

- The craftsmanship of tradesmen has been degrading in recent years.

At HAECO, performance of the maintenance function is not measured at the strategic level. The performance measures being tracked are either equipment based or used largely for operational management, i.e., cost control of the maintenance operations. They are not linked to issues or initiatives that are critical to support performance excellence of production operations, which include aircraft maintenance and provision of ground services on the airfield.

5.3. **Motorola Semiconductors, Hong Kong Manufacturing Plant**

Motorola Semiconductors Hong Kong manufactures semiconductor devices for the automotive, telecommunications, and electrical appliances industries. It has fully automatic facilities for assembly of semiconductor devices from wafers. The production processes take place in a clean room environment to ensure quality of the finished products.

In July 1996, the researcher visited its production site at Taipo Silicone Harbour, Hong Kong and interviewed the two informants (listed in Fig. 5.1) who were equipment engineers in the Automatic Assembly Division. The Silicone Harbour plant adopts the team-based management concept. Each manufacturing cell has a team of Technical Assistants (TAs) managed by an appointed leader. It has introduced Total Productive Maintenance (TPM) in its production departments. Routine servicing, trouble shooting, and preventive maintenance of production equipment are Production’s responsibility. Specialists (process engineers, equipment engineers, and equipment maintenance technicians) are deployed to handle design improvement, overhauls and trouble shooting. Plant facilities, such as environmental control equipment, utilities (water, electricity), nitrogen and
compressed air supply systems, are maintained by the centralized crew in the Facility Department.

While the equipment register and maintenance records are kept on paper, such data are normally not used for model-driven analyses that support maintenance decisions.

The company employs a number of recognition programs to encourage teamwork. In one such program, performance of a production team is assessed on the basis of six criteria: attainment of the output goal, cycle time, yield, attendance, 5S performance, and customer complaints. The weights, goals and assessment methods are reviewed semi-annually by the Production Manager in consultation with equipment engineers, process engineers and the Production Supervisor. Team performance is assessed at monthly intervals. The team with the highest score will get a Small Win. The best performing team in a quarter will be the Quarter Winner. Team members of the monthly winner and quarterly winner will receive coupons that can be used to trade for items from a gift catalog. Winner of the year will receive a medal and souvenirs.

In another program, the corporate performance is tracked at monthly intervals. Five performance indicators are used for the assessment, covering productivity, quality, on-time delivery, order booking, and billing. The results are posted up in the cafeteria for everyone to see. When the aggregate score of the assessment exceeds a threshold (80%), every employee will be treated to a shark’s fin feast.

The Automatic Assembly operation has heavy investment in production equipment. Thus, its production departments operate round the clock so as to maximize asset utilization. With the integration of production and maintenance through TPM implementation, the Automatic Assembly Division measures its maintenance performance using primarily equipment based indicators. The key measures are up-time and mean-time-between-assists ¹ (MTBA). The other dimensions of

³ An “assist” is an event that requires operator intervention to bring the machine back to normal operation. The fault may be due to machine malfunction, or problem with the material to be processed.
maintenance performance, such as financial and productivity, are not separately tracked because they are merged with those of production.

5.4. Shell Hong Kong

Shell has an oil and petrochemicals terminal in Hong Kong. Spanning an area of about 16 hectares, the terminal functions as an intermediate storage and distribution centre for refinery products serving customers throughout Hong Kong and Southern China. It also has production activity for blending of lubricants from bulk refinery feeds and additives. The installation consists of various types of purpose built structures including fuel and chemical tank farms, dangerous goods blending, storage and filling plant, bitumen plant and bitumen tank farm, bulk vehicle loading gantry, and jetties.

The Terminal’s plant and equipment must be strictly maintained to satisfy statutory regulations, corporate requirements, and the needs of Operations (the users) with respect to operational service and safety. Shell relies heavily on contractors to maintain its physical assets in the Terminal. Planned maintenance of instrumentation, plant, and civil works are performed by contractors specialized in these tasks. There are, however, a good number of ad hoc requests for maintenance and repair works that must be attended to every week. These jobs are assigned to contractors or in-house maintenance personnel.

Gary Chan, Senior Engineer of the Engineering Department, is responsible for managing maintenance operations in the Terminal. According to him, direct maintenance costs in 1996, the year when the researcher visited the installation, accounted for 12% of the terminal’s total operating costs. The percentage would be much higher when the hidden or consequential costs (loss of production, lowered efficiency, higher energy costs, process loss, demurrage, penalty for environmental damage, etc.) were also taken into account. A benchmarking exercise in 1994 showed
that the maintenance costs of a number of the terminal’s operations were much higher than those of similar installations elsewhere within the Shell Group of companies. This triggered the company to review its contracting strategies, search for industry best practices, new technologies and methodologies to reduce maintenance costs and improve maintenance performance (Chan 1997). The initiatives being pursued to enhance maintenance performance at the time of the visit included:

- Replacement of the out-dated computerized maintenance management information system by a full-function integrated one that runs under client/server Windows based environments.
- Review of contracting strategies and the practices of managing external service providers.
- Reliability-centred maintenance pilot studies.
- Introduction of Total Productive Maintenance.

The performance measures in use at the Terminal were not linked to any of these initiatives. Despite the significant role played by contractors in maintenance, their performance is monitored by the company using "hours per job" as the performance measure. The Senior Maintenance Engineer agreed that his maintenance performance measurement system needed to be reviewed to enhance its impact on business performance of the Terminal.

5.5. **ASM Pacific Technology**

ASM is a major supplier of semiconductor assembly equipment for the world-wide market. The range of equipment it manufactures include die and wire bonders, auto-moulding systems, and trim form systems. The company also produces leadframes for semiconductor products. It has production sites in Hong Kong, Shenzhen (the city in China next to Hong Kong), and Singapore.

The researcher visited the Shenzhen operation, known as the Sha Tau Kok (STK) Plant, in July 1996. He also interviewed P.K. Chan, the Plant’s Maintenance Manager. The STK Plant has a total workforce of about 2,000 employees, about 30 of them are in the Maintenance Department managed
by Chan. The team in the Maintenance Department is responsible for performing machine overhauls, preventive maintenance and corrective maintenance activities on plant facilities and production equipment. These assets include state-of-the-art automated equipment such as flexible manufacturing systems (FMS), CNC machining centres, precision grinding machines, EDM and wire-cut machines. Maintenance work in the Plant is largely done by the in-house team, the equipment supplier will be asked to provide specialist service only if such expertise is not available in the Plant. Instead of focusing exclusively on the technological aspects of maintenance operations, the Plant introduced TPM in 1995 to address the human dimension of maintenance management. The attitudes and behaviour of workers in China mainland are characterized as being passive, undisciplined, risk averse, evasive in taking new responsibilities, highly sensitive to peer judgement, and driven by short-term rewards and instant gratification. The attempt to mobilize such machine operators to play an active role in performing preventive maintenance tasks on production equipment is a major challenge. Chan is the champion of this transformation process. The experience of introducing TPM to the Plant is reported in Tsang and Chan (1997). Two of the methods that have been used to motivate employees to practice TPM are:

- Auditing the practice of TPM in production departments, and displaying the weekly audit reports on TPM notice boards.
- Giving recognition to departments that had successfully implemented TPM. This could be made in company events or during meetings.

The measures to track overall maintenance performance at the Plant are entirely equipment based — equipment availability and number of shut downs. Other measures such as operation efficiency and rate of quality are not tracked because Chan considers that these other measures depend on inputs from departments other than Maintenance.
5.6. Housing Department

The Housing Department is the executive arm of the Hong Kong Housing Authority (HA), a statutory body responsible for implementing the majority of Hong Kong's public housing programs. At the time of the visit, December 1997, the Authority had developed 660,000 leased flats plus 200,000 units under the Home Ownership Scheme. These together housed about one half of Hong Kong's population. The responsibilities of Housing Department include, among other things, construction, improvement, maintenance, and estate management of the Authority's rental properties. It also manages community facilities in housing estates developed by the Authority. These facilities include 1.6 million square metres of commercial and business space.

The implementation of all construction, improvement and maintenance works are outsourced. The Department's function in maintenance of the Authority's physical assets is to provide the related professional services. These include survey and appraisal services, providing technical feedback to the design team, making proposals on major refurbishment and improvement programs, documentation of contract work, inspection and acceptance of contract work, vetting and approval of fitting-out of commercial properties.

The Department has launched a number of initiatives to meet the rising expectations of the community due to continuous economic growth and recent political developments in the city. Examples of such initiatives as stated in the Authority's Annual Report for 1996/97 include:

... a Management Transformation Program was launched (in 1996) to enhance the quality and cost-effectiveness of maintenance services, operational efficiency and to maximize utilization of resources. These initiatives include the implementation of new strategies for maintenance work focusing on services standards and customer satisfaction, re-engineering of business processes, as well as reorganization of maintenance functions. Standardization of methodology, specifications and contract documentation ensure consistency, while the
development and implementation of the Maintenance Information and Drawing Management Systems facilitate better management in these areas. The establishment of focus groups with maintenance contractors has also encouraged commitment and partnership in these areas. (HKHA 1997)

To ensure the maintenance contractors are able to deliver high quality services, the Department uses a Maintenance Assessment Scoring System (MASS) to evaluate the performance and capabilities of these contractors. Two aspects of performance are assessed: work assessment which takes into account the contractual obligations on site and quality of works, and the management assessment which evaluates the quality and effectiveness of the contractor’s management in fulfilling their contractual obligations. The operation of a reward system offering preferential tendering opportunities to good performers, provides powerful incentives for quality achievement.

On a broader front of providing a master plan for various reform initiatives, the Department launched the corporate-wide Management Enhancement Program or MEP in early 1997. The program aims to achieve greater cohesiveness and clearer focus for the Department’s various activities. Corporate vision and mission, as well as the three Core Values — Caring, Customer-focused, and Committed — were identified. Under the program, reform and improvement initiatives have been identified and developed by cross-functional teams. On-going training of staff is also emphasized to redirect focus from an inward-looking body to a people-oriented and customer focused organization. A series of workshops and orientation programs have been launched to promote key management practices and behaviours that will support the Core Values, and to obtain staff’s buy-in to the process. On human resource management, a competency-based performance management and development system was being developed. Core-competency profiles for various jobs have been drawn up to provide a framework for recruitment, performance management, staff training and development.
According to Galvin Kitson, the Senior Quality Coordinator responsible for quality management of the Department’s maintenance functions, the measures of corporate performance in use at the time of the visit were primarily related to inputs and volume. As far as maintenance performance is concerned, the performance measures used include:

- Financial indicators, such as budget compliance.
- Indicators related to service standards, such as process time, response time.
- Equipment-based indicators, such as rate of breakdowns.

Kitson agreed that ideally, the key performance indicators in use should be linked to the organization’s espoused strategies, and be able to assess the cost-effectiveness of the related initiatives.

5.7. Dofasco

Dofasco is one of Canada’s largest steel producers, serving customers throughout North America with high quality flat rolled steels from facilities in both Canada and the U.S. The company’s advanced steel making facilities in Hamilton, Ontario are capable of producing about four million tons per year of hot-rolled, cold-rolled, galvanized, tin-plated, chromium-coated, and pre-painted steels. These steel products are sold to customers in the automotive, construction, energy, manufacturing, pipe and tube, appliance, container and steel distribution industries. The Hamilton operations have continually outperformed all other integrated steelmakers, currently generate greater earnings before interest and taxes (EBIT) per shipped ton than most mini-mills (Dofasco 1997).

The researcher visited the Hamilton Plant twice: in August 1996 and June 1997. In both occasions, he met with R.R. Gagnon, Maintenance Manager of Material Handling Services (MHS), and his colleagues to understand the company’s maintenance performance management practices. MHS operate and maintain heavy material handling equipment (e.g., bridge cranes), railway equipment,
process equipment (e.g., conveyors), trucks, miscellaneous plant and mobile equipment.

In January 1997, the Hamilton Plant started to adopt a structured methodology to manage the maintenance performance of its MHS and the operations (production) units. Selected workers, planners, and supervisors were involved in developing the performance measurement system which would meet the following objectives:

- Establish priorities and direction to monitor Maintenance Effectiveness that serve customer needs;
- Monitor internal and external costs;
- Establish a simple means for communicating performance results to internal and external customers using graphics;
- Provide direction for training requirements and personal development.

**Developing the Performance Management System**

There are three steps in the process. Step one is expectation analysis. It is to identify external and internal customers' expectations and translate them into goals of the Maintenance Department. For example, the Business Unit (MHS) expectation of “reducing generation of coke breeze on by-passed coke by 50% in 12 months” is translated into the Maintenance Department goals of “reducing premature failures by x % in 12 months” and “instituting quality control on maintenance work”. These goals are related to the “Quality” dimension of maintenance outputs. There are goals that relate to other dimensions of maintenance outputs. These other dimensions are: “impact on production throughput”, “customer service”, “employee development”, “equipment improvement”, “financial”, and “safety”.

In step two, the maintenance goals are translated into maintenance excellence requirements against the six tasks of the maintenance function: work identification, planning, scheduling, execution,
follow-up, analysis. The action plans for each of these six tasks are then formulated.

In step three, performance measures on attainment of maintenance goals and excellence requirements are identified. These measures for MHS — Lifting Equipment Repair identified in the pilot project are listed in Fig. 5.2 below.

<table>
<thead>
<tr>
<th>Dimensions of Maintenance Output</th>
<th>Goal Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of maintenance work</td>
<td>Number of failures in critical assets</td>
</tr>
<tr>
<td>Impact on throughput</td>
<td>Availability of critical assets</td>
</tr>
<tr>
<td>Customer service</td>
<td>% time critical assets met availability targets</td>
</tr>
<tr>
<td>Employee development</td>
<td>% employees whose training plans are on track</td>
</tr>
<tr>
<td>Equipment improvement</td>
<td>% W/O’s that are for equipment improvement</td>
</tr>
<tr>
<td>Financial</td>
<td>Total W/O costs</td>
</tr>
<tr>
<td>Safety</td>
<td>Reported injury frequency</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maintenance Excellence Requirements</th>
<th>Process Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work identification</td>
<td>% labour hours on pre-identified work</td>
</tr>
<tr>
<td>Planning</td>
<td>% W/O’s with labour estimate</td>
</tr>
<tr>
<td>Scheduling</td>
<td>% W/O’s on schedule ≥ 3 days prior to execution</td>
</tr>
<tr>
<td>Execution</td>
<td>% W/O’s completed when required</td>
</tr>
<tr>
<td>Follow-up</td>
<td>% executed W/O’s properly closed out</td>
</tr>
<tr>
<td>Analysis</td>
<td>% completion of root cause analyses</td>
</tr>
</tbody>
</table>

Fig. 5.2 Performance Measures for MHS — Lifting Equipment Repair

The expectation analysis, the maintenance excellence requirements, and the performance measures are reviewed annually when the business plan is being developed.

Data for performance measurement are captured and processed by the computerized maintenance information system (CMMS). Results are displayed in line graphs superimposed with trend lines and targets in a 13-month window. This way, both seasonal patterns and same-month-last-year results can be shown. Each top level performance measure can be drilled down to provide more details of
problems. For example, the top level measure of "number of failures" can be analysed by "failure category", "type of asset", and "equipment", etc. A large chart showing the up-dated graphs of all the top level measures that relate to a work group is also posted up on the shop floor.

It is also noteworthy that at Dofasco, the maintenance function does not have direct influence over strategic decisions of asset management, i.e., acquisition, replacement, and design improvement of physical assets, and options for delivery of maintenance services.

The company has two profit sharing plans and they are linked to performance. In the first plan, every employee gets the same amount of bonus skimmed from 14% of corporate profits. The second plan is known as the Variable Compensation Plan (VCP). Under this plan, employees may get from 1% to 50% of basic income, depending on seniority as well as actual corporate and departmental performance. The performance related factors featured in the VCP calculation are: achievement of financial goals, corporate customer focus, corporate safety, and departmental goals. The business plan, performance measures, and corporate profits are discussed at the State of the Union meeting, a quarterly event for every employee to attend.

5.8. Molson Breweries

Molson Breweries, founded in 1786, is the oldest brewer in North America and the largest in Canada. Currently, it has eight plants across Canada, producing more than 40 brands of beer for markets in Canada, the U.S., the U.K., and other overseas countries. The researcher interviewed Sukumar Roy, Maintenance Systems Manager, twice in his office in Etobicoke, Ontario. The first interview was conducted in August 1996 and the second one in June 1997. Roy joined the company in 1992 and was responsible for developing the maintenance performance indicators, as well as implementing the related infrastructural changes, such as training and the computerized Maintenance and Reporting System (MARS) in Molson's various plants. At the time of the interviews, his role
had been redefined to managing the MARS system that provides information for management control of maintenance operations and capital projects.

Roy pointed out that brewing is essentially a batch process and the packaging operation is a high-speed continuous process. Since it is a highly competitive business, reduction of manufacturing costs is crucial to improve competitiveness. Roy further stated that at Molson, senior management's focus of attention has a strong marketing bias.

The company has a decentralized structure with three regional organizations, each of which is a profit centre. Its three largest plants do not have dedicated maintenance departments; the maintenance function is under Production. This is the result of a major restructuring in December 1995 which is designed to improve communication between Maintenance and Production, which had been identified to be a problem in an earlier employee survey. A drawback of this change is that even though the maintenance budget is between 20 and 30% of total operating costs, Production is not interested in maintenance. It is regarded as a necessary evil by senior management, including Production.

Upgrading or replacement of equipment is driven by quality improvement, product change, and efficiency enhancement. The decision criterion for acquisition of major equipment is Return-on-investment (ROI). Life-cycle-costing (LCC) is not done in a disciplined manner. Capital investment proposals are evaluated by financial executives who tend to use the breakeven point and up-front costs as decisions criteria. This often leads to short-sighted investment decisions.

Common approaches adopted by the maintenance functions of Molson's various plants include:

- Upgrading tradesmen's skills, by hiring younger and better educated people and through attrition.
- Reengineering work processes. Examples of such efforts include installation of terminals on the shop floor so that production operators can raise maintenance work orders on the spot.
through an on-line system, and using bar codes for identification of work orders and spare parts thereby eliminating the storekeepers.

- Empowering equipment operators to do simple maintenance work.

The company adopts a fragmented approach to maintenance performance measurement. There is no standard framework shared by all plants. In general, the performance measures used have a financial and production bias. These include financial measures, process-related measures, and equipment effectiveness.

The computerized maintenance management system (MARS) is used to capture transaction data. However, with the exception of financial measures, such data are not analyzed to detect trends or to perform internal benchmarking. Roy commented that Molson does not have an established mechanism for organizational learning. Benchmarking is not practised in an organized manner and there is strong resistance in using performance measures for internal benchmarking.

Through Roy’s introduction, the researcher also interviewed Alan Gordon, the former senior manager at Molson’s corporate office championing an emphasis on maintenance. Based on years of actual combat experience as a senior executive at Molson’s corporate office, and as a consultant specializing in maintenance related projects at Coopers & Lybrand, Gordon has the following observations on industry’s common practice of maintenance management:

- In capital intensive organizations, management decisions fall into three areas, namely operations management, plant maintenance, and capital investments. The first two types of decisions belong to the operating budget and the third belongs to the capital budget. These two types of budget are considered differently. Operating budgets usually do not capture the attention of senior management unless it is in very bad shape.

- Among the three types of decisions mentioned above, the least complex decisions are those that relate to operations, and the most complex are those that relate to maintenance. Hence,
many operations managers do not understand the issues involved in maintenance decisions.

- The approach to maintenance varies from one industry to another, even from one company to another. Gordon cited the following examples

  i. Singapore Airline is one of the most profitable airlines in the world. It never keeps its aircraft for more than three years. Thus, it has a very small maintenance budget. By considering the totality of up-front investment as well as the operating and maintenance costs — life-cycle costing analysis — decisions optimizing the total cost of ownership can be made.

  ii. The automobile manufacturers replace their equipment fairly rapidly. Thus, their spare parts are often ordered only on demand.

- Maintenance will be of strategic importance only when availability and reliability are critical issues in the business of the organization, such as in the air force, the airlines, and the mining industry.

- When senior management place priority on product development, marketing and sales, they will not have a focus on maintenance. And to get the required emphasis on maintenance in operations management, the Operations Manager should have an engineering background.

5.9. Lever Pond’s

Lever Pond’s is the second largest producer of soap based products in North America, and the largest one in the world-wide market. The Toronto Plant visited by the researcher in June 1997 is a facility for making sulphonic acids and it has three processing areas for producing liquid detergent, powder detergent, and soap, respectively. The plastic bottles are also moulded in the plant. These products are made under the household brands of Sunlight (detergent) and Dove (soap).

At the visit, Stan Reid, Production Manager of the Plant, presented a brief history of TPM implementation there. At Lever Pond’s, the acronym TPM stands for Total Productive
Manufacturing — total employee involvement in providing equipment care and maintenance as an approach to enhancing productivity of manufacturing operations. A document entitled “Manufacturing Philosophy and Values” promulgating these ideas was compiled and communicated to all employees.

The TPM program was launched in 1996 after obtaining the support of the union. A five-year training program, covering all the 250 employees in the Plant, is the highlight of the initiative. The training, offered to groups of 10 employees, consists of a two-day course to be followed with a five-day workshop. Education and training are but one part of the master plan for TPM implementation. The introduction of autonomous maintenance, equipment improvement teams, planned and predictive maintenance are all covered in the master plan which was developed on the basis of the Japan Institute of Plant Maintenance (JIPM) model. The plant also followed the seven steps of autonomous maintenance proposed by Suzuki (1994). Visual control techniques are used extensively to provide clear indications of an item’s status. Transparent machine guards instead of stainless steel ones are used so that the moving parts in the processing machine are visible to the operator. Each production area has a TPM facilitator who is in charge of the tradesmen in the area and provides TPM training to them.

It has a central store for spare parts and a small central machine shop with six tradesmen to do planned maintenance work that cannot be handled by tradesmen in the production areas.

Maintenance performance measures used at Lever Pond’s included:

- Expenditure against budget
- Maintenance hours
- Production efficiency

Reid disclosed that Overall Equipment Effectiveness (OEE) as defined by Nakajima (1988) was planned to be tracked in future.
5.10. Generalizations

Findings from the sampled organizations can be generalized into the following points that relate to current industrial practices of maintenance performance management:

(1) It is a common phenomenon that maintenance is not given appropriate top management attention. Maintenance is often perceived as a necessary expense item, and featured on the hit list of cost reduction programs.

(2) Among the organizations covered in the study, only Dofasco is developing a maintenance performance management system that is clearly driven by business goals of the company.

(3) Organizations may use a variety of strategies to manage their physical assets. These range from people-oriented initiatives such as TPM, to engineering-based approaches such as RCM. However, maintenance performance measurement is seldom linked to such strategies.

(4) Performance measures are not identified through a structured and participative process. The practice piloted at Dofasco is a rare exception.

(5) Maintenance performance is typically measured to serve the needs of management control, not to provide prognoses for future performance. To bestow such measurement with prognostic power, measures ought to be identified with reference to a cause-and-effect model. It can be inferred from the case studies that this is rarely, if ever, done in industry.

(6) The strategic dimensions of asset management, such as maintenance service delivery options, acquisition, replacement, and improvement of physical assets, etc., fall outside the purview of the maintenance function in many organizations. Hence, performance in these aspects are often not tracked.

(7) The performance measures in common use do not provide a balanced assessment of organizational performance. They tend to focus on the concerns of operational management (efficiency, response time, service delays), equipment performance (reliability, availability,
fault rate), and resource consumption (cost, manpower). Soft measures such as those that relate to customers' and employees' perspectives are hard to find in many maintenance organizations.

(8) The alignment of performance measures at different levels of the organization is a common blind spot in maintenance performance management. This can be a serious issue for companies with a huge maintenance organization.

(9) Many maintenance organizations do not have reward and recognition systems that have a clear linkage with performance of the function.

(10) Communications on performance measures being tracked and results of the assessment are usually limited to those at the management level.
6. Survey on Performance Management Systems

6.1. The Survey

The literature review and findings of the field work in Phase I indicate that maintenance organizations seldom measure their performance using a balanced set of indicators, or regard performance measurement as a strategic management tool. It is therefore useful to know the typical profile of performance measures currently used in Hong Kong based companies, as well as other characteristics of the current performance management practices in these companies. A questionnaire survey to obtain such information was conducted in early 1999. The subjects polled in the survey were participants of an executive development program held in Hong Kong. They were senior executives or professional staff representing a wide range of organizations based in Hong Kong.

A more homogeneous sample consisting only of executives and professionals with responsibility for maintenance operations would provide more relevant information for the topic of this inquiry. However, this type of sample was not selected in the survey because the backgrounds of the course participants were not controlled, and the sample size would be small if the respondents were screened. The sampling method employed was a compromise amongst cost, relevance and precision considerations.

6.2. The Instrument

The survey instrument is shown in Appendix I. It has three parts. Part 1 asks the respondent to indicate the importance of 11 dimensions when his company or strategic business unit (SBU) measures its performance. These dimensions cover a wide range of perspectives — cost/financial, equipment performance, operational efficiency, time, customer, relationship, employee, safety and environment, organizational culture, innovation, progress tracking. The respondent can specify dimensions that fall outside the list if such dimensions are featured in the company/SBU's
performance management system. The response options for each dimension are: "very important", "somewhat important", and "not important".

Part 2 requests similar information; the respondent is asked to indicate the importance assigned to each of the listed dimensions when his organizational unit (it can be a department, or a section) measures its performance. The respondent can skip this part if he is the chief executive of his company or SBU.

Part 3 is designed to collect information on people’s perception on the performance management system in their organizations. This part has 17 statements that describe various aspects of the organization’s performance management system, expressed in a positive manner. Respondents are asked to indicate the extent to which they agree or disagree with these statements. A 5-point Likert scale with these values was used to capture responses: "strongly agree", "agree", "neither agree nor disagree, or don’t know", "disagree", "strongly disagree".

At the end of the questionnaire, respondents are also invited to give written comments on any aspects relating to the current performance management system in their organizations.

6.3. The Survey Findings

63 completed questionnaires were received from the participants, producing 63 valid responses to items in Part 1 of the questionnaire. However, there were only 61 valid responses to items in Part 2 because two of the respondents were chief executives. Part 3 was not completed properly by three respondents, providing only 60 valid responses to items in Part 3. Results of the survey are summarized in Appendices II and III.

Parts 1 and 2: Dimensions of Performance Measures

The "very important" scores of various dimensions of performance at SBU and unit levels, as rated by respondents, are ranked in descending order in Figures 6.1 and 6.2, respectively.
<table>
<thead>
<tr>
<th>Item No</th>
<th>Description</th>
<th>Very important</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01</td>
<td>Cost / financial return</td>
<td>79%</td>
</tr>
<tr>
<td>1.05</td>
<td>Customer: satisfaction, loyalty, etc</td>
<td>67%</td>
</tr>
<tr>
<td>1.04</td>
<td>Time: response time, recovery time, service delays</td>
<td>49%</td>
</tr>
<tr>
<td>1.03</td>
<td>Operation efficiency / productivity</td>
<td>49%</td>
</tr>
<tr>
<td>1.06</td>
<td>Relationships: customers, suppliers or contractors</td>
<td>43%</td>
</tr>
<tr>
<td>1.02</td>
<td>Equipment performance: reliability, availability, fault rate</td>
<td>41%</td>
</tr>
<tr>
<td>1.08</td>
<td>Safety and environmental management</td>
<td>37%</td>
</tr>
<tr>
<td>1.10</td>
<td>Innovation (technological or managerial), improvement</td>
<td>25%</td>
</tr>
<tr>
<td>1.09</td>
<td>Organizational culture</td>
<td>24%</td>
</tr>
<tr>
<td>1.07</td>
<td>Employee: capability, development, satisfaction</td>
<td>22%</td>
</tr>
<tr>
<td>1.11</td>
<td>Progress of strategic initiatives</td>
<td>21%</td>
</tr>
</tbody>
</table>

**Figure 6.1** Ranking of dimensions in performance measurement at SBU level  
(Based on 63 valid responses)

<table>
<thead>
<tr>
<th>Item No</th>
<th>Description</th>
<th>Very important</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.01</td>
<td>Cost / financial return</td>
<td>66%</td>
</tr>
<tr>
<td>2.04</td>
<td>Time: response time, recovery time, service delays</td>
<td>61%</td>
</tr>
<tr>
<td>2.05</td>
<td>Customer: satisfaction, loyalty, etc</td>
<td>59%</td>
</tr>
<tr>
<td>2.03</td>
<td>Operation efficiency / productivity</td>
<td>49%</td>
</tr>
<tr>
<td>2.02</td>
<td>Equipment performance: reliability, availability, fault rate</td>
<td>46%</td>
</tr>
<tr>
<td>2.08</td>
<td>Safety and environmental management</td>
<td>43%</td>
</tr>
<tr>
<td>2.06</td>
<td>Relationships: customers, suppliers or contractors</td>
<td>36%</td>
</tr>
<tr>
<td>2.10</td>
<td>Innovation (technological or managerial), improvement</td>
<td>34%</td>
</tr>
<tr>
<td>2.07</td>
<td>Employee: capability, development, satisfaction</td>
<td>33%</td>
</tr>
<tr>
<td>2.11</td>
<td>Progress of strategic initiatives</td>
<td>21%</td>
</tr>
<tr>
<td>2.09</td>
<td>Organizational culture</td>
<td>21%</td>
</tr>
</tbody>
</table>

**Figure 6.2** Ranking of dimensions in performance measurement at unit level  
(Based on 61 valid responses)
"Cost/financial return" is the top ranking dimension at both SBU level (79%) and unit level (66%). The next three top ranking dimensions in performance measurement at the two organizational levels are also identical. These dimensions are: "Customer: satisfaction, loyalty, etc.", "Time: response time, recovery, service delays", and "Operation efficiency/productivity".

It is encouraging to note that the "customer" and "time" dimensions of performance measurement are considered "very important" at both SBU and unit levels, by at least one half of respondents. However, not more than one third of the respondents indicated that the other drivers of business success or "soft" measures are "very important" dimensions in their performance management system. The four lowest ranking dimensions in performance measurement at the two organizational levels are found to be identical also. They are: "Innovation (technological or managerial), improvement", "Organizational culture", "Employee: capability, development, satisfaction", and "Progress of strategic initiatives".

"Equipment performance" and "Safety and environmental management" are not among the top ranking dimensions for performance measurement at both organizational levels. This can be explained by the fact that many of the companies represented by the respondents do not have significant maintenance operations. It is expected that these two dimensions will become the focus of attention in capital intensive enterprises.


For the purpose of summarizing the responses to items in Part 3, the 5-point response scale has been collapsed to a 3-point scale with these values: "strongly agree or agree", "neither agree nor disagree, or don’t know", and "disagree or strongly disagree". The "strongly agree or agree" scores of various items as rated by respondents are ranked in descending order in Fig. 6.3.
<table>
<thead>
<tr>
<th>Item No</th>
<th>Description</th>
<th>Strongly agree or agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.01</td>
<td>The Company/SBU's strategy is understood by those responsible for its</td>
<td>78%</td>
</tr>
<tr>
<td></td>
<td>implementation</td>
<td></td>
</tr>
<tr>
<td>3.07</td>
<td>Those performance indicators that relate to my area of responsibility are</td>
<td>72%</td>
</tr>
<tr>
<td></td>
<td>meaningful</td>
<td></td>
</tr>
<tr>
<td>3.09</td>
<td>All performance indicators are measured at the appropriate frequency</td>
<td>68%</td>
</tr>
<tr>
<td>3.05</td>
<td>The KPIs have strong linkage to strategic issues</td>
<td>65%</td>
</tr>
<tr>
<td>3.04</td>
<td>The KPIs at lower levels of the organization are identified through a</td>
<td>62%</td>
</tr>
<tr>
<td></td>
<td>participative process</td>
<td></td>
</tr>
<tr>
<td>3.02</td>
<td>Personal goals and competencies of individual staff are linked to SBU's</td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td>strategy</td>
<td></td>
</tr>
<tr>
<td>3.15</td>
<td>Quality and timely data are available for evaluating the KPIs</td>
<td>57%</td>
</tr>
<tr>
<td>3.08</td>
<td>The targets of performance indicators are established through a participative</td>
<td>55%</td>
</tr>
<tr>
<td></td>
<td>process</td>
<td></td>
</tr>
<tr>
<td>3.14</td>
<td>The KPIs in use provide useful information for carrying out the Company/SBU's</td>
<td>55%</td>
</tr>
<tr>
<td></td>
<td>strategy</td>
<td></td>
</tr>
<tr>
<td>3.05</td>
<td>The SBU's KPIs are identified through a participative process</td>
<td>55%</td>
</tr>
<tr>
<td>3.10</td>
<td>The Company/SBU's KPIs are effective tools for operational control</td>
<td>52%</td>
</tr>
<tr>
<td>3.17</td>
<td>Adequate resources are allocated to make the Company/SBU's strategy happen</td>
<td>50%</td>
</tr>
<tr>
<td>3.16</td>
<td>Reward &amp; recognition systems are aligned with Company/SBU's strategy</td>
<td>47%</td>
</tr>
<tr>
<td>3.06</td>
<td>The existing measurement system gives a balanced evaluation of my unit's</td>
<td>47%</td>
</tr>
<tr>
<td></td>
<td>performance</td>
<td></td>
</tr>
<tr>
<td>3.11</td>
<td>The SBU’s KPIs motivate staff members to create future value</td>
<td>43%</td>
</tr>
<tr>
<td>3.12</td>
<td>The KPI results are presented in a user-friendly manner</td>
<td>42%</td>
</tr>
<tr>
<td>3.13</td>
<td>The KPI results are widely communicated in my organizational unit</td>
<td>30%</td>
</tr>
</tbody>
</table>

Fig. 6.3 Respondents' perception on their company's performance management system
In this survey, 78% of the respondents (managers and professional staff) indicated that they are well informed of their company’s strategy, and 72% of them found the performance measures that relate to their area of responsibility are meaningful. However, the respondents’ perception on communication of performance results is least positive. The two lowest ranking items in Part 3 are:

- The Key Performance Indicator (KPI) results are presented in a user-friendly manner (42%).
- The KPI results are widely communicated in my organizational unit (30%).

The third lowest ranking item is: “The company’s KPIs motivate staff members to create future value.” Only 43% of the respondents either strongly agreed or agree with that statement.

6.4. Conclusion

This survey generates data for characterizing the performance management practices in Hong Kong based companies. Even though most of the sampled organizations do not have maintenance as one of their core competencies, their practices share common characteristics with those of maintenance organizations covered in the field work of Phase I. These shared characteristics are:

- The performance measures in common use do not provide a balanced assessment of organizational performance.
- Measures that relate to drivers of future performance, such as innovation, organizational culture, and employee capabilities are not widely used by companies in their management system.
- Many organizations do not have reward and recognition systems that are aligned with the company’s performance.
- Communications on performance measures being tracked and results of the assessment are usually limited to those at the management level.

These are areas to be addressed to enhance effectiveness of performance management systems.
7. The Action Research

This chapter presents the action research project conducted in the maintenance organizations of two Hong Kong companies, namely CLP Power and Mass Transit Railway Corporation.

7.1. CLP Power

CLP Power is a vertically integrated utility company serving 1.76 million electricity customers in Hong Kong. The geographical area covered by the company’s supply network extends to about 1,000 sq km representing 79% of Hong Kong’s population. It was previously structured to have three distinct organizations, namely, Generation Business Group (GBG), Transmission Business Group (TBG), Distribution and Customer Services Business Group (DACS). TBG managed the bulk delivery of electricity from the generation plants to the bulk and primary substations via a network of high voltage overhead lines, underground or submarine cables. At the bulk and primary substations, the high voltage electricity is stepped down and distributed to strategically located transformers which feed the customers. The distribution of low voltage electricity to customers was managed by DACS.

The manufacturing sector in the Hong Kong economy has been shrinking steadily since the early 1980s. This would have an adverse effect on the company’s total electricity sales if it had not been more than compensated by a robust growth of electricity demand generated by the thriving manufacturing activities in the neighbouring Pearl River Delta (PRD) during the same period. In fact, during 1991 to 1993, the total electric energy (kWh) supplied by the company increased at an average rate of 10.9% per annum. However, the sales of electricity suffered a significant (12.9%) setback in 1994 when a competitor, the Daya Bay Nuclear Power Plant (in Guangdong, Mainland China), started operation in March of that year (CLP Holdings, 1998). As the electric utility industry in PRD becomes more mature, CLP Power can no longer count on the
growth of electricity demand outside Hong Kong as a source of its profit growth. In the long run, the increasing number of electricity generation plants in South China will become CLP Power's competitors on its home market once Hong Kong's electric utility industry is deregulated.

The operation of CLP Power is currently governed by an agreement with the Hong Kong government, known as Scheme of Control (SOC). Under SOC, the company is allowed to charge tariffs designed to recover its costs plus an allowed after-tax return. While this agreement is still in force for a number of years, the rising expectations of well informed consumers, and growing demand of the community for protection of the environment are presenting an ever increasing challenge to the company to provide electricity reliably and securely to its customers at the lowest reasonable cost and in an environmentally sound manner. Recent developments of the local political systems have also provided people with increased channels to air their discontents through their representatives on the District Boards or the legislature, or the various pressure groups. Two of the issues vigorously monitored by these watchdogs are the tariffs charged by the utility companies, and quality of services they provide. Reform of the SOC and even deregulation of the industry are becoming real threats to the company.

In the light of the changed competitive landscape, CLP Power has to become a high quality and low cost provider of energy services in order to protect its traditional markets, and has to introduce innovative products and services to generate additional revenue. A major initiative designed to improve performance in the delivery of electricity to customers was the restructuring of the former TBG and DACS under four guiding principles, viz, focus on minimum cost options, clear accountabilities, flatter organization, and better service.

In late 1997, two new organizations were formed to replace TBG and DACS. The Power Systems Business Group (PSBG) was established to operate the "wires" business which combines the management of the high- and low-voltage systems to achieve a higher level of cost-
effectiveness. The new Marketing and Customer Services Business Group (MACS) handles the "retail" business of transmitting and distributing electricity to customers.

The restructuring exercise created upheaval in the organization in two ways. First, the integration of the "wires" business eliminated duplication of resources that were common to both the high voltage and the low voltage systems. As a result, jobs have been displaced making it possible to achieve significant downsizing of the organization. Second, the organizational structure had to be modified and work redefined so that higher quality service could be delivered with less resources. The success of this change depends a lot on empowerment and trust in the organization. Ironically, these two elements are prone to decline in the stressful downsizing process (Mishra, et al. 1998).

As an initial step to mitigate distrust, CLP Power organized a number of "Cultural Change" seminars well before the organizational change. Every member in the workforce had an opportunity to participate in these events, at which senior managers were invited to give presentations on the need and urgency of change. They also provided an open forum for employees to air their opinions on problem areas in the organization, express their concerns, and make recommendations for improvement. These efforts were made to create a positive attitude towards change and to cultivate an atmosphere of openness in the organization. Another move to pave the way for the restructuring was to introduce the Selective Voluntary Departure Scheme. Under this Scheme, selected employees could opt for voluntary separation with severance benefits. This was welcome by employees who were looking for early retirement, a change of employment, a switch to the self employed consultant status, or a chance to start a new business of their dream. Offering employees the choice has double benefits: employees would feel that they were in control, and it reduced the need for forced layoff. This act of caring for employees helped to build trust in the organization. Through this Scheme, the employee numbers in the
former TBG and DACS were reduced by more than 800, from an original strength of about 3,900.

After the restructuring was announced, people would have to be appointed to positions in the new organization. Since jobs and responsibilities had been reconfigured, it was imperative that the right persons be selected for the right positions. Thus, appointees were chosen on the basis of ability, without being constrained by the positions they previously held. These appointments were made in a cascading manner, starting from the top to ensure smooth transition. To avoid inflicting disempowerment upon the appointees, training programs designed to meet their development needs were provided, and the management information systems would be reconfigured to support decision making, planning and operation control in the new organization.

7.2. PSBG’s Maintenance Operations

PSBG manages a huge electricity transmission and distribution network consisting of overhead lines, underground or submarine cables, transformers, switchgear, and associated support facilities. Obviously, equipment reliability is a crucial factor for achieving a high level of system availability in order to deliver uninterrupted supply of electricity demanded by CLP Power’s customers. This, together with the sizeable maintenance budget, make maintenance a major issue of PSBG’s mission.

The initiatives adopted to optimize maintenance of the high voltage transmission system focused on three areas listed as follows:

- **Systems** — Transmission Operation & Maintenance System (TOMS), Automated Mapping & Facilities Management (AM/FM), Key Performance Indicators (KPIs), Benchmarking, Structured Approach to Strategic Procurement (SASP), Maintenance Service Agreement
People — Multiskilling, Performance Management System (PMS) / Productivity Improvement, Strategic Positioning of Resources, Direct Report to Site, Training & Development


---

*Fig. 7.1 Optimizing maintenance operations for CLP Power’s high voltage transmission system*

These initiatives were built on the foundation of two corporate programs, namely Operations Integrity Management System (OIMS) and Total Quality Management (TQM). Decisions relating to the maintenance regimes to be used for various types of equipment, the interval between inspections, overhauls or preventive replacements, etc., are driven by the methodologies of Reliability Centred Maintenance (RCM) and Risk Based Maintenance Management. Fig. 7.1
shows the framework embracing these initiatives (Brown 1997). The scope of this framework had been extended to cover also the activities of power distribution network after formation of PSBG.

7.3. Sponsor of the Action Research at CLP Power

The action research on introduction of balanced scorecards in CLP Power’s power transmission and distribution operations commenced in July 1997. It was sponsored by W.L. Brown, then Chief Engineer of Network Operations in the Transmission Business Group (TBG). His department (NOD) was responsible for the operation and maintenance of plant and facilities in the company’s high voltage power transmission network, commissioning of new transmission facilities, as well as provision of labour for construction work. S.H. Chan, then Engineering Services Engineer responsible for NOD’s asset utilization and management was the champion driving the first phase of the project.

Subsequent to the reorganization which happened soon after commencement of the project, Brown was redeployed as the Chief Engineer to head the Asset Management Department (AMD) in the newly established PSBG. A simplified organization chart of PSBG is shown in Fig.7.2. In his new post, Brown was responsible for formulating policies, establishing maintenance requirements, setting budgets for new works projects and the three operations departments (Regional) of the business group, initiating and implementing new development projects (i.e., development, design, construction and commissioning of new facilities) for the company’s transmission and distribution network. His department also tracks performance of the network operation by using appropriate Key Performance Indicators (KPIs). In the new line-up, S.H. Chan was appointed as the department’s Network Planning Manager. Management of the business group’s maintenance performance then falls into the portfolio of K.P. Liu, an Engineer in the

Fig. 7.2 Simplified Organization Chart of PSBG

7.4. PSBG’s Maintenance Performance Management System

KPIs made their début several years ago in the then Transmission O&M Branch as major elements in the annual Business Planning Process introduced at that time. Subsequent to that, organization of the transmission operations was restructured a number of times, culminating into the formation of the PSBG. The KPIs used in the Business Planning Process have undergone evolutionary change in such a volatile period. Fig. 7.3 shows the KPIs of Network Operations Department (NOD), the unit responsible for the operation and maintenance of CLP Power’s high voltage transmission network before the organizational change.

Fig. 7.3 Network Operations Department — Key Performance Indicators (1996)
To obtain background information for development of the balanced scorecard, an in-depth study on the practice of maintenance performance measurement in CLP Power's "wires" business was conducted. The first phase of that study took place before the restructuring in 1997. Company documents were examined and representatives of the major stakeholders of TBG's maintenance function were interviewed. These stakeholders included senior management and the operating units of Network Operations Department (NOD). The representatives polled in this phase are listed in Fig. 7.4.

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Position held at time of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.H. Chan</td>
<td>Asset utilization and management</td>
</tr>
<tr>
<td>C.P. Cheng</td>
<td>Training and development</td>
</tr>
<tr>
<td>K.B. Lam</td>
<td>Head, Circuits O&amp;M</td>
</tr>
<tr>
<td>Joseph Lai</td>
<td>Acting Head, Planning and Resources</td>
</tr>
<tr>
<td>K.C. Wong</td>
<td>Head, Commissioning</td>
</tr>
<tr>
<td>P.C. Lo</td>
<td>Head, Substation O&amp;M</td>
</tr>
<tr>
<td>S.J. Lam</td>
<td>Substation Construction</td>
</tr>
<tr>
<td>K.M. Chau</td>
<td>Circuits Construction</td>
</tr>
<tr>
<td>K.F. Tse</td>
<td>Technical audits</td>
</tr>
<tr>
<td>P.K. Lau</td>
<td>Head, Shenzhen operations</td>
</tr>
<tr>
<td>T.M. Chan</td>
<td>Change Management</td>
</tr>
<tr>
<td>C.L. Mak</td>
<td>Change Management</td>
</tr>
</tbody>
</table>

Fig. 7.4 NOD representatives interviewed in July 1997

Observations from these interviews are summarized as follows (Tsang and Brown 1999):

(1) TBG's KPIs were identified with inputs from the department heads, as an integral part of the annual business plan. While these KPIs had to be linked to the organization's Critical Success Factors (CSF), some of them, such as Capital Expenditure (Capex) and DIIR, were mandated by the corporate office or regulatory bodies. According to the spirit of the
Business Planning Process, the KPIs for NOD and those for its individual operating units were to be determined in a cascading manner to achieve vertical alignment between KPIs and TBG's strategy.

(2) The set of KPIs used to manage maintenance performance had been the result of evolution over the years. Initially, the KPIs were picked because they had always been tracked in the past. Subsequently other KPIs were added. Some of these more recent entries were introduced with reference to international standards for benchmarking purposes.

(3) The measures in use included financial indicators such as Operation & Maintenance (O&M) costs, and equipment-based or process-oriented indicators such as equipment availability and labour productivity.

(4) Other performance measures are used for operational control purposes. Examples of this type of KPIs in use within NOD's operating units include: % achievement against maintenance plan, manpower loss due to sick leave, system availability, equipment failure rates, etc.

(5) It is considered that the KPIs selected so far only meet the basic needs of the maintenance department for monitoring its quality and cost performance. They cannot provide management with a balanced assessment of overall performance in terms of the department's critical success factors.

(6) Targets for the KPIs are established primarily by extrapolation. For example, targets for the equipment failure rates are set using five-year moving averages, operating budgets are determined by extrapolation with adjustment for expected inflation and with the planned productivity improvement being factored in.

(7) Data capturing and reporting to support the performance management system are handled
by the computerised Transmission Operation and Maintenance System (TOMS).

The second phase of the study proceeded shortly after the new ‘wires’ business group, i.e., PSBG, was established. Stakeholders of the maintenance function not previously polled were interviewed by the researcher. These interviewees, listed in Fig. 7.5, are former staff of the defunct Distribution and Customer Services Business Group (DACS). Four out of the six in the group are from the 3 regional units which are responsible for operating and maintaining the “wire” assets of the business group. A simplified organization chart of the regional unit is shown in Fig. 7.6.

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Position held at time of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>K.P. Liu</td>
<td>Performance Management — Asset Management</td>
</tr>
<tr>
<td>K.L. Wong</td>
<td>Planning &amp; Design Manager — East Region</td>
</tr>
<tr>
<td>Y.L. To</td>
<td>Distribution Operations Manager — West Region</td>
</tr>
<tr>
<td>Y.S. Yip</td>
<td>Circuits O&amp;M — North Region</td>
</tr>
<tr>
<td>C.W. Luk</td>
<td>Transmission Plant O&amp;M — North Region</td>
</tr>
<tr>
<td>S.L. Wong</td>
<td>Information Systems — Asset Management</td>
</tr>
</tbody>
</table>

Fig. 7.5 PSBG representatives interviewed in February – March 1998

Fig. 7.6 Simplified Organization Chart of Asset Management Department, PSBG

New findings from the second round of interviews are outlined below:
(1) The scorecard for a region was developed using a bottom-up approach—the various branches in the region proposed their sets of KPIs to Planning & Design, which would consolidate them into a scorecard for submission to the General Manager of the business group. In the transition period at the time of the interviews, most key persons were new to the post. Therefore, the scorecards for individual branches were not yet fully developed.

(2) Even though not orchestrated by Asset Management, the scorecards used by the three regional units were very similar to each other. The KPIs in these scorecards fall into six categories:

1. safety
2. performance pledges to external customers
3. system performance
4. financial performance
5. productivity performance
6. inventory management performance

Categories 4 to 6 were introduced after the restructuring.

(3) KPIs were being used for internal benchmarking amongst the 3 regions. These include:

- fault rates (cable, overhead line), customer minute lost (SAIDI \(^1\)), O&M costs per employee, per customer, and per kWh sold.

(4) In the regional units’ scorecards, the KPIs that relate to CLP’s performance pledges (service standards) included: arrival on site within one hour after receipt of notification, 3-day advance notice for planned shutdown, and restore supply within 6 hours.

(5) Looking back to the days before the restructuring, there was not much participation from the regional units of the former DACS in developing the scorecard at the business group level.

(6) The informants agreed that the performance scorecards in use provided them with a clear

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\(^1\) SAIDI is *System Average Interruption Duration Index*. It is a measure of power loss per customer.
focus in managing their operations. However, using the performance data for judgemental purposes should be handled with caution. They pointed out that unsatisfactory performance with respect to certain KPIs could be due to uncontrollable factors, such as equipment design, thunder strikes, and third party damage. The aging of cables would increase the number of faults, and repair work to stop oil leakage in oil filled cables could be held up due to delay in getting the Excavation Permit. The latter problem often occurs on cables that run along roadways with heavy traffic. It was also realized that this type of problem would motivate managers to decommission aged cables on the basis of economic considerations.

With the BSC as a model, PSBG’s maintenance scorecards were biased on the financial and internal processes perspectives with insufficient focus on the customer and organizational development perspectives, even though efforts had been made to develop a learning culture and change readiness in the maintenance function. Specifically, appropriate KPIs for the following strategic objectives need to be identified:

- Nurturing an organizational culture that embraces mutual trust, teamworking and change — KPIs measuring the progress and effectiveness of the change initiatives.
- Developing a flexible and responsive workforce — KPIs measuring staff competencies and the extent of staff development needs

- Be customer focused — KPIs measuring customer satisfaction and relationships with customers

---

2 In the past, the organization was structured by specialization. Each branch head is a specialist in a specific field. After the restructuring, the branch head becomes a generalist. His scope of responsibilities has expanded and he needs to depend more on the technical knowledge of his team leaders to discharge his duties. Thus, the dilation of managers’ experience has to be compensated by more empowerment in the organization. Development of a multi-skilled workforce helps in achieving this strategic move.
Moreover, most of the KPIs in use were backward looking. These were outcome measures, also known as lag indicators. In order to inform managers to make projections on future performance, they should be supplemented by performance drivers, also known as lead indicators. These observations were shared with Liu, the CLP representative driving the project.

7.5. Asset Management’s Balanced Scorecard

After reviewing the existing practice of maintenance performance measurement, the researcher worked closely with Liu and his assistant to develop the Balanced Scorecard for Asset Management (AMD). It would become the top level scorecard for managing PSBG’s maintenance performance. The scorecards for line departments, i.e., the regional units, would then be developed in a cascading manner.

The Strategic Maintenance Performance Management Process introduced by Tsang (1998), shown in Fig. 2.6, was followed in developing AMD’s balanced scorecard. The corporate vision, PSBG’s mission, and its key result areas (KRAs) as documented in the business plan were studied, see Fig. 7.7. Such information was the driver of the various strategic initiatives pursued by PSBG, and these in turn were used to identify the KPIs in AMD’s balanced scorecard.

The project team also attempted to develop a model showing the cause-and-effect relationships of the various strategic objectives. It would be used as a tool for communicating the logic of the maintenance strategy espoused by Asset Management. Fig. 7.8 is the model produced by the team after several iterations. Each block in the model denotes a major strategic initiative or objective, labelled by a “verb-noun’ descriptor, such as optimize purchase practices, and increase customer satisfaction. This type of descriptor imposes clarity of intent, and it is more likely to generate action plans that will make a difference in future organizational performance.
Corporate Vision

To be the best utility in the world

PSBG's Mission

To deliver quality power supply to customers at low cost, through unified strategies that achieve operational excellence.

The Key Result Areas (KRAs) of PSBG for the 1998 are:

- Cost management
- Productivity improvement
- Supply reliability and quality
- Increase customer satisfaction
- Safety, health & environment
- Exploit external business

Fig. 7.7 Corporate Vision, and PSBG's Mission and Key Result Areas in 1998

The blocks were organized into the four perspectives of a typical balanced scorecard (BSC), namely financial, customer, internal processes, learning & growth. The logic embedded in part of the model and the initiatives encapsulated in some of the blocks are explained below:

- *Introduce new policies for asset acquisition.* These include efforts to migrate from detailed technical specification to functional specification for acquisition of new assets in the power system. It allows for more quality and competitive suppliers to be available for selection.

- *Apply new technologies to optimize system performance.* This includes actions such as acquiring mobile generators and maintenance-free power plants, applying no-dig technology for laying underground cables, replacing oil-filled cables with solid insulated ones, and introducing condition monitoring technologies. This initiative can be the antecedent of several other blocks in the customer perspective: *Improve safety, health & environmental performance, Improve supply reliability & quality, and Increase customer satisfaction.*

- *Increase customer satisfaction* supports the objective to *Increase asset utilization* because in a competitive business environment, customers have other options for energy supply.
Fig. 7.8 Cause-and-Effect Relationships of Asset Management's Strategic Objectives
Achieve **seamless flow of information** is the major objective that relates to performance tracking and decision making. This supports the initiative to **improve supply reliability & quality** because high risk items can be identified more quickly for corrective action.

Once the strategic objectives had been established, the scorecard measures could then be identified. These KPIs consisted of a mix of performance drivers (lead indicators) and outcome measures (lag indicators). Fig. 7.9 shows the list of candidates considered for inclusion in AMD's BSC. Consider objective II: **Optimize purchasing practices**. Obviously, "rejection rate of purchased items" and "delivery cycle time" measure the degree of success in achieving II. Hence, they are **lag indicators**. To accomplish this objective, a major thrust is to introduce competitive bidding in purchasing spares and supplies for maintenance work. In such case, "% of purchases with competitive bid" can be a **lead indicator** for II.

We should measure what matters, not what is nice to know. The attributes of good measures are:

- **Relevant** — The measures are linked to issues of strategic importance.
- **Meaningful** — The measures are meaningful to those whose performance is being measured and those who will act on the reported results.
- **Controllable** — Those who will act on the measurement can control the outcome.
<table>
<thead>
<tr>
<th>Strategic Objectives</th>
<th>Lag Indicators</th>
<th>Lead Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1: Productivity improvement</td>
<td>Staff performance rating (average and minimum)</td>
<td>Employee satisfaction index</td>
</tr>
<tr>
<td></td>
<td>Manpower per customer</td>
<td>Rate of employee suggestions</td>
</tr>
<tr>
<td>L2: Develop relationships / implement improvement programs with suppliers</td>
<td># of relationship agreements established</td>
<td># of meetings with suppliers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Value of joint improvement projects started</td>
</tr>
<tr>
<td>L3: Improve access to information</td>
<td>% of staff with access to MIS</td>
<td></td>
</tr>
<tr>
<td>L4: Improve competencies of staff</td>
<td>% match of the required skill profile</td>
<td>% completion of identified specialist training</td>
</tr>
<tr>
<td></td>
<td>Competencies rating (average and minimum)</td>
<td>Attendance of specialist training</td>
</tr>
<tr>
<td>11. Optimize purchasing practices</td>
<td>Rejection rate (by value) of purchased items</td>
<td>% of purchases (by value) with competitive bid</td>
</tr>
<tr>
<td></td>
<td>Delivery cycle time</td>
<td></td>
</tr>
<tr>
<td>12. Introduce new policies for asset acquisition</td>
<td>Rate of progress of specification migration</td>
<td>Rate of progress of specification review</td>
</tr>
<tr>
<td>13. Introduce new policies to optimize system performance</td>
<td>Delivery energy index</td>
<td># of review meetings</td>
</tr>
<tr>
<td>14. Apply new technologies to optimize system performance</td>
<td>ROI of investments in new technology</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>% completion of projects in progress</td>
</tr>
<tr>
<td>15. Achieve seamless flow of information</td>
<td>Rating on sharing of information and knowledge</td>
<td>% of IT projects completed vs plan</td>
</tr>
<tr>
<td>C1. Improve safety, health &amp; environmental performance</td>
<td>DIIR rate</td>
<td>Safety audit score</td>
</tr>
<tr>
<td></td>
<td># of accident and near miss incidents</td>
<td></td>
</tr>
<tr>
<td>C2. Increase customer satisfaction</td>
<td>Service pledges achievement index</td>
<td>Customer satisfaction index</td>
</tr>
<tr>
<td></td>
<td></td>
<td># of service standards reviewed</td>
</tr>
<tr>
<td>C3. Improve supply reliability &amp; quality</td>
<td>Customer-minute loss</td>
<td>% completion of the Y2K readiness program</td>
</tr>
<tr>
<td></td>
<td></td>
<td># of continuous improvement projects completed</td>
</tr>
<tr>
<td>F1. Best cost management</td>
<td>Operating cost per customer</td>
<td># of cost/benefit analyses performed</td>
</tr>
<tr>
<td>F2. Increase asset utilization</td>
<td>Utilization of installed capacity</td>
<td></td>
</tr>
<tr>
<td>F3. Increase return on assets</td>
<td>Operating cost to total asset</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 7.9 Potential Candidates of KPIs for Asset Management's Balanced Scorecard
A template that provides guidelines for defining good performance measures is shown in Fig. 7.10 (Neely, et al. 1997). It was introduced to company members of the project team for application.

<table>
<thead>
<tr>
<th>Item</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>Title of the performance measure</td>
</tr>
<tr>
<td>Purpose</td>
<td>Why this measure needs to be tracked?</td>
</tr>
<tr>
<td>Relates to</td>
<td>Should be linked to one or more strategic objectives</td>
</tr>
<tr>
<td>Target</td>
<td>Set both short-term (current year) and stretch targets</td>
</tr>
<tr>
<td>Formula</td>
<td>Defines how performance is measured</td>
</tr>
<tr>
<td>Frequency of measurement</td>
<td>How frequently is performance to be reported?</td>
</tr>
<tr>
<td>Frequency of review</td>
<td>How frequently is performance to be reviewed?</td>
</tr>
<tr>
<td>Who measures?</td>
<td>Who is to collect the data and report the measurement?</td>
</tr>
<tr>
<td>Source of data</td>
<td>State the source of raw data</td>
</tr>
<tr>
<td>Who owns the measure?</td>
<td>Who is accountable for meeting the performance target?</td>
</tr>
<tr>
<td>What do they do?</td>
<td>The management process that will be followed by the ‘owner’ when performance is behind target</td>
</tr>
<tr>
<td>Who acts on the data?</td>
<td>Who is responsible to react when data is reported?</td>
</tr>
<tr>
<td>What do they do?</td>
<td>The management process that will be followed in response to variation from expectation</td>
</tr>
<tr>
<td>Notes and comments</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 7.10** Template for Design of Performance Measures

The experience gained from this pilot work demonstrated that the template compels the manager to be explicit about what the measure meant for his operation — target, formula, and source of data have to be specified. The act of identifying the source of data directs the manager to determine the method of data collection and check availability of good quality data. It also triggers the manager to review relevance of the measure, taking into account the behavioural implications — *what do they do?*
7.6. **Deployment of Asset Management’s Balanced Scorecard**

A presentation on “Measuring Maintenance Performance Using Balanced Scorecards” had been delivered by the researcher to managers and engineers of the operating units, and executives of the Finance Department in the Business Group. The *what, why* and *how* of performance management using balanced scorecards were explained. It created an awareness of the new approach to managing maintenance performance in the organization.

Ideally, the stakeholders of PSBG’s maintenance operations — the Regional Managers as well as the branch heads of Asset Management’s various units — should be involved in developing AMD’s scorecard. Their participation in the process would be an invaluable learning experience in putting the new approach into practice. Issues such as impact of the performance measures on organizational alignment and employee behaviour, relevance and completeness of the measures selected, and availability of resources and infrastructure to support the management system would be considered more thoroughly with inputs from these stakeholders. It would also help to get their buy-in to the balanced scorecard thus produced. The next step would have been to deploy the top level (AMD’s) scorecard to the operating units (the Regions).

The above moves were not taken so far at the host organization because of the following reasons:

(1) *Departure of the sponsor*

W.L. Brown, sponsor of the project, had targeted “implementation of the balanced scorecard for measuring PSBG’s maintenance performance” as one of Asset Management’s major initiatives. He left the company while the project was in progress. His successor did not accord the project the same level of priority.

(2) *The upheaval of recent organizational changes*

The restructuring following the integration of the “wires” business created upheaval in the
Managers were new to their posts, many of them saw their roles changed from a specialist to a generalist. They were busy adjusting to the operational demands of their new capacity. Unless driven by strong leadership from the top, the unit managers preferred the tried and tested tools to new ones. Thus, they were quite hesitant to introduce new measures in managing their maintenance operations.

(3) The managers’ mindset

Most managers of the operating units are engineers by training. They have a tendency to focus on technical issues and solutions that will produce quick and tangible results. Liu once said, “If we organize an event to discuss topics related to productivity improvement or to introduce new maintenance technologies, we will get a large audience. However, when the topic is performance measurement, most managers and engineers will not be interested.” This, together with the lack of sustained sponsorship from the top and a strong advocate of the cause, explain why the open forum to discuss AMD’s balanced scorecard as suggested by the researcher is yet to be organized.

(4) Perceived function of the Balanced Scorecard

Through discussions with the informants and a study of the scorecards currently used by the operating units, most people in the host organization regarded the balanced scorecard merely as a framework for ensuring multiple perspectives are reflected in the set of performance measures being tracked. The more important function it can serve — the vehicle to inform staff of the organization’s strategic intent and to influence people’s behaviour to achieve the strategic objectives — was not widely recognized. Obviously, enhancing understanding of the BSC concept within the organization would be a definite advantage. This can be realized through widespread discussion and training.
7.7. Mass Transit Railway Corporation

Mass Transit Railway Corporation (MTRC), the other host organization of this action research project, is the owner and operator of Hong Kong’s mass transit railway system that serves commuters through a 74-kilometre network with 43 stations. The system carries more than 2.3 million passengers per weekday, making it the most heavily utilized (per track kilometre) urban railway in the world.

Ever since it started its passenger train service in 1979, the MTR system had been enjoying a number of strategic advantages, viz, air conditioned transportation service, fast and reliable movement of passengers, and clean environment. Thus, it was able to position itself as the premium service provider, charging relatively higher fares compared to other means of public transport. These advantages have been eroding gradually in recent years. First, innovations in transport management such as the likely introduction of cross-district bus-only lanes for corridors covering major commuter traffic will ease traffic congestion on main roads, thus enabling the public franchised buses to provide faster and more reliable service. Second, the other public franchised transport operators have been upgrading their service by putting an increasing number of cleaner and air conditioned buses into service. Third, the completion of a number of major highway projects had greatly improved inter-district movement of vehicles. With such growing competition from road transport providers, MTR’s overall market share started to fall since 1994. In 1994, it was 27.8% and it fell to 25.7% in 1998.

The repercussions of the current Asian economic turmoil posed additional challenge to the company. Hong Kong’s Gross Domestic Product (GDP) contracted 5% in 1998. This caused the overall public transport demand in the city to drop by 0.9% from the previous year. The company shared the blow of the recession as it registered in 1998 a 2% drop in total number of passengers carried by its system, to 794 million, as compared to 1997. In the light of the difficult economic
conditions, and taking into account the low inflation rate in Hong Kong, fares on the MTR system were frozen in 1998 (MTRC 1999).

The Airport Express — the railway link to the new airport — started its passenger service in mid 1998. The patronage of this route fell short of expectation by a wide margin due to dramatic drop in tourist arrivals coupled with fierce competition from other transport providers. This created yet another financial burden to the company in the short term.

To prepare for these challenges, the Corporation has increased its multi-skilling, redeployment and retraining programs to enhance staff’s ability to effectively utilise existing internal resources for meeting the needs of the Corporation in the coming years. Furthermore, Jack So, Chairman of the Corporation, states in the 1998 Annual Report that in 1998 “a comprehensive review of operating costs and capital expenditure plans was undertaken, as a result of which significant savings in costs have been identified through enhanced productivity, redeployment of staff and management rationalizations in areas which we believed will not compromise the safety or the efficiency of our services” (MTRC 1998).

7.8. MTRC’s Maintenance Operations

The Operations Engineering Department (OED) has more than 3,600 staff and is the largest department in the corporation. Its main functions include provision of engineering services to support the operating railway as well as future extensions, management of existing and future assets, and involvement in the planning, designing and implementation of new extensions of the railway. The department has the vision “To deliver excellent engineering services to customers”, which in turn supports the corporate strategy of serving customer needs by contributing to the provision of safe, reliable and efficient railway service through effective and efficient management of railway assets (OED 1998). Obviously, OED’s management focus is on
customer service standards, many of them are linked to equipment that interface with customers.

The long-term goals of the department can be categorized into five perspectives, as shown in Fig.7.11. These goals, in turn, identify the department’s critical success factors required to fulfill the corporate mission.

![Diagram of OED's Long-Term Objectives](image)

**Fig. 7.11 OED’s Long-Term Objectives**

The major initiatives adopted by OED to support the corporate strategy include:

(a) Sustaining employee participation programs such as

- *Top-Ten Scheme*, a management driven, team-based approach to enhancing customer service by continuous improvement of equipment reliability in service.

- Work Improvement Team (WIT) activities. WIT projects are identified and solved by the teams. Currently, more than 200 WIT Teams are in operation in the department.

- Staff Suggestion Scheme

(b) Participating in international benchmarking. The Corporation, represented by OED, is an active participant in the community of Metros (CoMet) group, an international body set up to
benchmark operations and practices of mass transit systems world-wide. It provides the Corporation the opportunity to share information, improve performance and measure its internal standards with other major operators.

(c) Implementing the Integrated Management System (IMS) that embraces the concepts of empowerment, leadership, reduced bureaucracy, and simplification.

(d) Developing an Integrated Documentation System for deployment on the Intranet to facilitate documentation maintenance and control, enhance usability, and ultimately improve operational efficiency.

(e) Developing a multi-skilled work-force, an initiative applied more extensively in the Airport Railway.

(f) Practicing condition-based maintenance through the use of non-destructive testing (NDT), vibration and noise monitoring techniques.

(g) Adopting the System Assurance methodology to manage projects that relate to safety critical systems.

The Maintenance Organization

A simplified organization chart of OED as of December 1998 is shown in Fig. 7.12.

![Fig. 7.12 Simplified Organization Chart of Operations Engineering Department (Dec. 1998)]
The line units that deliver maintenance and asset management services on the operating railway are headed by three managers:

- **Operations Engineering Manager (OEM)** — The categories of railway assets serviced by the OEM Group include system-wide equipment (such as overhead lines, signaling and telecommunications network), as well as station facilities (such as automatic fare collection and building services equipment) and rolling stock of the urban lines. It has three depots for train stabling and maintenance.

- **Maintenance Manager (LAR)** — This Group is responsible for the maintenance operations of the Lantau Airport Railway (LAR), covering station facilities, rolling stock and civil works. The LAR provides two services, namely a domestic mass transit service linking Central (the business district), Kowloon with Tung Chung (a new town on Lantau Island), called the Lantau Line (LAL), and a dedicated service linking Central and Kowloon with the airport, called the Airport Express (AEL). The trains used on this railway are different from those used on the urban lines. They are stabled and serviced in a fourth depot located on Lantau Island.

- **Civil Works Manager (CWM)** — This Group is responsible for managing and maintaining the civil, structural, building and architectural assets of the Railway. It deals with internal parties in rendering maintenance services on the permanent way (tracks, tunnels) and structures. It also deals with external parties in monitoring construction activities nearby the Railway to ensure the structural integrity and the safe operation of the MTR system.

Operations Engineering Design provides technical support services that relate to rolling stock as well as electrical and mechanical (E&M) facilities managed by OED. These services cover design of asset replacement and major capital works which include refurbishment of existing assets. The Group also provides maintenance support to these assets when they encounter
problems of repetitive failures, are involved in major incidents, or require design modifications.

**Discipline-based and Station-based Maintenance**

Both the urban lines and the LAR adopt similar practices for rolling stock and depot maintenance. However, they are structured differently in managing maintenance of assets other than rolling stock. The OEM Group adopts a discipline-based structure to handle this type of maintenance work. The Airport Railway (LAR) is confronted with new challenges — faster trains, longer at-grade open sections, airport interface management, a suspension bridge, and the introduction of platform screen doors and baggage handling systems. To meet these challenges cost-effectively, the LAR adopts the station-based approach to maintenance management. Its field maintenance units are organized by geographical regions, i.e., Lantau Island and In-town regions. Each region, which may cover one or more stations, has a team of technicians and tradespersons who collectively have all the required skills and resources to carry out the first line maintenance tasks in its stations. The reasons for applying this approach are:

- The stations are larger in size.
- It fosters ownership and teamwork in the maintenance crew.
- The structure is more user-friendly to the operating personnel, because each station is served by a dedicated team of maintainers.
- Many station facilities are computer controlled, thereby reducing the demand for skills in the conventional trades.
- By necessity, the front line employees must be multi-skilled to provide the necessary flexibility. This can be a motivating factor to them.
- Line replaceable units are used as a design principle whenever appropriate to enhance maintainability. For example, modular design is adopted in the baggage handling system so
that any failed module of a conveyor can be removed and replaced to recover the required function within 45 minutes.

- Only recovery-based service is provided for corrective maintenance (CM) jobs. Thus, less training is required to develop the necessary skills in the technical staff. Tony Yeung, Maintenance Manager (LAR), points out that the price of adopting this approach is higher stock carrying cost.

7.9. OED's Application of Balanced Scorecards

Performance measurement has always been a focus area in OED's management system. In July 1997, the balanced scorecard (BSC) and the strategic approach to performance management were introduced to T.P. Lo, OEM, by the researcher. In May 1998, OED started to apply the BSC concept to manage its performance on a trial basis. The strategic business units (SBU's) in the OEM Group were the initial users of balanced scorecards. These were section level scorecards. The OED scorecard was rolled out a short while later. The section level scorecards are linked to the OED scorecard in a cascading manner. Quality & Standards is the staff unit responsible for developing OED's BSC. It also provides technical support to the OEM Group in developing the section-level balanced scorecards within the Group.

After having used this management tool for several months, the senior management of the department decided that it was timely to take a critical evaluation of the efforts made so far. In September 1998, the researcher was invited by Y.K. Chan, Quality & Standards Manager (Q&SM), to conduct a review with the following objectives:

(a) Obtain insights into OED's current performance management system.
(b) Critique the design of the scorecards used in OED and OEM's SBU's.
(c) Make recommendations on future development of OED's BSC initiative.
Prior to the review, the researcher gave two presentations as part of the effort to promote awareness and enhance understanding of the balanced scorecard in OED’s new approach to performance management. The first presentation titled “A Strategic Approach to Managing Maintenance Performance” was delivered at the “Balanced Performance Scorecard Seminar” held in July 1998. The in-house event was attended by about 80 participants from the OEM Group and other Sections in OED. It generated considerable amount of interest in the audience as judged by the enthusiastic discussion and probing questions raised during the Q&A session. The second presentation titled “Managing Maintenance Performance with Balanced Scorecards” was given at the OED Senior Management Group Meeting held in August 1998. The issues discussed during the Q&A sessions after these presentations include:

- Critical success factors for applying the BSC concept in performance management.
- The process used by other companies in introducing balanced scorecards.
- The role of cascading balanced scorecards in achieving organizational alignment.
- Performance measures in the “Learning & Growth” perspective.

### 7.10. Critique of OED’s Maintenance Performance Management System

Company documents were studied to obtain information on the company’s vision, mission, as well as OED’s organization structure, management systems, strategies, initiatives and performance measures in use. The views of line managers were an important source of information for the review. Through Q&SM, requests for interviews were sent to managers in the department with responsibility for providing maintenance services. The managers who had responded and were interviewed by the researcher are listed in Fig. 7.13. These interviews were conducted in September 1998.
<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Position held at time of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tony Yeung</td>
<td>Maintenance Manager, LAR</td>
</tr>
<tr>
<td>Simon Wong</td>
<td>Electronic Workshop Manager</td>
</tr>
<tr>
<td>Adi Lau</td>
<td>Civil Works Manager</td>
</tr>
<tr>
<td>Francis Mok</td>
<td>Control &amp; Communications System Manager</td>
</tr>
<tr>
<td>P.T. Chin</td>
<td>Electrical &amp; Mechanical Services Manager</td>
</tr>
<tr>
<td>David Cheng</td>
<td>Fleet Manager (Rolling Stock Depots)</td>
</tr>
</tbody>
</table>

Fig. 7.13 OED managers interviewed in September 1998

These interviews typically focused on the following areas:

(1) Interviewee’s role in the maintenance operation.

(2) Existing practice of maintenance serviced by the interviewee’s unit.

(3) Key result areas and major initiatives of the interviewee’s unit.

(4) Existing practice of performance management

Records of these interviews were written and sent to the informants for confirmation of accuracy.

Subsequent to these interviews, a series of meetings were also held with the following staff members in the Quality & Standards Unit:

- Y.K. Chan: Quality & Standards Manager
- Felix Ng: Standards Manager
- K.W. Li: Standards Section Engineer
- Ryan Li: Productivity Engineer
- Yvonne Ng: Industrial Engineer

The following issues relating to the design and application of balanced scorecards were discussed:

(1) Methodology for identifying major initiatives in the Business Plan.
(2) Strategic issues identified by OED and the major initiatives developed to neutralize the perceived threats or exploit the envisaged opportunities.

(3) Design of the Balanced Scorecards being used in OED and the OEM Group.

(4) Setting of stretch (5-year) targets for performance measures.

(5) Validation of the causal relationships between action plans and their expected outcome.

(6) Analysis and presentation of measurement data.

**OED's Computerized Management Information Systems**

The Department has a well structured system for generating daily, weekly and monthly performance reports from its Maintenance Management Information System (MMIS). These reports provide very useful data for the detection and diagnosis of operational problems. However, they are not able to convey a clear message of OED’s strategic focus and what the Department believes to be the drivers of its future success.

Apart from the MMIS, other information systems are also being used to measure other aspects of performance. These include Sectional accounts generated from the financial information system, and data on staff training and nominations for training courses retrieved from the database maintained by Human Resources. These systems are designed for their specific purposes and are disjointed from each other, making it a strenuous task to review progress towards meeting strategic objectives. A properly designed balanced scorecard, which presents the strategic performance data from all the critical perspectives, can overcome this problem.

**OED's Balanced Scorecard**

Typically, a balanced scorecard features performance measures reflecting four perspectives — financial, customer, internal processes, and learning & growth. In OED’s core activities, safety of passengers, staff and contractors has always been a matter of utmost priority. To reflect the
emphasis on this issue, safety was added as a fifth perspective in its scorecard. The performance measures featured in OED's balanced scorecard for 1998 are listed in Appendix IV.

Another significant feature in OED's scorecard is the large proportion of performance measures (6 out of 17) that are linked to customer service, indicating the focus of attention on customer service targets. These are hard measures which are either equipment based, such as train reliability and escalator availability, or system oriented, such as frequency and total duration of train delays due to equipment failure. To enhance the efficacy of the scorecard, the following recommendations were made by the researcher (Tsang 1998b):

(a) In the Internal Processes perspective, it was suggested to include one or more measures relating to those end-to-end processes that are critical to satisfying customer needs. Typically, multiple parties are involved in such end-to-end processes. Service recovery time (average and the upper quartile), counting from the moment when an incident is reported to the time when service is returned to normal, is an example of these measures.

(b) The scorecard was useful for reviewing the past, but not for predicting the future. It was rich in outcome measures (the What items) but poor in performance drivers (the How items). More lead indicators ought to be introduced into the scorecard, and they should be linked to OED's strategic initiatives, such as implementation of the Integrated Management System (IMS) and development of a multi-skilled workforce.

(c) Another area in need of improvement was the weak connections between performance measures and the declared strategic objectives. 'What are the appropriate measures for the Learning & Growth perspective?' was a frequently asked questions raised by managers.

While generic measures such as employee satisfaction, employee loyalty and value added per employee may be considered, organization specific measures in this perspective can be identified through those strategic initiatives that relate to manpower development, knowledge
management, and organizational learning.

The likelihood of establishing the desired connections may be enhanced by adopting a Strategy Planning and Deployment framework that features a structured approach to identifying performance measures and setting objectives and targets. An example of this framework is presented in Fig. 8.7 and 8.8 in Chapter 8.

Appendix VI shows a list of possible candidates of performance measures for OED’s Scorecard, their classifications as well as their links to strategic objectives and major initiatives. The objectives and initiatives stated in the Appendix are fabricated only for illustration purposes.

**Section-Level Balanced Scorecards**

The OEM Group had taken the lead of cascading OED’s BSC into scorecards for its various sections. The balanced scorecard of Rolling Stock Depot, one of the SBUs in the OEM Group, is given in Appendix V. These second-tier scorecards serve as the vehicle for deploying departmental objectives to individual sections in the Group. As such, many of the measures and their related targets in the section-level scorecards are scaled down replicas of those in the Departmental Scorecard. If these measures are to produce real impact, they may need to be customized (in terms of definition and scope) to make them both meaningful and controllable at the working (section) level. In some cases, it may be necessary to include section-specific measures that have no similar counterparts in the higher level Scorecard.

By virtue of the cascading process, the shortcomings in OED’s scorecard identified earlier are also inherited by the section-level scorecards. In order to achieve vertical alignment of strategic objectives and major initiatives, the prescriptions for improving the top-level scorecard also apply to the design of scorecards at this level. These include establishing clear connections between strategic objectives and performance measures, as well as enriching the mix of lead
indicators in the scorecard. The sections are also encouraged to incorporate customized (section specific) measures in their scorecards, following the guideline that measures are meaningful to and controllable by the users.

The internal processes perspective at the section level is also labeled as the productivity perspective. It gives an impression that this perspective focuses mainly on efficiency, even though some of the measures in that perspective may be indicators of effectiveness.

Change of Mind-set

The problem encountered at CLP regarding the perceived function of the balanced scorecard is also found in OED. Stakeholder participation, widespread discussion and training are essential to develop a better understanding of the BSC concept in the organization for successful application of the balanced scorecard.

Appropriate modification to the existing scorecards is also considered necessary in order to get the full benefits of applying balanced scorecards. The upheaval of today's business environment mandates fast adaptation to changed market conditions so as to guarantee future success. For example, outsourcing more maintenance work may be an appropriate strategic move in periods of rapid expansion and tight labour market. However, the same move will be ill conceived in a depressed market when the company continues to adhere to a policy of maintaining a stable workforce. The balanced scorecard needs to faithfully reflect changes in strategic direction.

7.11. Feedback from Questionnaire Surveys

A questionnaire survey was conducted in early February 1999 to solicit views on OED's Performance Management System after introduction of the balanced scorecards. The instrument used in Phase I was modified for use in this survey. There are five sections in the questionnaire, viz,
(1) Sections 1 and 2 are new additions in the instrument. They ask respondents to indicate their observation on the focus of discussions in Annual Management Reviews and Monthly Management Reviews, respectively.

(2) Sections 3 and 4 were sections 1 and 2 in the instrument used in Phase I. They ask respondents to indicate the importance of 11 dimensions in measuring OED’s Departmental and Sectional performance, respectively.

(3) Section 5 was section 3 in the earlier instrument. Some of the items in the latter had be removed because staff’s opinion on those issues had been polled in an earlier survey covering a separate theme (see Appendix VII for a listing of the removed items). After the trimming, this section has 10 statements that describe various aspects of OED’s Performance Management System.

The questionnaire was sent to all 29 members of OED Management Committee. Completed questionnaires were received from 9 members, the results of which are summarized below.

**Sections 1 & 2: Focus of Management Reviews**

<table>
<thead>
<tr>
<th></th>
<th>Relative amount of time spent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; ¼</td>
</tr>
<tr>
<td>*<em>Annual Management Reviews (7 responses <em>)</em></em></td>
<td></td>
</tr>
<tr>
<td>1.01 Review of strategic issues</td>
<td>2 29%</td>
</tr>
<tr>
<td>1.02 Discuss implications of issues</td>
<td>2 29%</td>
</tr>
<tr>
<td>1.03 Review past performance</td>
<td>2 29%</td>
</tr>
<tr>
<td><strong>Periodic Management Reviews (9 responses)</strong></td>
<td></td>
</tr>
<tr>
<td>2.01 Review of strategic issues</td>
<td>6 67%</td>
</tr>
<tr>
<td>2.02 Discuss implications of issues</td>
<td>3 33%</td>
</tr>
</tbody>
</table>

* 2 respondents did not complete Section 1 because they stated that the Annual Management Review was not yet held.

**Fig. 7.14** Focus of OED’s Management Reviews
The responses to Sections 1 and 2 indicate that the focus of discussions is slightly biased towards review of past performance. The bias is more obvious in Periodic Management Reviews. However, 43% (3 out of 7) of the respondents indicated that at Annual Management Reviews about ½ to ¾ of the time was spent to discuss implications of strategic issues.

Sections 3 & 4: Dimensions of Performance Measurement

The “very important” scores of various dimensions as rated by respondents are ranked in descending order in Fig.7.15 and Fig.7.16.

3 of the 4 top ranking dimensions in OED’s top level performance measurement are identical to the 3 top ranking dimensions in sectional performance measurement. They are: “Cost/financial return”, “Equipment performance: reliability, availability, fault rate”, and “Safety & environmental management”. This list of top ranking dimensions differs from that obtained in the Phase I survey. It shows greater emphasis on equipment performance and safety and environmental management in a large maintenance organization such as OED.

The 3 lowest ranking dimensions in departmental performance measurement are: “Progress of strategic initiatives”, “Relationships: customers, suppliers or contractors”, and “Innovation (technological or managerial), improvement”. The first and the third of these dimensions also rank among the bottom 3 in sectional performance measurement. These results are similar to the corresponding findings from the Phase I survey polling executives from different types of organizations based in Hong Kong.

These results indicate that in OED, performance measurement at both departmental and sectional levels focuses primarily on conventional and “hard” measures, while performance drivers or “soft” measures are less emphasized.
### Measurement of departmental performance

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.02</td>
<td>Equipment performance: reliability, availability, fault rate</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>3.04</td>
<td>Time: response time, recovery time, service delays</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>3.01</td>
<td>Cost / financial return</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>89%</td>
</tr>
<tr>
<td>3.08</td>
<td>Safety and environmental management</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>89%</td>
</tr>
<tr>
<td>3.03</td>
<td>Operation efficiency / productivity</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>56%</td>
</tr>
<tr>
<td>3.05</td>
<td>Customer: satisfaction, loyalty, etc</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>44%</td>
</tr>
<tr>
<td>3.07</td>
<td>Employee: capability, development, satisfaction</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>33%</td>
</tr>
<tr>
<td>3.09</td>
<td>Organizational culture</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>33%</td>
</tr>
<tr>
<td>3.11</td>
<td>Progress of strategic initiatives</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22%</td>
</tr>
<tr>
<td>3.06</td>
<td>Relationships: customers, suppliers or contractors</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11%</td>
</tr>
<tr>
<td>3.10</td>
<td>Innovation (technological or managerial), improvement</td>
<td>0</td>
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<tr>
<td></td>
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<td>0%</td>
</tr>
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</table>

Fig. 7.15  Ranking of dimensions in measurement of OED's performance

### Measurement of sectional performance

<table>
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<th>Description</th>
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<tr>
<td>4.01</td>
<td>Cost / financial return</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>78%</td>
</tr>
<tr>
<td>4.02</td>
<td>Equipment performance: reliability, availability, fault rate</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>78%</td>
</tr>
<tr>
<td>4.08</td>
<td>Safety and environmental management</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>78%</td>
</tr>
<tr>
<td>4.03</td>
<td>Operation efficiency / productivity</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>67%</td>
</tr>
<tr>
<td>4.07</td>
<td>Employee: capability, development, satisfaction</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>67%</td>
</tr>
<tr>
<td>4.04</td>
<td>Time: response time, recovery time, service delays</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>67%</td>
</tr>
<tr>
<td>4.05</td>
<td>Customer: satisfaction, loyalty, etc</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>33%</td>
</tr>
<tr>
<td>4.06</td>
<td>Relationships: customers, suppliers or contractors</td>
<td>3</td>
</tr>
<tr>
<td></td>
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<td>33%</td>
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<td>4.10</td>
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<td>22%</td>
</tr>
<tr>
<td>4.11</td>
<td>Progress of strategic initiatives</td>
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</tr>
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<td></td>
<td></td>
<td>11%</td>
</tr>
<tr>
<td>4.09</td>
<td>Organizational culture</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11%</td>
</tr>
</tbody>
</table>

Fig. 7.16  Ranking of dimensions in measurement of Sectional performance
Section 5: Perceptions on OED’s Performance Management System

The data in this section are summarized using a collapsed 3-point scale, as explained on page 6-4. Fig. 7.17 shows the “strongly agree or agree” scores of various items, ranked in descending order.

At least 78% of the respondents consider that:

- All performance parameters are measured at the appropriate frequency.
- The scorecard measures that relate to respondent’s area of responsibility are meaningful.
- The targets of scorecard measures are established through a participative process.

At the bottom of the ranked list are the following statements with which only 33% of the respondents agreed:

- Quality and timely data are available for evaluating the scorecard measures.
- Reward & recognition systems are aligned with OED’s strategy.

These are the areas to be addressed in refining OED’s Performance Management System.

Other comments made by respondents are:

- “We should try and link the cause/effect of our performance to the customer and provide visibility of this.”
- “Should we have a new scorecard format that shows the trends over say 12 months?”
- “The system must be easy to understand and be able to capture the attention of shop floor staff.”
- “It (the balanced scorecard) enables us to focus more on monitoring real cost and cost effectiveness of our sections in the Department.”
The targets of scorecard measures are established through a participative process

Personal goals and competencies of individual staff are linked to strategy

The scorecard that applies to my unit provides a balanced assessment of our total performance

The scorecard results are presented in a user-friendly manner

The scorecard results are widely communicated in my organization unit

Adequate resources are allocated to make the strategy happen

Quality and timely data are available for evaluating the scorecard measures

Reward & recognition systems are aligned with OED’s strategy

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree or agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>All performance parameters are measured at the appropriate frequency</td>
<td>8</td>
</tr>
<tr>
<td>The scorecard measures that relate to my area of responsibility are meaningful</td>
<td>7</td>
</tr>
<tr>
<td>The targets of scorecard measures are established through a participative process</td>
<td>7</td>
</tr>
<tr>
<td>Personal goals and competencies of individual staff are linked to strategy</td>
<td>6</td>
</tr>
<tr>
<td>The scorecard that applies to my unit provides a balanced assessment of our total performance</td>
<td>5</td>
</tr>
<tr>
<td>The scorecard results are presented in a user-friendly manner</td>
<td>5</td>
</tr>
<tr>
<td>The scorecard results are widely communicated in my organization unit</td>
<td>5</td>
</tr>
<tr>
<td>Adequate resources are allocated to make the strategy happen</td>
<td>5</td>
</tr>
<tr>
<td>Quality and timely data are available for evaluating the scorecard measures</td>
<td>3</td>
</tr>
<tr>
<td>Reward &amp; recognition systems are aligned with OED’s strategy</td>
<td>3</td>
</tr>
</tbody>
</table>

Fig. 7.17 Respondents’ perception on OED’s performance management system

In another survey conducted by OED in late 1998, the opinions of its management and supervisory staff on broader issues were polled. Three of the questions asked in that survey were also related to the current practice of performance management (see Appendix VII). The related results are:

- 60% of the respondents agreed that Executive Managers and Section Heads have direct involvement in setting direction for achieving the departmental objectives, as well as developing and implementing management systems to manage the department. There was a comment that Executive Managers concentrate on some objectives but not too keen on
others, such as productivity management issues.

- 43% of the respondents agreed that leadership, purpose and objectives of the department are well understood by all staff members. Suggestions and comments made by the respondents on this issue include: (a) enhancing the on-line documentation system to allow rapid retrieval of information on vision, mission and objectives via the Intranet; (b) ensuring good communication with staff whenever there is change in leadership, purpose and objectives.

- Only 35% of the respondents agreed that departmental performance indicators were in place, covering the aspects of safety, financial, customer, business processes as well as learning & growth, to help focus on business results and improvement actions. Some respondents suggested that the adequacy and effectiveness of existing customer service targets should be reviewed, and a methodology for deployment of departmental measures into sectional measures be devised.

These findings reinforce the point made in §7.10 Critique of OED’s Performance Management System that promotion and training on the BSC concept should be intensified, and widespread discussion in the development of the scorecards should be encouraged (Change of Mind-set, page 7–33).

7.12. Analysis and Presentation of Performance Data

The difficulties of observing the effects of change initiatives were discussed at length between the researcher and the Quality & Standards (Q&S) group. These can be due to a number of reasons, such as the time lag between cause and effect is much longer than the review cycle, the prescription is not effective in producing the desired change, the implementation is flawed, or the action addresses the wrong problem. Using multi-variate regression analysis to predict future performance would require the use of sophisticated model because results of the output measures
are highly auto-correlated, that is, the results of one period are affected by those of earlier periods.

The *Data Envelopment Analysis* (DEA) technique, introduced in Chapter 2, §2.7, can be used to compare the organization’s multi-dimensional performance during one period with that of other periods. However, the measures involved are typically generic input and output measures. Performance drivers, which inform stakeholders the ‘how’ of achieving performance excellence in the future, may change with time in response to new business realities. Thus, they cannot be featured in a DEA.

The analysis of data on individual measures was another contentious issue considered. The (Q&S) group was advised that snapshot data should be interpreted with caution because deviations from the average can be random variations of a stable process. This is particularly relevant to those measures that relate to rare events, such as industrial accidents. In such case, “time between accidents” or “accident rate” are more appropriate measures than “number of reportable accidents”. Cumulative measures such as moving averages can also be used to smooth out period to period fluctuations. However, there is a catch — they are less sensitive to detect non-random changes in performance.

The monthly results of balanced scorecards are shown in a tabular format, see Fig. 7.18.

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
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<tr>
<td>Safety Accident Injury Rate</td>
<td></td>
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<td></td>
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<tr>
<td>Reportable Accident Freq. Rate for Contractors</td>
<td></td>
<td></td>
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</tbody>
</table>

**Fig. 7.18** Template of OED’s Monthly Balanced Scorecard

OED also uses a radar chart to present snapshots of balanced scorecards. They call it the
'Performance Wheel', as illustrated in Fig. 7.19. Each sector represents the result of a measure for the period under review. The 5-year targets of the scorecard measures are shown as equidistant from the centre, thus forming the Wheel's rim. Similarly, the current year's targets are shown as the arcs of a smaller concentric circle (shown in dotted line). The actual results of the measures are plotted with reference to their deviations from these sets of near-term and long-term targets.

![Performance Wheel Diagram](image)

**Fig. 7.19** OED's Performance Wheel

Colour codes are used to provide additional information on the status of individual results: a data point shown in red indicates that it has a deteriorating trend; a measure that is improving is shown in green; and a measure that shows steady performance is in black colour. The Executive
Information System will be enhanced to enable users to retrieve drill-down information, such as the performance trail (run chart) in the past 12 months or breakdown (the lower level measures), of a particular measure by picking the relevant segment of the Performance Wheel displayed on screen.

7.13. The Next Move at MTRC

While there is room for improvement in their application of balanced scorecards, the executive managers and supervisory staff in OED are enthusiastic about the initiative. M. Brown, Chief Engineer (Operations), who is in charge of OED, finds the balanced scorecard “to be an effective, holistic and well-balanced tool for the department to assess its performance, identify improvement opportunities, and initiate improvement actions on a continuous basis” (Brown and Chan 1999). He is also upbeat about the value of the Performance Wheel as it enhances visibility of the department's performance on the current key business issues and critical success factors.

As part of its efforts to prepare for the tough challenges ahead, the Company is integrating its Operations and OED functions. Encouraged by the enthusiasm generated through the pilot application in OED and the positive staff feedback on its worth, balanced scorecards will continue to be applied in the restructured organization. Obviously, the top level scorecard will have to be modified to embrace the additional function after the restructuring.
8. Discussion

8.1. Scorecard for Maintenance Performance Management

The Problem of Awareness

Findings from the case studies reported in this thesis indicate that many capital intensive organizations do not pay sufficient attention to managing their maintenance performance even though excellence in maintenance is key to the success of their business. Companies like CLP Power, MTRC and Dofasco where performance measurement is emphasized in maintenance management are the exceptions rather than the norm. This phenomenon is due to the following reasons:

(a) Allocation of resources for maintenance is typically made through the operating budget. Managers therefore regard maintenance as an expense item, not an investment to prevent loss of service to customers and to ensure fast recovery of failed assets that are mission critical. As a result, managers tend to focus their attention primarily on the near-term issue of improving the bottom line — reduction of maintenance costs. Apart from maintenance, there are other stages of an asset's life cycle, including asset creation/construction (upstream) and asset replacement/disposal (down-stream). Maintenance should be intimately involved in these activities either as a party in the decision making process or as the implemeneter of the design. Thus, managers should regard maintenance as an investment that will provide the needed capability to deliver products and services to customers.

(b) Managers perceive measurement of maintenance performance only as a diagnostic function for management control. The role it can play in sharpening strategic focus, aligning efforts, and shaping desired behaviour throughout the organization is rarely recognized by managers.
Most managers responsible for maintenance operations are engineers by training. As such, they tend to hold the view that problems have abstract solutions and that those solutions can, in principle, be implemented in the real world. The engineering culture in these managers makes them preoccupied with designing humans out of the systems rather than into them (Schein 1996). Therefore, these managers are more likely to manage their maintenance performance by tracking only equipment based or process based measures. Measures that reflect the worth of human assets in the organization are seldom tracked.

From these observations, the following proposition is made:

**Proposition 1** — *Maintenance performance management is emphasized in organizations where maintenance is regarded as an investment, an integral part of asset management, and where managers have a holistic but not machine-centric mind-set.*

**Design of the Scorecard**

The balanced scorecards developed by the proactive maintenance organizations covered in the action research have these characteristics:

(a) Safety performance is one of the focus areas closely tracked by management using the maintenance scorecard. This is because maintenance typically involves high risk activities leading to potentially catastrophic industrial accidents. Within the four-perspective framework of a typical balanced scorecard, measures on safety performance can be grouped under the “Customer” perspective. Safety performance is a customer issue because a maintenance unit’s safety record projects an image on the quality of its management as judged by its clients. Furthermore, safety performance is closely scrutinized by the regulators and industrial accidents with actual or potential fatalities are
widely publicized by the media. To highlight the importance attached to the issue, MTRC even includes “safety” as one of the perspectives in its maintenance scorecards.

(b) Equipment based performance measures are usually grouped under the “internal processes” perspective in the maintenance scorecard. However, some organizations classify these measures under the “customer” perspective when they relate to mission critical assets that interface directly with external customers. For example, ‘escalator availability’ and ‘rolling stock availability’ are measures under the “customer” perspective in MTRC’s maintenance scorecards.

(c) The typical maintenance scorecards are rich in outcome measures but poor in performance drivers. Outcome measures are generic. They are only useful for reviewing the past and for benchmarking across multiple organizations. To predict future performance, managers need to refer to lead indicators. These are performance drivers unique to the organization because each organization has its own theory of performance excellence which is embodied in its strategy.

The problem identified above reflects that the weak linkage between performance measures and the espoused strategy is a common feature of maintenance scorecards. This is confirmed by results of the questionnaire surveys reported in Chapters 6 and 7 which show that “Progress of strategic initiatives” is ranked among the least important (measured) dimensions of performance in Hong Kong based organizations. The linkage problem is due to inadequate understanding of the perceived function of the balanced scorecard. The scorecard is not just a tool for ensuring that multiple perspectives are represented in the measures it contains. More importantly, it can be used to articulate the strategic focus of the organization in a form meaningful to those who will make things happen.
The following proposition can be made from the foregoing analysis:

**Proposition 2** — *Managers with a good understanding of the balanced scorecard concept will be able to use the balanced scorecard to inform people of the key result areas and show them how exemplary maintenance performance in these areas can be achieved.*

(d) "Organizational Culture" and "Innovation and Improvement" are regarded as critical result areas in most organizations. However, they are often least adequately covered in the trial versions of maintenance scorecards. This is due to the novelty of taking measurements on these dimensions. Questionnaire surveys and interviews are useful for the purpose of evaluating organizational culture. "Innovation and Improvement", on the other hand, can be inferred from "organizational learning" which goes through three overlapping stages: cognitive, behavioural, and performance improvement. In the cognitive stage, members of the organization are exposed to new ideas, expand their knowledge, and begin to think differently. In the behavioural stage, members begin to internalize new insights and alter their behaviour. In the third stage, these changes in behaviour culminate into measurable improvements in results such as reduced outage of service, shorter service recovery time, and optimized life-cycle costs. Questionnaire surveys and interviews that focus on attitudes and depth of understanding can be used to assess the cognitive level of learning in the organization. Direct observation techniques such as operation audit or inviting outside consultants to attend meetings are useful to measure the behavioural change in the learning organization (Garvin 1993). Measures of the desired performance results are usually adequately covered in the scorecard. The challenge is to develop appropriate instruments and methodology for measuring changes in the cognitive level and behaviour so that the learning within the organization can be tracked over time.
Other Tools of Performance Measurement

Both the cause-and-effect diagram and the template for design of performance measures had been tested in the action research and found to be very useful for development of the maintenance scorecard. The cause-and-effect diagram (Fig. 7.8, page 7-15) helps to stimulate discussions to identify strategic initiatives and to elucidate how these initiatives are related to each other in a coherent manner that will lead to superior maintenance performance. It is a highly effective communication tool to inform people what are important outcomes and how these results reinforce each other to deliver excellent service to customers.

The performance measure template (Fig. 7.10, page 7-18) is a design checklist. It guides managers to ask a series questions about the ‘what’, ‘why’, ‘how’, ‘where’, ‘who’, and ‘when’ of the measure under consideration. The Socratic style of iterative questioning and reflexive thinking involved is likely to produce performance measures that are relevant, meaningful and controllable, and these measures will drive the desired behavioural change in the organization. It also directs managers to consider operational issues such as the method for collecting data, and the availability of good quality and timely data. To reinforce ownership, each performance measure’s definition should be agreed and accepted by the manager accountable for the result. This can be achieved by getting the owners involved in designing these measures.

The cause-and-effect diagram and the performance measure template are not mere design tools, they are vehicles that facilitate learning about the organization’s theory of maintenance excellence.

Validation of the causal relationship between strategy and performance results using quantitative techniques is not straightforward because maintenance performance has multiple dimensions and there may be long gestation between the introduction of changes and the effect they have on performance. The complication in analysis is exacerbated when the strategic
direction of the organization changes before the effects of the previous strategy have fully developed. This is a problem faced by organizations experimenting with various initiatives to sharpen their competitive edge in this era of turbulence.

When only generic input and outcome measures are considered, the Data Envelopment Analysis (DEA) technique, introduced in §2.7 (pages 2–29 to 2–31), is useful to compare the maintenance organization’s multi-dimensional performance during one period with that of other periods. The technique can also be used to compare the performance of multiple maintenance organizations for benchmarking purposes. However, the analysis cannot inform people of the means to produce superior results because the time-dependent and context-specific performance drivers are not featured in DEA.

Results of measurements should be widely publicized at all levels of the organization to promote accountability and stimulate the pursuit of excellence. Putting the scorecard results on a Web page accessible via the Intranet maximizes visibility. While run charts of individual measures provide valuable information about the trends of these measures, a consolidated view that summarizes snapshot of achievements versus targets, and the trends of all the scorecard measures is very effective in capturing people’s attention. The Performance Wheel used by MTRC is an example of such a user-friendly presentation tool (Fig. 7.19, page 7–41).

8.2. Successful Application of BSC in Maintenance Management

The lessons learned from the action research indicate that the following conditions are conducive to successful application of balanced scorecards in maintenance performance management:

(a) A participative and social process is in place

The social system involved in a change process requires three types of key players: the
sponsor, the champion and owners of major change initiatives. Executive leadership is essential to mobilize the workforce to set the change process in motion. The sponsor is the leader who is accountable for the results of the change. He establishes the context — purpose and rationale, as well as the expected outcome — of the transformation, creates the social network for change, and provides the needed resources to make it happen. A senior manager with jurisdiction over asset management is a suitable sponsor for introducing balanced scorecards to manage maintenance performance. The departure of the sponsor may undermine sustainability of the change effort. Priority previously accorded the new initiative may be lowered and support for the transformation may even be removed.

The leader engages one or more champions to promote the use of balanced scorecards, develop the top level scorecard, drive the development of lower level scorecards, and ensure that necessary resources and support systems are available. While the sponsor creates the ‘demand for change’, the champion is instrumental to delivering the ‘supply of change’, through influence and communication. He gets the involvement of the stakeholders in designing the scorecards. Executive managers or people from the staff unit responsible for setting service standards and tracking actual performance are appropriate candidates as champion of the transformation.

The manager directly responsible for delivering the results of a measure featured in a maintenance scorecard is the owner of that measure. To nurture broad-based ownership of the scorecard, it is essential to have the participation of stakeholders in developing the maintenance scorecards and defining the measures.

(b) There is widespread understanding of the balanced scorecard concept

It follows from Proposition 2 (page 8–4) that when managers have a good understanding of the balanced scorecard concept, they will use the scorecard to inform people the contents (the ‘What’) of the strategic objectives, and the courses of action (the ‘How to achieve these
objectives?'). Widespread discussion and training on the performance management system are extremely useful in upgrading the requisite knowledge in the organization. After this has been done, getting people involved in developing the maintenance scorecards will elevate organizational learning beyond the cognitive level. People are putting the concept into practice.

(c) The organization's maintenance strategy is widely communicated

Communications of maintenance strategy must address the context, content and the courses of action for achieving superior maintenance performance. These are answers to the 'Why', 'What' and 'How' of the maintenance strategy. Context should articulate the reasons for adopting the espoused strategy in terms of the organization's internal environment as well as the realities of its external environment. While executive management realizes the rationale for embracing the strategy, the justification is often lost on the rest of the organization as they, from their much limited perspective, only see part of the whole picture. When clearly expressed and widely communicated, context can rally the entire organization around a shared mission (Hamilton and McDonald 1999).

Content describes what need to be accomplished — the strategic objectives and their target values, expressed in terms meaningful to people at working level. Moreover, linking performance measurement to attainment of strategic objectives, one of the core concepts of balanced scorecard, makes the typically abstract strategy as real (tangible) as possible. Courses of action refer to the major initiatives formulated to bridge the gap between the status quo and the future state as specified by the strategic objectives.

The dynamics of widely communicated context, content and courses of action of the maintenance strategy produces organizational alignment. When this is achieved, the benefits of local autonomy can be maximized and entrepreneurial flair in the organization will not detract from the shared mission of the organization.
(d) The momentum of change must be maintained

In the initial stage, the measures included in the maintenance scorecard may not be perfect. However, it is preferable to maintain some momentum in the process and not to introduce a pause in progress while the imperfections of the measures chosen are analysed. Moreover, having some measures is better than having none, particularly in cases where previously there have been no measurement in certain perspectives such as ‘learning and growth’. Encouraging this is important for the learning process. In the early stages, it is more important to encourage the generation of ideas, the growth of confidence, enthusiasm than it is to insist on absolutely valid measures and resulting activities (Daniels and Burns 1997).

(e) The support infrastructure must be in tune with the espoused strategy

The performance management system does not exist in isolation. It needs the support of other infrastructural elements in the organization. These include management information systems, reward and recognition, as well as the resource allocation mechanism. They must be in tune with the espoused strategy in order to send an unequivocal and coherent message to employees about the strategic intent encapsulated in the maintenance scorecards. The management information must be able to provide quality and timely data for the measurements in the scorecards. Furthermore, results of the scorecards should be presented in a user-friendly manner, and they should be made accessible to as many employees as possible to create an atmosphere of openness and to stimulate the pursuit of excellence.

It is a common phenomenon that strategic planning and operational budgeting are disconnected processes (Kaplan and Norton 1996b). This way, resources allocated through the annual budgeting process may not be adequate to deliver the short-term expectations of the strategic objectives as documented in the maintenance scorecards. To prevent such problems, the strategic planning and annual budgeting processes should be integrated. The resource allocation
model for deployment of discretionary funds must be tuned so that projects contributing to the fulfilment of strategic objectives will receive their fair share of resources.

Inputs from the stakeholders of the maintenance function are essential in setting targets and tuning the infrastructural matters discussed above.

In the knowledge economy, the organization's most valuable asset is the energy and loyalty of its people — the intellectual capital that can quit and go to work for competitors. The reward and recognition system regularly undermines that commitment. Consider a case in which continuous improvement and emphasis on staff development are the key elements of the chosen strategy for maintenance. Even though the maintenance scorecard signals a balanced focus on both financial indicators and performance drivers, teams and individuals are rewarded solely on the basis of their performance as reflected by short-term indicators such as cost savings and head count reduction. Obviously, the reward and recognition system is encouraging people to behave in a manner which is at variance with the strategic intent (Tsang 1998a). Tuning the reward and recognition system in support of strategic objectives removes mixed messages sent to people in the organization. This issue is discussed further in § 8.3 that follows.

Inputs from the stakeholders of the maintenance function are essential in tuning these infrastructural matters.

8.3. The Approach to Managing Maintenance Performance

The contemporary business environment is highly turbulent. The direct forces creating the turbulence in maintenance operations have been discussed in Chapter 1. These include changes in the technical system — emerging trends of operations strategies, and technological changes that open new opportunities and present new challenges to maintenance. The business imperative of the larger whole, the corporation, also has an impact on maintenance management, particularly
in capital intensive settings. The likelihood of deregulation in what used to be highly regulated businesses (e.g., CLP Power), the erosion of competitive edge due to the changed market infrastructure and the emergence of new competitors (as in the case of MTRC) are examples of these market forces with profound repercussions in maintenance operations. The scenario confronted by the host organizations covered in the research study (Chapter 7) illustrates such market forces in action. Operating in this type of turbulent environment, what had served us well yesterday may not be appropriate to ensure competitiveness tomorrow. Socio-technical System analysis (STS), first introduced in Chapter 2 (pages 2-26 to 2-27), provides a methodology to design a performance management system that will fit in the specific operating environment. Fig. 8.1 compares the characteristics of effective maintenance organizations in stable and turbulent environments, respectively. These characteristics are grouped under five categories, namely business environment, technical system, environmental/technical interface, social system, and work design.

**Environment/Technical Interface**

Features of the business environment and the technical system (maintenance technology and methodology) have been discussed in earlier chapters. The interaction between these two systems produces significant impact on maintenance management. In a stable environment, the focus of management is to maximize return on assets. With a high level of predictability of operational needs (low risks), "arms length" relationships with customers (the operations/production department), contractors and other stakeholders (employees, regulators, etc.) were adequate. In a turbulent environment, the frequent introduction of process innovation and new technology is designed to fulfill a different mandate — to support creation of competitive edge. This approach involves considerable risks, and its success depends a lot on close working relationships of multiple stakeholding groups. Fig. 8.2 maps these stakeholding groups to their traditional roles...
in asset management. These stakeholders should work as partners. In fact, the demarcation between groups is getting blurred as the traditional roles are undergoing transformation. For example, in organizations which practice TPM, the operators' role is redefined to include also routine inspection, cleaning, lubrication and minor repair of their machines, as well as involvement in improvement activities for enhancement of equipment and people performance.

<table>
<thead>
<tr>
<th>External Environment</th>
<th>Stable</th>
<th>Turbulent</th>
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<tbody>
<tr>
<td>Business Environment</td>
<td>Regulated</td>
<td>Deregulated</td>
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<tr>
<td></td>
<td>Seller's market</td>
<td>Buyer's market</td>
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<tr>
<td></td>
<td>Source of competitive edge remains valid</td>
<td>Loss of competitive edge</td>
</tr>
<tr>
<td>Technical System (maintenance technology and methodology)</td>
<td>Tradition bound</td>
<td>Process innovation</td>
</tr>
<tr>
<td></td>
<td>Matured technology</td>
<td>Disruptive technology</td>
</tr>
<tr>
<td>Environmental/Technical Interface</td>
<td>Strategic Goals</td>
<td>Maximize return on assets</td>
</tr>
<tr>
<td></td>
<td>Risks</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Relationship with customers, contractors, other stakeholders</td>
<td>Arms length</td>
</tr>
<tr>
<td>Social System</td>
<td>Employment requirement</td>
<td>Stable</td>
</tr>
<tr>
<td></td>
<td>Skill requirement</td>
<td>Specialized</td>
</tr>
<tr>
<td>Work Design</td>
<td>Task design</td>
<td>Mostly individual task design</td>
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<tr>
<td></td>
<td>Structure</td>
<td>Rigid/Mechanistic</td>
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<td></td>
<td>Information flow</td>
<td>Predominantly vertical</td>
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<tr>
<td></td>
<td>Performance Management</td>
<td>Transactional</td>
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<td></td>
<td>Reward &amp; recognition</td>
<td>Individual and seniority based</td>
</tr>
</tbody>
</table>

Fig. 8.1 A STS-based framework for determining the approach to managing maintenance performance
<table>
<thead>
<tr>
<th>Stakeholding Group</th>
<th>Primary role in maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td>Commission and maintain assets</td>
</tr>
<tr>
<td>Operations</td>
<td>Use the assets to produce or deliver services</td>
</tr>
<tr>
<td>Engineering</td>
<td>Learn from the design of existing assets</td>
</tr>
<tr>
<td>Human resources</td>
<td>Recruit and develop the manpower required by maintenance</td>
</tr>
<tr>
<td>MIS</td>
<td>Provide IT support for work planning and performance tracking</td>
</tr>
<tr>
<td>Purchasing</td>
<td>Source and purchase assets, materials, supplies, and services</td>
</tr>
<tr>
<td>Suppliers</td>
<td>Supply equipment, materials, tools, software, and training</td>
</tr>
<tr>
<td></td>
<td>Supply contract labour</td>
</tr>
<tr>
<td></td>
<td>Provide maintenance services</td>
</tr>
<tr>
<td>Regulators</td>
<td>Protect the interests of the public</td>
</tr>
</tbody>
</table>

Fig. 8.2 Stakeholding groups and their traditional roles in asset management

The rapid introduction of new technology typically requires significant input from suppliers and outside experts. Trust, shared interest, collaboration for mutual benefits — the ingredients of partnership relationships — are essential for successful technology transfer. Within the organization, partnership relationships should also be developed between management and the employee, and between different units to smoothen transformations such as restructuring of the organization. The adoption of a fair process embodying the three mutually reinforcing principles of engagement (participation), explanation (open communication), and expectation clarity is the key to drive out fear, earn the trust of those affected, and most importantly, to achieve alignment of goals to make changes happen (Kim and Mauborgne 1997). Taylor and Felten (1993) summarize the essence of stakeholder participation in complex systems that are in a state of flux: “Participation in learning to understand (analysis), discovering what to change (design), and in organizing to succeed (implement) is empowerment. Anything less is not likely to be as effective.”
Social System

Turbulence in the environment has its impact on the social system of maintenance. No longer are the employment requirements of maintenance practitioners (professionals and tradesmen) stable. Expectation of fast response, speedy and cost effective service, interdisciplinary nature of technical systems, rapid technological changes, and the option of alternative service delivery are the contemporary forces driving the need for flexibility in maintenance service providers. Multi-skilled and flexible maintenance practitioners are more likely to be able to satisfy these multiple requirements than those undertaking narrowly defined tasks using a limited set of skills. Multi-skilling can occur within a functional grouping by extending over a number of craft skills, such as merging the trade classes of jointers and oil fillers required for laying oil filled cables in power transmission systems. It may also occur across a number of disciplines to support commissioning of plant equipment and other general types of activities. However, wholesale adoption of multi-skilling in the workforce may not be advisable. For example, it is not desirable to make certain grades of employee multi-skilled when it runs the risk of diluting special expertise required to support superior technical training, or compromising adherence to safety operating standards.

Work Design

The technical system, the social system and its environment are brought together when maintenance work is designed. It is management's responsibility to develop a work design that will achieve an optimal fit between the organization and its environment. Work design includes a number of organizational elements: task design, structure, information flow, performance management, reward and recognition. The implications for these dimensions are summarized in Fig. 8.1. These implications are derived from the following principles of STS design (Taylor and Felten 1993):
• Minimal critical specification — specify as little as possible, and identify only what is essential and critical to the organization's success.

• Boundary location — organizational units (work teams) are designed to facilitate sharing or flow of information, knowledge, and skills.

• Multi-functionality — tasks performed by individual members should be structured to achieve higher flexibility, enhance adaptability, and reduce waste.

• Human values — design work that will motivate employees.

• Support congruence — management should be consistent and that its actions should be compatible with its expressed philosophy.

Maintenance work in a stable environment can be effectively performed by employees whose tasks are individually and narrowly defined. The clear definition and demarcation of work serves as a useful coordination mechanism when the nature of work does not change much over time. In the contemporary scenario, however, maintenance operations are highly complex and fraught with uncertainties. The complexity comes from the variety and novelty of technologies embedded in the technical system, as well as the multi-dimensional performance requirements, the profile of which may shift with the prevailing forces operating in the external environment. The uncertainties in maintenance operations arise from risks of developing expertise in servicing a new generation of assets, and the likelihood of obsolescence of the new capabilities being acquired. In the face of these challenges, the STS design principles of 'minimal critical specification', 'boundary location' and 'multi-functionality' suggest that maintenance service providers should organize its workforce into autonomous work groups, each responsible for delivering “one-stop-shop” service to clients. The group should possess all the knowledge, skills, and abilities needed to produce a complete and identifiable output. The migration from discipline-based to station-based structure in the organization of front-line maintenance
operations for a railway system is one such example. Another form of work group design that offers flexibility is to integrate the workforce for construction, operation and maintenance. At the level of individuals, the ‘multi-functionality’ principle suggests that maintenance professionals should be deployed to manage end-to-end work processes covering design, planning, organization, resourcing, and control of jobs concerning creation, commissioning, maintenance, refurbishment or disposal of physical assets. Rigid and mechanistic structures that preserve stability are ill-fitted in an environment where speed and uncertainty are the imperative. Organic and networked structures are more agile in rendering fast recovery services to mission critical operations and in making adjustment to change.

Shani, et al (1992) summarize the centrality of the social system in change management this way: “critical management problems arise not in the adjustment of the technical system, but in the adjustment of the social system. Not only are the time frames required for adjustment much longer, but the problems of interpersonal relations and organizational structures are far less transparent and much less easy to define than those of technology.” In order to foster a culture where change is the norm, the ‘human values’ in the STS design principles must be addressed to motivate employees through empowerment. This implies that members of a maintenance team should have access to information on and control of variances (deviations from normal, expected or average state of throughput) that occur in their work. Information should go first to the point of action instead of vertically through the hierarchy. This will enable self-management and avoid micro-management. Sharing of information horizontally across units is also essential for internal benchmarking and organizational learning.

Performance management in a stable environment is used primarily as a control tool. Thus, it focuses on the transactional aspects of maintenance, using outcome measures such as maintenance cost per unit of output, average service recovery time, availability of revenue
generating assets, etc as performance indicators. In an era where an organization’s competitive edge can be eroded or even wiped out quickly as the playing field is reconfigured, strategic directions have to be reviewed constantly and new ones adopted swiftly to avoid the threats and exploit the opportunities created by the changed environment. A performance management system that focuses on strategic dimensions is a mechanism that can nimbly align efforts in the organization toward the shared vision. The balanced scorecard with its measures linked to the espoused strategy informs people of what are the drivers of performance excellence and the extent to which the performance targets have been achieved. It influences people’s behaviour so that it is in line with the strategic intent of the organization.

Reward and recognition are typically individual and seniority based. These could be effective for developing employee loyalty. However, teamworking, multi-functioning, resourcefulness and work related knowledge — the personal attributes in demand in turbulent time — are not particularly encouraged in such systems. ‘Support congruence’ in STS design suggests that organizations should not say one thing and do another, i.e., say one thing and reward another. Pfeffer (1996) asserts that “rewards and measurements need to be aligned with the ways in which people are to be managed”. Formation of autonomous work groups will be difficult, if not impossible, to produce superior performance if reward and recognition are not group and skill based.

8.4. A Framework for Managing Maintenance Performance

Fig. 8.3 shows a five-step framework for managing maintenance performance.

Step 1: Formulate Maintenance Strategy

Strategy is the organization’s theory of performance excellence. It communicates the organization’s long-term goals and the approach to achieving these goals. The maintenance
strategy to be pursued should align with the corporate vision and business strategy. It should be formulated with participation of the stakeholders of maintenance — senior management, key personnel in the maintenance units, and the users of maintenance services — using techniques such as focus group discussions, scenario planning, and SWOT (strengths, weaknesses, opportunities and threats) analysis.

Figure 8.3  A framework for managing maintenance performance

Step 2: Establish Strategic Objectives, Set Targets

The strategy formulated in the previous step is often too abstract to frontline staff who play a crucial part to make things happen. It is therefore necessary to articulate the espoused strategy in terms meaningful to the them. Thus, the strategy needs to be translated into strategic (long-term)
objectives, the attainment of which can be determined by appropriate performance measures with their related targets. The strategic objectives are built around the multiple perspectives in the Balanced Scorecard to encourage behaviour leading to sustainable improvement. Instead of following the common practice of extrapolating from past performance results, it is advisable to set challenging yet credible stretch performance targets on the basis of what have been attained by best-in-class organizations identified through benchmarking exercises.

Again, it is desirable that decisions in this step are made with full participation of the stakeholders. The cause-and-effect diagram and the performance measure template are useful tools to show the logics behind the selected strategic objectives and the performance measures featured in the maintenance scorecard.

**Step 3: Develop Initiatives and Action Plans**

Strategic initiatives have to be mapped out and specific action plans developed in order to meet the strategic objectives. The Planning Matrix used in Quality Function Deployment (QFD) can be put to good use in this step. The rows in the matrix are used to list the strategic objectives identified in step 2, and the columns are used to indicate the necessary initiatives and action plans. If a relationship exists between a pair of strategic objective and initiative, its intensity (strong, moderate, or slight) is indicated by an appropriate symbol in the cell formed by the intersection of the related row and column. Fig. 8.4 is an example of a Planning Matrix. A check of the entries in the matrix will expose anomalies such as strategic objectives not addressed by any initiative/action plan (objectives corresponding to empty rows), conflicting action plans, and action plans not contributing to the fulfilment of any strategic objective (action plans corresponding to empty columns). The matrix also gives information for prioritizing the initiatives/action plans. Performance measures are then identified and their targets established.
These are used to track progress of the initiatives/action plans. Whilst performance measures that are derived from strategic objectives are primarily *outcome measures* (*lag indicators*), those that are linked to initiatives usually are *performance drivers* (*lead indicators*).

<table>
<thead>
<tr>
<th>1999 Strategic Objectives</th>
<th>1999 Action Plans</th>
<th>Targets</th>
<th>1999 Strategic Objective Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce number of accidents &amp; reportable incidents</td>
<td>Implement Safety Management Systems &amp; related award schemes</td>
<td></td>
<td>Reduce staff accident rate to 0.70</td>
</tr>
<tr>
<td>Improve response time for incident recovery</td>
<td>Set-up on-site recovery teams at strategic locations</td>
<td>Reduce number of more than 30-minute delay to zero</td>
<td></td>
</tr>
</tbody>
</table>

|--------------------------|---------------------------------------------|-------------------------------|------------------------------------------|

**Fig. 8.4** Linking strategic objectives to action plans
Step 4: Rationalize the Maintenance Scorecard

Typically, a large number of performance measures can be identified in Steps 2 and 3. Recognizing the limited attention span of the manager, the Balanced Scorecard should have around 20 performance measures. Thus, only performance measures that have a strong linkage with strategic objectives or major initiatives will find their way to the Scorecard. A template for documenting the finished design of the Balanced Scorecard has been introduced in Chapter 2 on page 2–17. It is reproduced in Fig. 8.5 shown below.

<table>
<thead>
<tr>
<th>Mission &amp; Strategy</th>
<th>Objectives</th>
<th>Measures</th>
<th>Targets</th>
<th>Action Plans</th>
<th>Perspective</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Financial</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Customer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Internal Process</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Learning &amp; Growth</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 8.5 Template for Design of the Balanced Scorecard

Once the top level maintenance scorecard has been designed, the strategic objectives and related performance measures will be deployed to various units in the organization for formulation of the lower level scorecards following a procedure similar to the one just described.

At MTRC, the strategic objectives down to the section level are derived from the long-term objectives of the operating railway in a cascading manner using a three-phase process, as illustrated in Fig. 8.6.

Again, if a relationship exists between the entries of a row and a column, its strength (strong,
moderate, or slight) will be indicated by an appropriate symbol in the cell formed by the intersection of the column and the row. Different weights are assigned to different symbols according to its intensity. For example, weights for strong (©), moderate (©) and slight (Δ) relationships can be 10, 5, and 1, respectively. Blank cells in the matrix will have zero weight. By aggregating the weights in each column, the objectives in the columns can be prioritized accordingly. Those objectives with higher priorities are then deployed to the next level matrix as the row entries.

![Diagram](image)

**Fig. 8.6** Formulation of departmental and sectional objectives at MTRC

**Step 5: Measure Performance and Review**

The Balanced Scorecard should not be cast in stone. Typically, it is subject to critical review annually when the new business plan is being developed. However, managers should scrutinize the design at more frequent intervals, say in the monthly management meetings, to validate its currency. In particular, it should be revised to faithfully reflect changes in strategic direction, or when use of irrelevant performance measures is detected.

The structured approach to strategy planning and deployment recently adopted by MTRC’s Operations Engineering Department (OED) is an implementation of the above framework. An outline of OED’s process is shown in Fig. 8.7 and Fig. 8.8.
Fig. 8.7  Formulation of Departmental Plan, Operations Engineering, MTRC
Fig. 8.8  Formulation of Sectional Plan, Operations Engineering Department, MTRC
9. Conclusion

9.1. Research Accomplishments

Performance management is gaining recognition as a strategic issue in senior management. For example, in an international standard, ISO/CD2 ISO 9004:2000, Quality Management Systems — Guidance for Performance Improvement \(^1\), clause 5.1.1 states that “Top management should also define a mechanism for evaluation of performance in the strategic decision making process, which is their direct responsibility.” Performance management involves establishing a mechanism to communicate the organization’s strategic intent, influencing employees’ behaviour for the benefit of the organization, tracking progress towards targets, and reviewing effectiveness of action plans. A key element in performance management is the measurement of organizational performance. The importance of performance measurement in the pursuit of performance excellence is echoed in two of the core concepts embedded in the assessment criteria of Malcolm Baldrige National Quality Award (MBNQA) of the U.S.\(^2\) These core concepts are:

- **Management by Fact** — “Performance measurements must derive from the organization’s strategy and provide critical data and information about key processes, outputs, and results. Many types of data and information are needed for performance measurement and improvement.”

- **Results Focus** — “An organization’s performance measurements need to focus on key results.”

\(^1\) ISO/CD2 ISO 9004:2000 is a Committee Draft of the revised ISO 9004 standard scheduled for publication by International Standardization Organization (ISO) in fourth quarter 2000.

Thus, organizational performance should be measured in a balanced manner, taking into account multiple perspectives — financial/non-financial, internal/external, performance drivers/outcomes, etc. The balanced scorecard is a vehicle to meeting the needs of performance management as set out above.

Previous studies on balanced scorecards focussed primarily on their application in managing performance at corporate and business unit levels. The extent to which balanced scorecards can be applied to manage performance of maintenance operations in capital intensive organizations is a largely unexplored research area. This research is an investigation into an uncharted area of maintenance management. The study was performed using the action research methodology with the researcher playing an active role in transforming the maintenance performance management systems in the collaborating organizations.

The contributions of this research project in adding knowledge to maintenance performance management are summarized below:

(a) The common practices of maintenance performance management have been documented and their deficiencies identified. The findings highlight the need to adopt a strategic and holistic approach to measuring maintenance performance in capital intensive organizations (§5.10). A suitable approach that involves the use of balanced scorecards for performance measurement has been proposed (pages 2–21 to 2–22). Design of these scorecards should be driven by the organization's maintenance strategy. The principal dimensions of maintenance strategy have been analyzed and the related key decisions identified (Chapter 3). The key elements of implementing organizational transformation triggered by a change of maintenance strategy are also examined.

(b) A socio-technical system (STS) based framework has been proposed for determining the approach to maintenance performance management that will fit in the specific operating
environment (§8.3). The framework organizes the characteristics of a maintenance organization into five categories, namely business environment, technical system, environmental/technical interface, social system, and work design. A comparison of these characteristics under stable and turbulent environments, respectively, is also presented.

(c) A five-step framework for managing maintenance performance in capital intensive organizations has been proposed (§8.4). It is designed to achieve alignment in the organization for performance excellence. Issues such as strategy formulation and deployment, linkage between performance measurement and the strategic focus of the maintenance operation, and review of the measurement system are addressed in the framework.

(d) The characteristics of the initial balanced scorecards developed by maintenance organizations are identified (Design of the Scorecard, pages 8–2 to 8–4). These scorecards are typically machine-centric, rich in outcome measures but poor in performance drivers, and the linkage between scorecard measures and the espoused strategy of the maintenance organization is weak.

(e) Two propositions on maintenance performance management are derived from the findings of this research project, viz:

**Proposition 1** — *Maintenance performance management is emphasized in organizations where maintenance is regarded as an investment, an integral part of asset management, and where managers have a holistic but not machine-centric mind-set* (page 8–2).

**Proposition 2** — *Managers with a good understanding of the balanced scorecard concept will be able to use the balanced scorecard to inform people of the key result areas and show them how exemplary maintenance performance in these areas can be achieved* (page 8–4).
(f) The tools for design, deployment and validation of the maintenance scorecards have been identified (Other Tools of Performance Measurement, pages 8–5 to 8–6). These include cause-and-effect diagram, performance measure template, planning matrices, and data envelopment analysis (DEA). The presentation and interpretation of scorecard results are also discussed with users in the action research.

(g) Conditions conducive to successful applications of balanced scorecards for maintenance performance management have been identified through observations from the action research (§8.2). These include:

- A participative and social process is in place
- There is widespread understanding of the balanced scorecard concept
- The organization’s maintenance strategy is widely communicated
- The momentum of change must be maintained
- The support infrastructure must be in tune with the espoused strategy

9.2. Limitations of this research project

The inquiry into application of a strategic and holistic approach to managing maintenance performance is constrained by the availability of suitable subjects — maintenance organizations which would take the pioneering step to put it into practice are rare. As a result, the action research methodology was adopted in this study, and only two maintenance organizations of the target group — capital intensive businesses — were successfully recruited as collaborating partners. In this type of study, the researcher was not a mere observer; he also played the active role of a change catalyst in the transformation process. Data rich in contextual information were collected and they were validated by subjects of the study. A possible weakness in this study is the researcher’s biased perceptions of the observed phenomena. To overcome this problem, and
resources permitting, multiple investigators should be deployed to collect data from each sampled organization. This strategy offers three key advantages. First, the multiple observers enhance the creative potential of the study. Second, the convergence of observations from multiple investigators enhances confidence in the findings. Third, conflicting perceptions of different investigators prevents premature closure of the research.

With just two test sites, only exploratory study can be performed. It would be desirable to recruit more maintenance organizations as subjects of the investigation so that between-case analyses can be performed to validate the theories and frameworks developed by the exploratory study. With a reasonable sample size, quantitative research designed to test hypotheses derived from theories can also be performed. Strategic performance management is currently an emerging concept. It takes time for the diffusion of the concept to reach a state such that the concept is turned into practice in more than a handful of pioneering maintenance organizations. Thus, hypothesis-testing type of quantitative research has to wait until that time comes.

The use of data envelopment analysis (DEA) technique to track multi-input and multi-output productivity of a maintenance organization has been suggested as a means to review effectiveness of the strategy in use. The problems likely to be encountered in such application need to be identified through testing with field data. However, this was not performed in the study because strategy-driven performance measurement was only introduced for just over one year in the test sites. To smooth out seasonal effects, yearly data should be used in the evaluation. Thus, data from several years would be required in order to have meaningful analysis.

The questionnaire survey conducted at MTRC in February 1999 had two shortcomings. First, the response rate (9 out of 29) was low. It could be the effect of questionnaire blues because the same group of staff had been polled in another questionnaire survey on a related but different theme administered in November 1998. If the two surveys were integrated into one, the response
rate would be much higher and people's perception could be determined with a higher level of confidence. The second problem with the survey is that it only captured a snapshot of the situation in an early stage of the transformation. Similar surveys should be conducted at say yearly intervals to assess progress made in embedding strategic performance management in the organization's systems.

There is room for improvement in the balanced scorecards used at CLP Power and MTRC. The imperfections in these scorecards are largely attributed to insufficient understanding of the theory underlying the new measurement tool. The five-step performance management framework proposed in Chapter 8 is expected to solve this problem through widespread discussion and training built into the process.

Performance drivers, organizational culture, innovation and improvement are the common blind spots in maintenance scorecards developed at the test sites. More guidance should have been given to managers of the host organizations as an antidote to the problem. However, even with such efforts, less than perfect scorecards may still be used because of other considerations such as unavailability of quality and timely data, and managers' desire to minimize changes in the performance measures currently being tracked (the comfort of the status quo).

9.3. Recommendations for Future Study

Possible extensions of this research project that will address its current limitations have been discussed in the preceding section. Other suggestions for future research work on maintenance performance management are listed below:

(a) Revisit the application of balanced scorecards in the maintenance organizations of CLP Power and MTRC, and review the progress made in embedding strategic performance management in their operations.
(b) Formulate methodologies and develop tools to identify measures relating to performance drivers, organizational culture, innovation and improvement that communicate the strategic intent of the maintenance organization.

(c) Develop tools to validate the causal relationships between strategic initiatives and performance results. The time lag between action and effect, as well as likely changes in strategic directions present tremendous challenge to such an undertaking.

(d) Determine the type of reward and recognition system that will reinforce vertical alignment and horizontal integration to achieve excellence in maintenance performance.

(e) Perform empirical studies to validate the two propositions on maintenance performance management presented in Chapter 8.

(f) Perform empirical studies in maintenance organizations to validate the favourable conditions for application of balanced scorecards identified in this study.

(g) Use the STS-based framework proposed in Chapter 8 to analyse the observed characteristics of high performance maintenance organizations operating in turbulent environments, with the practice of performance management as one of the focus areas of the study.

9.4. Concluding Remarks

Maintenance performance management involves much more than measuring performance of physical assets. The process that delivers asset performance in support of existing business operations and contributing to long-term success of the organization must be managed too. Capital intensive organizations need to address the issue as a matter of strategic importance and measure maintenance performance holistically using balanced scorecards. The five-step framework proposed in this thesis provides the road-map for making the paradigm shift in
managing maintenance performance. The tools and lessons learned from the action research are useful to organizations which will take the challenge of adopting the approach in their pursuit of sustainable excellence in maintenance performance.

What makes an organization tick are the hearts and minds of its people. When people have shared objectives aligned with those of the organization, action plans are clearly communicated to those responsible for implementation, work is structured to achieve fast response and minimize loss, and efforts are reinforced by support systems, these people (who may include external partners such as suppliers and external service providers) will have the intrinsic motivation to make performance excellence a reality.

Performance measurement is a hallmark of strategic maintenance performance management. However, the performance measures being tracked will only provide useful information for guiding management decisions and shaping desirable behaviour if they are linked to the espoused maintenance strategy, and the results of these measurements are widely communicated to stimulate discussion and facilitate organizational learning. A good understanding of the balanced scorecard concepts is essential to do a proper job of performance measurement.
10. References


Chan, Kar Ling, 1997, *Development of a Maintenance System for a Petrochemical Oil Terminal*, MSc in Engineering Business Management dissertation, University of Warwick, UK


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———, 1998b, *Review of OED’s Application of Balanced Scorecards*, a report submitted to Mass...
Transit Railway Corporation in December 1998


Appendices

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Questionnaire on Performance Management System in Your Organization  A–1

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Appendix I
Questionnaire on Performance Management System in your Organization

1.0 Please ✓ the importance of the following dimensions when your Company / Strategic Business Unit (SBU) measures its performance:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Very Important</th>
<th>Somewhat Important</th>
<th>Not Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01 Cost / financial return</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>1.02 Equipment performance: reliability, availability, fault rate</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>1.03 Operation efficiency / productivity</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>1.04 Time: response time, recovery time, service delays</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>1.05 Customer: satisfaction, loyalty, etc</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>1.06 Relationships: customers, suppliers or contractors</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>1.07 Employee: capability, development, satisfaction</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>1.08 Safety and environmental management</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>1.09 Organizational culture</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>1.1 Innovation (technological or managerial), improvement</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>1.11 Progress of strategic initiatives</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>1.12 Others (please specify)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

2.0 Please ✓ the importance of the following dimensions when your organizational unit evaluates its own performance:
(skip this section if you are the Chief Executive of your Company or SBU)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Very Important</th>
<th>Somewhat Important</th>
<th>Not Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.01 Cost / financial return</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2.02 Equipment performance: reliability, availability, fault rate</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2.03 Operation efficiency / productivity</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2.04 Time: response time, recovery time, service delays</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2.05 Customer: satisfaction, loyalty</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2.06 Relationships: customers, suppliers or contractors</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2.07 Employee: capability, development, satisfaction</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2.08 Safety and environmental management</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2.09 Organizational culture</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2.10 Innovation (technological or managerial), improvement</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2.11 Progress of strategic initiatives</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2.12 Others (please specify)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
3.0 Please ✔ the extent to which you agree or disagree with the following statements: (KPI stands for Key Performance Indicator)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree, or don’t know</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Company/SBU’s strategy is understood by those responsible for its implementation</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Personal goals and competencies of individual staff are linked to SBU’s strategy</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The SBU’s KPIs are identified through a participative process</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The KPIs at lower levels of the organization are identified through a participative process</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The KPIs have strong linkage to strategic issues</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The existing measurement system gives a balanced evaluation of my unit’s performance</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Those performance indicators that relate to my area of responsibility are meaningful</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The targets of performance indicators are established through a participative process</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>All performance indicators are measured at the appropriate frequency</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The SBU’s KPIs are effective tools for operational control</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The SBU’s KPIs motivate staff members to create future value</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The KPI results are presented in a user-friendly manner</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The KPI results are widely communicated in my organizational unit</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The KPIs in use provide useful information for carrying out the Company/SBU’s strategy</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Quality and timely data are available for evaluating the KPIs</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Reward &amp; recognition systems are aligned with Company/SBU’s strategy</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Adequate resources are allocated to make the Company/SBU’s strategy happen</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

4.0 You are welcomed to give other comments on the existing performance management system, in the following space (use a separate sheet if you need more space):

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

............. Thank you for taking the time to complete this questionnaire ............
Appendix II

Dimensions in measuring performance of Company / SBU
(63 valid responses)

<table>
<thead>
<tr>
<th>Item Nº</th>
<th>Very important</th>
<th>Somewhat important</th>
<th>Not important</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01</td>
<td>50</td>
<td>79%</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>14%</td>
<td>6</td>
</tr>
<tr>
<td>1.02</td>
<td>26</td>
<td>41%</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>40%</td>
<td>19%</td>
</tr>
<tr>
<td>1.03</td>
<td>31</td>
<td>49%</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>43%</td>
<td>8%</td>
</tr>
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<td>1.04</td>
<td>31</td>
<td>49%</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>46%</td>
<td>5%</td>
</tr>
<tr>
<td>1.05</td>
<td>42</td>
<td>67%</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>27%</td>
<td>6%</td>
</tr>
<tr>
<td>1.06</td>
<td>27</td>
<td>43%</td>
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Dimensions in measuring performance of an Organizational Unit
(61 valid responses)

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## Appendix III

**Perceptions on Company's Performance Management System**

*(60 valid responses)*

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<th>Item No</th>
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Appendix III

(Continued)

Perceptions on Company’s Performance Management System

Collapsed Response Scale

(60 valid responses)

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<th>Item No</th>
<th>Strongly agree or agree</th>
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Appendix IV

Performance Measures in OED's Balanced Scorecard for 1998

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Performance Measure</th>
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<tr>
<td>Safety</td>
<td>OED Staff Accident Injury Rate</td>
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<tr>
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<td>Reportable Accident Frequency Rate of OED Contractors' Staff</td>
</tr>
<tr>
<td></td>
<td>Operating Railway Risk Index</td>
</tr>
<tr>
<td>Financial</td>
<td>OED Maintenance Costs / Passenger Journey @ 90's Price</td>
</tr>
<tr>
<td></td>
<td>OED Maintenance Costs / Revenue Car-km @ 90's Price</td>
</tr>
<tr>
<td></td>
<td>Capital Works Costs Achieved : Total Depreciation Charge</td>
</tr>
<tr>
<td>Customer</td>
<td>Gate &amp; Ticket Machine Reliability</td>
</tr>
<tr>
<td></td>
<td>Nº of Train Service Delays &gt; 5 min. due to Equipment Failure</td>
</tr>
<tr>
<td></td>
<td>Sum of Initial Delays &gt; 5 min. due to Equipment Failure (min.)</td>
</tr>
<tr>
<td></td>
<td>EMU Performance (kkm / incident)</td>
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<td>EMU Availability (%)</td>
</tr>
<tr>
<td></td>
<td>Escalator Availability (%)</td>
</tr>
<tr>
<td></td>
<td>Platform Screen Door Availability</td>
</tr>
<tr>
<td>Internal Processes</td>
<td>CM Recovery Time Against Down Time</td>
</tr>
<tr>
<td></td>
<td>Percentage Coverage of Scheduled PM (%)</td>
</tr>
<tr>
<td></td>
<td>Capital Works Achievement</td>
</tr>
<tr>
<td>Learning &amp; Growth</td>
<td>Training Hours Ratio</td>
</tr>
<tr>
<td></td>
<td>Internal Promotion and Transfer Rate</td>
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Note: The item shown in *italics* will be included in LAR’s Balanced Scorecard to be rolled out in 1999.
## Appendix V

### Performance Measures in RS Depots Section's Balanced Scorecard for 1998

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Performance Measure</th>
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<tbody>
<tr>
<td><strong>Safety</strong></td>
<td>Staff Accident Injury Rate&lt;br&gt;Reportable Accident Frequency Rate of Contractors&lt;br&gt;Operating Railway Risk Index</td>
</tr>
<tr>
<td><strong>Financial</strong></td>
<td>Capital Works Costs Achieved : Total Depreciation Charge&lt;br&gt;Maintenance Costs per Passenger Journey @ 90's Price&lt;br&gt;Maintenance Costs per Revenue Car km @ 90's Price&lt;br&gt;<em>Budget Maintenance Costs</em>&lt;br&gt;<em>Actual Maintenance Costs</em></td>
</tr>
<tr>
<td><strong>Customer</strong></td>
<td>N\textsuperscript{2} of Train Service Delays &gt; 5 min. due to RS's Equipment Failure&lt;br&gt;Sum of Initial Delays &gt; 5 min. due to RS's Equipment Failure (min.)&lt;br&gt;EMU Performance — Rolling Stock (kkm / incident)&lt;br&gt;EMU Availability (%)</td>
</tr>
<tr>
<td><strong>Internal Processes</strong></td>
<td>Response to Failure (%)&lt;br&gt;Percentage Coverage of Scheduled PM (%)&lt;br&gt;Capital Works Achievement</td>
</tr>
<tr>
<td><strong>Learning &amp; Growth</strong></td>
<td>Training Hours Ratio&lt;br&gt;Internal Promotion &amp; Transfer Rate&lt;br&gt;<em>Safety Training Hours Ratio</em>&lt;br&gt;<em>Cumulative Skill Gate 1 Achievement</em>&lt;br&gt;<em>Cumulative Skill Gate 2 Achievement</em>&lt;br&gt;<em>Labour Efficiency</em></td>
</tr>
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Note: Items shown in *italics* are not direct derivatives of performance measures in OED's Balanced Scorecard.
### Appendix VI

**Possible Candidates of Performance Measures in OED’s Scorecard**

(For illustration only)

<table>
<thead>
<tr>
<th>Strategic Objectives</th>
<th>Lag Indicators</th>
<th>Lead Indicators</th>
<th>Strategic Initiatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1: Maximize utilization of railway assets</td>
<td>Mtnc cost / passenger journey</td>
<td>Turnover rate of spares inventory</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mtnc cost / revenue car km</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Re-investment ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1: Delight customers with reliable railway service</td>
<td>N(^a) of train service delays due to equipment failures / month (^3)</td>
<td>% coverage of assets with RAMS analysis</td>
<td>Initiatives that focus on:</td>
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<tr>
<td></td>
<td>kkm / rolling stock incident</td>
<td></td>
<td>☀️ building relationships with customers and contractors</td>
</tr>
<tr>
<td></td>
<td>Sum of initial delays (^4)</td>
<td></td>
<td>☐ planning service recovery from equipment failures</td>
</tr>
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<td></td>
<td>Train availability</td>
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<td></td>
<td>Gate &amp; ticket m/c reliability (^5)</td>
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<tr>
<td></td>
<td>Escalator availability</td>
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<tr>
<td>S1: Achieve exemplary safety (&amp; environmental) performance in OED's operations (^6)</td>
<td>Lost time injury rate</td>
<td>Safety audit scores</td>
<td>Initiatives that focus on enhancing EHS performance</td>
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<td>Reportable accident rate of contractor’s labour</td>
<td>Railway Risk Index</td>
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<tr>
<td>I1: Provide efficient maintenance services to the operating railway</td>
<td>Time for service recovery</td>
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<td>Streamline service recovery operations</td>
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<tr>
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<td>Cycle effectiveness of CM jobs</td>
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</tr>
<tr>
<td></td>
<td>% coverage of scheduled PM</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Capital works achievement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I2: Enhance effectiveness of OED's management processes</td>
<td>Score of self-audit</td>
<td>% completion of IMS</td>
<td>Implement the IMS</td>
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<tr>
<td>I3: Leverage deployment of internal resources &amp; assets</td>
<td>% of non-core activities outsourced</td>
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<td>Exploit strategic outsourcing opportunities</td>
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<tr>
<td>Strategic Objectives</td>
<td>Lag Indicators</td>
<td>Lead Indicators</td>
<td>Strategic Initiatives</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>--------------------------</td>
<td>-----------------------------------------------------</td>
<td>------------------------------------------------------------</td>
</tr>
<tr>
<td>L1: Increase employee productivity</td>
<td>kkm / staff hour</td>
<td>Rate of employee suggestions</td>
<td>WIT activities</td>
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<tr>
<td>L2: Develop employees’ competencies to meet future needs</td>
<td>Training hours ratio, % completion of identified specialist training</td>
<td>Climate survey results</td>
<td>Introduce station-based / system-wide maintenance organization</td>
</tr>
<tr>
<td>L3: Develop a flexible and empowered workforce</td>
<td>% of cross-trained employees</td>
<td>% completion of the Integrated Documentation System</td>
<td>Develop a multi-skilled workforce</td>
</tr>
<tr>
<td>L4: Improve access to information</td>
<td></td>
<td></td>
<td>Implement the IDS (Integrated Documentation System)</td>
</tr>
</tbody>
</table>

Remark: Performance indicators not featured in OED’s existing BSC are italicized in the above table.

End Notes
1. Re-investment Ratio = capital work project costs : total depreciation charge.
2. Turnover Rate of Spares Inventory is an appropriate measure when inventory management is under the control of OED.
3. N° of train service delays due to equipment failures.
4. Sum of initial delays — the criticality of a delay varies with the time of its occurrence. Furthermore, should this measure be normalized by kkm or passenger journeys?
5. Gate & ticket m/c reliability is measured in number of transactions / failure of all AFC’s machines.
6. Strategic objectives relating to "environmental and safety performance" can be classified under the "Internal Processes" perspective.
7. % completion of identified specialist training — % match of the required skills profile can be equivalent to this measure.
8. Internal promotion rate — The rationale of including this indicator in the BSC is to be established.
## Appendix VII

### Items not included in Section 5 of the Questionnaire on OED's Performance Management System

<table>
<thead>
<tr>
<th>Item</th>
<th>Similar items featured in another survey conducted by OED earlier</th>
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<tr>
<td>3.01 OED's strategy is understood by those responsible for its implementation</td>
<td>Q1 The <em>leadership, purpose and objectives</em> of the department are well understood by all staff members.</td>
</tr>
<tr>
<td>3.03 OED's scorecard measures are identified through a participative process</td>
<td>Q2 Executive Managers and Section Heads have direct involvement in setting direction for achieving the departmental objectives, as well as developing and implementing management systems to manage the department.</td>
</tr>
<tr>
<td>3.04 Sectional scorecard measures are identified through a participative process</td>
<td></td>
</tr>
<tr>
<td>3.05 The scorecard measures are linked to strategic issues.</td>
<td>Q3 Departmental performance indicators were in place, covering the aspects of safety, financial, customer, business processes as well as learning &amp; growth, to help focus on business results and improvement actions.</td>
</tr>
<tr>
<td>3.10 OED's scorecards are <em>effective tools for operational control.</em></td>
<td></td>
</tr>
<tr>
<td>3.11 OED's scorecards <em>motivates staff members to create future value.</em></td>
<td></td>
</tr>
<tr>
<td>3.14 The scorecards in use <em>provide useful information</em> for carrying out OED's strategy.</td>
<td></td>
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* The numbers in column 1 refers to the items in Section 3 of the Questionnaire shown in Appendix I.

† The earlier survey was on *Implementation of the Integrated Management System (IMS) in OED*. It was conducted only a short while before the *Performance Management System (PMS) Survey*. The *IMS Survey Questionnaire* was sent to 52 management and supervisory staff in the Department and 40 of them responded.