CRANFIELD UNIVERSITY

HUANG, KUANG-CHUNG

THE DEVELOPMENT OF AN INTEGRATED MANUFACTURING PERFORMANCE MEASUREMENT AND EVALUATION FRAMEWORK

2000

SCHOOL OF INDUSTRIAL AND MANUFACTURING SCIENCE

PhD THESIS

Abstract

With the end of the Cold War and the subsequent reduction in defence spending, the Taiwanese defence industry has encountered great difficulties. Recently, the Government announced that at the end of 2006, all military plants should move from the public sector to the private sector. The aim being not only to maintain a manufacturing capability sufficient to ensure the technical competence and resources necessary for an effective and timely response to a mobilisation but also to reduce government infrastructure costs. However, unless the military plants take more aggressive action to assess their management and manufacturing weaknesses effectively, their modernisation efforts will not succeed.

This research is concerned with the development of a methodology for manufacturing performance measurement and evaluation to help Taiwanese military plants develop and maintain a competitive advantage. The basic concept of the proposed framework is based on the Balanced Scorecard concept. However, the structure and procedures have been further developed to reflect Taiwan's specific requirements. In particular, the proposed framework provides a structure and tools to tackle a number of key requirements, such as the need to provide both internal and external measures as a means of both qualitatively and quantitatively prioritising and evaluating manufacturing strategic concerns, and the need to show continuously where improvement needs to be made.

Industrial case studies have shown that the proposed framework is both feasible and effective when applied within the particular environment of Taiwanese military plants. In addition the proposed framework has highlighted some theoretical and practical problems associated with the design and development of manufacturing performance measurement and evaluation framework.

Due to its generic nature, through interviews with three UK companies, it was demonstrated that the proposed framework could also be applied to other societies and industries, either public or private, to solve their manufacturing performance measurement and evaluation problems.

Acknowledgements

Firstly, I thank my wife, Hwei-Shiang, and my daughters, Shang-Jung and Shang-Yi, for their loving and continuous encouragement.

I am extremely grateful to Professor John M Kay, the supervisor of this project. It would have been impossible to complete the thesis without his guidance and help. I express my sincere gratitude.

Also, I wish to thank Dr. Bin Wu for his support, and my colleagues for their support and valuable advice.

Sincere appreciation is extended to the support given by the members of the management of the case companies, both in the UK and Taiwan.

CONTENTS

List of Figures

List of Tables

Table of acronyms

Acronym	Definition
ABC	Activity-Based Costing
BMP	Best Manufacturing Practices
BPR	Business Process Reengineering
BSC	Balanced Scorecard
CAD	Computer Aided Design
CIM	Computer-Integrated-Manufacturing
DoD	Department of Defence
EQA	European Quality Awards
GAO	General Accounting Office
GOCO	Government Own, Contractor Operation
ISO	International Standards Organisation
JIT	Just-In-Time
LCC	Life-Cycle Cost
MND	Ministry of National Defence
MRP II	Manufacturing Resource Planning
NATO	North Atlantic Treaty Organisation
OM	Operations Management
PM	Performance Measurement
PMQ	Performance Measurement Questionnaire
PMS	Performance Measurement System
QFD	Quality Function Deployment
SMART	Strategic Measurement Analysis and Reporting Technique
SPC	Statistical Process Control
SQC	Statistical Quality Control
SWOT	Strengths, Weaknesses, Opportunities, Threats
TQM	Total Quality Management
WBS	Work Breakdown Structure

CHAPTER 1 INTRODUCTION

Chapter 1 introduces the major themes of this thesis. It first discusses the role of performance measurement in the manufacturing environment, its evolution and influences. Then, the research problems and objectives are introduced and finally the structure of the thesis is presented.

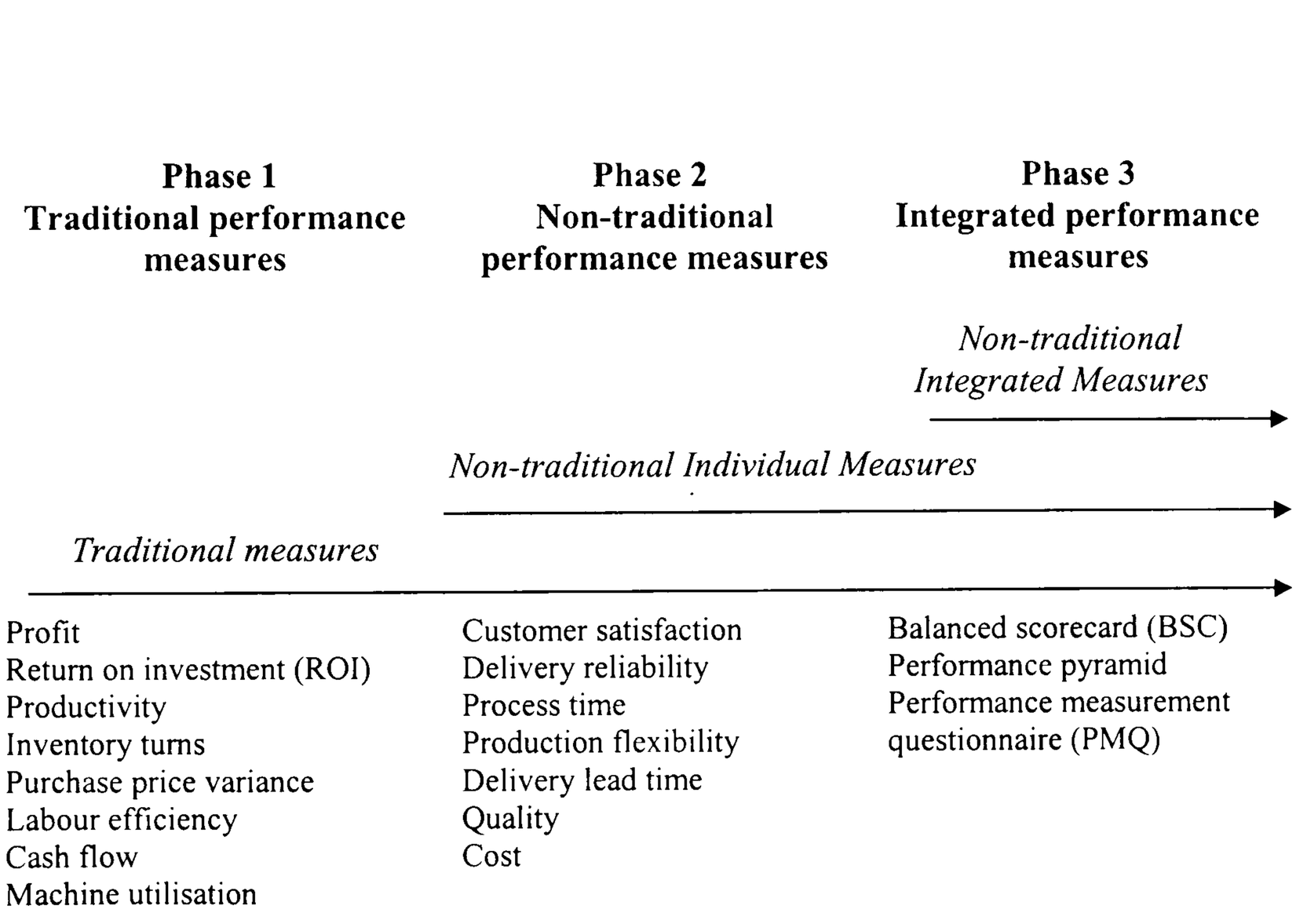
1.1 Background

The global market has changed from manufacturer and supplier oriented to customer oriented. In order to adapt to this change, companies have used many different manufacturing technologies and philosophies. These concepts, such as just-in-time (JIT), total quality management (TQM), or computer-integrated-manufacturing (CIM), involve focusing on the customer and looking at a business from the outside in rather than the inside out. All these changes, which are dramatically changing both the products and processes of modern manufacturing, share one basic goal: to have high quality, dependable delivery, more variety, shorter lead times, and lower costs. A critical enabler in achieving desired goals is the ability to measure performance (Harbour, 1993).

Performance measurement describes the feedback of information on activities with respect to meet customers expectations and strategic objectives. Effective measurement is critical to an accurate assessment of performance. It is the key to understanding an organisation's capability to produce a product and the quality of the product produced. It is also a tool for evaluating the effectiveness of manufacturing strategy and for determining the degree to which improvements need to be made to ensure a company's long-term success. The purpose of performance measurement is to evaluate and quantify the current state of the company, and highlight where improvement has been made and which areas need to be improved (Walsh, 1996).

Crawford and Cox (1990) and Hronic (1993) recognise that performance measurement in a company should continually change in order to remain effective. Typically, the evolution of performance measures, along with changes in the manufacturing environment, can be divided into two categories – traditional and non-traditional measures - and three phases, as shown in Figure 1.1 (Ghalayani et al. 1997;

Ahemd et al. 1999). The first phase, which began in the 1880s and ended in the 1980s, concentrated on financial measures such as profits, return on investment, inventory turn over, and productivity. Within this stage, measures were based on the traditional system of management accounting. However, such measures do not provide the right kind of information to allow a company to remain competitive in the 'new' manufacturing environment. As a result, the need to develop a more strategic and operational based performance measurement is essential (Kaplan, 1990). The second phase, which started in the early 1980s, is characterised by non-financial measures. Characteristics of the measurement at this stage are: performance measures are primarily related to manufacturing strategy, foster improvement rather than just monitor performance, and change with the dynamics of the market place (Maskell, 1991). The third phase is characterised by the integrated use of financial and non-financial measures. These integrated systems examine performance from multiple angles and examine the trade-offs in an attempt to guard against sub-optimisation (Kaplan and Norton, 1996). The major difference between the second and the third phase is that the former focuses on the critical measurement factors, whilst the latter emphasises integration and balance.



(Source: modified from Ghalayani et al. 1997; Ahemd et al. 1999)

Figure 1.1 Evolution in measurement approaches

In recent years, more and more companies are recognising the need to incorporate non-financial measures into their measurement framework, encouraged by the performance measurement models and quality awards that are rapidly gaining in popularity, such as the Balanced Scorecard, ISO9000, the Malcolm Baldrige Award, and the UK and European Quality Awards. However, although all the current performance measures highlight the importance of strategy and critical success factors, seldom do they provide us with a guide on how to measure them (Fry, 1995). Similarly, although non-financial measures are viewed as important, the knowledge about how to use them and how to measure them are still limited (Balkcom et al. 1997). Several studies support this view:

- Neely et al. (1995) note that although different measurement frameworks have been developed and provide criteria for measurement system design, a generally applicable systematic approach to performance measurement has not been developed.
- Walsh (1996) states that many authors have concentrated on 'what' the performance indicators are that should be measured and 'how' the measurement should be defined. Few of them have placed an emphasis on 'where' the processes need to be measured.
- Kaplan and Norton (1992) claim there is no standardised approach to develop and implement performance measurement systems. More recently, Bititci (1997) suggests that it is essential to have an integrated set of performance measures to eliminate conflicts within a company strategy, improvement projects and performance measures.
- Ghalayini et al. (1997) argue that even though companies have employed performance measurement in an integrated form, there are still many problems in today's manufacturing environment that need to be considered. They further state that performance measurement systems are used primarily as monitoring and controlling tools and fail to support continuous improvement of key performance measures.

Another issue is that many companies have developed specific performance measures in response to the identification of areas of low performance. This has led to

incomplete performance measurement systems geared towards short-term objectives. The absence of well developed and effectively executed manufacturing performance measures has been identified as a major reason why managers can not have the operational information they need for their decision-making (CIMA, 1995).

As manufacturing performance measures still have some areas that need to be explored, it is essential to conduct a detailed study to identify their problems and opportunities. To link theory with practice, this research takes the need for performance measures of the Taiwan defence industry as a starting point to explore knowledge in this area, to evaluate performance measurement concepts, and to suggest the most promising solution.

1.2 Problems of Taiwan Defence Industry

With the end of the Cold War and the subsequent reduction in NATO (North Atlantic Treaty Organisation) defence spending, many western defence industries have encountered great difficulties. These companies have focussed their activities in the Asian and Middle East markets. In recent years, as competition has increased rapidly in Taiwan, Taiwan's defence industry has reached a dilemma: since the in-country manufacturing programmes began to decline, there has been increased pressure to close down more military plants. On the other hand, a growing concern has focused on how the industrial base can be maintained without large development and production programmes. In order to respond to and balance those demands, in 1997, the Government implemented a GOCO (government owned, contractor operation) programme and announced that at the end of 2006 all military plants should move from the Ministry of National Defence (MND) to the private sector. The aim is not only to maintain a manufacturing capability sufficient to ensure the technical competence and resources necessary for an effective and timely response to a mobilisation but also to reduce MND infrastructure costs.

However, although GOCO can temporarily relieve pressure from the closure of military plants, a new challenge has also emerged, that is how to effectively and efficiently produce high-quality products within limited workforce, spending, and resources, especially with little government support. In understanding their situation, military leaders have recognised that in order to ensure the military plant's long-term

success it is essential to change their current focus not only to increase competitiveness but also to keep the industrial base viable. They also know that the key to achieving the desired goal is the ability to measure performance. As the internal/external environment has been changed, the performance measurement system in Taiwan's military plants must also change to remain effective. The question is what kind of performance measurement framework can meet the needs of Taiwan's military plants after the reorganisation.

1.3 Research Objectives

The original objective of this research is concerned with solving the performance measurement problem for the Taiwan defence industry. However, the basic goal of the Taiwan defence industry is similar to that of other leading companies around the world, that is to have high quality, dependable delivery, high flexibility, shorter lead times, and lower costs. Also there is no unifying methodology for applying performance measures in the manufacturing industry (Ghalayini and Noble, 1996). Therefore, it is rational to take a broader viewpoint to develop a set of generic manufacturing performance measures and an evaluation framework that can not only meet Taiwan's defence industry performance measurement requirements but can also be applied to other companies. In particular, it concentrates on the techniques of manufacturing systems status monitoring and continuous improvement monitoring. The aim is to improve manufacturing competitiveness by overcoming the limitations of the existing performance measurement systems and in order to motivate continuous improvement. Other objectives include:

1. Identifying what to measure and how to measure. According to Kaplan and Norton (1992) the use of performance measures in manufacturing is not new. Companies have been measuring costs, quality, quantity, cycle time, efficiency, productivity, etc., as long as ways to measure those things have existed. What is new is to determine what should be measured in order that they might better control, understand, and improve what they do. Schmenner and Vollmann (1994) argue that most companies are both using wrong measures and failing to use the right measures in the correct ways. Therefore it is important to identify the critical dimensions in a performance measurement system (what to measure) and the optimum characteristics of the measures (how to measure).

2. Developing a mechanism to connect manufacturing strategy, overall system status monitoring, and continuous improvement monitoring. Although all the current approaches highlight the need to link corporate strategies to manufacturing strategies and hence performance, few structured techniques have been suggested, particularly in a systematic sense. Also, although previous authors argue performance measures should foster continuous improvement, little has been published to provide us with a guide on how to link them with strategy and the overall system. Therefore, it is important to investigate and structure the connection between manufacturing strategy, overall system status monitoring, and continuous improvement in order to provide a complete cycle of performance measurement and to supplement the above deficiencies.

1.4 Research Strategy and Approach

In order to achieve the research objectives, two principal concepts should be explored: an investigation of the problems and specifications of the requirements for the development of the manufacturing performance measurement and evaluation framework; and an investigation of the overall system status monitoring and continuous improvement monitoring processes. The first concept involves the specification of the construction of the manufacturing performance measures and evaluation framework within which a generic methodology can be applied. The second concept involves the specifications of the performance measures and evaluation elements, matrix, tools, and their relationships with the suggested framework.

According to the above, a number of research approaches were adopted primarily based on the practical techniques and a rigorous review of the literature for each of the two concepts. The research strategy was to focus on the link between theory and practice in order to prevent the "laboratory in the woods" (Foster, 1986). The industrial link included both Taiwan and UK companies. The practical work was supplemented by a review of the literature in the research domain and an analysis of the techniques and the available performance measurement systems design methodologies. The research approach itself will be described in further detail in Chapter 3 and briefly introduced below:

1. Justify research aim and objective through interviews with the management of Taiwan's military plants and relevant theories studied.
2. Investigate requirements for the development of performance measures and evaluation framework.
3. Review models and techniques which have been advocated for measuring performance.
4. Identify the necessary inputs to the performance measures and evaluation framework design.
5. Develop suggested framework by taking specific requirements into consideration. Company visits have been undertaken to this end.
6. Modify framework.

1.5 Industrial Context

The research has been carried out with the collaboration of a number of companies including both public and private sectors within two countries, Taiwan and the UK. The Taiwan military plants involved included, Lin-Ko Missile System Development Centre, In-Ger General/Utility Vehicle Development Centre, and Nai-Tou Armour Vehicle Development Centre. Throughout the course of the research some UK companies were involved with respect to the provision of information and advice, including DuPont Ltd., OXOID Ltd., and Tatung (UK) Ltd.

1.6 Structure of Thesis

This thesis adopts a structure of discussion and presentation as outlined below (see Figure 1.2):

Chapter 2 reviews the literature in order to provide a basis for the development of the suggested framework, by reviewing the ideas and current thinking in the field of manufacturing performance measures. It first provides an overview of performance monitoring in general. The desirable characteristics of manufacturing performance measures are discussed. Then it moves on to examine how the traditional techniques have come in for some severe criticism in recent years. Finally, it presents some modern techniques of performance measurement based on non-financial sources of information.

In Chapter 3, the research methodology is discussed; some of the main problems of research in this area are identified and the chosen approach is described and justified. Various methods that could be used to test the suggested framework are also introduced.

Chapter 4 gives an overview of the suggested framework which is developed from literature sources and from a series of interviews with management who work in the case companies in Taiwan, with the aim of preventing any purely theoretical aspects of performance measures system design.

Chapter 5 presents the complete procedures of the suggested framework, which follows a step-by step guide including generic reference tables which are designed to be completed at each stage.

Chapter 6 performs the testing and evaluation of the structure and procedures of the suggested framework. The survey and case study results are brought together in this chapter. An example to illustrate the practical application of the model is first introduced. It then describes the results and findings of the rest of the case studies using the model.

In Chapter 7, the conclusions drawn from the research are summarised and its impact on the practice of the suggested framework is discussed. The advantages and disadvantages of the research methodology are briefly discussed. The limitations of the research are noted and some suggestions for further work are also given.

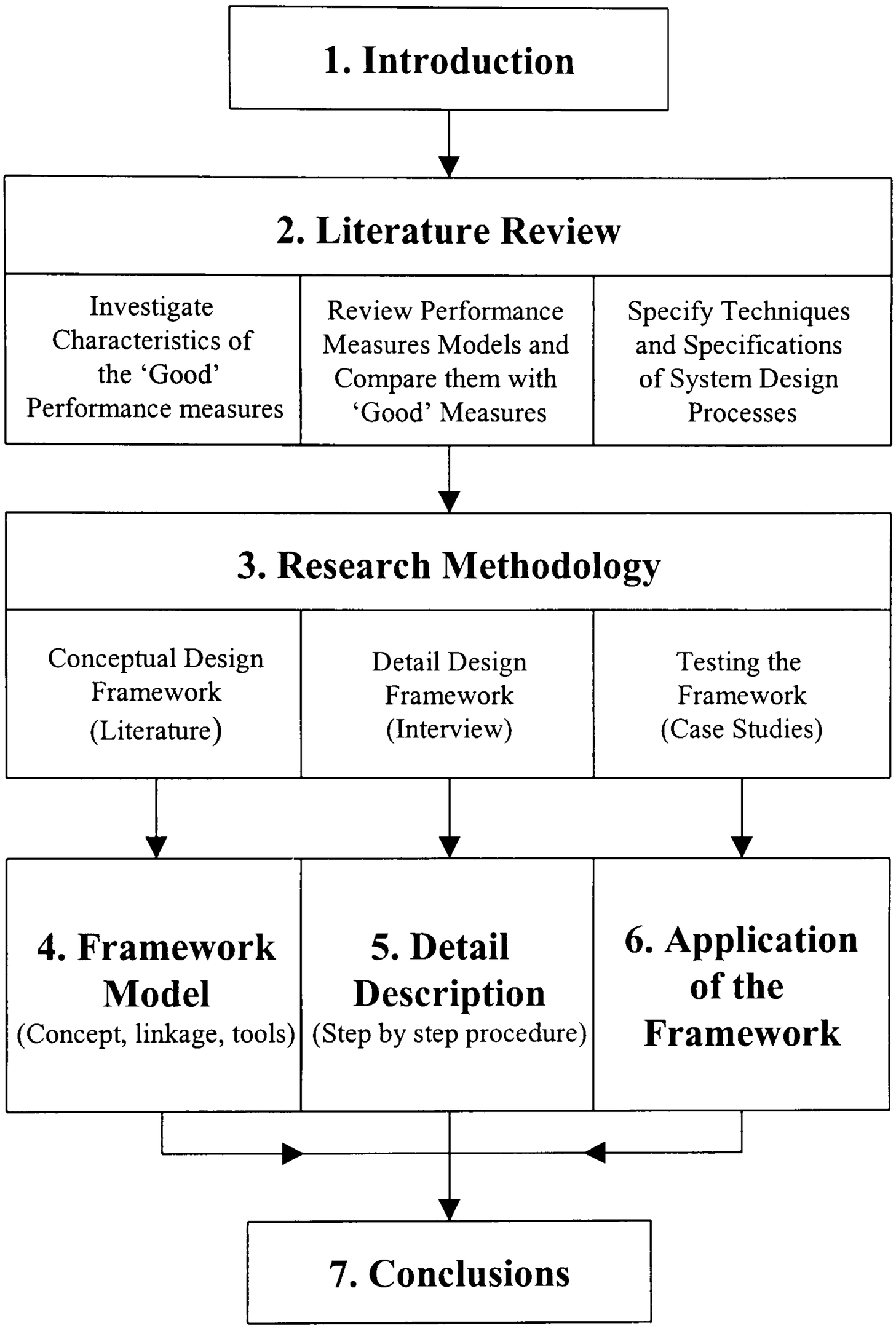


Figure 1.2 Structure of thesis

CHAPTER 2 LITERATURE REVIEW

2.1 Overview

This chapter reviews the relevant and current techniques to measure manufacturing performance, including their theory, processes, approaches, and criteria. It provides a basis for the development of the concepts of a framework to be suggested, using the ideas and current thinking in the field of manufacturing performance measurement. In particular, it is to assess a number of current techniques for performance measurement and evaluation, to analyse their advantages and disadvantages, and to try to identify an appropriate process that embraces the design principles of a good performance measurement and evaluation system.

The first part reviews manufacturing performance measures in general to try to find a set of rigid principles to guide the research. The second part conducts a serial study of current practices in manufacturing measurement modules to find their theory, constraints, and strong/weak points, in accordance with the principles discovered previously and provides a comparison among modules. These include individual as well as integrated financial/non-financial measures for performance evaluation. Also, quality award models and self-assessment processes, and other techniques such as benchmarking which are rapidly gaining in popularity and provide a means for companies to compare their own performance with "international best practice", will also be discussed. The final part is conclusions and suggestions.

2.2 Performance Monitoring in Context

Performance measures are recognised as an important element of the overall control management. Managers directing the efforts of a company have a responsibility to know how, when, and where to start with a wide range of changes. These changes cannot be successfully implemented without knowledge of the appropriate information upon which they are based. Performance measurement is the key (White, 1996).

Performance measurement describes the feedback or information on activities with respect to meeting customer expectations and strategic objectives (Zairi, 1994). Effective measurement is critical to an accurate assessment of performance. It helps set targets, monitor progress, and motivate organizational strategic objectives. However, as Ganapathy and Goh (1997) suggested, such measures will be more useful if they can also serve as a diagnostic aid to better understand the reasons why a company is performing well or poorly. Therefore, a well-designed system of performance measurement must incorporate the ability to both monitor and diagnose performance.

Kaplan (1984) says that an effective performance measurement system should consist of not only the traditional financial and cost-accounting criteria used by upper management but also tactical-performance criteria that are used to assess the firm's current level of competitiveness and direct its efforts in attaining a desired competitive position. The roles of performance measurement can be categorised into two aspects: (1) it provides the company with a method to assess its current competitive position with respect to its competitors and the demands of the market and identify avenues for improvement; and (2) it is to monitor the company's progress in moving towards its strategic objectives (Wisner and Fawcett, 1991). One of its main purposes is to evaluate and quantify the current state of the company, and highlight where improvements have been made and which areas still need to be improved (Walsh, 1996).

However, it is not enough simply to measure performance. Dhavale (1996) notes that performance must also be analysed and evaluated. He further states that a performance measurement system involves determining what to measure, identifying data collection methods, and collecting the data. While evaluation comprises assessing progress towards achieving performance expectations, usually to explain the relationships that exist between programme activities and outcomes. Additionally, performance measurement is concerned with process or product optimisation through increased efficiency and effectiveness of the process. These actions occur in a continuous cycle, allowing options for expansion and improvement of the work process or product when better techniques are discovered and implemented (NPR, 1999).

2.2.1. A view of manufacturing

Before discussion of manufacturing performance measures, it is necessary to know what is manufacturing and what is manufacturing strategy. Traditionally, manufacturing is focussed on the process of converting inputs (materials, energy, and information) into outputs (goods and services). The conversion process takes place inside a factory, and comprises the use of facilities (hardware), procedures (software), and people (Basu and Wright 1996). The purpose of manufacturing, as Skinner (1969) suggests, is "…to serve the company – to meet its needs for survival, profit, and growth."

Maskell (1991) argues that in the past two decades, due to increased global competition and faster technology changes, traditional manufacturing has been shown to have deficiencies. Manufacturing excellence or world-class manufacturing has become dominant. Basu and Wright (1996) say that creating the best factory is of little benefit if the whole spectrum of the business, internally and externally, has not been addressed. Manufacturing should be defined in a wider sense. It should be concerned with the complete manufacturing business, that is placing emphasis on the links between the product and other functions in the company, as well as suppliers, customers, and others outside the company. These include marketing, research and development, the supply chain, financial and information management, human resources, and general management, and also with external factors such as environment and safety, customer care, and competition (Clark and Zirner. 1993).

2.2.2 What is manufacturing system?

Manufacturing system is recognised as a production function that converts the raw materials into the finished products. It is the collection of machines, transportation elements, computers, storage buffers and other items, including people, that are used together for manufacturing (Gershwin, 1994). Several researchers have placed their concerns in this area (Young and Mayer 1984, Black 1991, Hitomi 1994a, Hull1998). Among them Hitomi (1994a) categorises manufacturing system into three aspects which is accepted in this research:

1. *The structure aspect.* The manufacturing system includes workers, production facilities, and equipment.

2. *The transformational aspect.* The manufacturing system is recognised as a production function that concerts the raw materials into the finished products with the aim to maximise productivity.
3. *The procedural aspect.* The manufacturing system is the operating procedures of production. This constitutes the so-called management cycle, i.e., planning, implementation, and control.

2.2.3 What is manufacturing strategy?

Webster's Dictionary (1990) defines strategy as: "the art of devising or employing plans toward a goal." There are several levels of strategy within the corporate structure. A business might have individual functional strategies such as marketing/sales, manufacturing, R&D, and accounting/control. The functional strategy specifies how it will support the desired business strategy and how it will complement other functional strategies. For each strategy to be effective, it must ensure the consistent support of other strategies, while manufacturing strategy is an integral component of the overall corporate strategy (Hill, 1993).

Miller et al. (1989) define manufacturing strategy as "... a projected pattern of manufacturing choices formulated to improve fundamental manufacturing capabilities and to support a business and corporate strategy." Manufacturing strategy allows an organisation to question where it is now, and where it must be for both the short term and the long term. However, a manufacturing strategy is not just a piece of paper. It is a dynamic document that requires an understanding of what manufacturing is and how manufacturing fits into the overall operation of a business (Hitomi, 1994b).

Ward et al. (1990) suggest that the content of manufacturing strategy can be captured in two broad categories:

1. Decision areas that are of long term importance in the manufacturing function, and
2. Competitive priorities based on corporate and business goals.

A manufacturing strategy comprises a series of co-ordinated decisions. The conceptual can be traced back to Skinner (1974). He suggested five areas where trade-off decisions had to be made to ensure a fit between business strategy and

manufacturing: (1) plant and equipment; (2) production planning and control; (3) labour and staffing; (4) product design/engineering; and (5) organisation and management. In the following years, different authors have proposed many strategic decision areas for manufacturing (Buffa, 1984; Hayes and Wheelwright, 1984; Fine and Hax, 1985). Table 2.1 compare the lists offered by the authors cited above.

	Skinner (1974)	**Hayes & Wheelwright (1984)**	**Buffa (1984)**	**Fine & Hax (1985)**
Structural	Plant & equipment	Capacity Facilities Technology Vertical integration	Capacity/location Product/process Technology Vertical integration	Capacity Facilities processes & technologies
Infrastructure	Production planning & control Organisation & management Labour & staffing Product design	Production planning & control Quality Organisation Workforce New product development	Strategic implications of operating decisions Workforce & job design Position of production system	Product quality Human resources Scope of new products

Table 2.1 Strategic Manufacturing Decisions

2.2.4 Definition of performance measures

Performance measures have been defined as a tool to compare actual results with a pre-determined goal and to measure the extent of any deviation (Fortuin, 1988). They quantitatively tell us something important about our products, services, and the processes that produce them (NPR, 1999). Zairi (1992), from the TQM viewpoint, defines performance measures as the amount of some quality factors that permit evaluation of that factor in numbers. Hronec (1993) states that performance measures assess how well the activities within a process or the outputs of a process achieve a specified goal.

More recently, according to the Department of Trade and Industry's definition, it is (Neely, 1996):

The process of quantifying purposeful action where the process of quantification is measurement and purposeful action equates with performance.

Similarly, the US General Accounting Office has defined performance measurement as (GAO, 1998):

The ongoing monitoring and reporting of programme accomplishments, particularly progress towards pre-established goals.

In general, therefore, performance measures are used to evaluate, control and improve a company's production process to ensure the achievement of its goals and objectives. If results differ from objectives, an organisation can analyse the gaps in performance and make adjustments. Performance measures are also used to compare the performance of different companies, plants and individuals. In addition performance measures provide a means of capturing performance data which can be used to inform decision making (Neely et al. 1997). The importance of performance measurement is well summarised by the US Foundation of Manufacturing Committee of the National Academy of Engineering (Heim and Compton, 1992):

World-class manufacturers recognise the importance of metrics in helping to define the goals and performance expectations for the organisation. They adopt or develop appropriate metrics to interpret and describe quantitatively the criteria used to measure the effectiveness of the manufacturing system and its many interrelated components.

2.2.5 Why measure manufacturing performance

Gibson et al. (1995) say that in the complex and competitive manufacturing environment, it is necessary for companies to continually improve their quality and productivity of products and services to stay ahead of the competition. Also, to achieve goals, manufacturing companies have to measure. Yet manufacturing companies can effectively improve only what they can effectively measure (Chang and Young, 1995). Therefore, in order to achieve continuous improvement, Kaplan and Norton (1992) state that a manufacturing company needs a method to help managers understand "where we are now", to help them plan "where we want to go", and to tell them "when we have arrived". Having data is fundamental, for, as the old saying goes, "If you cannot measure an activity, you cannot control it. If you cannot control it, you cannot manage it." Without dependable measurements, intelligent

decisions cannot be made (Kaplan, 1991).

Measurement is the basis through which it is possible to control, evaluate, and improve processes. Fitzgerald et al. (1991) recognised that managers continuously need to access the relevant and valid information about performance in order to adequately focus on two questions that are basic to good management: (1) how well are we doing? and (2) how can we do better? Through systematic measurement and evaluation of performance, the result of performance measures is obtained that assists in developing a better understanding of: how well the existing systems and products perform; how well systems and products meet customer requirements; and whether the systems, and how products provided are consistent with future manufacturing strategy. Measurements therefore, can be used for (Chang and Young, 1995):

1. Control: Measurements help to reduce variation.
2. Self-assessment: Measurement can be used to assess how well a process is doing, including improvements that have been made.
3. Continuous Improvement: Measurements can be used to identify defect sources, process trends, and defect prevention, and to determine process efficiency and effectiveness, as well as opportunities for improvement.
4. Management Assessment: without measurements, there is no way to be certain we are meeting value-added objectives or that we are being effective and efficient.

2.2.6 Benefits of performance measures

Lingle and Schiemann (1996) contend that measurement plays a crucial role in translating business strategy into results. In their survey of top American companies, they have found that companies with effective measurement tend to anticipate the future and are likely to remain competitive in a radically changing environment. Performance measurement yields many benefits for an organisation. One benefit is that it provides a structured approach to focus on a company's vision, strategy, goals, and performance. Another benefit is that it provides a mechanism to report programme performance to high level management (Kaplan, 1996). Besides, performance measurement can help companies (Harbour, 1997):

- Track progress in achieving desired performance goals.
- Control performance within predetermined boundaries.
- Identify problem areas and possible problem causes.
- Show where improvement needs to be made.
- Ensure decisions are based on fact, not on emotion.
- Identify whether suppliers are meeting requirements.
- Compare and benchmark competitors' performance with its own.
- Help to set future targets
- Drive change.

2.3. Traditional and non-traditional performance measures

2.3.1 Traditional performance measures

Traditionally, the measures used to evaluate a company's performance have been primarily based on conventional accounting systems. Earnings per share, inventory turns, return on investment, purchase price variance, labour efficiency, and machine utilisation are examples of these measures. Such measures are focussed on local measures of efficiency and productivity (Neely et al. 1997). Among them, productivity and cost are the most frequently used measure of manufacturing performance. Manufacturing companies monitor employee productivity, facility output, and direct and overhead costs for a variety of time frames. This is because only costs are available and easy to measure (Najarian, 1993). Whereas the purpose of financial accounting measurement, according to Maskell (1991), is to report the company's activities to interested parties outside the company, a company's cost accounting measure is supposed to provide information useful to managers' planning and control decisions.

Financial accounting was developed over a century ago. Manufacturing systems and practices have changed enormously since then, particularly in the last two decades, but accounting systems have not kept up (Kaplan, 1984). It has been argued that the conventional reports about the financial performance of a business are much like the scoreboard at a baseball game (Fisher, 1992). A scoreboard tells a player whether he is winning or losing the game, but it tells him little about what he is doing right or wrong about the fundamentals of baseball. Also, although traditional performance

measures are useful at measuring the end result of performance, they are less useful for monitoring and diagnosing performance at the operational level. This is because financial measures typically indicate the state of performance but do not reveal the reasons for such performance (Ganapathy and Goh, 1997). Besides, financial measures are emphasised on local rather than global measures of performance (Gibson et al. 1995). Therefore, financial accounting measures in general would provide managers with a knowledge of the system performance that reflect the results of past decisions, but not the actionable steps needed for surviving in today's competitive environment.

Especially, Kaplan and Norton (1996a) who conducted a corporate performance measurement benchmarking of 31 US organisations discovered that only 27 per cent of participants' measurement criteria were financial measures, the remaining 73 per cent represented non-financial measures such as quality, customer satisfaction, productivity, workforce and market indicators. According to them, non-financial measures that monitor and diagnose operational performance are needed.

A summary of the deficiency of financial measures is illustrated in Table 2.2. From Table 2.2, it is obvious that although financial accounting measures continue to receive some attention, seldom of them can provide the right kind of information to allow a company to create a competitive advantage through manufacturing. Also, although they might serve as warning signals about performance problems, they do not communicate the reasons for the problems and, therefore, are not useful to decision makers. On the other hand, from those deficiencies, they provide an opportunity to develop new systems to prevent any shortcomings.

Deficiencies of financial accounting measures for manufacturing businesses	
They can not provide the information for management to make critical business decisions.	Cross and Lynch, 1988/1989
They often include too many different measures, which makes it difficult to understand the 'big picture'.	Keegan et al. 1989
They do not cover manufacturing performance relative to the competitive capabilities.	Dixon et al. 1990
They are not directly related to the strategy of the company.	Maskell, 1991
They produce bottom-line financial results too late for carrying out corrective action.	Maskell, 1991
They reflect the results of past decisions, not the actionable steps needed for surviving in today's competitive environment.	Fisher, 1992
They are unable to help organisations implement modern management concepts, such as JIT and TQM among others.	Kaplan, 1991
They typically indicate the state of performance but do not reveal the reasons for such performance.	Meyer, 1994
They do not adequately trace costs of products, processes, activities etc.	Bititci, 1994
They do not recognise the need for business integration.	Bititci, 1994
They emphasise local rather than global measures of performance.	Gibson et al. 1995
They are not suited to diagnose deficiencies at the operational level.	CIMA, 1995
They are not easy to understand by employees.	Fry, 1995
There is no linkage between performance measures and strategic objectives.	Dhavale, 1996
They are unable to link a company's long-term strategy with its short-term actions.	Kaplan and Norton, 1996a

Table 2.2 Summary of the deficiencies of financial measures for manufacturing businesses

2.3.2. Non-traditional performance measures

As a result of the limitations of the traditional performance measures, attempts have been made to develop a set of better balanced measures that would provide management and operators with on time information that is necessary for daily decision making (Dixon et al. 1990). Such measures, according to Ghalayini and Noble (1996), should be flexible, primarily non-financial, and able to be changed as needed. Although there is no fixed formula for developing relevant and meaningful measures, there are some principles to apply (Maskell, 1994).

Several researchers have taken a strategic look at the characteristics of performance measures and what the appropriate responses should be. Lynch and Cross (1992) say that good systems include the need to: link operations to strategic goals, integrate financial and non-financial information, measure what is important to customers, motivate operations to exceed customer expectations, identify and eliminate waste. Caplice and Sheffi (1995) argued that a "good system" should be comprehensive,

causally oriented, vertically integrated, horizontally integrated, internally comparable and useful. Ghalayini and Noble (1996) asserted that to overcome the limitations of traditional performance measurement new systems should be dynamic, stress the importance of time as a strategic performance measure and link the areas of performance and performance measurement to the factory shop-floor. A summary of the characteristics of a good set of performance measures proposed by several researchers is illustrated in Table 2.3, and can be categorised into the following common aspects:

- Performance measures should be derived from strategy.
- Performance measures should include both financial and non-financial measures.
- Performance measures should be simple to understand.
- Performance measures should provide timely and accurate feedback.
- Performance measures should be an integrated set, balanced in their application.
- Performance measures should reflect the business process – i.e. both the supplier and customer should be involved in the definition of the measure.
- Performance measures should focus on improvement rather than just monitoring.

A major benefit of non-financial measures is that they can usually be reported on a more timely basis than financial measures. As a consequence, if a non-financial measure indicates poor performance, action can often be taken before negative financial consequences occur. In addition, non-financial measures are easy to understand and are always available. This provides instant feedback regarding the performance of the company (Tatikonda, 1998). The main differences between traditional and non-traditional performance measures can be seen in Table 2.4.

Maskell (1991)	**Lockamy (1995)**
• Directly related to strategy. • Be primarily non-financial. • Vary between locations. • Change over time. • Be simple and easy to use. • Provide fast feedback of information. • Foster improvement rather than just monitor performance.	• Encompass the entire product-delivery system, from the supplier to the customer. • Be consistent with the manufacturing objectives of the facility. • System information must be shared between organisational levels to provide organisational focus.
Dhavale (1996)	**Ghalayini and Noble (1996)**
• Make performance measures understandable. • Be clear about what is being measured. • Ensure that data can be collected. • Make the performance measures timely. • Link the performance measures to strategy. • Tailor performance measures for different levels of management. • Avoid allocations. • Encourage the good of all. • Make performance measures relevant • Improve communication. • Stress teamwork. • Avoid proxies and surrogates. • Shoot high. • Act rather than react.	• A clearly defined set of improvement areas and associated performance measures that are related to company strategy and objectives. • Stresses the role of time as a strategic performance measure. • Allows dynamic updating of the improvement areas, performance measures and performance measures standards. • Links the areas of improvement and performance measurement to the factory shop-floor. • Used as an improvement tool rather than just monitoring and controlling tool. • Considers process improvement efforts as a basic integrated part of the system. • Uses historical data of the company to set improvement objectives and to help achieve such objectives.
Allen (1993)	**DTI (1998)**
• The measurement criteria must be developed in conjunction with the individual, function, or organisation being measured. • The ultimate goal here is not just to monitor status, it is to improve performance, thus it is important to have the "buy in" of the group responsible for making it happen. • Ease of data collection. • Timeless: time lag between data collecting and publication of the measurement. • Frequency: measurement frequency. • Trend identification: to review trends, reinforcing the concept of continuous improvement. • Transparency: easy to understand and use.	• Should contain a balanced mix of financial and non-financial measures. • Can help to predict what is about to happen and what has happened. • Can encourage people to do the things that management desire. • Should be an integral part of a systematic process for reviewing the measures and stimulating purposeful action.

Table 2.3 Characteristics of non-traditional performance measures

Characteristic	Traditional performance measures	Non-traditional performance measure
Basis of system	Accounting standards	Company strategy
Types of measures	Financial	Operational and financial
Audience	Middle and top managers	All employees
Frequency	Lagging (weekly or monthly)	Real-time (hourly or daily)
Linkage with "reality"	Indirect, misleading	Simple, accurate, direct
Shop floor relevance	Ignored	Used
Format	Fixed	Flexible/variable
Local-global relevance	Static, non-varying	Dynamic, situation structure dependent
Stability	Static, non-changing	Dynamic, situation timing dependent
Purpose	Monitoring	Improvement
Support for new improvement approaches (JIT, TQM, CIM)	Hard to adapt	Applicable
Effect on continuous improvement	Impedes	Support

(Source: Ghalayini et al. 1997)

Table 2.4. A comparison between traditional and non-traditional performance measures

2.4 Examine performance measurement

Beamon (1999) suggests that performance measurement research should focus on analysing performance measurement systems that are already in use, categorising performance measures and then studying the measures within a category, and establishing rules of frameworks in which performance measurement systems can be developed for various types of systems. Neely et al. (1995) conducted a comprehensive literature review of performance measurement and categorised it into three different areas:

1. The individual performance measures. These focus on individual performance measures by examining various dimensions of quality, cost, time and flexibility from a strategic perspective.
2. The performance measurement system (PMS). This develops a performance measurement framework for relating functional or local performance to the overall business level performance.
3. The relationship between the PMS and the environment in which they operate. This examines the interaction between a performance measurement system and its internal and external environment.

According to the above, in the following sections of performance measurement analysis, it is essential firstly to identify what will be measured by focusing on the competitive criteria that have been identified as part of the manufacturing strategy (individual measures). Then, it moves to focus on the existing performance measurement models. Finally it examines quality awards and self-assessment processes, and benchmarking (environmental considerations). Together with the characteristics of 'good' performance measures identified above, the aim is (1) to conduct a detailed performance measurement study to know their concepts, process, and criteria (section 2.5.), (2) to identify deficiencies and gaps of the existing performance measurement models by comparing them with the characteristics of 'good' measurement (section 2.6, 2.7, 2.8), and (3) to specify key issues for the development of a suggested framework (section 2.9).

2.5 Performance measurement and competitive priority

Zairi (1996) states that performance measurement in the context of the manufacturing environment can be meaningful only if it focuses on strategic aspects as much as on opportunities for improvement. Skinner was the first to link manufacturing strategy and performance measurement together (White, 1996). He argues that in selecting performance measures companies have too often tended to choose the historical ones of cost or efficiency, and this can lead to a mismatch between corporate strategy and the competitive focus on the operations function (Skinner, 1969). He further suggests that manufacturing controls should focus on cost, quality, inventory, and time, and the results should be measured in terms of productivity, service, quality and return on investment (1974). Following the work of Skinner, Wheelwright (1984) goes on to suggest that performance measures should be tied to the company's strategy as reflected by its "competitive criteria". Manufacturing competitive criteria provide an indication of customer requirements with respect to the manufacturing systems in strategic terms (Hayes and Wheelwright, 1984; Voss, 1992). However, they do not have to be a reflection of the existing strengths of a company (De Meyer et al. 1989). Instead, they are the ways that a manufacturing company chooses to compete in the marketplace. They are the key factors that help determine the company's ability to compete effectively (Flynn et al. 1999).

The importance of competitive priority, as Hendricks et al. (1996) stated, is that: "*To remain competitive, companies need to institute a balanced set of financial and non-financial performance measures that relate directly to the organisation's mission, objectives, strategies, and competitive criteria such as delivery, quality, flexibility, and financial performance. Without them, companies won't have an accurate picture of how they are performing, in which areas they are achieving success, and in which areas they need to make changes.*" Therefore, the competitive priorities of the business have to emphasise corporate, business and manufacturing strategies, as well as measures on various hierarchical levels (Jonsson and Lesshammar, 1999).

Leong et al. (1990) claim that it is widely accepted that the manufacturing competitive criteria, and the key dimensions of manufacturing's performance, can be defined in terms of quality, delivery speed, delivery reliability, cost, and flexibility. Depending on the authors or the specific organisation, the number of manufacturing competitive criteria can vary widely (see Table 2.5). For example, Maskell (1991) categorises performance measures using the preceding competitive priorities, but adds employee relationships as a sixth category. The American, Europe, and Japan leading manufacturing companies have been reported as deploying four broad categories of competitive criteria for use by operational managers. They are quality, delivery, flexibility, and cost. These competitive criteria all have characteristics that serve as the basis for measurement. They are discussed below:

Competitive Criteria	Skinner (1974)	Wheel-wright (1984)	Richard-son et al. (1985)	Leong (1990)	Maskell (1991)	Roth & Miller, (1992)	White (1996)	Neely et al. (1996)
Quality	✓	✓	✓	✓	✓	✓	✓	✓
Flexibility	✓	✓	✓	✓	✓	✓	✓	✓
Delivery reliability	✓	✓	✓	✓	✓	✓	✓	✓
Delivery speed			✓	✓	✓		✓	✓
Cost	✓	✓	✓	✓	✓	✓	✓	✓
Human resources					✓			✓
Innovation			✓					
Organisation								✓
Customer service						✓		

Table 2.5 Performance measures in manufacturing modelling

- **Quality measures** are the way customers define it. From a performance measurement standpoint, quality means that the products or services meet and exceed the desires and expectations of the customers. This category measures the "goodness" of the product or service in the eyes of the customers including: performance, features, reliability, conformance, technical durability, serviceability, aesthetics, value for money, etc.
- **Delivery measures** are the function of the speed of the organisation. How fast can the organisation be responsive to outside influences, either through customer orders, a change in competition, or a change in the environment? This category measures the "goodness" of the process including: delivery lead time, delivery speed, manufacturing lead time, due data performance, frequency of delivery, etc.
- **Flexibility measures** are the measurement regarding the manufacturing system's adaptability to changes in the manufacturing environment, either external or internal. This category measures the "ability" of flexibility including: material quality, output quality, modification, volume, product mix, resource mix, etc.
- **Cost measures** are the financial performance measures; the money spent on the people, processes, or organisation. This category measures the economics of "goodness" including value added, selling price, running cost, service cost, profit, etc.

Table 2.6 provides a list of some of the characteristics associated with them. It is noted that the competitive criteria adopted in this research here have been expanded to six areas of quality, delivery lead-time, delivery reliability, volume flexibility, design flexibility, and cost. This is because, according to White (1996), they are widely accepted in manufacturing environments, both academic and practice.

Competitive Criteria	Function	Performance Measures
Quality	Producing a product that performs well to specification	Quantify the "goodness" of a product that performs well to specification
Delivery lead-time	Delivering the product within the lead-time required by the customer	Quantify the "goodness" of delivering products within the lead-time required by the customer
Delivery reliability	The ability to deliver on schedule	Quantify the "goodness" of delivery on schedule
Design flexibility	The ability to produce products to a customer specification	Quantify the "ability" to produce products to a customer specification
Volume flexibility	The ability to supply fluctuating volumes without compromising lead-time	Quantify the "ability" to supply fluctuating volumes without compromising lead-time
Cost	Selling at the lowest price	Quantify the economics of "goodness"

(Source: Wheelwright, 1984; DTI, 1992; Neely, et al. 1996; White, 1996)

Table 2.6 Competitive criteria definition and performance measures

The competitive priorities provide the first level for classifying manufacturing performance measures. It is to put them at the top level because manufacturing's performance relative to these priorities can determine whether or not an organisation can be successful in obtaining its strategic objectives (Neely et al. 1996). The next is to identify the subsequent levels of performance measures within each category of competitive priorities. Many authors have defined different sets of performance measures (see, for example, Dixon et al. 1990; Gibson et al. 1995; Ghalayini et al. 1997; DTI, 1998). Among them, White (1996) provides the most comprehensive study of classifying and categorising each performance measure found in the literature survey, as shown in Table 2.7.

In summary, developing competitive criteria can help a company focus on what is really important to its ultimate success. However, it must be recognised that many of the competitive criteria identified above are not independent. For example, it is clear that performance measured by cost depends directly on much of the product, process, and system performances. Similarly, the actions that determine quality measures have an impact on a host of other measures, for example, process yield, product costs, use of facilities, levels of implement, material scrap, labour hours per process, and fraction of repeat sales to customers. It is evident that care must be taken in interpreting a combined list of measures (Heim and Compton, 1992). By focusing attention simultaneously on the competitive criteria, a company can optimise the

results of the processes, and can optimise the results of the whole manufacturing system.

Cost measures	Quality measures	Flexibility measures	Delivery measures	Speed measures
Cost relative to competitors	Perceived relative quality performance	Production cycle time	Perceived relative reliability	Lead time
Manufacturing cost	Quality relative to competitors	Set-up time	Reliability relative to competitors	Cycle time
Total product cost	Product reliability relative to competitors	Perceived relative volume flexibility	% on-time delivery	Order processing time
Direct labour	Customer satisfaction	How well plant adapts to volume change	Due date adherence	Response time
Indirect labour	Reputation	Smallest economical volume	% increase in portion of delivery promises met	% on-time for rush jobs
% improvement in labour	Expected product life	Lot size	% of orders with incorrect amount	Paperwork throughput time
Relative labour cost	Number of complaints	Ability to perform multiple tasks efficiently	Schedule attainment	Material throughput time
Labour productivity	Service call rate	Number of job classifications	Average delay	Value added as percent of total
Labour efficiency	Retention rate	% work force cross-training	% reduction in lead time per product line	Elapsed time
% reduction in employee turnover	Renewal rate	% programmable equipment	% improvement in output	Distance travelled
Materials	Value of returned merchandise	% multipurpose equipment	% reduction in purchasing lead time	Decision cycle time
Inventory	Field failure	% of slack time for equipment, labour		Time lost waiting for decisions
Scrap	Mean time between failures	% products using pull system		New product introduction vs. competition
Repair or rework	Uptime percentage	WIP		Development time for new products
Cost of quality	Pass rate	Vendor lead time		Break-even time
Design cost	% conformance to targets	% of material readily obtainable		Time from idea to market
R&D cost	% with no repair work			Average time between innovations
Overheads	% repair reduction			Number of changes in projects
	% scrap value reduction			Engineering time
				Time from customer need recognition to delivery

(Source: White, 1996)

Table 2.7 Examples of performance measures for manufacturing competitive criteria

2.6 Existing performance measurement models

When developing a performance measurement system, it is essential to consider conceptual frameworks to stimulate what should be measured. Also it is useful to review other frameworks to identify new ideas and approaches that might help for the development of the system (Kapklan, 1996).

A number of performance measurement models have been developed in the past in an attempt to overcome some of the problems associated with traditional performance measurement systems. Among those developed include the balanced scorecard (Kaplan and Norton, 1992, 1996), the performance pyramid (Lynch and Cross, 1991), and performance measurement questionnaire (Dixon et al. 1990).

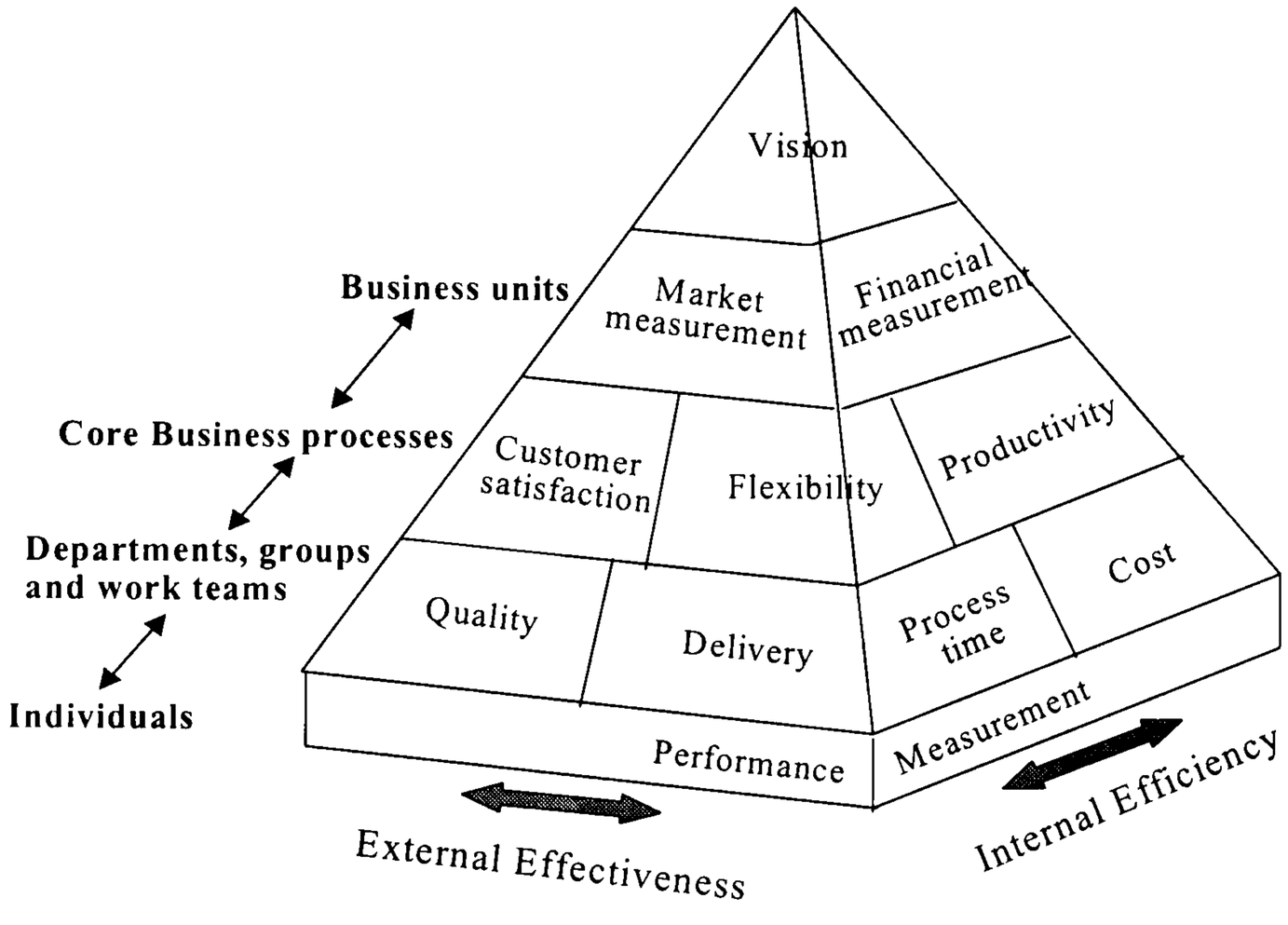
2.6.1 The strategic measurement analysis and reporting technique (SMART) system

The SMART system was developed by Wang Laboratories, Inc. as a result of dissatisfaction with traditional performance measures such as utilisation, efficiency, productivity, and other variances. It provides a strong focus on linking the measurement of organisational performance to the strategic planning process. The objective is to integrate both financial and non-financial measures, to link manufacturing to the strategic goals of the company, to concentrate the measurement system design on satisfying customer needs, and to develop a system that fosters constant evolution in terms of performance measurement (Lynch and Cross, 1991).

Lynch and Cross (1991) report that the SMART system is a model to describe how objectives are communicated down to the shop floor and how measures can be rolled up at various levels in the organisation. It consists of a four-level pyramid of objectives and measures, shown in Figure 2.1.

1. At the top of the pyramid is the corporate vision. This vision forms the basis for corporate strategy which defines what markets the company will compete in, product scope, and services provided.
2. At the second level, objectives for each business unit are defined in market (external focus) and financial (internal focus) terms. Strategies are then formulated, describing how these objectives can be achieved.
3. The business operating system at the third level is the starting point for effective measurement and control at the department level. It defines all activities, policies, procedures, and priorities required to implement the strategy in terms of customer satisfaction, flexibility, and productivity. The aim of this level enables department measures to focus on the effectiveness of the entire operating system rather than on the efficiency of a single department. The relationships between the business operating system objectives and the top-level market and financial goals are illustrated by their position in the pyramid; that is, the market measures are supported by customer satisfaction and flexibility, and the financial measures are supported by flexibility and productivity. While customer satisfaction means how customer expectations regarding quality and delivery are managed; flexibility indicates the responsiveness of the operating system; and productivity refers to how resources are managed.

4. The last level in the hierarchy is operational measures that are the key to achieving strategic results. At this level, the objectives are converted into specific operational criteria: quality, delivery, process time, and cost. These four criteria for department measures can translate strategic direction into department action.



(Source: Lynch and Cross, 1991)

Figure 2.1 Performance pyramid for identify performance measures

SMART supplies an approach for understanding and defining objectives and metrics appropriate for each level of the organisation. It is a good communications tool for showing how the key elements of business success are linked and who in the organisation is responsible for each element. The difference of the SMART approach to performance measurement from other internal control systems is that the former is a strategic-driven performance system and is designed to evaluate the overall organisational performance, while the latter is designed to evaluate the department's performance. Unlike other control systems that are monitoring past performance, SMART provides a framework for a management control system that allows it to continually self-adjust to the future needs of the business, in accordance with customer expectations. The main strength of the SMART system is that it integrates corporate objectives with operational performance measures. Also, it measures departments and functions on how they are contributing separately and together in

meeting their strategic mission (Cross and Lynch, 1988/1989). However, there are some weaknesses in the SMART system:

- It does not provide any mechanism to identify key performance indicators for quality, cycle time, cost and delivery (Ghalayini and Noble, 1996).
- It is not always possible for top level management to direct a specific strategy to business units (Ballantine and Brignall 1995).
- It does not take competitor/best practice environment into consideration.

According to the above, some key issues which are important and relevant to the purpose of this research can be identified. They are:

1. Performance measures play an important role to link operations with strategic goals.
2. Performance measures should focus on financial and non-financial measures.
3. Performance measures should be directly related to a company's competitive priority.
4. Performance measures should build consensus horizontally across functional or department lines.
5. Performance measures should not only relate to each competitive priority but also must be properly oriented toward different levels of an organisation to ensure performance can be measured and controlled.

2.6.2 The performance measurement questionnaire (PMQ)

The alignment among a company's strategy, actions and performance measures is crucial. Mcmann and Nanni (1994) say that one major problem of the performance measurement and control system is that an organisation's internal achievement measures may lack congruence with its stated strategy and intended actions for executing that strategy. To assist in the understanding of this alignment, Dixon et al. (1990) have developed a diagnostic tool called the performance measurement questionnaire (PMQ), as shown in Figure 2.2. It is a questionnaire-based method to check the relationship between an organisation's strategy, actions, and measures.

Long-run importance of improvement	Improvement areas	Effect of current performance measures on improvement
None >>>> Great		Inhibit >>>> support
1 2 3 4 5 6 7	Quality	1 2 3 4 5 6 7
1 2 3 4 5 6 7	Labour efficiency	1 2 3 4 5 6 7
1 2 3 4 5 6 7	Machine efficiency	1 2 3 4 5 6 7
1 2 3 4 5 6 7	Volume flexibility	1 2 3 4 5 6 7
1 2 3 4 5 6 7	Product technology	1 2 3 4 5 6 7

(Source: Dixon et al. 1990)

Figure 2.2 Performance measurement questionnaire (Example)

According to Dixon et al. (1990), the PMQ consists of four parts, although most emphasis is placed on parts two and three. The first part provides general data to be used to classify the respondents. The second part assesses the company's competitive priorities and performance measurement system. It consists of items labelled as "improvement areas". The respondent is asked to circle a number on each side of the table. The third part looks for opinions on the relative importance of a range of performance factors and the extent to which these are currently given emphasis by the company. The last part of the questionnaire asks the respondents to provide performance measures that best evaluate their own performance and to make any comments they wish about the questionnaire. Through the selection of appropriate internal performance measures companies can then improve their competitiveness.

The PMQ was given to management to evaluate the existing performance measurement system of the company and to provide input for development of a new performance measurement system. Through the selection and adoption of appropriate internal performance measures companies might improve their competitiveness and financial performance. The objectives of PQM is to help managers identify the improvement needs of their organisation, to determine the extent to which the existing performance measures support improvements and to establish an agenda for performance measurement improvements (Dixon et al., 1990).

The PMQ provides a questionnaire with 39 generic performance measures that range from "yields" and "cost of quality" to "unit overhead costs" and "return on investment". The results are evaluated in four ways: alignment, congruence, consensus and confusion. Alignment analysis is conducted to investigate in general terms how well a company's actions and measures complement its strategy. Congruence analysis is conducted to provide a detailed understanding of how well the

measurement system supports an organisation's actions and strategy. Consensus analysis is carried out by grouping the data by management level or by functional group. This analysis shows the effect of communication. The goal of confusion analysis is to determine the extent of consensus (standard deviation) regarding each improvement area and performance measure (Dixon, 1990).

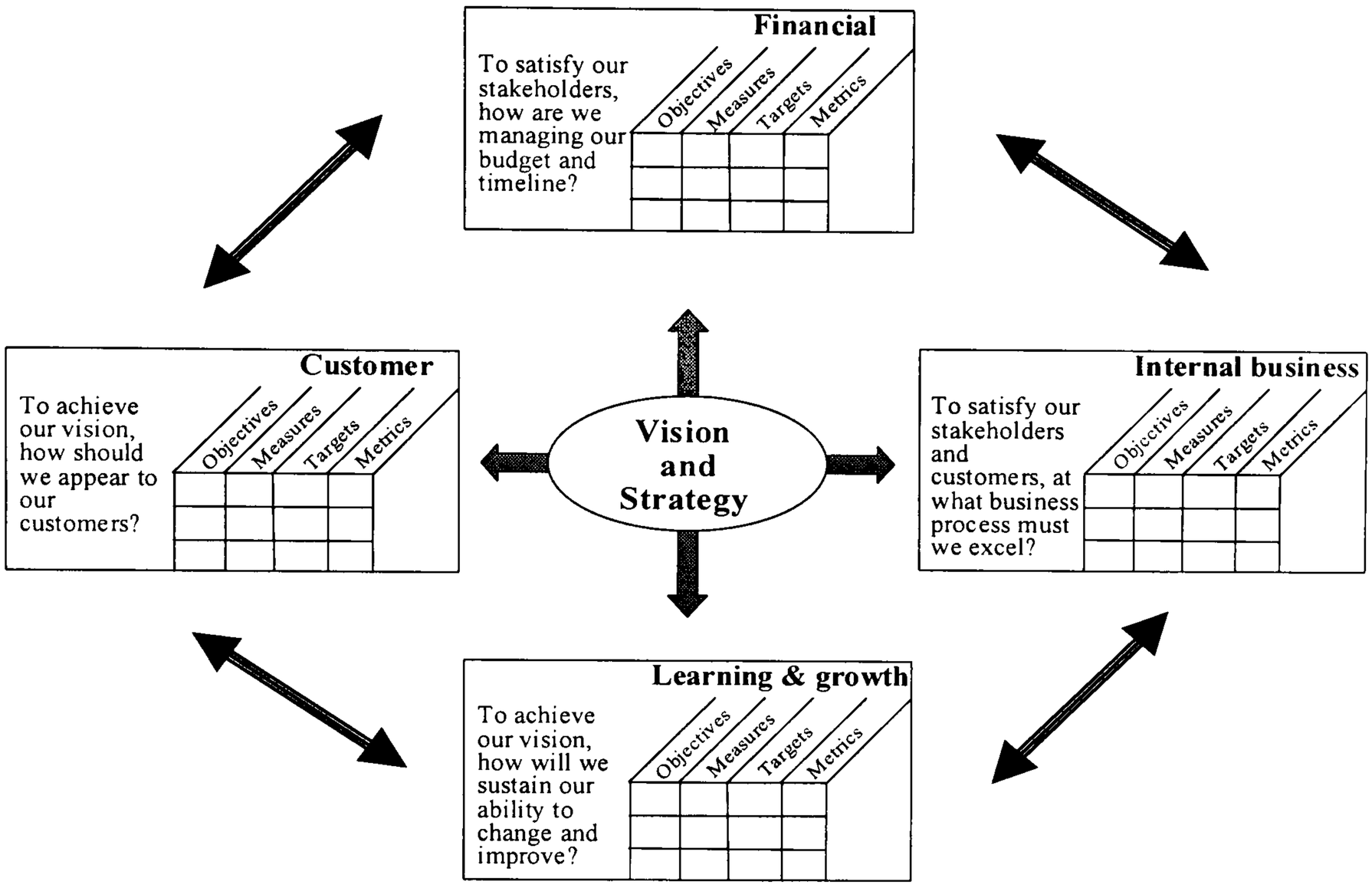
PMQ can assist an organisation in understanding the effectiveness of its existing performance measures and how they can be aligned to strategies and actions through the use of the PMQ. According to Dixon et al. (1990), the PMQ has advantages in several areas. It provides a mechanism to identify the improvement areas of the company and their associated performance measures. Second, it can help in determining the congruence of an organisation's strategies, actions, and measures. Third, it can assist in evaluating the effectiveness and efficiency of the existing internal performance measures. Fourth, it provides a starting point for organisation self-assessment and communication. Besides, it is simple to do and enables an organisation to develop performance measures that can meet its specific requirements.

The disadvantage of the PMQ is that it does not provide guidance on how to assign departmental performance measures, or to develop a performance measurement from the company's strategies. Ghalayini et al. (1997) argue that although PMQ does address the importance of alignment between actions, strategies, and performance measures, it does not explain how to achieve this alignment. White (1996) considers that although PMQ is designed to identify inconsistencies between the performance measures and company strategy, it does not indicate how to select those measures. Another weakness of the PMQ, like SMART, is that it does not take into account the concept of continuous improvement. As a result more work is required to link these areas of improvement and performance measures to the factory shop-floor (Gregory, 1993).

2.6.3 Balanced Scorecard

Kaplan and Norton (1992) introduced the concept of balanced scorecard for measuring the performance of an organisation. Balanced scorecard is a strategic management system for achieving long-term goals. It allows management to translate strategy into a clear set of objectives. These objectives are then further translated into

a system of performance measurements that effectively communicates the strategic focus to the entire organisation.



(Source: Kaplan and Norton, 1996a)

Figure 2.3 The balanced scorecard links strategic objectives to actions

Kaplan and Norton (1996a) say that the balanced scorecard is a conceptual framework for translating an organisation's strategic objectives into a set of performance indicators distributed among four perspectives: financial, customer, internal business processes, and innovation and learning, as shown in Figure 2.3. The financial perspective examines how well the business is doing in satisfying the needs of the owners or shareholders. The customer perspective examines how customers see the organisation. The internal business perspective examines the activities, processes and programmes at which the organisation must excel. The innovation and learning perspective examines ways the organisation can continue to improve and create value by looking at processes, procedures and access to information to achieve the business strategies.

The balanced scorecard approach is defined as a set of measures which employs a family of indicators for measuring performance across the organisation that can be

used to identify the resources needed to achieve the results desired. An example of balanced scorecard measures is illustrated in Table 2.4. Some indicators are used to measure an organisation's progress toward achieving its vision. Other indicators are applied to measure the long-term drivers of success. Through the use of the balanced scorecard, an organisation monitors both its current performance (financial, customer satisfaction, and business process results) and its efforts to improve processes, motivate and educate employees, and enhance information systems its ability to learn and improve.

Financial perspective	
Goals	**Measures**
Survive	Cash flow
Succeed	Quarterly sales growth and operating income by division
Prosper	Increased market share

Customer Perspective	
Goals	**Measures**
New products	Percent of sales from new products
Responsive supply	On-time delivery
Preferred supplier	Share of key accounts' purchases
Customer partnership	Number of co-operative engineering efforts

Internal Business Perspective	
Goals	**Measures**
Technology capability	Manufacturing geometry vs. competition
Manuf'ring excellence	Cycle time
	Unit cost yield
Design productivity	Engineering efficiency
Product introduction	Actual introduction schedule vs. plan

Learning & Growth Perspective	
Goals	**Measures**
Technology leadership	Time to develop next generation
Manufacturing learning	Process time to maturity
	Percent of products that equal 89% sales
Product focus	New product introduction vs. competition
Time to market	

(Source: modified from Simons, 1995)

Figure 2.4. Examples of balanced scorecard measures

Kaplan and Norton (1996b) state that the balanced scorecard is unique in its emphasis on placing the organisation's strategic vision at the centre of the performance measurement structure. Traditional performance measurement systems try to keep individual and organisational units in compliance with a pre-determined plan. The balanced scorecard provides managers with the ability to measure in a different way – to translate and communicate the vision and strategy of an organisation, to help align individual, organisational, and cross-departmental initiatives to achieve a common goal. Management can use the scorecard as a communication, information, and learning system, not as a traditional control system, for the balanced scorecard is

designed to be used in this way. However, the measures must provide a clear description of the organisation's long-term strategy for competitive success (Butler et al. 1997).

When using the balanced scorecard, development of strategic goals is the first step in creating a performance assessment process that is designed to support accomplishment of the strategic vision. Only after the organisation knows where it wants to go, can it then develop the performance measures that will help to ensure the accomplishment of the strategic objectives. Also, Kaplan and Norton (1996b) note that using the balanced scorecard must identify the right measures. If not, measurement may focus their efforts on activities that do not move the organisation towards the long-term success.

The strengths of balanced scorecard can be categorised into the following aspects (Ghalayini and Noble, 1996a):

- It describes the vision of the future for the entire organisation and translates it into action.
- It summarises many different management reports of a company into one.
- It enables an organisation to link performance measurement with its strategic goals.
- It allows management to consider all the key indicators measure at the same time.
- It helps to communicate business and departmental objectives to the people and teams who perform the work.
- It facilitates the strategy review that permits organisation learning.

Gregory (1993) points out that although the balanced scorecard framework helps us to understand the different perspectives of the performance measurement system and the balance between the measures, it does not tell us exactly what the measures should be. It also does not take competitor/best practice into consideration (Bourne, 1999). Besides, Ganapathy and Goh (1997) argue that the balanced scorecard is mainly designed for high level management to provide them with an overall view of organisational performance. It is not designed for the shop-floor level.

2.6.4 Summary of existing integrated performance measurement systems analysis

The three integrated performance measurement systems discussed have been developed in an attempt to provide an overall view of company performance and to produce the most promising solution for the vision success. The SMART system links an organisation's strategy and operation together by translating objectives from top down, and measures from the bottom up. The PMQ uses a questionnaire-based method to audit and prioritise performance measurement systems and to establish an agenda for improvement. The Balanced Scorecard approach integrates strategic, operational, and financial measures. Goals are set using the four perspectives: financial, customer, internal, and innovation/learning. A summary of the comparison of the three integrated performance measurement systems is illustrated in Table 2.8.

	The balanced scorecard *(Kaplan and Norton, 1996a)*	**The SMART system** *(Lynch and Cross,1991)*	**PMQ** *(Dixon et al. 1990)*
Type	A conceptual model with key criteria for creating a performance assessment process to support the accomplishment of strategic vision	A conceptual model with vertical integration and horizontal measurement for assessing a company's external effectiveness and internal efficiency	A guideline approach and benchmark for identifying performance gaps and improvement areas
Purposes	To develop a framework for an integrated performance system for strategic, operational, and financial measures	To link manufacturing to the strategic goals and to concentrate the measurement system on satisfying customer needs	To use a questionnaire-based method to audit and prioritise performance measurement systems
Focuses	Financial/non-financial and internal/external measures	Financial/non-financial, Qualitative/quantitative, and Internal/external measures	Financial/non-financial, qualitative/quantitative, and internal/external measures
Measures	Performance measures are defined by the four 'perspectives': customer, financial, internal business, and learning and growth	Performance measures is defined by customer satisfaction, flexibility, and productivity	Performance measures are defined by the competitive priorities and performance measurement system assessment

Table 2.8 Comparison of the integrated performance measurement systems

Some lessons learned from this section which are important for the development of manufacturing performance measurement systems are shown in Table 2.9.

Characteristics/dimensions of integrated measurement systems	Lessons learned
• The SMART system provides a strong focus on linking the measurement of organisational performance to the strategic planning process. It attempts to integrate corporate objectives with operational performance measures. It also acts as a communication tool for showing how the key elements of business success are linked and who in the organisation is responsible for each element. • The PMQ provides a mechanism to identify the improvement areas of the company and their associated performance measures. It tries to determine the extent to which the existing measurement system supports such improvement areas. • The Balanced Scorecard attempts to integrate four important performance perspectives in one simple and easy-to-use management report. It is intended for top management in an organisation to be able to obtain a quick and comprehensive assessment of the organisation in a single report.	• Performance measures should derive from strategy and concentrate on the alignment of strategy, action, and measures (BSC, SMART). • Performance measures should consider both financial and non-financial measures, including competitive criteria such as quality, delivery, flexibility, and cost (BSC, SMART). • Performance measures should take the hierarchical approach into account, that is, to use competitive criteria as the first level and then cascade down into different level of measures within the organisation (SMART). • Manufacturing performance measures should also define different "perspectives" of measures, which are different from BSC concerned. Instead, those perspectives should focus on the capacity, facility, technology, etc. of manufacturing strategy policy areas (BSC). • Performance measures should look ahead to predicting, achieving and improving future performance (BCS, SMART, PMQ). • By taking PMQ technique, the accomplishment of performance measurement system can be evaluated to identify its effectiveness and efficiency (PMQ).

(Sources: Kaplan and Norton, 1996a, Lynch and cross, 1991, Dixon et al. 1990)

Table 2.9 Lessons learned from the integrated performance measurement system

According to tables 2.7 and 2.8, the balanced scorecard can be viewed as a more suitable approach for the design and development of manufacturing performance measurement system. Because it is not only employed a family of indicators for measuring performance across the organisation that can be used to identify resources needed to achieve results desired, but also concerned with the balance of measures. Other methods such as SMART approach (in order to identify how manufacturing strategy are communicated down to the shop floor and how measures can be rolled up at various levels in the organisation), and PMQ technique (to check the relationship between an organisation's strategy, action, and measures) can also be used in this research.

2.7 Award models and self-assessment processes

In discussing performance monitoring, it is also necessary to talk about self-assessment because performance measurement has a close relationship with total quality management (TQM) (Zairi, 1996). Self-assessment, according to the British Quality Foundation (1995), is to review and compare an organisation's performance against a recognised model of business excellence. Therefore, in carrying out self-

assessment, the first thing should be to look at the existing models and use an appropriate model of excellence against which to assess one's own organisation (Hake, 1996). Typically, this involves the self-assessment processes of a proven excellence measure as a basis for development of a company-specific process. Self-assessment helps organisations in many ways, including (British Quality Foundation, 1995):

- Identify what is done well.
- Identify what needs to be improved.
- Identify where best practices exist.

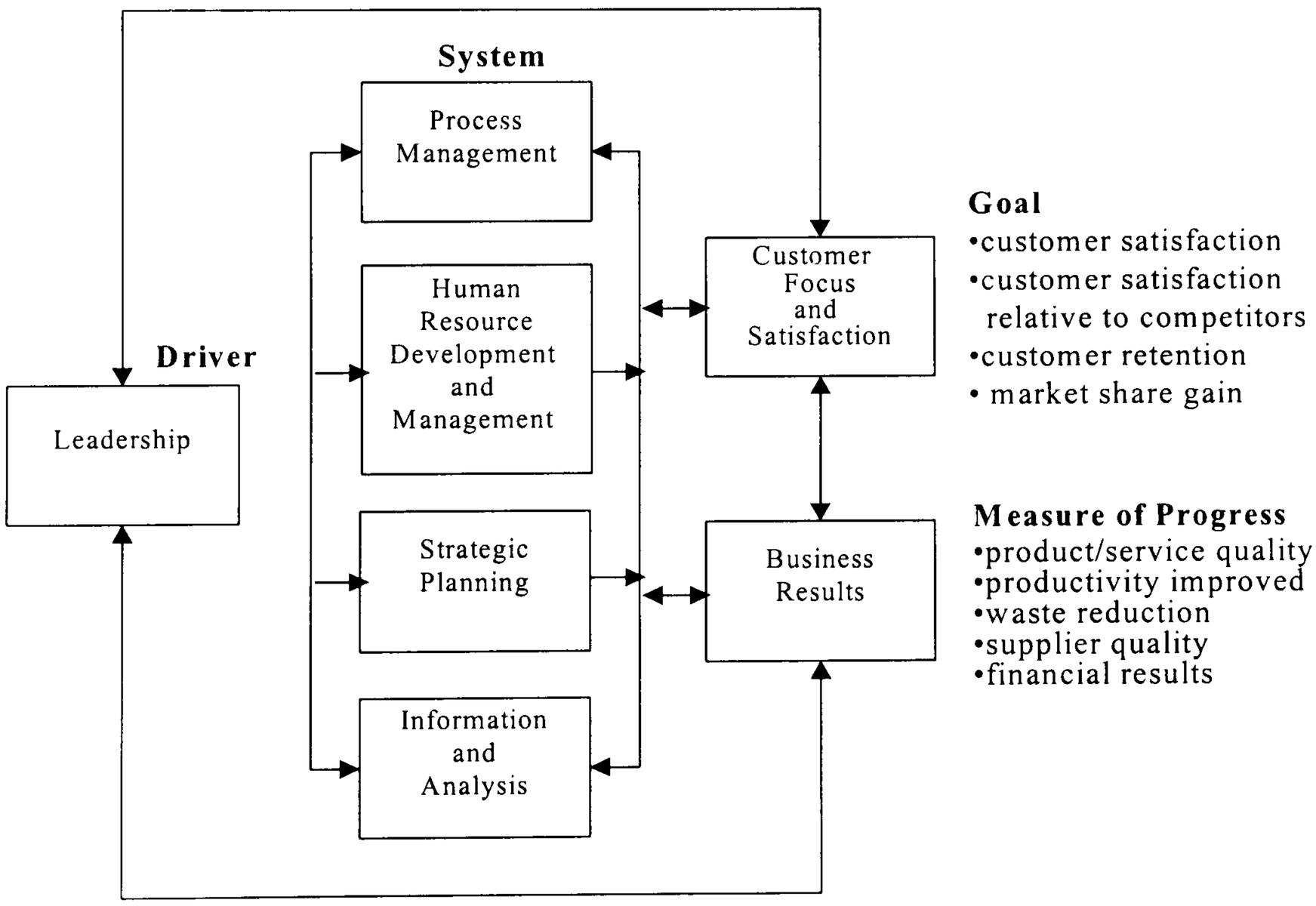
Self-assessment framework is therefore not a means to win awards but serves as a vehicle to pursue continuous improvement and become more competitive. It involves selecting an appropriate model (for example the European Quality Award) for comparison, collecting data from appropriate sources and having a comparison process that compares the two. It provides organisations with a means to measure their position against a set of world-class criteria, and to identify their strengths and weaknesses in the key areas of business (Zairi, 1996). Several national and international quality awards have been established to promote quality and serve as models of self-assessment. Three of the most famous and now widely used frameworks are the Malcolm Baldrige National Quality Award, the European Quality Award, and the Deming Prize.

2.7.1 The Malcolm Baldrige National Quality Award

The Malcolm Baldrige National Quality Award for performance excellence, and its scoring guidelines, presents a diagnostic instrument to help an organisation identify organisational strengths, as well as key areas for improvement to achieve higher levels of performance. It is a non-prescriptive method of assessing the capabilities of an organisation. The purpose of the award is to develop guidelines and criteria that companies can use to evaluate their quality improvement efforts, through the promotion of (Blazey, 1997; Baldrige Award Web site, 2000):

An understanding of the requirements for performance excellence and competitiveness improvement and sharing of information on successful performance strategies and the benefits derived from using these strategies.

The award framework has four basic elements: driver; system; measures of progress; and goal; and are divided into seven examination categories. A total of 1000 points are allocated to these seven categories. Each emphasizes a major quality system requirement and includes a set of specific areas to address the type and amount of information that applicants should provide (Garvin, 1991). The award is basically a measure of a company's competitiveness, and it places great emphasis on continuous improvement in response to market pressure from customer demands, competitors and acceptable industry standards and performance. The framework illustrated in Figure 2.5 indicates the relationship between the four basic elements, examination categories and items. It also shows that these inter-relationships are dynamic and changes in one area will affect the other areas (Ghobadian and Woo, 1996).



(Source: Baldrige Award web site)

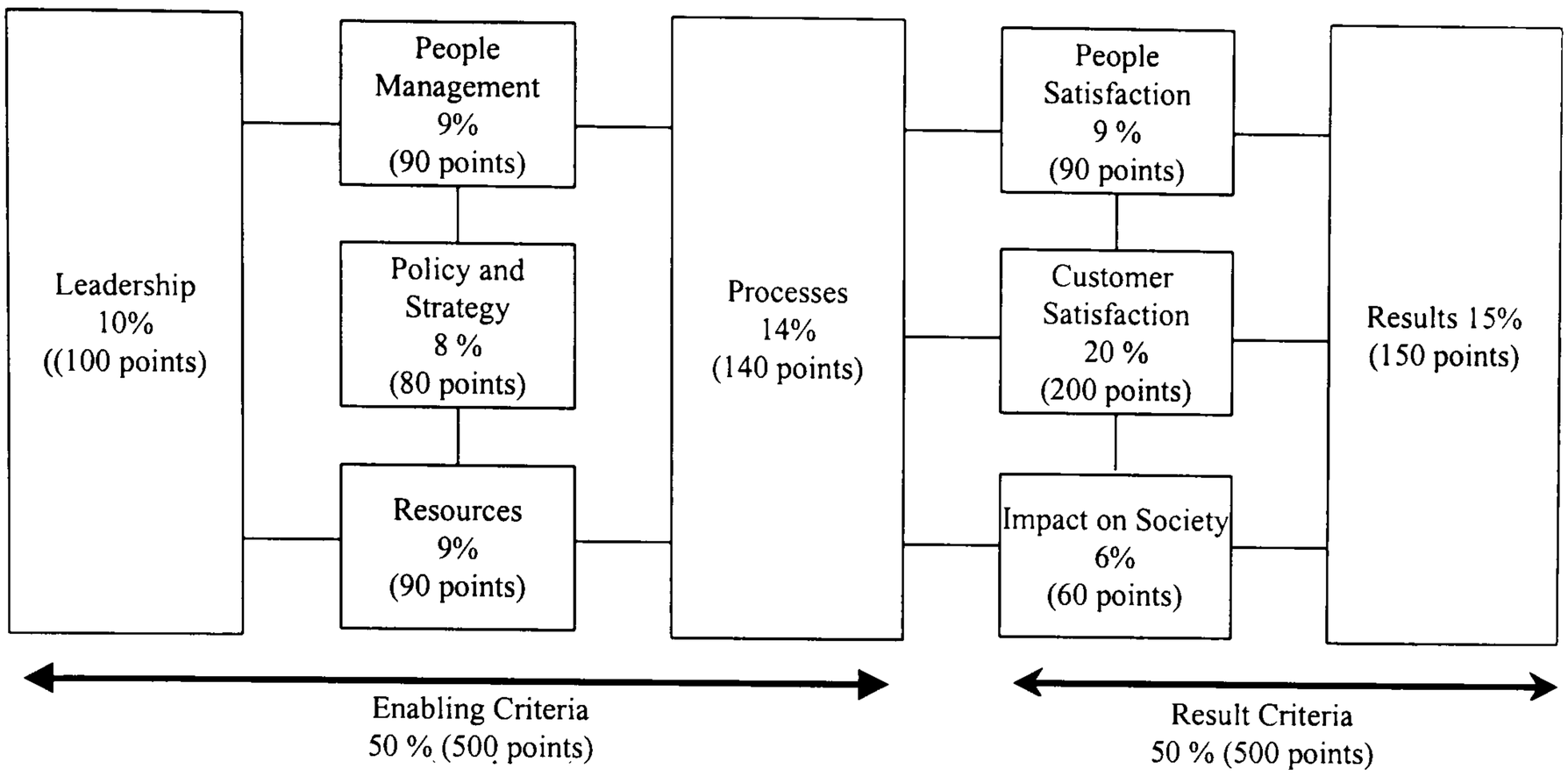
Figure 2.5 The Baldrige Award

2.7.2 The European Quality Awards (EQA)

Zairi (1994) states that the EQA is a framework that can be used to assess a company's progress towards excellence, as shown in Figure 2.6. EQA assessment criteria have nine categories and a maximum of 1000 points is allocated to these nine award criteria. Unlike the Baldrige award framework, the criteria are divided into two groups: 50 per cent of the assessment marks are given to enablers and 50 per cent for results. The enabling criteria are concerned with how the organisation approaches each of the criterion parts, and the results criteria are concerned with what the organisation has achieved (British Quality Foundation, 1995).

EQA assesses how the customer and people satisfaction, impact on society, and business results are being achieved through leadership, people management, policy and strategy, resources and processes (Bohoris, 1995). The aim is to enhance the position of companies in the world market through accelerating the acceptance of quality as a strategy for global competitive advantage, and stimulating the development of quality improvement activities (Ghobadian and Woo, 1996). A company may be assessed against the model by a process of self-assessment. This is then examined by a team of assessors and then a jury. A site visit may then be organised to review the results, and to clarify and verify outstanding issues (British Quality Foundation, 1994).

The model not only provides a direction for quality improvement focus, but also offers a benchmark of world-wide best practice. Although the EQA and Baldrige award share some common criteria, there are some differences between those two awards, especially in areas such as impact on society and business results. This is because EQA has had a policy of supporting the evolution of the European Common Market. As a consequence, it takes the view that the customer, employees, and the community play an important role in quality improvement and the future success of the organisation (Nakhai and Neves, 1994).



(Source: European foundation of business excellence model web site)

Figure 2.6 European Foundation of Business Excellence Model

2.7.3 The Deming Prize

Ishikawa (1989) points out that the Deming Prize serves as symbol for company-wide quality efforts, the pursuit of continuous improvement, and the extension of quality management to the suppliers of the firm. Its framework is focussed on the implementation of a set of principles and techniques, such as process analysis, statistical methods, and quality circle (Zairi, 1996). The Deming prize evaluates the operations of a company against 10 criteria but, unlike the Baldrige Award and EQA, all criteria have equal scoring weights. See Table 2.10.

Deming Prize	Baldrige Award	European Quality Award
1. Company policy and planning	1. Leadership (95)	1. Leadership (100)
2. Organisation and its operation	2. Strategic planning (75)	2. Policy and strategy (80)
3. Education and its extension	3. Customer and market focus (60)	3. People management (90)
4. Assembling and disseminating information and its utilisation	4. Information and analysis (150)	4. Partnerships and resources (90)
5. Analysis	5. Human resource focus (140)	5. Processes (140)
6. Standardisation	6. Process management (180)	6. Customer results (200)
7. Control	7. Business results (300)	7. People results (90)
8. Quality assurance		8. Society results (90)
9. Effects		9. Key performance results (150)
10. Future plans		
Equal points	Total points 1,000	Total points 1,000

(Source: internal business excellence and awards models, web. w3. nbs.ntu.ac.uk. 1999)

Table 2.10 The Deming, Baldrige, and European Quality Awards Criteria

In comparison with the Baldrige Award, Dooley et al. (1990) argue the most significant difference of the Deming Prize is "to award prizes to those companies that are recognised as having successfully applied company-wide quality control based on statistical quality control and are likely to keep up it in the future." Therefore, most Deming Prize criteria are mainly based on the application of statistical techniques, even though criteria such as company policy and planning, results, or future plans are primarily concerned with quality assurance activities and quality results. While human resource development, customer satisfaction, impact on society, and business results that are the concerns of the Baldrige Award and EQA are not included in the Deming Prize domain (Bohoris, 1995).

2.7.4 Summary of quality awards analysis

The overall approach of the Deming Prize is the control of processes that ensure the quality of goods and services. It also concentrates on aspects of continuous improvement and relations with suppliers. The Baldrige award considers that quality is customer-driven and therefore focuses on customer satisfaction and competitive comparisons. The EQA focuses on relations with the community as well as customers and employees satisfaction. Table 2.11 provides a comparison of the three quality awards. It is apparent that the EQA, Baldrige, and Deming schemes demonstrate significantly similar characteristics. However, the Baldrige award seems to be the slightly more comprehensive and demanding of the three, and reflects more the nature of domestic business in the United States.

A conclusion that is relevant to the development of performance measurement systems which has been learned from this section is shown in Table 2.12.

	Deming Prize (1996)	Baldrige Award	European Quality Award
Purpose	Promote quality assurance through statistical quality control techniques	To improve the competitiveness of an organisation through delivery of ever increasing value to the customer and improvement of overall operational performance	To enhance the performance and effectiveness of all European organisations through the promotion of TQM.
Type	A management model with key criteria for assessing Deming prize applications.	A management model with core values and key criteria for self assessment and external assessment of operational performance	A management model and benchmark for self assessment of operational performance.
Approach	Process control to ensure product or service quality	Emphasis on customer satisfaction to achieve competitiveness	Similar to Baldrige Award but with a broad point of view in pursuing excellence
Focus	Quality is defined by the producers	Quality is defined by the customer	Quality is defined by the customer, employees, and social community
Scope	Manufacturing industries, private or public organisation, small companies	Manufacturing Industries, Service Industries, Small businesses	Manufacturing Industries, Service Industries, Small businesses
Contribution	Dissemination of company-wide quality control/total quality control, continuous improvement, relations with suppliers	Customer satisfaction, competitive comparisons and benchmarking, self-appraisal model	Relations with the community, customer satisfaction, employee satisfaction, financial and non-financial results
Complexity	Medium	High	Medium to High
Geography	Japan, some Asian and American companies	US, some Japanese, some European.	European(Adopted also by British Quality Foundation)

(Source: British Quality Foundation, 1995, Bohoris, 1995; Zairi, 1996)

Table 2. 11 Quality Award Comparisons

Characteristics/Dimensions of Quality Awards	Lessons learned
• Indicate the importance of quality and continuous improvement to achieve business excellence • Use world-class quality criteria to assess business progress; to identify improvement opportunities; and to establish and deploy action plan. • Focus on future • Provide a vehicle for identifying best practices • Improve the ability to measure improvements by documenting processes and results • Provide a process to accelerate improvement across the organisation • Encouraging objective assessment through third party involvement	• Form Quality awards criteria, it is obvious that performance measures should world class management practices and appropriate leadership into consideration. • Quality awards criteria can serve as the foundation in developing the specific manufacturing performance measures criteria. • Manufacturing performance measures should not only focus on manufacturing systems performance itself but also place emphasis on the associated criteria such as management, customer expectation, organisation, human resource, etc. • Similar to self-assessment, performance measures should provide a framework to tie all the efforts together to identify what is done well, what needs to be improved, and where best practices exist • Performance measurement should take quality awards criteria or manufacturing best practice self-assessment criteria into account to assess their quality and completeness of the defined system criteria • A good performance measurement should provide the opportunity to benchmark and compare an organisation's performance with competitors/best practices

(Source: Zairi, 1996; Rich, 1997)

Table 2.12 Lessons learned from the Quality Awards

2.8 Benchmarking

Camp (1989) defines benchmarking as a continuous process of measuring products, services and practices against the toughest competition or those companies recognised as world leaders and highlights the following issues concerning benchmarking:

- Benchmarking is about measurement.
- Benchmarking can be applied to all facets of the business, including products, services, and practices.
- The focus of benchmarking is external to the organisation.
- Effective benchmarking must be a continuous process, and not a one-off exercise to be disregarded thereafter.

Similarly, American Productivity & Quality defines it as (APQ, 1993):

The process of continuously measuring and comparing one's business processes against comparable processes in leading organisations to obtain information that will help the organisation identify and implement improvements.

In general, therefore, benchmarking is the continuous process of measuring one product or process against another similar product or process to identify best practices (Walleck et al. 1991). It involves the systematic and continuous process of comparing the performance of an organisation against the performance of the business leaders world-wide. This is especially important because it is the only way to get a good view of where the company stands in the world, for internal analysis cannot provide that invaluable perspective (Kaydos, 1991). The goal of benchmarking is to identify the best practices of industry and to adapt those practices that are beneficial to the organisation. Czuchry et al. (1995) state that the key to effective benchmarking lies within what is to be benchmarked, and with whom it will be benchmarked.

The approaches to benchmarking can be divided into four main categories (Camp, 1989; 1993):

- Internal benchmarking. This refers to making comparisons with other parts of the same organisation, such as other departments or other sites, with the objective of establishing standards within the organisation. This is the starting point for the overall benchmarking process, since a company must understand its own products or work processes before they can be compared to those of other companies.
- Competitive benchmarking. This involves the investigation of a direct competitor, with the aim of identifying a company's current position compared to market or industry standards. The purpose is to enable companies to compare their performance with competitors in the same industry. As it is almost impossible to get a full knowledge of how a direct competitor operates, competitor benchmarking is more difficult to perform than internal benchmarking (Miller et al. 1992).
- Functional benchmarking. This involves comparing the company with typically non-competitive organisations, which carry out the functional activities of interest, such as warehousing or procurement. This approach to benchmarking has many advantages as functional leaders are easily identified and new practices can be discovered.
- Generic benchmarking. This involves comparing business processes across various functions and in different industries. The aim is to produce the most innovative ideas for 'breakthrough' improvements.

Table 2.13 shows their importance in comparison with one another (Hodgetts, 1998).

Type of Benchmarking	Activity performed	Amount of Improvement
Internal	Compare similar processes within the company	10%
Competitive	Make specific competitor-to-competitor comparisons	20%
Functional	Compare specific functions to similar functions at industry leaders	35%
Generic	Compare unrelated practices or processes	>35%

(Source: Adopted from Hodgetts, 1998)

Table 2.13 Contributions of different types of benchmarking to improvements

Further, according to the process level involved within the organisation, three different types of benchmarking can be used (Andersen and Pettersen, 1996):

- Process benchmarking. This focuses on work processes or operating systems (e.g. production, recruitment, customer complaints, procurement) to produce bottom line results, such as increased productivity, reduced cycle time, lower costs, improved sales, reduced error rates, and improved profit.
- Performance benchmarking. This focuses on product and service comparisons, such as price, technical quality, and analysis of operating statistics. The purpose is to determine one's status compared to other companies, identify areas in need of improvement, and set realistic targets based on performance levels achieved by others.
- Strategic benchmarking. This is a comparison of the strategic choices and dispositions made by other companies. The aim is to collect information to improve one's own strategic planning and positioning.

Many researchers have proposed different process models describing the steps of benchmarking such as Alcoa's six-step benchmarking; Vaziri's seven step benchmarking; Xerox's ten-step benchmarking process; and AT&T's 12-step benchmarking process (Vaziri, 1992; Czuchry et al., 1995) (see Table 2.14). The analysis of various benchmarking methodological approaches is shown in Table 2.15. Regardless of the number of steps, each model shares some common elements (Korpela and Tuominen, 1996).

- Planning. This is to identify key performance measures for each function of a company's operations. During this phase, the product or process to be benchmarked is identified. Also, what kinds of data need to be gathered and how to collect those data are also identified. One method to gather data is through a questionnaire to the benchmarking competitor that specifically addresses the area being benchmarked.
- Data analysis. This is to measure the internal performance levels of the company as well as the performance levels of the competitors. In this phase, all aspects of the identified competition or benchmarking partner (competitor or world class organisation) are analysed to determine variations between the two similar products or processes. The information is compared for similarities and differences to identify improvement areas.

- Integration. This is to compare performance levels in order to identify areas of competitive advantage and disadvantage. It is where the findings are communicated, goals are established, and a plan of action is defined.
- Implementation. This is to implement programmes for closing the gap between the internal operations and the other companies. It consists of initiating the plan of action and monitoring the results. The product or process that was benchmarked continues to be monitored for improvement and should be benchmarked often to ensure the improvement is continuous.

Alcoa's 6-Step Benchmarking Process	**Vaziri's 7-Step Benchmarking Process**
1. Deciding what to benchmark 2. Planning the benchmarking project 3. Understanding your own performance 4. Studying others 5. Learning from the data 6. Using the findings	1. Identify critical success factors 2. Identify competitor or best-in-class 3. Gather data 4. Analyse findings 5. Communication 6. Strategize 7. Solve problem
Xerox's 10-Step Benchmarking Process	**AT&T's 12-StepBenchmarking Process**
1. Identify what is to be benchmarked 2. Identify comparative companies 3. Determine data collection method and collect data 4. Determine current performance levels 5. Project future performance levels 6. Communicate benchmark findings and gain acceptance 7. Establish functional goals 8. Develop action plans 9. Implement specific actions and monitor progress 10. Recalibrate benchmarks	1. Determine who the clients are 2. Advance the clients from the literacy stage to the champion stage 3. Test the environment 4. Determine urgency 5. Determine scope and type of benchmarking needed 6. Select and prepare the team 7. Overlay the benchmarking process onto the business planning process 8. Develop the benchmarking plan 9. Analyse data 10. Integrate the recommended actions 11. Take action 12. Continue improvement

(Source: Vaziri, 1992; Czuchry et al., 1995)

Table 2.14 Benchmarking process models

Criteria	Xerox	Aloca	AT&T	Vaziri
Strategic focus	Moderate	Strong	Strong	Strong
Operational focus	Moderate	--	--	--
Customer focus	Strong	Strong	Weak	Strong
Process based	Moderate	Weak	Strong	Strong
Linked to TQM	Moderate	Strong	Strong	Strong
Continuous (PDCA)	Strong	--	Strong	Moderate
Learning organisation	Strong	--	--	--

(Source: Camp, 1989; Vaziri, 1992; Zairi, 1996)

Table 2.15 Analysis of various benchmarking approaches

Manufacturing companies can use benchmarking to measure their product, service, and processes against those of their toughest competitors and other best-in-class companies. Through benchmarking, managers can identify what is done well in the system, identify what needs to be improved, through gap analysis, and identify where best practices exist, through external benchmarking (Rich, 1997 and British Quality Foundation, 1995). The most important benefit of benchmarking is that it allows a company to see beyond its existing paradigms of process performance. As it benchmarks other organisations, it greatly improves the likelihood of seeing tomorrow's solutions to today's problems, and of adopting a wider reaching strategy than a localised approach. The potential benefits of benchmarking are summarised in Table 2.16.

Objective	Without benchmarking	With benchmarking
Defining customer requirements	Based on history	Based on market reality
	Acting on perception	Acting on objective evaluation
Establishing effective goals	Lack external focus	Credible; customer-focused
	Reactive	Proactive
	Lagging industry	Industry leadership
Developing performance measures	Strengths and weaknesses not understood	Solving real problems
		Performance outputs known; based on 'best on class'
Becoming competitive	Internally focused	Understand the competition
	Evolutionary change	Revolutionary ideas with proven performance
	Low commitment	High commitment
Industry practices	Not invented here	Proactive search for change
	Few solutions	Many options
	Continuous improvement	Breakthroughs

(Sources: Modified from Camp, 1989)

Table 2.16 Potential benefits of benchmarking

Benchmarking has not gone without criticism. Boxwell (1994) presents three common criticisms as follows:

- *Spying:* Benchmarking has been termed as corporate spying or industrial espionage. Boswell notes that in Japan, knowledge of the competition is part of every manager's job description which has contributed to the dominance of certain industries.

- *Copying:* Benchmarking results in copying, reducing creativity and may be harmful in the long-term success. However benchmarking is not meant to make managers copycats but to make them learn new ways of thinking about old problems.
- *Not invented here:* There may be resistance to anything that originates outside the organisation, because of the "That way will not work for us – we are different" syndrome. This argument may be damaging to the long-term health of the organisation. Learning from the success stories of implemented benchmarks may change this opinion.

In summary, benchmarking is an important element of the foundations of manufacturing measurement. Without good benchmarking a company cannot ensure that its current level of performance is appropriate. Also, it cannot ensure that the objectives established for future improvement are adequate. Although there are advantages and disadvantages of benchmarking, some important points which are relevant to performance measurement system design can be drawn from the above discussion (See Table 2.17).

Characteristics/Dimensions of Benchmarking	Lessons Learned
• It is a process of finding and implementing best practices that accelerate the rate of improvement by providing real-world models realising improvement goals. • Organisations must change to stay ahead of competitors, and benchmarking is a system for managing that change. • It promotes quantum leaps in performance. • It helps to establish effective goals and measures productivity. • It encourages striving for excellence, breakthrough thinking, and innovation. • It emphasises sensitivity to changing customer needs. • It creates a better understanding of competitors and the dynamics of the industry. • It provides a sense of urgency for business process improvement. • It ensures that the best industry practices are included in work processes.	• Performance measures should encompass an extensive range of internal/external measurement include qualitative, quantitative, product-focused, and system-wide measures. • Benchmarking process provides an approach for the development of manufacturing performance measurement processes. • In order to make useful comparisons between companies, it is important to use a number of indicators and drivers to measure performance, rather than just one overall measure. • Performance measures should take benchmarking process as a tool to identify solutions for product or process improvement. • Performance measures should not be limited to measure itself. It should also involve action plan development and continuous improvement monitoring.

(Source: Camp, 1989)

Table 2.17 Lessons learned from benchmarking

To conclude, Table 2.16 has illustrated some lessons learned from benchmarking which is beneficial for this research. In addition, the benchmarking process (e.g. planning, data analysis, integration, and implementation) can be viewed as a suitable approach for developing manufacturing performance measures processes.

2.9 Conclusion

As far as the techniques of manufacturing performance measures are concerned, it is evident that a substantial amount of relevant research has been carried out with structured approaches, tools and techniques developed to help the tasks involved. Theoretically, the nature of manufacturing performance measures can be summarised as a method to help a company monitor the attainment of its products, processes or services so as to identify gaps, and to provide new action plans or new goals for these to be improved. A summary of the literature review is illustrated in Table 2.18.

Despite the fact that the procedures are generally logical and well documented, the current manufacturing performance measurement approaches seem to be weak in providing specific guidance or techniques to help the measurement and evaluation involved. This is particularly true at the system specification definition stage, when a company is expected to develop an effective performance measurement system. Other criteria that are important for the design and development of a set of performance measures and evaluation framework which are missing from literature are highlight in the following:

- Manufacturing performance measurement is not a new topic. Every company has its own method to measure performance. However, there has been little prior research in this area, especially in the aspect of manufacturing system's performance measurement
- Also, although there are many well-developed performance measurement models, seldom have they provided us with a guide to link performance measures with performance measurement, especially in the gap analysis.
- The existing integrated performance measurement systems have indicated the importance of continuous improvement for a company's long-term success. Yet,

no one has shown how to measure the continuous improvement and to link them with the overall system performance as a whole.

- Quality award criteria such as Malcolm Baldrige National Quality Award provide us an opportunity to examine the organisation's performance in comparison to world-class companies. However, such criteria are mainly focussed on the company-wide quality performance, which can not meet the specific manufacturing performance measurement requirements.
- Although the link between manufacturing strategy, performance measures, and actions has shown its importance, there is little guidance in dealing with their linkage and interface, especially in the area of performance measures and action plan selection.
- There is no comprehensive framework to show an overall picture/process of manufacturing performance measures.
- Like the integrated performance measures, such as SMART, Balanced Scorecard, PQM, although they provide us a generic measurement framework, there is no general rule to follow.
- There is no single picture that can encompass the necessary information such as a company's strategic goals, current performance, and performance gaps to provide managers with performance analysis and decision making tools.

According to the concepts of manufacturing performance measurement and the findings from relevant literature study, a number of key questions need to be addressed, such as: how does a company know what should be measured and how will it be measured (this is of particular importance for the Taiwanese military plants which have encountered a great deal of difficulty in moving from the public sector into the private sector)? In an attempt to improve the situation in general, and to find an effective approach to adopt such techniques in Taiwanese military plants in particular, an extended manufacturing performance measurement and evaluation framework needs to be developed and the following issues addressed:

- The need to provide a closed-loop mechanism for both overall system status monitoring and continuous improvement monitoring.

- The need for a more structured way to link manufacturing strategy to the process of performance measurement and evaluation.
- The need to provide help and guidelines which provide an in-depth balance of measures across the content of manufacturing strategy choices, that is capacity, facility, technology, vertical integration, quality, information system, organisation, etc.
- The need to provide both internal measures and external benchmarking to evaluate manufacturing strategic concerns.

To address these general research issues, the next chapter develops research methodology for this study.

	Description
Summary of literature review	***Dimensions/characteristics of manufacturing performance measurement at the 1st (business) level: to define performance measurement systems specification*** • Strategic driven: It should be capable of linking operations to strategy (Cross and Lynch, 1991). • Capture customer's voice: It should initiate from the identification of product group and market requirements (Neely et al. 1996). • Hierarchical approach: It needs to develop a hierarchical approach that shows clear linkage to the manufacturing strategy and goals (Harbour, 1993). • A balanced set of measures: It should provide a balanced picture of measures as well as short term and long term goals (Kaplan and Norton, 1992). • Respond to multiple priority: It should focus on competitive priority measures (quality, delivery, flexibility, and cost) across manufacturing strategic choices (capacity, facility, technology, suppliers, organisation, etc.) (Neely et al. 1996). • Process focus: It should provide a mechanism that can be used to control and improve the activities at the functional level and factory shop floor (Fitzgerald et al. 1991). • Ensure a narrow focus: It should focus on manufacturing processes and critical successful factors measures (Hronec, 1993) • Foster continuous improvement: A measurement system should focus on continuous improvement, rather than just compliance and control (Dixon et al. 1990). • Demonstrate results and use in decision making: The results of performance measures should develop the strengths/weakness, area of improvement, and action plans to provide management with a decision making reference (Kaplan and Norton, 1996). ***Dimensions/characteristics of performance measurement at the 2nd (functional) level: to establish performance measurement system*** • Performance measures at this level should focus on the competitive priority and their interrelationship among different functions/departments. • The key elements of performance measurement system design such as performance goals, performance indicators/drivers, tools/metrics should be identified at this level. • It should act as a matrix of vertical integration (external/internal needs analysis and synthesis) and horizontal (functional) measures. • The number of performance measures for each goal at a given organisational level should be limited to the vital few, normally they are limited to 20 measures. • Those vital few measures should cover the key performance dimensions that will enable an organisation to assess accomplishments, make decisions, realign processes, and assign accountability. • The relevant evaluation and analysis tools should be identified. ***Dimensions/characteristics of performance measurement at the 3rd (operational) level: implementation*** • It involves the activities such as performance measures, data collection, analysis, and feedback. • The frequency of measures should be defined (DOE, 1996). • It should provide data for external comparison (Hayes et al. 1988) ***The process of a balanced set of performance measures should:*** • Identify what kind of competitive environment the business faces. • Identify the generic strategy and business mission of the company. • Identify the manufacturing processes. • Develop performance measures and evaluation framework. • Use the framework in the company. • Transfer performance data into information for decision making.
Missing from	• Although manufacturing performance measurement is not a new topic, there has

literature review	been little prior research in this area, especially in the aspect of manufacturing system's performance measurement • Also, although there are many well-developed performance measurement models, seldom have they provided us with a guide to link performance measures with performance measurement, especially in the gap analysis. • The existing integrated performance measurement systems have indicated the importance of continuous improvement for a company's long-term success. Yet, no one has shown how to measure the continuous improvement and to link them with the overall system performance as a whole. • Quality award criteria such as Malcolm Baldrige National Quality Award provide us an opportunity to examine the organisation's performance in comparison to world-class companies. However, such criteria are mainly focussed on the company-wide quality performance which can not meet the specific manufacturing performance measurement requirements. • Although the link between manufacturing strategy, performance measures, and actions has shown its importance, there is little guidance in dealing with their linkage and interface, especially in the area of performance measures and action plan selection. • There is no comprehensive framework to show an overall picture/process of manufacturing performance measures. • Like the integrated performance measures, such as SMART, Balanced Scorecard, PQM, although they provide us a generic measurement framework, there is no general rule to follow. • There is no single picture that can encompass the necessary information such as a company's strategic goals, current performance, and performance gaps to provide managers with performance analysis and decision making tools.
Action to be taken	• The need for a more structured way to link manufacturing strategy to the process of performance measurement and evaluation. • The need to provide a closed-loop mechanism for both overall system status monitoring and the continuous improvement monitoring • The need to provide both internal measures and external benchmarking to evaluate manufacturing strategic concerns. • The need to provide help and guidelines which provide an in-depth balance of measures across the content of manufacturing strategy choices, that is capacity, facility, technology, vertical integration, quality, information system, organisation, etc.

Table 2.17 Summary of literature review

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Overview

The objective of this research is clear. It is to develop a set of generic manufacturing performance measures and an evaluation framework that can not only meet the Taiwanese military plant's requirements but can also be applied to other industries, either public or private. Chapter 1 gave a general idea of why it is needed to conduct this research. Chapter 2 reviewed performance measures theory and models. Some important techniques and methods that are important for the development of the proposed framework have also been identified. Chapter 3 is focused on the justification of the research requirements or specifications, and develops a logical and actionable research approach that can be applied in the course of this research. The identification of the requirements for the development of the proposed framework is mainly based on two aspects: the specifications of performance measurement systems for Taiwan's military plants and the analysis of academic theory and industrial practice. For only if the research requirements have been identified, can the design of the research methods be effectively determined (Blaxter et al. 1996). According to this, Chapter 3 is categorised into three sections:

Justification of research specifications.
Investigation of research methods and techniques.
Development of research methodology.

3.2 Justification of research specifications

Being government organisations, there are many advantages for Taiwan's military plants. For example, they are fully government supported, there are stable annual orders, their mission statements and strategy are "pure" and clear, and there are only limited customers and services. However, with the advantages, there are also some disadvantages. One of the key issues is that since they have long been without any competition, some performance measurement criteria such as cost and flexibility are seldom considered by the management. The overall productivity and efficiency are low, especially when compared with private companies (ROC Annual Defence Report 1998). As the Government has decided to move the military plants from the public

sector into the private sector, the current advantages of the military plants can hardly exist. More over, those disadvantages will become burdens as a result. Changes of the entire entity of Taiwan's military plants have become not only necessary but also urgent in order to meet the objectives of the privatisation programme, that is increasing competitiveness and decreasing costs.

Along with the changes, the Taiwanese military plant's current performance measures that mainly focus on the individual performance and report system such as budget, quality, production schedule, and inventory level can no longer meet the needs of the privatisation programme. It is essential to develop a new performance measurement system. Table 3.1 listed the requirements specification of the Taiwanese military plant's new performance measurement systems. They were identified by the analysis of the current performance measurement system, the needs of the privatisation programme, and discussions with military officials. However, as the aim of this research is to develop a generic performance measurement system that can meet the Taiwanese military plant's requirements, and can be applied to other industries, it is insufficient to merely take the Taiwan military plant's requirements in the design and development of the proposed framework. It is necessary to take other design criteria such as the key factors of the existing performance measurement models and industrial best practice into consideration.

Table 3.1 also identified the six areas of design criteria that were essential for the proposed framework design and development, as a result of the analysis of the literature review and in accordance with the Taiwanese military plant's requirement specifications. Although the first two issues are mainly in response to Taiwan's military plants specific requirements, they are relevant to other industrial requirements. While the rest are directly deduced from the results of the literature review.

- The need to develop a performance measurement and evaluation framework that is simple to use.
- The need to develop a system that both indicates current performance and predicts future requirements.

- The need for a more structured way to link manufacturing strategy to the process of performance measurement and evaluation.
- The need to provide a closed-loop mechanism for both overall system status monitoring and continuous improvement monitoring
- The need to provide both internal measures and external benchmarking to evaluate manufacturing strategic concerns.
- The need to provide help and guidelines which provide an in-depth balance of measures across manufacturing strategy choices.

Requirements of Taiwan's military plants performance measurement system	Characteristics of a 'good' performance measurement system (The results of literature review)	Justification of the requirements for the proposed performance measures and evaluation framework
• It should match the plant's new culture. • It should be clearly defined and easy to understand. • It should be practical and simple to use. • It should be integrated over both the functions and hierarchy. • It should provide data for monitoring past and planning future performance. • It should provide data for external comparison. • It should encompass both financial and non-financial measures. • It should provide managers with a 'one-shot' picture of system performance, performance gaps, and areas that need to be improved.	• Strategically driven: It should be capable of linking operations to strategy (Cross and Lynch, 1991). • Capture customer's voice: It should be initiated from the identification of product group and market requirements (Neely et al. 1996). • Hierarchical approach: It needs to develop a hierarchical approach that shows clear linkage to the manufacturing strategy and goals (Harbour, 1993). • A balanced set of measures: It should provide a balanced picture of the manufacturing as well as short term and long term goals (Kaplan and Norton, 1996). • Respond to multiple priority: It should focus on competitive priority measures (quality, delivery, flexibility, and cost) across manufacturing strategic choices (capacity, facility, technology, vertical integration, and human resource) (Neely et al. 1996). • Process focus: It should provide a mechanism that can be used to control and improve the activities at the functional level and factory shop floor (Fitzgerald et al. 1991). • Ensure a narrow focus: It should focus on manufacturing processes and critical successful factors measures (Hronec, 1993). • Foster continuous improvement: A measurement system should focus on continuous improvement, rather than just compliance and control (Dixon et al. 1990). • Demonstrate results and use in decision making: The results of performance measures should develop the strengths/weakness, areas for improvement, and action plans to provide management with a decision making reference (Kaplan and Norton, 1996b).	• The need to develop a performance measurement and evaluation framework that encompasses both financial and non-financial measures, and is simple to use. • The need to take both the present performance requirements and predicted future requirements into consideration. • The need for a more structured way to link manufacturing strategy to the process of performance measurement and evaluation. • The need to provide a closed-loop mechanism for both overall system status monitoring and continuous improvement monitoring • The need to provide both internal measures and external benchmarking to evaluate manufacturing strategic concerns. • The need to provide help and guidelines which provide an in-depth balance of measures across manufacturing strategy choices.

Table 3.1 Justification of the requirements of the suggested performance measures and evaluation framework

3.2 Investigation of research methods and techniques

This section is concerned with the research methods and techniques used in this study. There are a number of research methods available to the research. Several authors (Kaplan and Norton, 1996a; Lockamy, 1998; Jonsson and Lesshammar, 1999) have argued for applying a case study approach to the field of manufacturing performance measurement research. Other researchers such as Sweeney (1994), White (1996), and Neely et al. (1996) have used survey method. However, due to the exploratory nature of this study, an empirical research methodology is required. Therefore, it is essential to conduct a review of the available research methods and then select the most promising approach in order to ensure that the development of the suggested framework can meet both Taiwan's military plants and the research requirements.

3.2.1 Action research

Mansell (1991) points out that action research is a collaborative process which involves the analysis of the problem, the construction of plans for intervening in the problem domain and the execution of such plans. Elliot (1991) defines action research as "small-scale intervention in the functioning of the real world and a close examination of the effects of such intervention." It is concerned with diagnosing a problem in a specific context and attempting to solve it in that context (Grant, 1996).

The characteristic of action research, according to Cohen and Manion (1989), is that:

It is essentially an on-the-spot procedure designed to deal with a concrete problem located in an immediate situation. This means that the step-by-step process is constantly monitored over varying periods of time and by a variety of mechanisms (questionnaires, interviews, and case studies) so that the ensuing feedback may be translated into modifications, adjustments, directional changes, re-definitions, as necessary, so as to bring about lasting benefit to the ongoing process itself rather than to some future occasion, as is the purpose of more traditionally oriented research.

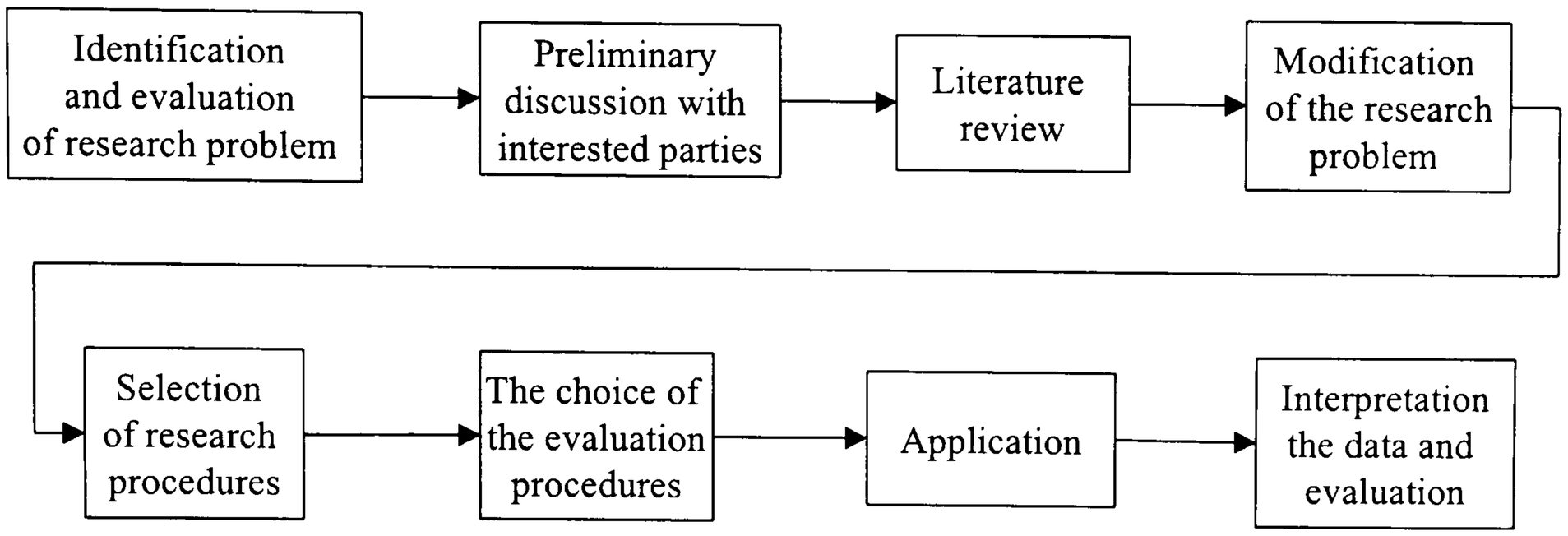


Figure 3.1 Action research model (Source: Cohen and Manion, 1989)

Benbasat et al (1987) recognise a particular feature of the action research is that the researcher involved needs to adapt the approach to the situation factors present in the case. They further state in order to ensure a rigorous approach, elements of subjectivity by the researcher need to be reduced as much as possible, and both the framework and method of the researcher's intervention in the problem situation have to be defined prior to the intervention. Therefore, it has been suggested that researchers should be directly involved in the research application and not merely as observers in order to: define and understand the events through involvement; bring knowledge which they have applied and not just acquired; advise on the relevance of approaches, their application and their evaluation; and to create new knowledge and concepts from the work undertaken (Hill, 1987).

The strength of action research, according to Elliot (1991), lies in its ability to deal with the emergent nature of human systems. He further points out that "this approach is particularly useful to provide a theoretical frame of reference for intervention within an organisation and to guide systematic investigation and critical analysis of the problem situation".

However, according to the definition and features of action research, it is concerned with diagnosing a problem in a specific context and attempting to solve it in that context. It is usually involved researchers and practitioners work together and observe/measure at the same time. Therefore, although action research has received

rather more publicity over the years (Blaxter et al 1995), it is not applicable in this research.

3.2.2 Case study

The concept of the case study refers to an intensive examination of a single unit. It is a research method of finding out some aspects of the reality by taking a small number of examples of something and examining them in detail (Greenfield, 1996). Yin (1989) recognises that the case study is the preferred methodology when examining contemporary events in which the relevant behaviours cannot be manipulated. Yin (1993) further states that the case study is the method of choice when the phenomenon under study is not readily distinguishable from its context. In addition, Blaxter et al. (1996) suggest that the case study is ideally suited to the needs and resources of the small-scale researcher. It allows a focus on just one example, or perhaps just two or three. So the purpose of a case study is to discover significant variables, to discover relationships amongst them, and to lay the groundwork for more systematic and rigorous testing of hypotheses/questions (Langrish, 1993).

McCutcheon and Meredith (1993) note that the case study research could provide a mechanism for examining "real-world" conditions that operations management (OM) models are attempting to describe. By its nature, a case study is usually involved in an empirical investigation of a phenomenon within its real life context, often using multiple sources of evidence. It can be particularly useful when one needs to understand some particular problem or situation in great depth and where one wishes to obtain lots of rich information. Eisenhardt (1989) reports that one of the advantages of the case study method is the in-depth understanding of the dynamic present within single settings. Other advantages of this approach include (Hinnells, 1993):

- They are useful for exploratory studies in relatively new areas of research.
- Cases do not have to be representative of a large sample.
- Case studies can be useful in their ability to trace changes over time.

Case studies can either be undertaken in depth singly or across several sites. A criticism of multiple case studies is that, while they might provide more generalised conclusions than those provided by a single case, they suffer from a number of variables that change from case to case and hence from a difficulty in interpretation (Westbrook, 1995).

Given the above reason, case study can be viewed as a more suitable approach for investigating manufacturing performance measurement methodologies, because it is not only concerned with the practical success of the case under investigation, but also with the addition to knowledge.

3.2.3 Survey

The survey approach is one of the most widely used approaches. It is a systematic method of collecting information from a selected group of people by asking a series of questions (Greenfield, 1996). Blaxter et al. (1996) consider that there are four techniques for collecting data: documents, interviews, observations, and questionnaires. Several authors such as Bolden et al. (1997), White (1996), CIMA (1995) have suggested applying interviews and questionnaires in the field of manufacturing performance measurement research. Cohen and Manion (1989) argue although interviews and questionnaires are research techniques, they are normally considered as survey methods in social research. Interviews and questionnaires can also play a part in action research and case studies in the organisation or manufacturing field (Hutton, 1990).

Cohen and Manion (1989) define "interview" as "a two-person conversation initiated by the interviewer for the specific purpose of obtaining research-relevant information, and focused by the researcher on content specified by research objectives of systematic description, prediction, or explanation". Hughes (1996) suggests four kinds of interview that may be used as research tools, as shown in Table 3.2.

Types	Informal Interview	Interview guide approach	Standardised open-ended interview	Closed quantitative interviews
Character	There is no predetermination of question topics and wording.	Interviewer decides sequence and wording of questions in the course of the interview.	All respondents are asked the same basic questions in the same order.	Responses are fixed: respondent chooses from among these fixed responses.
Strengths	Increases the salience and relevance of questions.	The outline increases the completeness of the data and makes data collection systematic for each respondent.	Respondents answer the same questions, thus increasing comparability of responses. Data are complete for each person on the topics addressed in the interview.	Data analysis is simple. Responses can be directly compared and easily aggregated.
Weaknesses	Different information collected from different people with different questions.	Important and salient topics may be inadvertently omitted.	Little flexibility in relating the interview to particular individuals and circumstances.	Respondents must fit their experiences and feelings onto the researcher's categories. May be perceived as impersonal, irrelevant and mechanistic.

(Source: Hughes, 1996)

Table 3.2 A comparison of four types of interview

Mashall and Rossman (1989) point out that the interview has both advantages and disadvantages as a research technique. One advantage, for example, is that it allows for greater depth than is the case with other methods of data collection. A disadvantage, on the other hand, is that it is dependent on the ability of the researchers to be resourceful, systematic, and honest; to control bias. The purpose of interviews, according to Patton (1980), is "*to find out what is in and on someone else's mind. We interview people to find out from them those things we cannot directly observe.*"

As the interview method involves questioning or discussing issues with people. it can be a very useful technique for collecting data which would be unlikely to be accessible using techniques such as questionnaires. For the questionnaire approach, involving large samples but less depth of inquiry, has generally been used in studies of strategy content rather than process (Thomas, 1996). Moore (1987) considers that poor response rate is the typical shortcoming of questionnaire-based research. Swink and Way (1995) observe that such surveys are often compromised by the prohibitive cost of administering large sample questionnaires, to the extent that there is often neither the sample size of a survey nor the detail from a more focused study. A comparison of interviews and questionnaires is illustrated in Table 3.3.

Consideration	Interview	Questionnaire
Opportunities for asking	Extensive	Limited
Opportunities for probing	Possible	Difficult
Relative magnitude of data reduction	Great	Mainly limited to restoring
The number of respondents who can be reached	Limited	Extensive
Rate of return	Good	Poor
Sources of error	Interviewer, sample,	Limited to sample
Overall reliability	Quite limited	Fair
Emphasis on writing skill	Limited	Extensive

(Source: Tuckman, quote from Cohen and Manion, 1989)

Table 3.3 A comparison of interviewing versus questionnaire

Accordingly, the interview method (more specifically the open-ended interview) and not the questionnaire was adopted in this research. One of the primary purposes of the interviews used in this research was to investigate the performance measurement system used by the case companies and to identify their comments about the proposed framework in order to modify the proposed process or methods.

The following table provides an overview of the basic methods to collect data.

Method	Overall Purpose	Advantages	Challenges
Survey Questionnaire	When need to quickly and easily get lots of information from people to a non threatening way	-can complete anonymously -inexpensive to administer -easy to compare and analyse -administer to many people -can get lots of data -many sample -questionnaire already exist	-might not get careful feedback -wording can bias participant's responses -are impersonal -in survey, may need sampling expert -does not get full story
Interviews	When want to fully understand someone's impressions or experiences, or learn more about their answers to questionnaire	-get full range depth of information -develops relationship with participants -can be flexible with participants	-can take much time -can be hard to analyse and compare -can be costly interviewer can bias participant's responses
Case study	To fully understand or depict participant's experiences in a programme, and conduct comprehensive examination through cross comparison of cases	-fully depicts participant's experience in programme input, process and results -powerful means to portray programme to outsiders	-usually quite time consuming to collect, organise and describe -represents depth of information, rather than breadth

(Source: Greenfield, 1996; Blaxter, 1996)

Table 3.4 An overview of the basic methods to collect data

3.3 Development of research methodology

The objectives of this research are to (1) develop a set of manufacturing performance measures and an evaluation framework to solve a 'real-world' problem that Taiwan's military plants encountered, and (2) provide the suggested framework with a wider applicability within other industries. According to this, the research should focus

beyond the development of a descriptive theory at the development of a process which would provide management with a practical approach to improve their performance measures programme.

Following the reasons given above and based on the objectives of the research, this research applied primarily a mix of case study and survey research methods. Also, dependent on the issues being addressed and the type of information being retrieved, a number of different techniques were also used throughout the research. For example, a case study was used to test the suggested model, and open-ended interviews were used in the form of questions asked prior to and during the case study. This research adopts a five-stage research method, as shown in Figure 3.2. The five stages are:

1. Analysing initial problems. This involves the use of the interview technique to identify Taiwan's military plant problems and expectations. The identified data was then analysed, together with the results of the initial literature review to determine performance measurement gaps and opportunities that can be applied to supplement those gaps.
2. Specifying the proposed framework specifications. A logical literature review process has been adopted: investigation of the characteristics of a 'good' manufacturing performance measurement system (system), analysis of the current performance measures models and processes (sub-system), and identification of the key performance indicators and metric (element).
3. Developing the performance measures and evaluation framework. In order to ensure the quality of the proposed framework, a postal interview was sent to the Army Material Command and its military plants. The returned interview data was then analysed to see if the proposed framework could be accepted. The data was also analysed to determine if there was a need for improvement.
4. Testing the performance measures and evaluation framework. This involved the use of the case study. Three Taiwan military plants, which were the sponsor companies of this research, participated in this activity. After the analysis of the case study data, the initial draft of the proposed framework was refined and provided to the three case plants for further review.

5. Investigating the wider applicability of the performance measures and evaluation framework. The purpose of this stage was to achieve the second objective of the research - to investigate whether the proposed framework can apply to other industries. By using interview techniques, the investigation involved three UK manufacturing companies.

In addition, dependent on the characteristics of research requirements, the type of information being retrieved, and the model being tested/validated, a number of different methods were used throughout the research. Also, due to the different geographic locations of Taiwan and the UK, some postal and telephone interviews were applied. A detailed description of the various stages of the research and the methods used in this research are listed in Table 3.4.

3.4 Conclusion

Two primary objectives have been achieved in this chapter: (1) Determine the requirements for the development of the proposed framework. Six aspects of 'needs' or specifications have been identified which are important for the development of the proposed framework. They also serve as the checkpoint to ensure the quality of the designed framework. (2) Design the research methodology. A logical five-stage research process has been developed that not only serves as the guideline for the accomplishment of the research but also ensures that the research activity is as designed. The next chapter, according to the developed approach, is then focused on the development of the proposed framework.

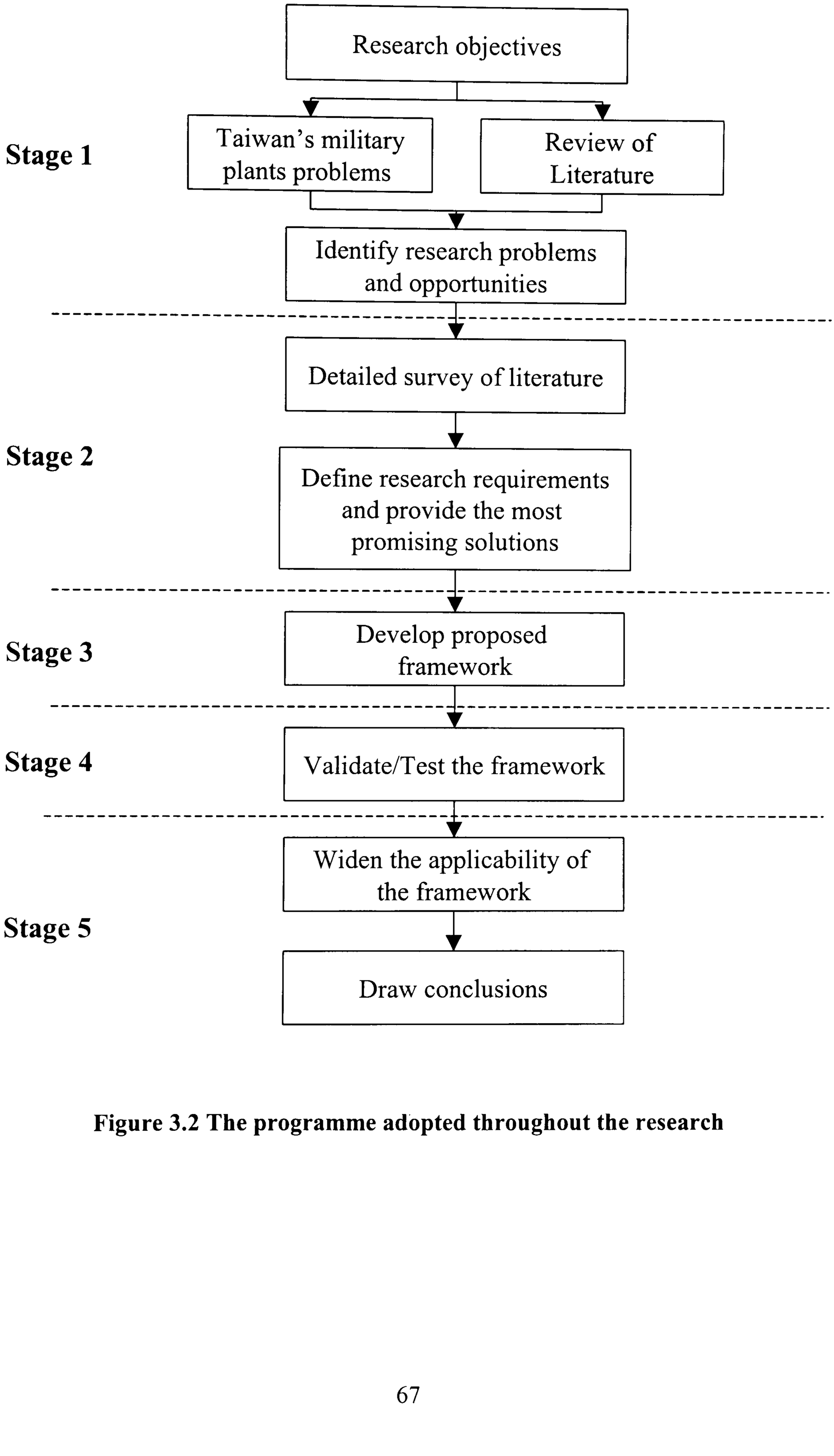


Figure 3.2 The programme adopted throughout the research

Stage	Objectives	Methods	Actions	Comments
Stage 1 Initial analysis	• Understand Taiwanese military plants' current performance measurement system (PMS) deficiencies and opportunities. • Survey current PMS models and theory.	Survey of literature, interview	• Study of Taiwan's National Defence Privatisation Programme and the annual assessment report of the military plants • Interviews with three different levels of management: the Ministry of National Defence (MND) (policy), Army Material Command (control), and the military plants (operation). • Review of current performance measures and evaluation techniques to identify opportunities	• The objective of this stage is to conduct an analysis of Taiwan's military plants current PMS to know their deficiencies and future needs. Then, it is focused on the literature review to identify technological opportunities that can be applied to supplement the gaps of the old and the new PMS. • The interview information was supplemented by documentary analysis of each plant's PMS.
Stage 2 Specifying the proposed framework specifications	• Define Taiwan's military plant 'new' PMS requirements. • Clarify the characteristics of the 'good' PMS. • Identify gaps and suggest techniques or methods to match the requirements.	Survey of literature, interview	• Analysis and determination of Taiwan's military plant PMS specification. • Evaluation of the feasibility of the alternative approaches through literature review. • Refine the proposed PMS specifications. • Suggestion of the most promising solutions.	• Based on the gaps identified in Stage 1, Taiwan's military plants 'new' PMS specifications were determined through interviews and discussions with the three levels of management, as discussed above. • The literature review at this stage was divided into three sections: (1) identification of the characteristics of the 'good' PMS, (2) current PMS models analysis, and (3) the analysis of the relevant field approaches. The characteristics of the 'good' PMS played an important role to compare the results of section (2) and (3) in order to identify deficiencies, gaps, and opportunities. • The final PMS specifications for the proposed framework were determined by taking both Taiwan's military plants 'new' PMS requirements and the results of literature review into consideration and analysis.
Stage 3 Development of the proposed framework	• Design the PMS framework. • Determine the structure and procedures of the proposed PMS.	Survey of literature, interview	• Specification of a complete prototype methodology, incorporating the extended techniques into the procedures and taking the Taiwanese military plant's specific requirements into consideration.	• The establishment of the proposed PMS framework involved the acquisition and synthesis of information from three major sources: the literature, Taiwan's military plants, and the Army Material Command. • For quality assurance, a meeting of case study participants, including management from the three Taiwanese military plants, was conducted to obtain comments on the initial draft of the proposed framework.

(Continue over page)

Table 3.5 The development of the performance measurement and evaluation framework

Stage	Objectives	Methods	Actions	Comments
Stage 4 Testing the proposed framework	• Validate the proposed framework • Refine the proposed processes, methods, and improve practice.	Case study, interviews	Application of the proposed framework on the three Taiwanese military plants, with the researcher's active participation involving: 1. Briefing about the proposed framework. 2. Collection data and analysis. 3. Based on the results, validate and improve the proposed framework. Other methods such as postal and telephone interviews were also used after the research beck to the UK.	• The case study included three Taiwanese military plants, including missile system development centre, utility vehicle development centre, and armour vehicle development centre. • In conducting the case studies, the researcher interviewed all the three military plants commander or deputy commander, senior engineers, functional/shop managers, line managers, and operators in accordance with the designed procedures and tables of the proposed framework. • The three case plants generally gave a positive feedback to the proposed framework. The analysis of the case study results was to try to answer the following questions: 1. Does the proposed framework meet the design specifications? 2. If not, where and how does it need to be improved? 3. Is there any feedback that can be applied to improve the proposed model, either positive or negative? • After the case study, the initial draft of the proposed framework was refined, and the subsequent draft was provided to the three case plants for review. The subsequent drafts were also distributed to the MND and Army Material Command and other military depots.
Stage 5 Investigating the wider applicability of the proposed framework	• Seek feedback of the proposed framework from the selected UK companies. • Clarify the proposed processes and methods • Expand the utilisation of the proposed framework	Interviews.	• Interviews with the selected UK companies: 1. To know their current practice and future plans of PMS. 2. To acquire their comments and suggestions about the proposed framework. • Analyse the feedback information and make changes for the proposed framework, if needed	Three UK manufacturing companies were selected because of their unique characteristics, which provided benefits for the accomplishment of this research. 1. Company D: This company used to be part of UK ICI (Group), and was sold to America two years ago. The transition of this company from the UK to the USA and the change of PM management were the interest for this research. 2. Company E: This medium manufacturing company has currently applied SAP III into the PMS. Also this company has strongly relied on benchmarking in performance measures. 3. Company F: This is a Taiwanese owned company. The interview with this company was to try to identify the difficulties and conflicts of the proposed framework applied into different cultures and thinking companies, that is Western and Eastern.

Table 3.5 The development of the performance measurement and evaluation framework

CHAPTER 4 PROPOSED MANUFACTURING PERFORMANCE MEASURES AND EVALUATION FRAMEWORK

4.1 Overview

The review of current manufacturing performance measurement models given in Chapter 2 has shown that although the frameworks are generally logical and well documented, there seems to be a general weakness in providing specific guidance or techniques to aid the development of such approaches. This is particularly true for the measurement of continuous improvement and when a company is expected to carry out a valid performance evaluation. When this is combined with the overall requirements identified in Chapter 3 regarding the specific Taiwanese military plants privatisation programme, it is clear that an extended framework for the purpose of manufacturing performance measurement and evaluation will be needed.

This chapter suggests an extended measurement scheme which, compared to the existing approaches, provides a more comprehensive way of monitoring not only the overall system's performance but also continuous improvement performance. In particular this chapter discusses the linkages, techniques and tools that should be incorporated into the overall process of performance measures.

The structure, contents and techniques of the extended performance measures and evaluation framework as suggested here are generic. Hence, dependent on specific requirements, every company should be able to adopt and implement it in a flexible way to suit the needs of manufacturing companies within different industries either private or public. In particular, this generic framework recognises the following key requirements as outlined in Chapter 3.

- The need to develop a performance measurement and evaluation framework that focuses on customer needs and measures only what is important.
- The need to develop a system that both indicates current performance and predicts future requirements.
- The need for a more structured way to link manufacturing strategy to the process of performance measurement and evaluation.

- The need to provide a closed-loop mechanism for both overall system status monitoring and continuous improvement monitoring.
- The need to provide both internal measures and external benchmarking to evaluate manufacturing strategic concerns.
- The need to provide help and guidelines which provide an in-depth balance of measures across manufacturing strategy choices.

The following definitions and terminology are used in this chapter.

- ***Products/Service***. Products and services are treated alike – they are simply the output of a process such as computer boards (products) or training modules (services).
- ***Performance objective***. This is a critical success factor in achieving the organisation's strategy. If it is not achieved, the likely result would be a significant decrease in customer satisfaction.
- ***Performance measures***. Performance measures are quantitative/qualitative evaluations of the products or services of a process or system (a metric used to quantify the efficiency and/or effectiveness of action).
- ***Performance measurement.*** A process of assessing progress toward achieving predetermined goals (a process of quantifying the efficiency and effectiveness of action).
- ***Performance management.*** The use of performance measurement information to effect change in organisational culture, systems and processes to meet strategic goals.
- ***Performance measurement system.*** The set of metrics used to quantify the efficiency and effectiveness of actions.

Other terms related to performance measurement and management used in this chapter are defined in the Glossary.

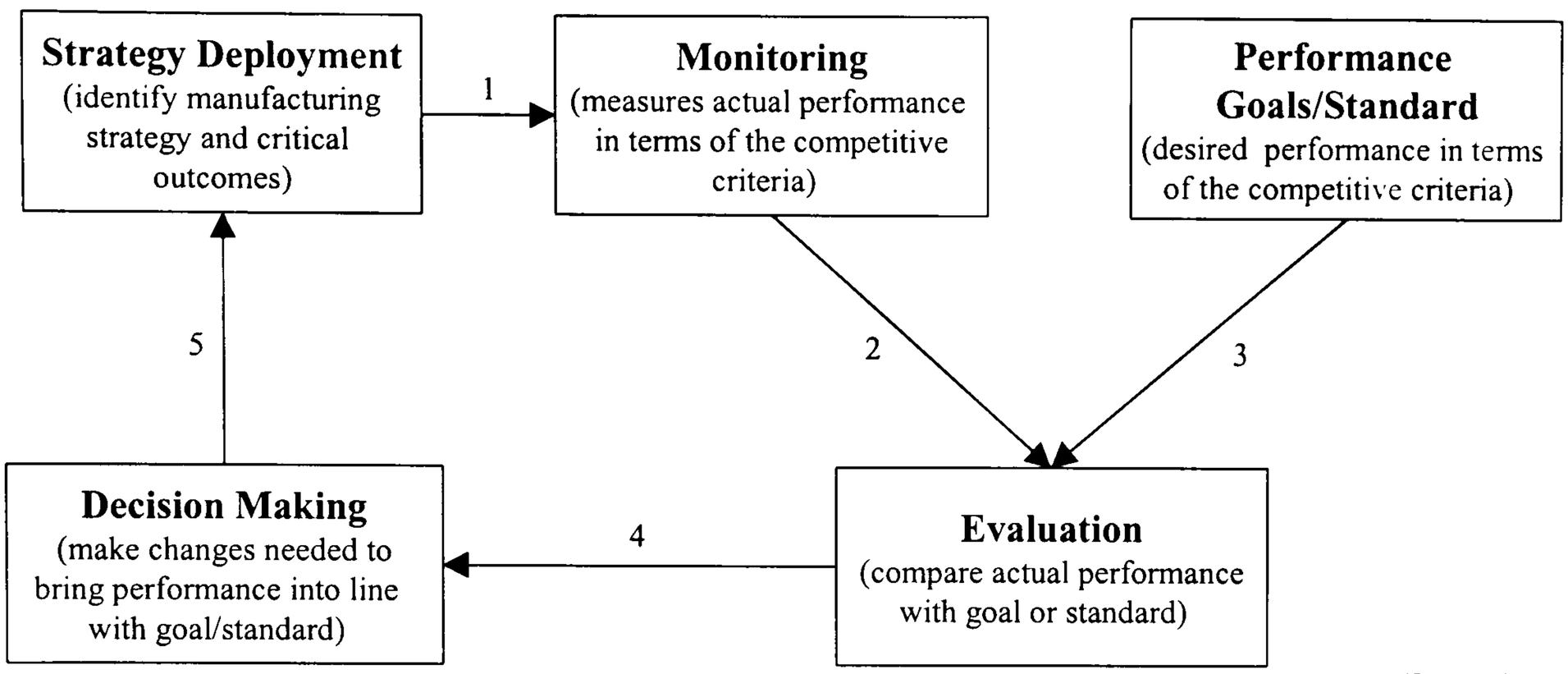
4.2 The foundation of the proposed framework

As discussed in Chapter 2 (the literature review), a manufacturing company can only stay in business by being competitive, either through offering superior products or

through more favourable terms than their competitors. In order to ensure that a company achieves a strategically competitive position and that different parts of the organisation are pulling their weight in a combined effort to maintain this position, some form of coherent performance monitoring of both individual units as well as the whole is essential. The aim of performance measurement is to provide usable information to motivate behaviour leading to continuous system improvement (Ghalayini et al., 1997).

Accordingly, defining the right measures is critical to achieving the desired results (Manoochehri, 1999). When deciding on what to measure, the proposed framework starts with the manufacturing company's purpose: its vision and strategy. Manufacturing performance measures should link directly to the strategic objectives. As the strategic objectives are deployed and cascade down to lower level goals, they define what the performance measures should be for the lower levels in the manufacturing systems. Once the goals for each unit, such as departments, plants, work centres, or individuals – are defined, the performance measurement systems can be established.

The basic feedback loop of the proposed manufacturing performance measurement framework shown in Figure 4.1 presents a systematic series of steps for maintaining conformance to goals/standards by communicating performance data back to the decision maker to take appropriate action. According to Kaplan and Norton (1992), the message of the feedback loop is that in order to achieve the goals/standards management has the responsibility to know: what is to be done, what is being done, and when to take corrective action. Without the basic feedback loop, a performance measurement system cannot ensure an effective and efficient operation. It also cannot conform to customer requirements as a result (NPR, 1998).



(Steps 1-5)

Figure 4.1 Basic feedback loop of the proposed framework

4.3 The structure of the proposed framework

The basic structure of the proposed manufacturing performance measurement and evaluation framework, as shown in Figure 4.2, is primarily based on balanced scorecard measures. Other models and techniques such as performance measures hierarchy, Deming cycle, and benchmarking process have also been applied for the development of the framework. Typically, the proposed framework is a method of assessing performance that consists of three main sections:

- ***Specification of strategy-oriented performance measurement***. The purpose of this is to dis-aggregate strategic concerns into operational level measurements and then measure the current system according to the relevant parameters.
- ***Overall system status monitoring***. Based on the operational level measurements of the current system, this section produces an integrated assessment of the system's overall performance against its current strategic goal. It also determines whether further actions are needed and, if so, identifies the necessary programmes of continuous improvement.
- ***Continuous improvement monitoring.*** The structure of this section is similar to the above. However, the focus here is the monitoring and assessment of the improvement of system performance as a direct result of the action plan initiated.

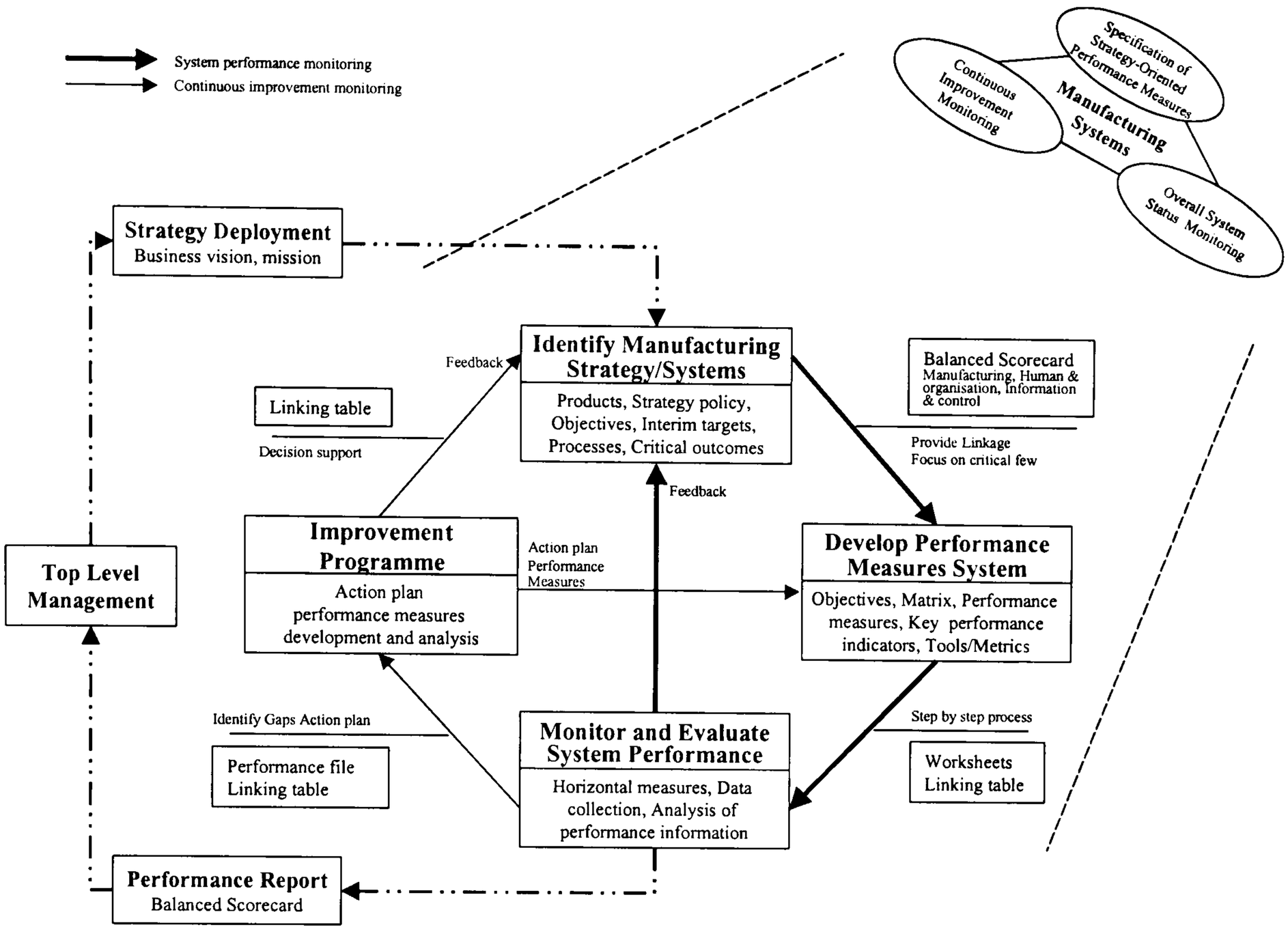


Figure 4.2 The manufacturing performance measures and evaluation framework

The proposed framework presented here is based on the view that customer expectations are the key when developing functional strategy, whilst performance measurement plays the role of the facilitator to ensure progress towards pre-established goals. Consequently, it is important to ensure that the measures of performance on how to meet customer needs and what constitutes the performance factors are recognised. Then the comparison with the goal is established to monitor the overall system status. If there is no significant variance, then the data collection cycle is continued. If there is a variance between the goal and the performance measure, a report to the decision-maker should be made to make corrections to bring the performance back into line with the desired goal. The proposed framework as specified in Figure 4.2 has the following main features:

- It provides a closed-loop mechanism for both monitoring and continuous improvement of the system.
- It is completely integrated with the business/manufacturing strategy domain. Strategic concerns are dis-aggregated into operational level measurements through

a top-down manner, whereas the actual operational level measurements are aggregated back following a bottom-up approach to reflect the system's current performance against its strategic goal.

- It is dynamic in nature and allows the systematic revision of critical areas, performance measures, historical data, decisions, and outcomes.
- Both the present performance requirement (based on an internal gap analysis) and predicted future requirement (based on an external gap analysis) can be taken into consideration.
- Both global optimisation (through overall system performance monitoring) and local optimisation (through continuous improvement monitoring) can be achieved.
- It is concerned with the long-term health of manufacturing unlike the tracking costs and the maximising of profitability levels to the detriment of neglecting processes and their management and control.
- It is a tool for balancing multiple measures (quality, delivery lead-time, delivery reliability, design flexibility, volume flexibility, and cost) across multiple functional areas (manufacturing processes, human resource and organisation, and information and control).

4.3.1 Functional performance measures

The development of the functional performance measures of the proposed framework is primarily based on the balanced scorecard and system hierarchy concept. The balanced scorecard approach is defined as a set of measures which employs a family of indicators for measuring performance across the organisation that can be used to identify the resources needed to achieve the results desired. Four perspectives - financial, customer, internal business process, and learning and growth - provide a balanced picture of current operating performance as well as the drivers of future performance (Kaplan and Norton, 1992).

However, since this research is focused on the investigation of the manufacturing performance measures, the 'four perspectives' of balanced scorecard measures that develop from a business point of view can not encompass every aspect of the manufacturing strategy choices (capacity, facility, technology, vertical integration, human resources, organisation, information system, etc.) (Wheelwright, 1984). Hull (1998) further categorises the manufacturing strategy choices into three principal

manufacturing architectures which are adopted in the proposed framework and are considered as the specific manufacturing balanced scorecard measures. They are:

- **Manufacturing processes architecture.** This represents the nature of the manufacturing operation, including the machines, transportation and storage equipment and the other facilities required to support the manufacturing process and directly related to manufacturing a product. This also describes the flow of materials throughout the system.
- **Human and organisational architecture.** This represents the organisational structure and the interactions of the employees within the manufacturing system, including their roles, responsibilities and reduction tasks. The focus of this architecture is improving the manufacturing systems' operational and cost performance.
- **Information and control architecture.** This represents the planning and control functions of the manufacturing system and the processes involved in decision making. The architecture also describes the flow of data and information throughout the system.

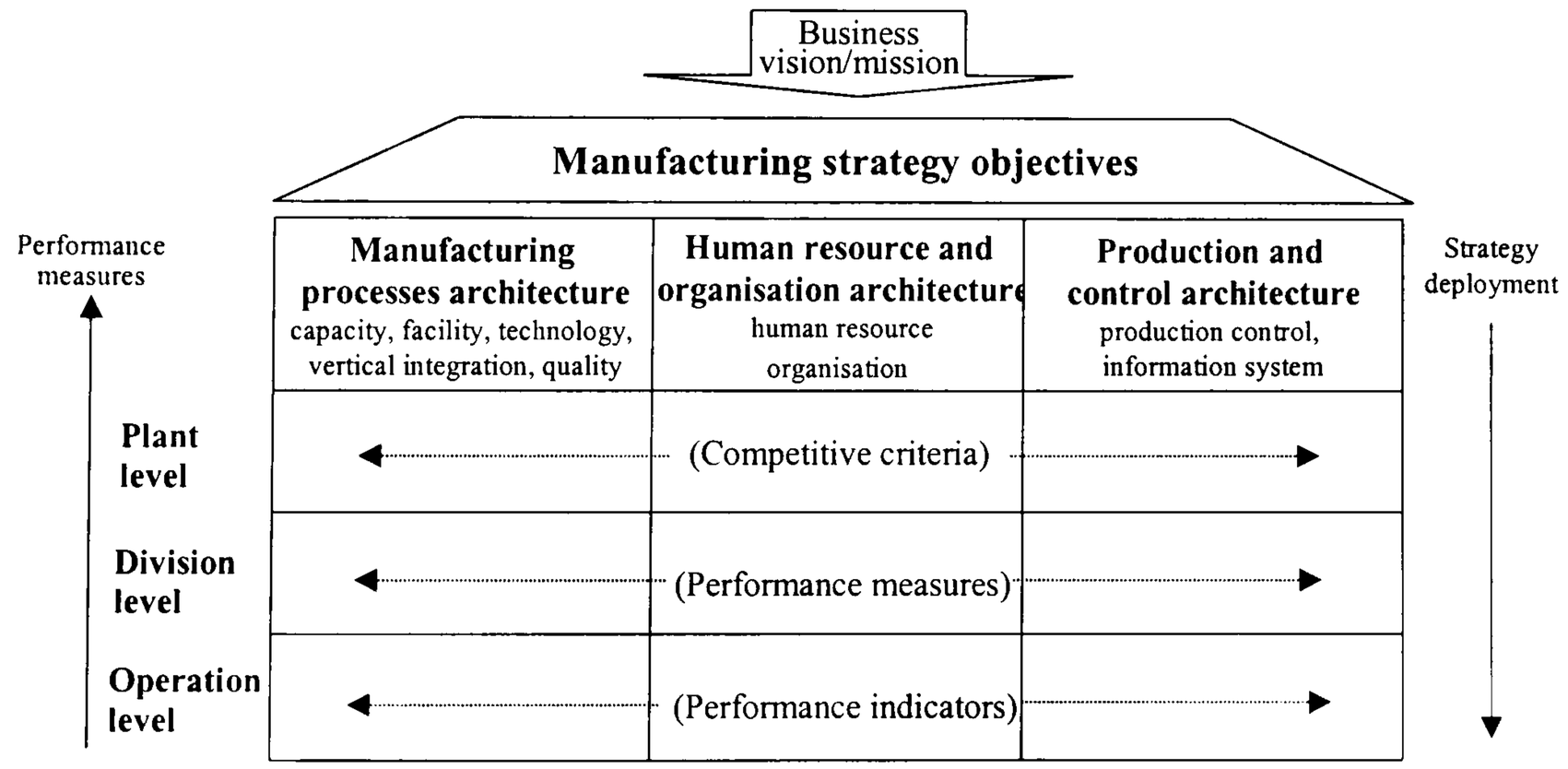


Figure 4.3 The balanced scorecard approach

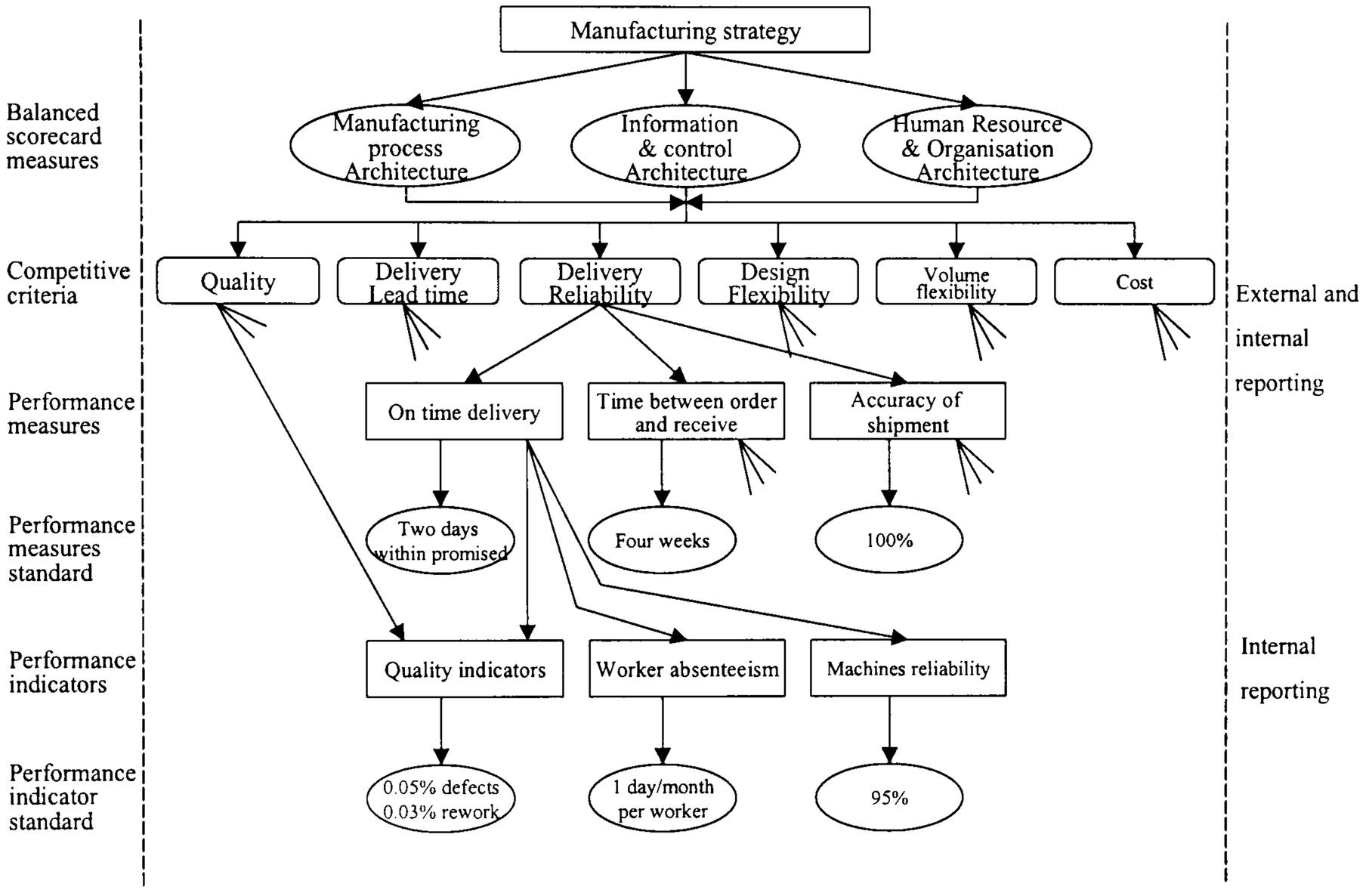
In Figure 4.3, the three principal manufacturing architectures are responsible for determining the competitive criteria that will be used within the framework. The competitive criteria are defined as the areas that management determines to be important for the company's long term success (Mapes et al. 1997). They are essentially providing an indication of the customer requirements with respect to the manufacturing systems in strategic terms (Hay and Wheelwright, 1984). Also they are the key factors that help determine the company's ability to compete effectively (Flynn et al. 1999).

Competitive criteria are determined based on the manufacturing strategy and processes. Other tools such as performance measurement questionnaire (PMQ) can also be applied to help their development. Depending on the specific organisation, the number of manufacturing competitive criteria can vary widely (White, 1996). This research adopts six areas of competitive criteria: quality, delivery lead-time, delivery reliability, volume flexibility, design flexibility, and cost. This is because they appear to have been most widely accepted in the manufacturing strategy environment (White, 1996).

Once the competitive criteria are determined, the next step is to select performance indicators to help in measuring and improving operational performance, for performance indicators are the focal point for achieving improvements with respect to the overall performance measures (Fortuin, 1988). The selected performance indicators are designed for internal use only and are not reported to management. The purpose is to guide management when looking at the results of the aggregated performance indicators (e.g. quality, delivery, flexibility, and cost). This reduces the burden on management to be concerned with a large number of performance measures and allows them to focus on a few critical measurements.

Figure 4.4 illustrates the relationships between competitive criteria, performance measures, and performance indicator (Galayini et al. 1997). The relationship shows the hierarchy of the different activities within the organisation where these activities should be measured, controlled, and improved in order to achieve the objective. Figure 4.5 also shows how the performance measures and the performance indicators for different competitive criteria are related. For example, some of the performance

indicators for quality, that is defect and rework rates, are also performance indicators for delivery. The identification of the interaction between different performance measures and performance indicators helps management determine how to improve the performance of the competitive criteria by focusing on one performance indicator.



(Source: modified from Ghalayini et al. 1997)

Figure 4.4 The performance measurement system hierarchy example

4.3.2 Process overview

The process of the proposed framework, modified from Deming's Total Quality Management (1982), is a continuous cyclical process. Its task is not only concerned with the business/manufacturing strategy of the company but also takes system performance monitoring and continuous improvement monitoring into account. Figure 4.5 shows a high-level block diagram of the proposed framework process. This is a guideline intended to show the process generically.

The proposed framework begins with an analysis of manufacturing strategy, processes and products to understand its strategic objective, current situation, and opportunity. It moves to a development of performance objectives, measures, and goals in a matrix

of manufacturing strategy choices such as facility, capacity, technology, vertical integration, human resources, organisation, and information system (horizontal measures) and competitive criteria such as quality, delivery, flexibility, and cost (vertical measures). Further, it measures the overall system performance, and both monitors and stimulates appropriate improvements in manufacturing performance. A detailed description of the process steps will be provided in Chapter 5 and the work sheets are provided in the Appendix D.

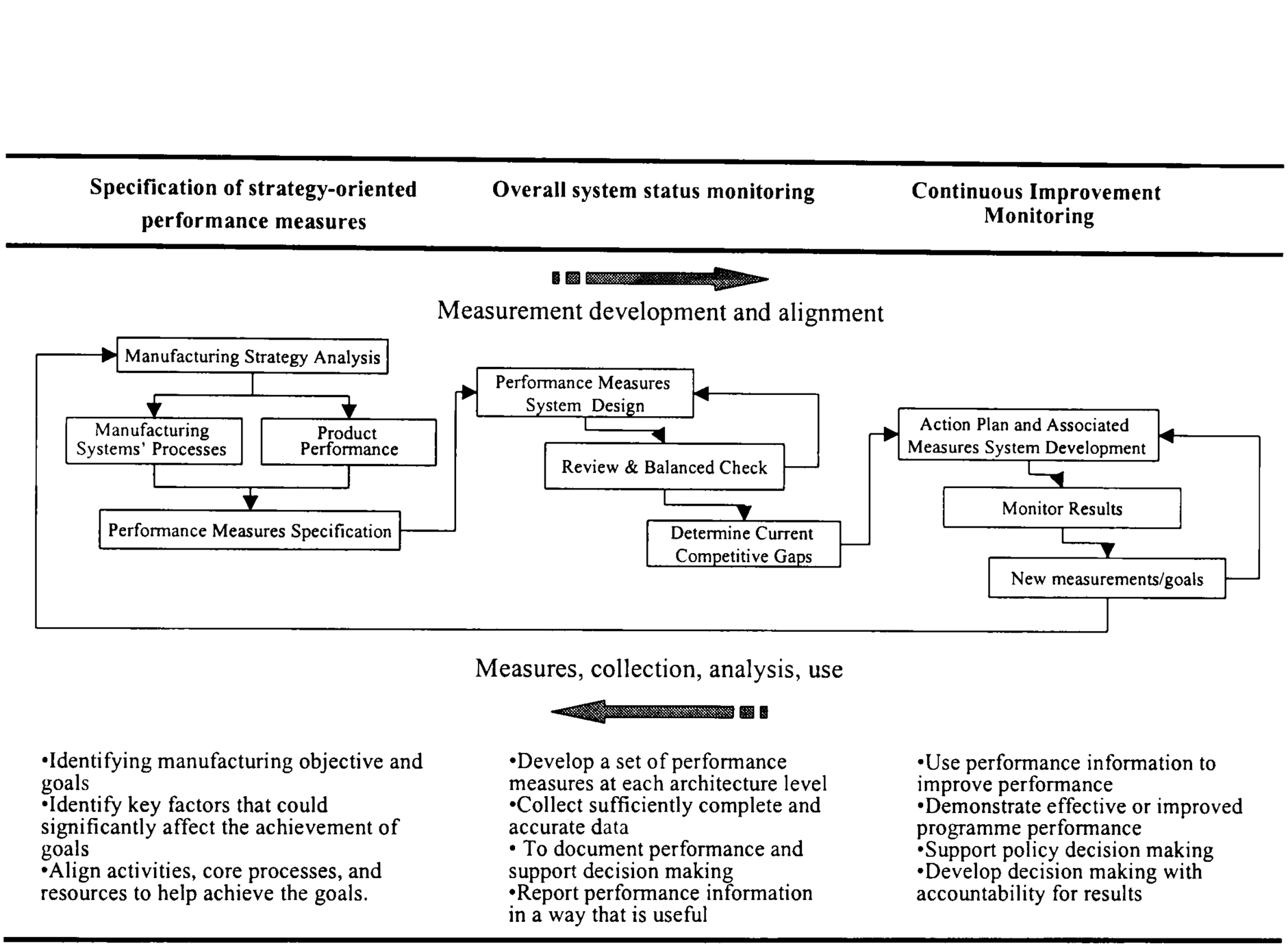


Figure 4.5 The process of the proposed framework

4.3.3 Linkages

As shown in Figure 4.6, there are four linkages between the four functional areas within the manufacturing performance measures and evaluation framework. In order to assist the selection of suitable performance measures, as a general guidance a number of additional help tables are provided here to illustrate the generic relationships involved in the analysis. These include:

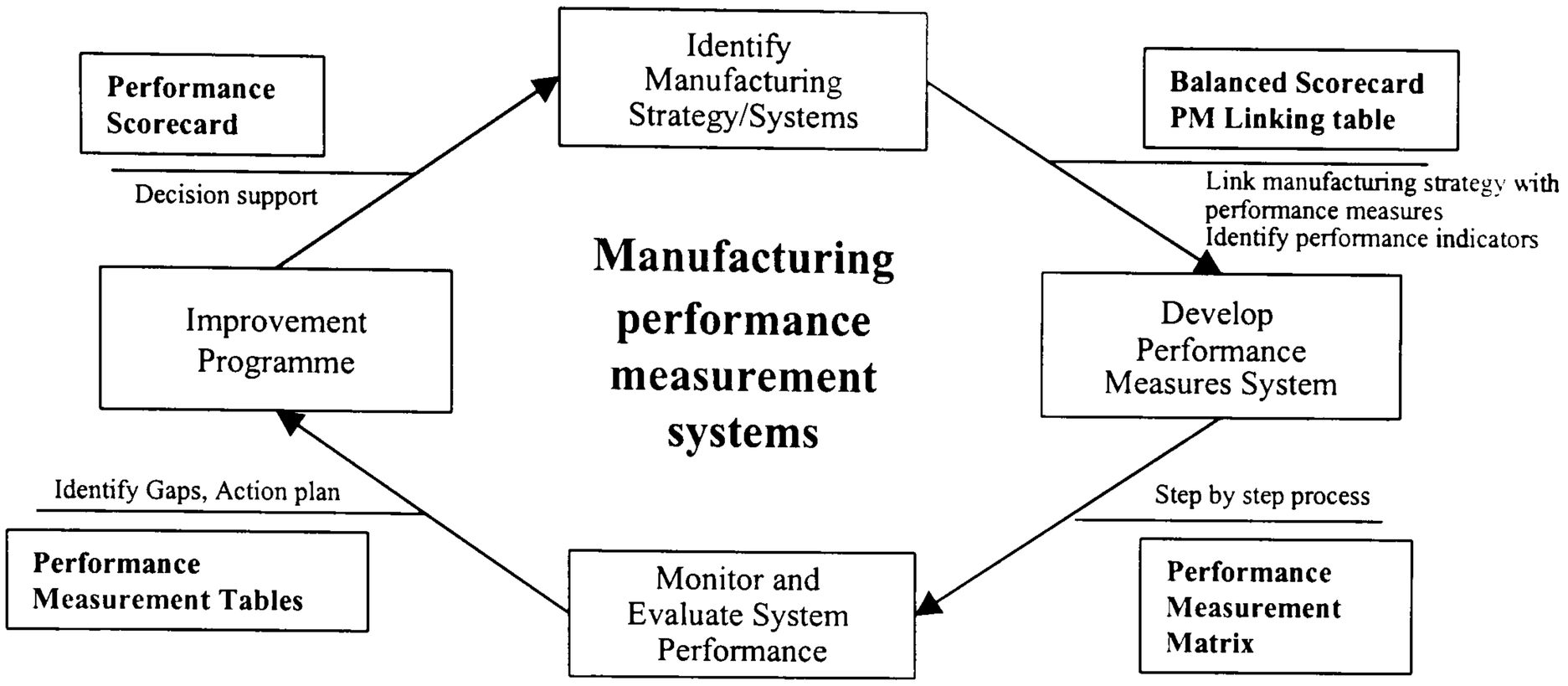


Figure 4.6 The linkage of the performance measurement framework

The manufacturing strategy/systems – performance measurement system design linkage. This uses the balanced scorecard approach to link manufacturing strategy and performance measures. It specifies the competitive criteria and the associated performance indicators, and achievement level/target of achievement. To help this key process, a table (PM linking Table1) illustrating the generic relationships between performance parameters and performance indicators, as shown in Table 4.1, is provided to provide general guidance. This cause-effect table aims to help the identification of the right indicators to use for any given strategic concerns.

The performance measurement system design – data collection and evaluation linkage. A three by six matrix, shown in Table 4.2, supports dynamically considered performance measures. Across the top of the matrix are the competitive criteria: quality, delivery, flexibility, and cost. Along the sides of the matrix are performance measures through the manufacturing policy areas in terms of the three principal architectures: manufacturing processes, human and organisation, and information and control. The matrix translates manufacturing strategy into a set of performance measures distributed among the three architectures. Through the use of the matrix, a manufacturing system monitors both its current performance and its efforts to improve processes. The main purpose of the matrix is to allow management to understand and develop performance measures that balance manufacturing processes, human and organisation issues, and information and control systems, in a way that

matches manufacturing strategies and goals in terms of quality, delivery, flexibility, and cost.

Performance Measures / Performance Indicators		Quality																
		Rework rate	Scrap rate	Pass rate	Field failure	Reject rate	Packaging quality	Material yield	Supplier quality	No. of complaints	Warranty claims	Service call rate	Supplier certification	Process capability	% conform to targets	% with no repair work	Assembly line defects rate	Lapse, renewal, retention ra
Quality	Incoming quality	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X
	First pass yield	X	X	X				X	X	X		X	X	X	X	X	X	X
	Not right first time	X	X	X		X			X	X		X		X	X	X	X	X
	Reject rate		X	X		X			X	X			X	X	X	X	X	X
	Supplier quality	X	X	X	X					X		X	X		X	X	X	X
	Process waste yield	X	X	X				X		X	X			X	X	X	X	X
	Customer complaints	X	X	X	X		X			X	X	X	X		X		X	X
Delivery Lead time	Time between order and delivery	X	X	X			X	X					X	X		X	X	X
	Vendor lead times							X					X		X			
	Manufacturing cycle time	X	X	X			X	X				X		X		X	X	X
	No. of change in project	X	X	X	X		X	X		X	X	X			X	X	X	X
Delivery	% on time deliveries	X	X	X			X					X	X		X	X	X	X
	Speed of set ups													X				X
	Inventory accuracy																	X
	Forecast accuracy	X	X	X	X		X					X	X	X	X	X	X	X
	No of days of late shipments		X				X											X

Table 4.1 PM linking Table Number 1 – Performance parameters and indicators (partial)

The data collection and evaluation – continuous improvement linkage. Two tables have been developed to help the accomplishment of this process. The PM linking Table 2 - relationship between strategic concerns and system consideration aims to provide a general guidance to establish performance gaps and identify reasons for under performance, as shown in Table 4.3. The PM linking Table 3 - relationship between strategic concerns and general action plans aims to provide general guidance to relate strategic aims to general actions that can be initiated accordingly. This is similar in structure and purpose to PM linking Table 1 (Table 4.2), but with its contents and relationships modified and presented specially for the purpose of

continuous improvement, as shown in Table 4.4. The complete PM linking tables are illustrated in Appendix E.

Manufacturing Architecture		Competitive Criteria					
		Quality	**Delivery Lead time**	**Delivery reliability**	**Design flexibility**	**Volume flexibility**	**Cost**
Manufacturing Process	Capacity Facility Technology Vertical integration Quality	*Overall equipment effectiveness* *Vendor quality*	*New product introduction vs. competition* *Cycle time* *Order process time*	*Delivery schedule attainment* *% reduction in lead time per product line*	*Perceived relative product flexibility* *Vendor lead time*	*% programme equipment* *smallest economical volume* *set up time*	*Design cost* *Energy* *Utilities* *Overhead* *Scrap cost* *Repair cost* *Quality cost*
Human & Organisation	Human resource Organisation	*Budget of training programmes*	*% reduction in employee turnover*	*Labour efficiency*	*% workforce cross training*	*% increase in number of direct labour skills*	*Absence rate*
Information & Control	Production control Information system	*Stock turns* *Schedule attainment*	*Decision cycle time* *Time lost waiting for decision*	*Schedule attainment*	*% equipment slack time* *Flexibility relative to competitors*	*Cycle time* *Perceived relative volume flexibility*	*Stock turn* *Distribution cost* *Material cost*

(Source: White, 1996, DTI, 1998)

Table 4.2 The performance measurement matrix example

Competitive Criteria	Problem Domain	Strategy Implementations	Policy Area									
			Cap.	Fac.	Prs.	Ver.	Ven.	Org.	H.R.	Prd.	Ctr.	Qty
Quality	Yield problem, reject	Improvement conformance quality										X
	Too old plant and equipment	Improve safety rework		X					X			
	Unreliable supplier quality	Improve vendor quality										X
	Availability of qualified workers	Increase environmental safety/protection						X				
	Availability of qualified supervisors	Improve pre-sales service and technical support			X							
	Producing to high quality standards											
	Work environment	Improve after-sales service										X
	Producing to quality standard	Initiate vendor certification or qualification					X					X
Delivery Lead-Time	Unreliable supplier lead times	Reduce manufacturing lead time			X							
	Long lead time	Reduce procurement lead time			X							
	Problems to response to fast orders	Reduce new product development cycle				X						
	Unreliable supplier lead times	Increase throughput									X	
	Communication with top management	Increase delivery speed			X							
	Communication with other functions	Improve inter-functional communication						X				
	Ineffective material control systems	Reduce set up times			X							
	Availability of qualified supervisors											
	Poor sales forecasts	Narrow product line	X									
	Falling behind in information technology	Rapid deliveries/meeting orders									X	
	Inability to manage expediting orders	Shorter production lead times				X						
Design Flexibility	Too many different products	Reduce number of vendors					X					
	Too many engineering changes	Increase delivery reliability			X							

(Note: Cap: Capacity; Fac: Facility; Prs: Process and technology; Ver: Vertical integration; Ven: Vendor Relations; Org: Organisation; HR: Human resource; Prd: production control; Ctr: control; Qty: Quality)

Table 4.3 PM linking Table Number 2– Strategic performance and causes (partial)

Policy Area	Strategy Implementations	Action Plans	Competitive Criteria					
			Qty	DL	DR	VF	DF	C.
Capacity	Develop capacity strategy	Capacity expansion		X		X		
	Expand existing facilities for economies of scale	Product standardisation					X	
	Convert capacity to new products	Reconditioning of physical facilities						X
	Increase capacity	Automating jobs		X				
	Increase ability to make rapid volume changes	Expand existing facilities			X			
Facility	Determine facility locations and missions on new competition	Reconditioning physical plants				X		
	Consolidate manufacturing operations to realise economics of scale	Closing and/or relocating plants						X
	Evaluate impact of new distribution patterns on facility location	Reduce size of manufacturing units						X
	Increase products produced by existing facilities	3-shifts production		X				X
	Reconditioning physical plants	Plant modernisation programme						
	Locate facilities to obtain cost advantages in labour, materials	Work environment improvement	X					
	Evaluate the need to upgrade manufacturing methods, remove	Plant relocation						X
	Bottlenecks, and improve materials handling in existing facilities	Automation/computerisation						
Vertical Integration	Re-evaluate make/buy decisions	Vendor lead-time reduction		X				
	Evaluate opportunities for vertical integration	Rapid prototyping				X		
	Negotiate volume contracts	Customer involvement in design					X	
	Reduce inbound and outbound freight costs	Supply chain partnering	X					
	Evaluate benefits of sole sourcing vs. multiple sourcing	Outsourcing						X
	Consider need for JIT delivery	Customer feedback	X					
	Reduce number of vendors	After-sales support			X			
	Re-evaluate make/buy decisions	Predicting customer requirements		X				
Vendor Relation	Evaluate potential new suppliers	Vendor quality	X					
	Initiate vendor certification/qualification	Vendor certificate	X					
	Evaluate potential new suppliers and contractors	Single sourcing						X
		Vendor training	X					
		Improve vendor/buyer relation	X					
		Vendor/buyer technical exchange/support	X					X

(Note: Qty: Quality; DL: Delivery Lead-time; DR: Delivery Reliability; VF: Volume Flexibility; DF: Design Flexibility; C: Cost)

Table 4.4 PM linking Table Number 3 – Strategic concerns and action plans (partial)

The continuous improvement – manufacturing strategy/system linkage. Again, this is to use a performance scorecard, shown in Table 4.5, to allow management to assess the aggregate effect of performance indicators (e.g. quality, delivery) at the same time. It also provides a good idea of the progress of the organisation from a variety of perspectives. The statistic process control tools such as radar diagram and run chart are also used to distinguish between the internal and external system performance gaps in order to provide management with a one-shot picture of the current situation, performance gaps, and areas for improvement. The aim of the statistic process is to prevent defects rather than allowing defects to occur. A detailed description of the radar diagram is provided in the next section.

Balanced Scorecard		Performance Measures			Performance Level					
Perspective	*Objectives*	*Operation measures*	*Division measures*	*Plant level measures*	*1*		*2*		*3*	
					T	*A*	*T*	*A*	*T*	*A*
Manufacturing process	Production development	% scrap rate % rework rate	% first pass yield	manufacturing on time, on budget						
Human resource & organisation	Workforce competency, development	% worker by skill area	% worker professionally certified	% quality budget devoted to education						
Information & control system	Automation, robot	% decrease in application software fail	Mean time to solve critical defects	% computer availability						

(Note: T: Target, A: Actual)

Table 4.5 A performance scorecard example

4.3.4 Tools

(1) System utility function (U)

The first tool used in the proposed framework is the system utility function which is used to logically associate a set of individual requirements that are related to different product groups, to the overall manufacturing system as a whole in order to measure its effectiveness.

The system utility function described below provides a three-step approach to the specification of the strategic-oriented performance measures. The first step ascertains the relative importance of each of the system's product groups. The second step identifies the relative importance of each of the competitive criteria with respect to the individual product groups. The final step repeats the analysis but attempts to identify the performance of the individual product groups with respect to the manufacturing criteria. This allows for a gap analysis to be executed to identify the areas for improvement. Hence the system utility function can be considered to be a function of the product group importance, the importance of the competitive criteria for the individual product groups and the performance of the individual product groups with respect to the competitive criteria (EPSRC Report, 1997).

System Utility Function (U) = $Fn\ [I(\pi), N(\chi, \pi), \theta(\chi, \pi)]$,

Where: I = Relative importance
N = Requirements
θ = Performance
π = Product/product group
χ = Manufacturing competitive criteria

(2) Radar diagram

The second tool used in the manufacturing performance measures framework is to apply the "radar diagram" to distinguish between the internal and external system performance gaps (Hodgetts, 1998). The difference between these two is illustrated in Figure 4.7. Whereas the internal gap helps a company identify the difference between its strategic goals and its current systems performance, the external gap is based on the current manufacturing best-practice through benchmarking, both providing an indication of future requirements.

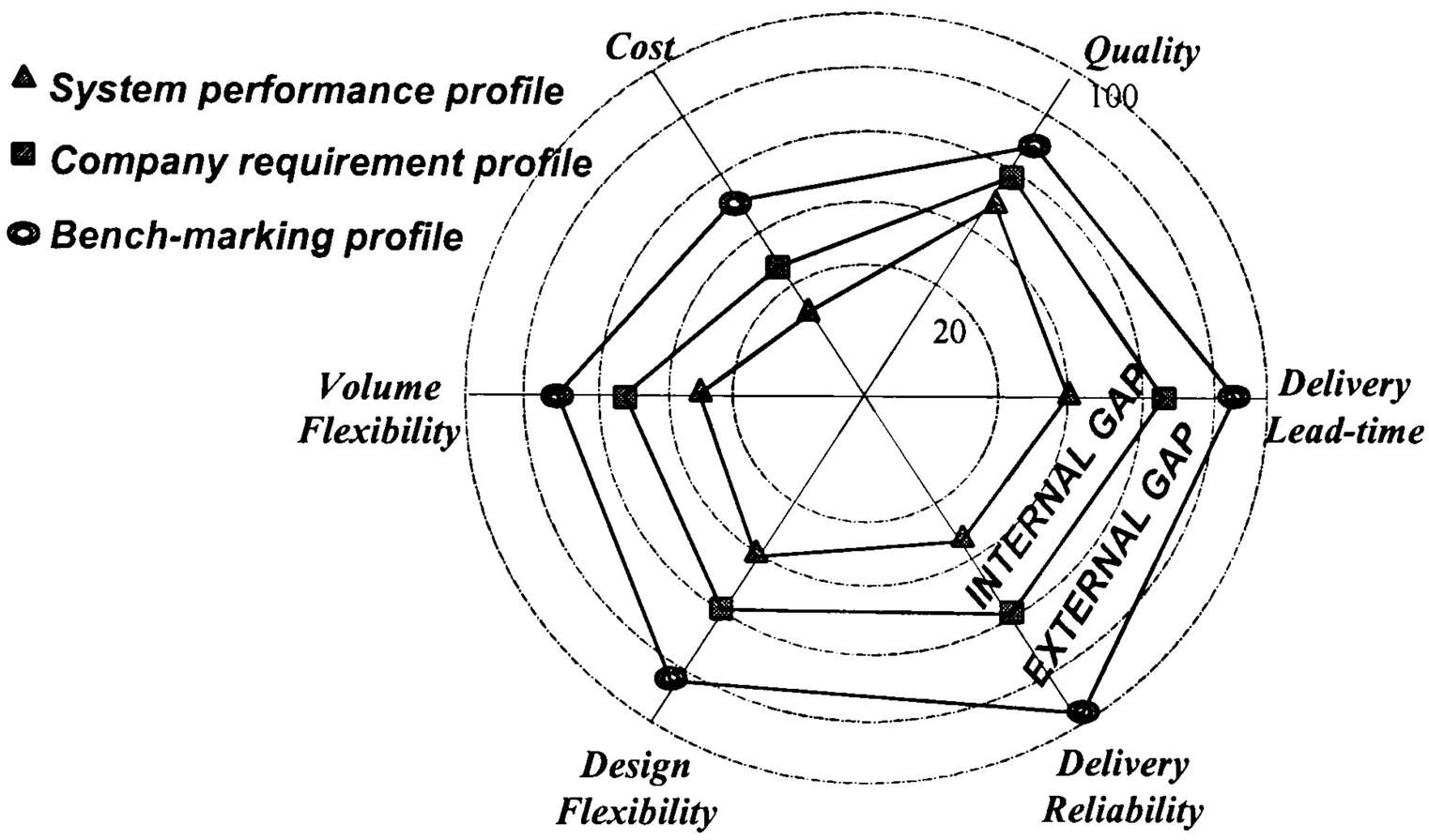


Figure 4.7 A radar diagram

In Figure 4.7, six manufacturing competitive criteria have been developed for evaluation purposes, so the radar diagram is hexagonal in shape. Each of the six points of the hexagon represents one of the competitive criteria and is labelled accordingly. In addition, in each case a 100-point scale derives from the origin of the diagram to the hexagonal point. This scale is used to record the actual performance of the particular competitive criteria.

The primary benefit of the type of analysis provided in Figure 4.7 is that the overall company requirement profile is compared against the system performance profile to identify the overall performance gap. It also helps the company identify where its performance gaps are greatest vis-à-vis world-class companies. This provides the company with a basis for its continuous improvement efforts.

4.4 Characteristics of the proposed framework

The proposed framework has many characteristics such as "a balanced set of measures" which have been discussed in Section 4.3.1. Other characteristics include:

- Selection of a set of "Critical Few" measures.
- Process and outcome measures.

- Vertical integration of measures.
- Horizontal alignment of measurement.

4.4.1 Critical few measures

Critical few factors, according to Brown (1994), are the areas in which "good" performance is necessary to ensure attainment of the goals outlined by the company's manufacturing objectives. Skinner (1974) argued that a plant cannot perform well in every yardstick and that each manufacturing company should focus on a few performance measures. Brown (1994) states that the most common mistake organisations make is measuring too many variables, and the next most common mistake is measuring too few. Although there is no right number of strategic measures, Harbour (1993) suggests the number of critical few measures should not exceed 20, depending on the complexities of the organisation.

Accordingly, the next step of proposed framework, after generating a large number of measures, is to conduct a detailed study to narrow down those measures to the critical few. The selection of a critical few set of performance measures should place attention on the need for a balance between local and global requirements, as well as financial and non-financial measures. One way to reduce the number of measures is to combine those identified measures. Another method would be to rank the measures according to their importance and to keep only the most critical (Brown, 1996).

4.4.2 Process and outcome measures

Performance measurement is the key driver for continuous improvement. Measures for improvement can be classified in two ways: (1) process measures which include effectiveness, efficiency, process consistency/variability, and quality output level, and (2) outcome measures which include customer satisfaction, employee satisfaction, product performance, financial performance, and other key business targets (Zairi, 1996).

However, in practice most manufacturing performance measures are outcome oriented. This is because management tends to think of measuring performance in terms of results. Outcome measures of a manufacturing process such as schedule and

cost might indicate that production is late and over budget. However it does not indicate what to do differently. In contrast, process measures such as consistency of performance and dependability during the course of production might indicate what went wrong (Hronec, 1993). Therefore, it is important to measure manufacturing processes to understand process capabilities and to measure a product that meets the customer's performance, cost, and schedule requirements (Manoochehri, 1999).

The proposed framework adopts a combination of process and outcome measures which provides an effective assessment, as shown in Figure 4.8. In this case, process measures record whether or not what was done was done correctly and if the products or services were provided as intended. Outcome measures assess whether the completed work contributed to the organisation's accomplishments.

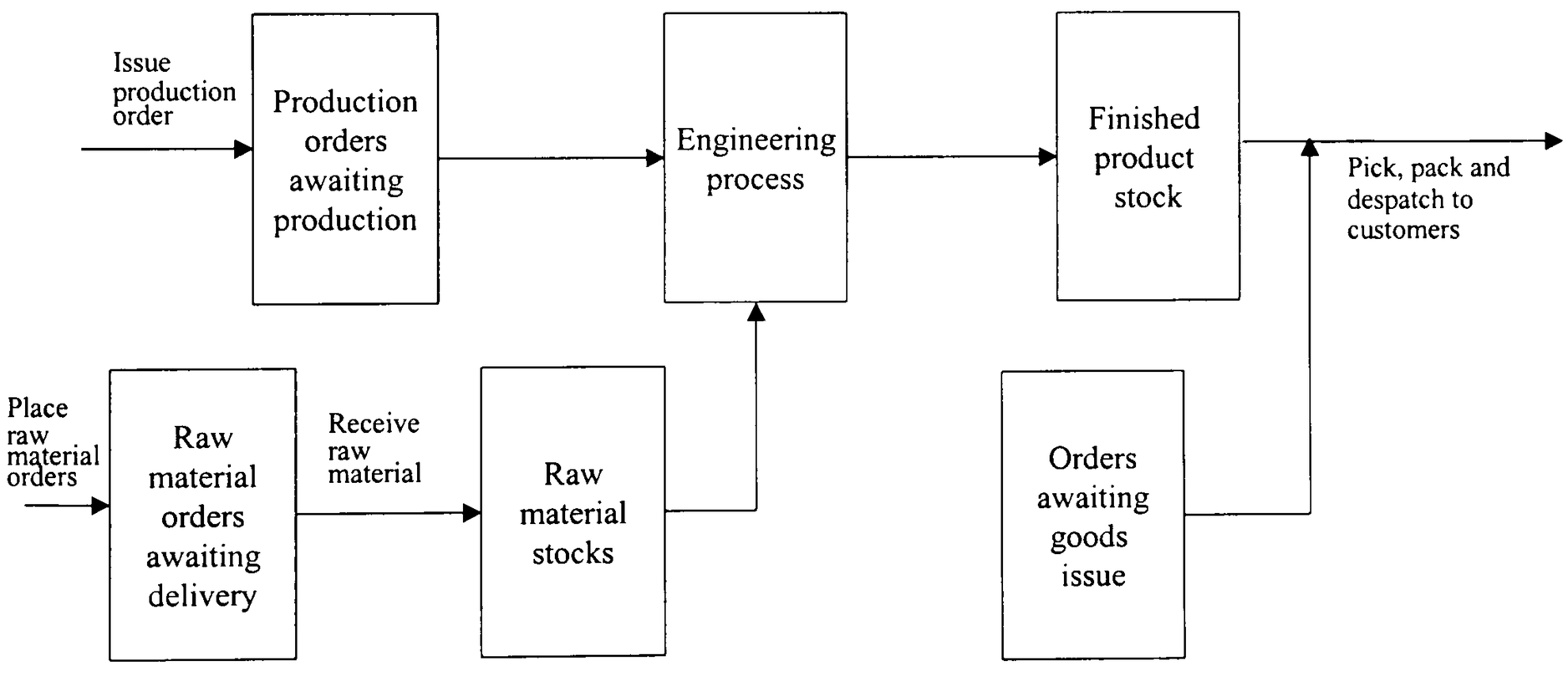


Figure 4.8 Process and outcome measures within the proposed framework

4.4.3 Vertical integration of measures

Santori and Anderson (1987) argue that measures should not only relate to each critical success factor but should place emphasis on the levels of an organisation in order to measure and control activities among them. Lynch and Cross (1991) state good performance measures should have a range of hierarchical levels dependent on

the output and customer being considered. There is no single measure that can adequately capture all aspects of performance in a company. Rarely can a single level of a specific measure be used throughout an organisation. Therefore a hierarchy of the same measure is needed.

Figure 4.5, the proposed framework performance measures hierarchy, shows how the proposed framework can be developed following the flow-down of strategic guidance from the strategy level down to the operational level. The hierarchy consists of three levels, with measures at each different level intended for different purposes. The metric at the first level is used to monitor and benchmark manufacturing system performance while both the second and third level of measures are intended for diagnostic purposes; that is, they help explain why the primary measure did or did not achieve the desired result.

The development of the proposed framework hierarchy helps management ensure that relevant and meaningful performance related information is collected and distributed within the right levels of an organisation. The benefits of developing a hierarchy of manufacturing performance measures in the proposed framework include:

- It collects lower-level measures which can easily be combined and rolled up to create higher-level measures. (Higher-level measures do not have to be directly measured. Instead, they can simply be summed from previously collected measures.)
- It represents an excellent diagnostic performance measurement system. Higher-level measures can easily be decomposed to lower-level elements.
- It aligns the lowest level of performance measures with the strategic goals of the manufacturing system.
- It places emphasis on manufacturing strategic objectives.

4.4.4 Horizontal alignment of measures

Typically manufacturing companies are functionally segmented: product. quality, R&D, manufacturing, maintenance, and so forth. Yet, although companies are organised functionally, they provide products or services to their customers

horizontally, not through marketing or manufacturing. Since performance measures such as lead-time, flexibility, and quality cannot be fulfilled by one department alone, departments must work together to satisfy customer needs. Accordingly, manufacturing performance measures should also reflect a horizontal view in order to ensure the optimisation of workflow across all processes and organisational boundaries (Hronec, 1993).

The concept of horizontal alignment of the proposed framework is focused on the three architectures of balanced measures: manufacturing process, human resource and organisation, and information and control. As a product flows through engineering development, production, and delivery, the competitive criteria measures are maintained to ensure full customer satisfaction. Together with vertical integration of measures, quality, delivery, flexibility, and cost, a complete cycle of manufacturing performance measures has been developed to monitor the system's performance and support decision making in pursuing continuous improvement, as shown in Figure 4.9.

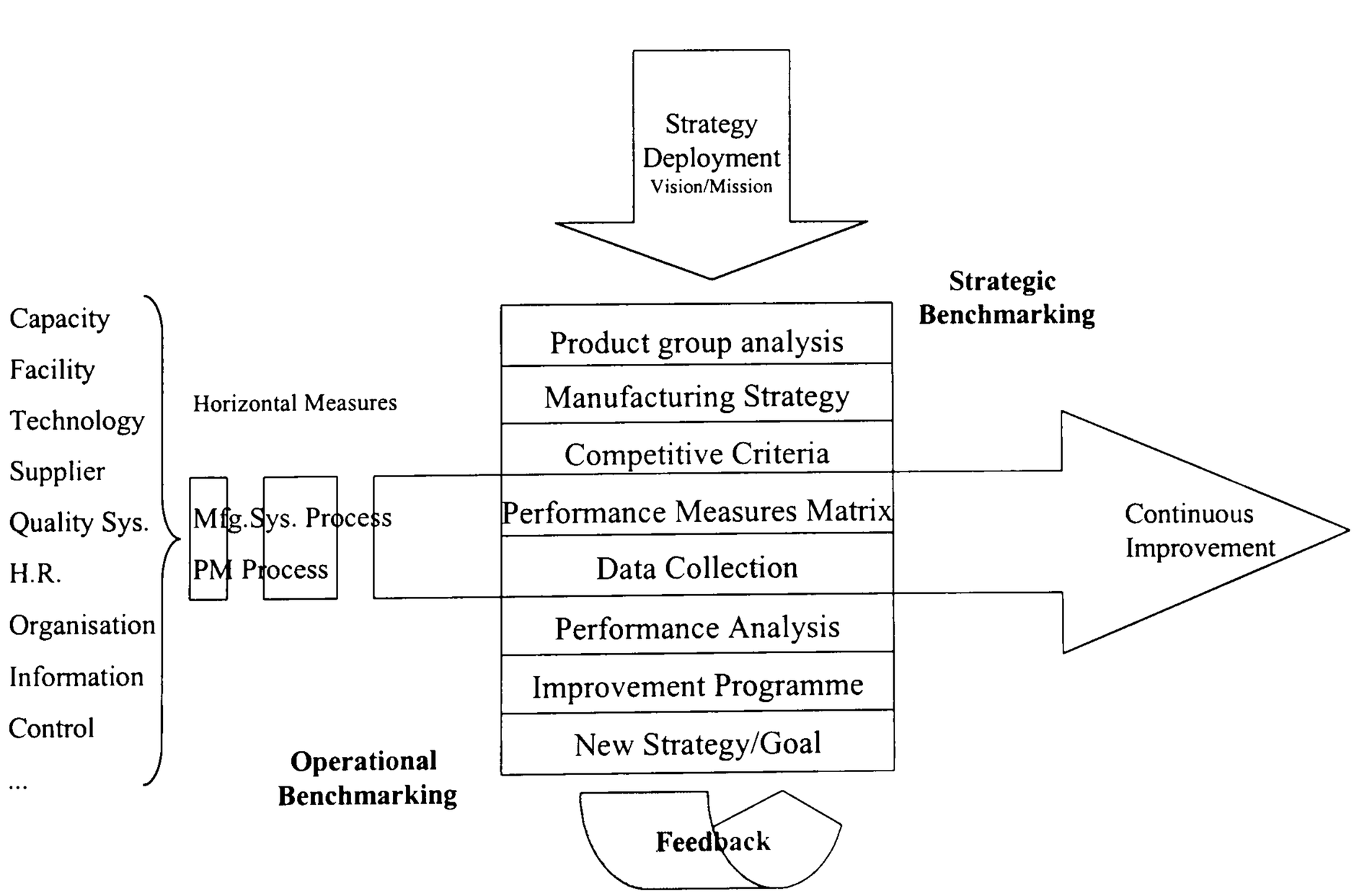


Figure 4.9 Proposed dynamic performance measures framework

4.5 Application of performance information

It is accepted that performance measurement is not an end in itself, but a tool for more effective management. Also a performance measurement system should not only indicate what happened, but also tell us why it happened and what to do about it (Lockamy III, 1998). Earlier parts of this chapter focused on concepts, processes, and key issues of the proposed framework, such as how the process of system wide performance measurement provides an effective approach to achieving a "top-down" strategic alignment. It is now necessary to look at how to manage measurement results to the benefit of the manufacturing company, and how the proposed framework can be used to drive performance improvement. The section provides insights for management's use of performance data to drive manufacturing performance improvement. It addresses the use of performance information for analysis and decision-making.

Typically, performance measurement provides the basis for a company to monitor how well it is progressing towards predetermined goals, and helps to identify areas of strength and weakness. It also provides the necessary data to show how activities support strategic goals. As the performance measurement serves as a supporting tool, the extent of decision-making is determined by the quality and completeness of performance information. Therefore, in order for a company to make effective use of the results of measurement, a performance measurement system should have the ability to make the transition from performance measurement to performance management (NPR, 1999).

To effectively move from performance measurement to performance management, the ability to use performance information to improve performance and support decision-making is crucial. The performance measurement information has many uses. Primarily, this data shows a company's current and past levels of performance. It can also provide an indication of future performance. These levels of performance provide management with such necessary information as "Where we are?" "Where do we want to go?" and "How can we achieve it?" (Keegan et al. 1991).

In practice, performance information should be used at all levels of management to drive performance improvement. It tells the management of a manufacturing system

about its present condition. It also allows the management to objectively measure the current system performance against others through benchmarking. In turn, benchmarking aids in identifying potential areas of performance improvement. Accordingly, it is essential to establish an appropriate method for presenting key performance information in a way that promotes the attainment of manufacturing objectives.

4.5.1 For determining gaps between goals and reality

Performance results of the proposed framework can be used to determine gaps between specific strategic objectives and actual achievement. The causes of these gaps are analysed, and counter measures developed and implemented. Whenever there is a gap between current results and a manufacturing objective, there is an opportunity for process improvement.

For the gap analysis, a crucial question is how logically to associate a set of individual requirements that are related to different product groups, to the overall manufacturing system as a whole in order to measure its effectiveness. Starting from a basic analysis of product groups, a series of utility functions and profiles can be constructed to assess the requirements of the manufacturing system and the current performance of the existing manufacturing system in meeting those requirements. This technique provides a unified way of relating individual product requirement profiles to the overall systems profile, and analysing the effectiveness of the current manufacturing system in relation to its strategic requirements. A gap analysis can then be executed in order to identify the areas for improvement in a flexible way dependent on the specific needs:

(a) *Products-related requirement/system gap analysis.* With this approach the individual profiles of the key product groups can be compared to the system profile to identify product groups performance gaps.

(b) *Plant-wide requirement/system gap analysis.* With this approach the overall requirement profile is compared against the system profile to identify the system-wide performance gap, formulating future improvement programmes which aim to satisfy the system-wide manufacturing requirements.

4.5.2 For use in benchmarking

Sweeney (1993) argues that performance information can stimulate benchmarking and the aim of benchmarking is to stimulate improvement. Benchmarking is the process by which companies compare performance, in order to search and implement the best practices. It involves the systematic and continuous process of comparing the performance information of an organisation against the performance of the business leaders world-wide. Benchmarking is a useful approach that can be adopted at this stage to develop the future actions needed to achieve winning strategies by identifying any possible superior performance from other companies in the market, with the aim of achieving world class manufacturing. That is, to become a manufacturer that can compete with the best anywhere in the world (Rich, 1997).

Benchmarking can be used by organisations for comparison of internal operations, competitor-to-competitor products, industry standing, and generic business functions or processes (Camp, 1989). The most important benefit of benchmarking is that it allows a company to see beyond its existing paradigms of process performance. As it benchmarks other organisations, it greatly improves the likelihood of seeing tomorrow's solutions to today's problems, and of adopting a wider reaching strategy than a localised approach. The potential benefits of benchmarking were summarised in Table 2.15, Chapter 2.

Accordingly, manufacturing companies can use the performance information for benchmarking in order to compare their product, processes, and service against their competitors and other best-in-class companies. Through internal/external benchmarking, management can identify what is done well in the manufacturing system, identify what needs to be improved, and identify where best practices exist.

4.5.3 For driving continuous improvement and learning and/or business process reengineering (BPR)

Performance results can be used to determine gaps between manufacturing strategic objectives and actual achievement. The causes of these gaps are analysed, and counter measures developed and implemented. Wherever there is a gap between current results and strategic objectives, there is an opportunity for improvement. Small scale continuous improvement and dramatic process reengineering are the

common response of the manufacturing industry to the identification of gaps between objectives and achievement (Wu and Hull, 1997).

Continuous improvement and learning refer to ongoing, incremental and major, improvements. Continuous improvement is defined in the US Department of Energy (DOE, 1996) as, "The unending betterment of a process based on constant measurement and analysis of results produced by the process, and the use of that analysis to modify the process." It focuses on improving customer satisfaction through continuous and incremental improvements to processes, including removing unnecessary activities and variations. For many organisations the concept of continuous improvement can be optimised by the plan-do-check-action cycle. Other tools can be used including Histogram, Brainstorming, Gantt chart, Control chart, benchmarking, and so on (Kaye and Anderson, 1999).

Business Process Reengineering is "the analysis and design of workflow and processes within and between organisations" (Davenport & Short 1990). Teng et al. (1994) define BPR as "the critical analysis and radical redesign of existing business processes to achieve breakthrough improvements in performance measures." It aims to increase performance by radically re-designing the organisation's structures and processes.

BPR is therefore the more radical redesign of the current system and its processes with the intent of increasing customer satisfaction. Davenport and Short (1990) prescribe a five-step approach to BPR:

(1) *Develop the business vision and process objectives:* BPR is driven by a business vision which implies specific business objectives such as cost reduction, time reduction, output quality improvement. These are the same as the action plans suggested in Table 4.6 – strategic concerns and action plans.
(2) *Identify the processes to be redesigned*: BPR focuses on the most important processes or those that conflict most with the business vision.
(3) *Understand and measure the existing processes*: The aim of this step is to avoid the repeating of old mistakes and to provide a baseline for future improvements.

(4) *Identify IT levers*: This is because IT capabilities can strongly influence process design.

(5) *Design and build a prototype of the new process*: The actual design should not be viewed as the end of the BPR process. Rather, it should be viewed as a prototype, with successive iterations.

The difference between continuous improvement and BPR is illustrated in Table 4.6.

	Continuous Improvement	**Business Process Reengineering**
Level of change	Incremental	Radical
Starting point	Existing Process	Clean Slate
Frequency of change	One-time/Continuous	One-time
Time required	Short	Long
Participation	Bottom-Up	Top-Down
Typical Scope	Narrow, within functions	Broad, cross-functional
Risk	Moderate	High
Primary Enabler	Statistical Control	Information Technology

(Source: Davenport, 1993)

Table 4.6 Continuous improvement versus business process reengineering (BPR)

4.6 Conclusion

The manufacturing performance measures and evaluation framework introduced in this chapter is a conceptual framework for translating a company's manufacturing strategy into a set of performance indicators distributed among three architectures: manufacturing processes architecture, human and organization architecture, and information and control architecture. It emphasises the positioning of the manufacturing strategy at the centre of the performance monitoring structure. It is a tool designed to measure a manufacturing system's performance. Also it is structured to measure progress against defined short-term and long-term goals, to use customer inputs in setting those goals, and to have an internal balance measure. When using the framework, development of strategic goals is the first step in creating a performance assessment process that is designed to support the accomplishment of the strategic objectives. Only after the organisation knows where it wants to go can it develop the performance measures that will help ensure attainment of the manufacturing strategy objectives.

CHAPTER 5 DEVELOPMENT OF FRAMEWORK

5.1 Overview

As discussed previously, performance measurement involves determining what to measure, identifying data collection methods, and collecting the data. Evaluation involves assessing progress towards achieving performance expectations. Following the structure of the manufacturing performance measurement and evaluation framework as presented in Chapter 4, this chapter specifies the functionality and procedures to develop the performance measures system and its supporting information, focusing in particular on the specification of strategy-oriented performance measures, overall system status monitoring, and the continuous improvement monitoring cycle in the manufacturing system.

The aim of this chapter is to develop processes for design, development, and implementation of successful performance measurement systems that allow management to make good decisions and take positive actions that will improve organisation performance. To accomplish this aim, a methodology for design, development, and implementation of a measurement system is presented, with the emphasis on the balanced measures and performance measures hierarchy that must be carefully addressed by the management.

Stivers et al. (1998) states that to develop a successful performance measurement system, managers must clearly understand the interests of the customers, the strategic objectives of the company, and every aspect of the company's business processes. Only then can they be assured that the performance measurement system includes the right factors, both financial and non-financial. Also, according to Chapter 2 – literature review, an effective performance measurement system should be:

- Focused on customer needs and measure only what is important (Kaplan, 1991).
- Based on the clear identification of the organisation's key processes, which have the most impact on the success or failure of the business goals (Harbour, 1997).
- Top-down and include critical success factors, a mix of financial and non-financial data, and a balance between different perspectives (Lakshmi et al. 1998).

Accordingly, the development of the proposed framework should involve: (1) the identification of manufacturing systems processes, goals, interim targets and the important financial and non-financial key factors, (2) the development of the performance measurement system and measurement of those key factors, and (3) the use of key factors in developing and monitoring the strategic plan. The overall proposed framework system flow is shown in Figure 5.1.

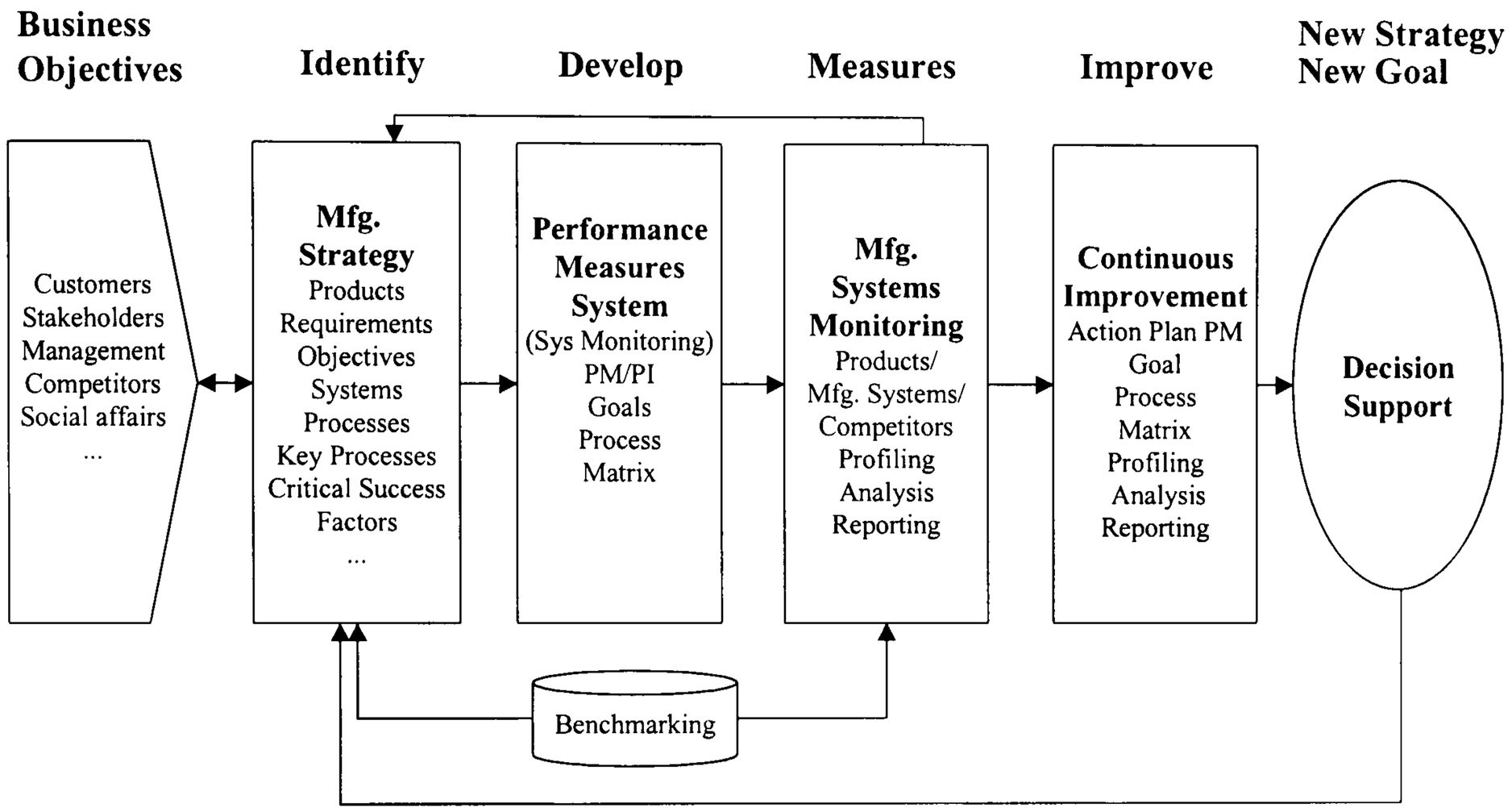


Figure 5.1 The proposed framework system flow

5.2 Overview of the proposed framework procedure

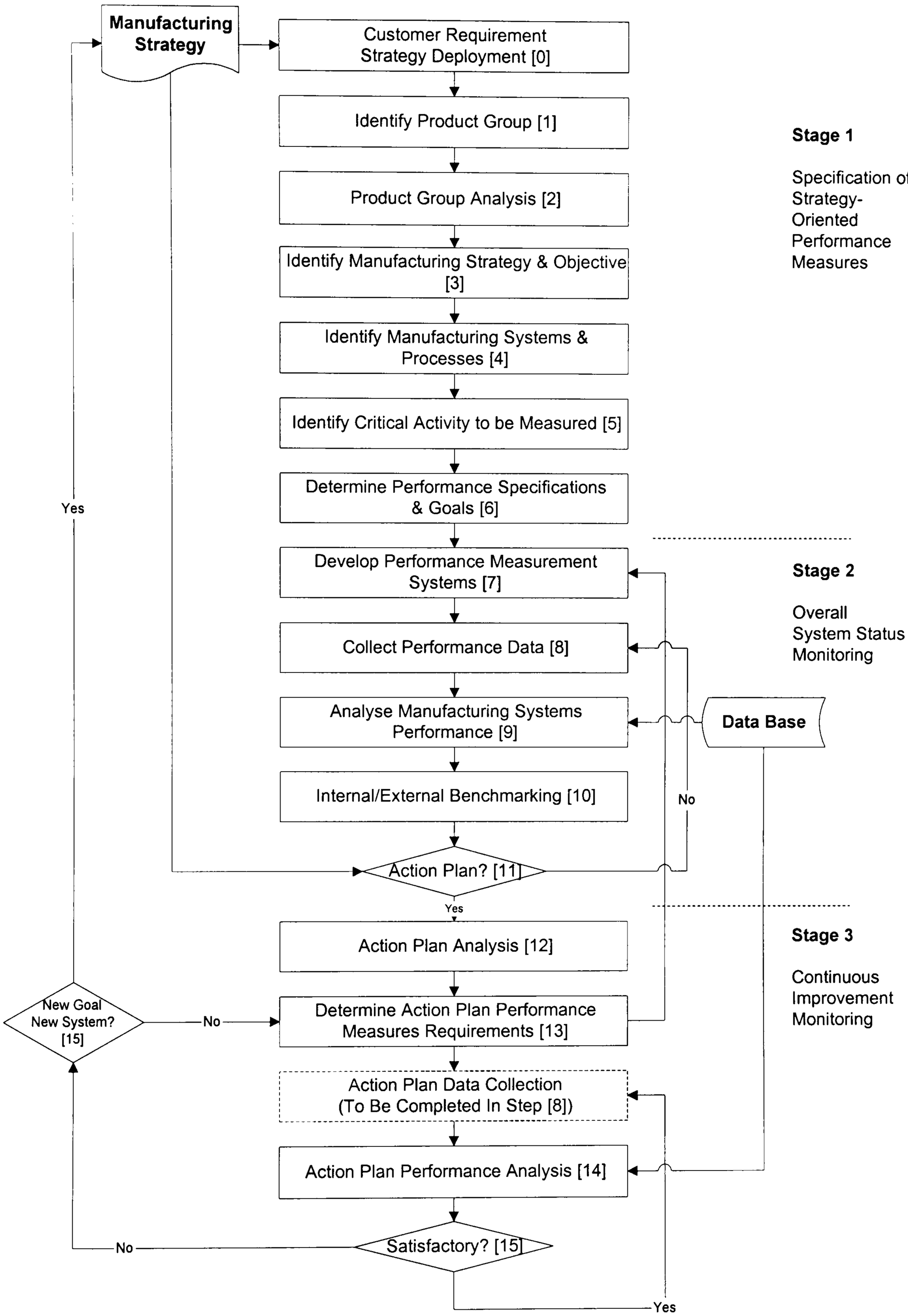
The procedure to develop the proposed framework is a cascading one. It starts with the analysis of manufacturing strategy, and rolls down to goal setting and the identification of key processes and critical activities. These critical activities are required to achieve the goals and the strategy. It is important to identify key processes and critical activities because they indicate what is truly important to the organisation (Chang and Young, 1995).

The process is then focused on the development of performance measures, indicators, and matrices in accordance with the identified critical activity. It allows management to start to understand and develop performance measures that balance multiple measures (quality, delivery, flexibility, and cost) across three manufacturing

architectures (e.g. manufacturing processes, human and organisation, and information and control) in a way that matches manufacturing-specific strategies, goals, and processes. What makes this approach particularly useful is that it allows the company to focus on a host of areas that are critical to success, measure and plan performance in each of these areas, and then make an overall evaluation of the external and/or world-class performance standing.

Figure 5.2 shows a block diagram of the performance measurement process. It has been separated into 15 discrete steps. The structure, contents and techniques of the measurement as suggested here are generic. Hence, different companies who best know their own internal processes should be able to adopt and implement it in a flexible way to best fit their operation. The purpose of the suggested measurement system is to provide the user with the information about actions she/he has to take to achieve the strategic goal.

As a process, the proposed framework is not simply concerned with collecting data associated with a predetermined performance goal. It involves prevention and detection of performance variance with the aim to achieve conformance of the products or services to the customer's requirement. In addition, it is concerned with process optimisation through the increased efficiency and effectiveness of the manufacturing system or product produced, in a continuous cycle. A brief description of each of the process steps is given in Table 5.1.



(0-15 steps)

Figure 5.2 The proposed framework process

Step	Description	Outputs
1. Identify products.	The first step is to conduct a clear review of products a company produces. If a company's products can not be identified, how can they be effectively measured? Also, since a company seldom produces only one product, product grouping becomes crucial to streamline performance measures.	A list of products or product groups that the manufacturing company produces.
2. Analyse product groups	This is to perform an in-depth analysis of product groups previously defined in order to provide a broad understanding of their functional performance and situation among competitors and to identify the product groups which are the most important to the company.	A list of product performance and grouping of products.
3. Identify manufacturing strategy and objectives	It is to identify business objectives and manufacturing short/long term strategic goals and key factors necessary to achieve the goals. Once the goals and key factors have been classified, it becomes easy to start identifying importance measures.	A list of current and future manufacturing strategy in terms of competitive criteria and manufacturing strategy choice.
4. Identify manufacturing systems.	The purpose of this step is to know existing manufacturing policies, activities, and core processes in specifying how the systems' operations will produce the desired outputs and outcomes, and distinguishing what are the critical activities to be measured and their priority.	A list of manufacturing processes, key processes, and flow diagrams for these key processes.
5. Identify critical activities to be measured	The critical activity is the crucial activity where it makes the most sense to locate a control point and define an individual performance measure within a process.	A list of the critical activity areas for the key processes.
6. Determine performance Goals	All performance measures should be tied to a predefined goal, even if the goal is at first somewhat subjective. Having goals is the only way to meaningfully interpret the results of measurements and gauge the success of the manufacturing systems.	A list of goals for each critical activity within the key manufacturing processes.
7. Establish performance measurement	In this step, a performance measurement system is built by identifying individual measurement. Two major tasks are involved in this step: to specify quantifiable, readily measurable performance indicators; and to develop performance measures systems to assess strategic progress.	The performance measures matrix and their components
8. Collect data	The data that needs to be collected depends on the indicators that are chosen. In addition to writing down the numbers, it is necessary to perform an assessment to determine the quality of data. For accurate data is more important than precision.	A growing list of performance data.

Table 5.1 Summary of the proposed framework process

Stage	Description	Outputs
9. Analyse actual performance	In this step, the raw data are formally converted into performance measures, displayed in an understandable form, and disseminated in the form of a report.	The individual product group, overall manufacturing system, and manufacturing strategic profiles can be drawn.
10. External/Internal comparison	The aim of this step is to identify external/best practice performance in order to provide a basis for continuous improvement efforts.	A presentation of the performance information in the form of a report
11. Determine if corrective action is necessary	This is a decision step. If the variance is large, corrections will need to be made to bring the performance back into line with the desired goal. If the variance is small, the process is probably in good shape. However, re-evaluating performance goals should be considered to make them more challenging.	Action plan to implement change or re-evaluate goals.
12. Action plan analysis	This step only occurs if corrective action is expected to be necessary. The actual determination of the corrective action is part of the quality improvement process, not the performance measurement process. This step is primarily concerned with improvement of the manufacturing system. By studying the action plan's objectives, processes, and critical success factors, the aim is to identify performance measures requirements and goals in response to the improvement programme. The internal/external factors that could affect goal achievement should also be identified.	A successfully implemented action plan
13. Establish action plan performance measurement	The process is the same as in Step 7 but focuses on the development of improvement programme performance measures including: performance goals, indicators, tools, metrics etc.	Action plan performance measures matrix and their components.
14. Analyse and benchmark action plan performance	It is to examine the effectiveness of the chosen indicators by comparing performance data with the goals. The purpose is to improve the measures for the next measurement cycle, and to look for ways to improve the performance and effectiveness of action plan(s).	A list of action plan performance variance identified through gap analysis.
15. Decision making – new action plan or new goal	The final step is to describe action plan(s) for meeting unmet goals or to explain why a goal should be modified. If previously set objectives were attained with great difficulty, then it may be reasonable to re-adjust expectations, and vice versa.	New goals, measures, or no change

(Restate the title from the previous page)

5.1 Summary of the proposed framework process

5.3 Stage 1 - Strategy-oriented performance measures

When designing performance measurement systems, it is necessary to decide first what to measure, and how to measure it (Bititci, 1994). This section consists of a number of steps as shown in Figure 5.3, with the main aim being to define the overall context of the proposed framework in order to help a company align performance measures with its manufacturing strategy. As an integral part of the manufacturing system, the performance measures here should always be tied to the system's current goals or objectives. Therefore it is important that the performance measurement of the monitoring function is based on the identification of the manufacturing system's key processes, which have the most impact on the success or failure of the organisation's goals. The following key points in this stage include:

- Focus on customer needs,
- Measure only what is important, and
- Involve employees in the choice and implementation of the measures.

There are a number of sources that should be examined as the first stage in establishing a set of meaningful and integrated performance measures:

- Outputs of the strategic planning process: to specify the company's mission and what directions the company should move to achieve those objectives.
- Analysis of key processes: the processes that have the most impact on the success or failure of the organisation's goal.

Thus a performance measurement system enables the organisation to ensure its progress along an appropriate path as it moves from its current state to a future state. Therefore, the vision and mission statements for the manufacturing strategy should be treated as the foundation of the system status monitoring function (Kaplan and Norton, 1996a). With such a foundation to provide the direction and reason, quantitative objectives can be defined to assess the progress toward the vision.

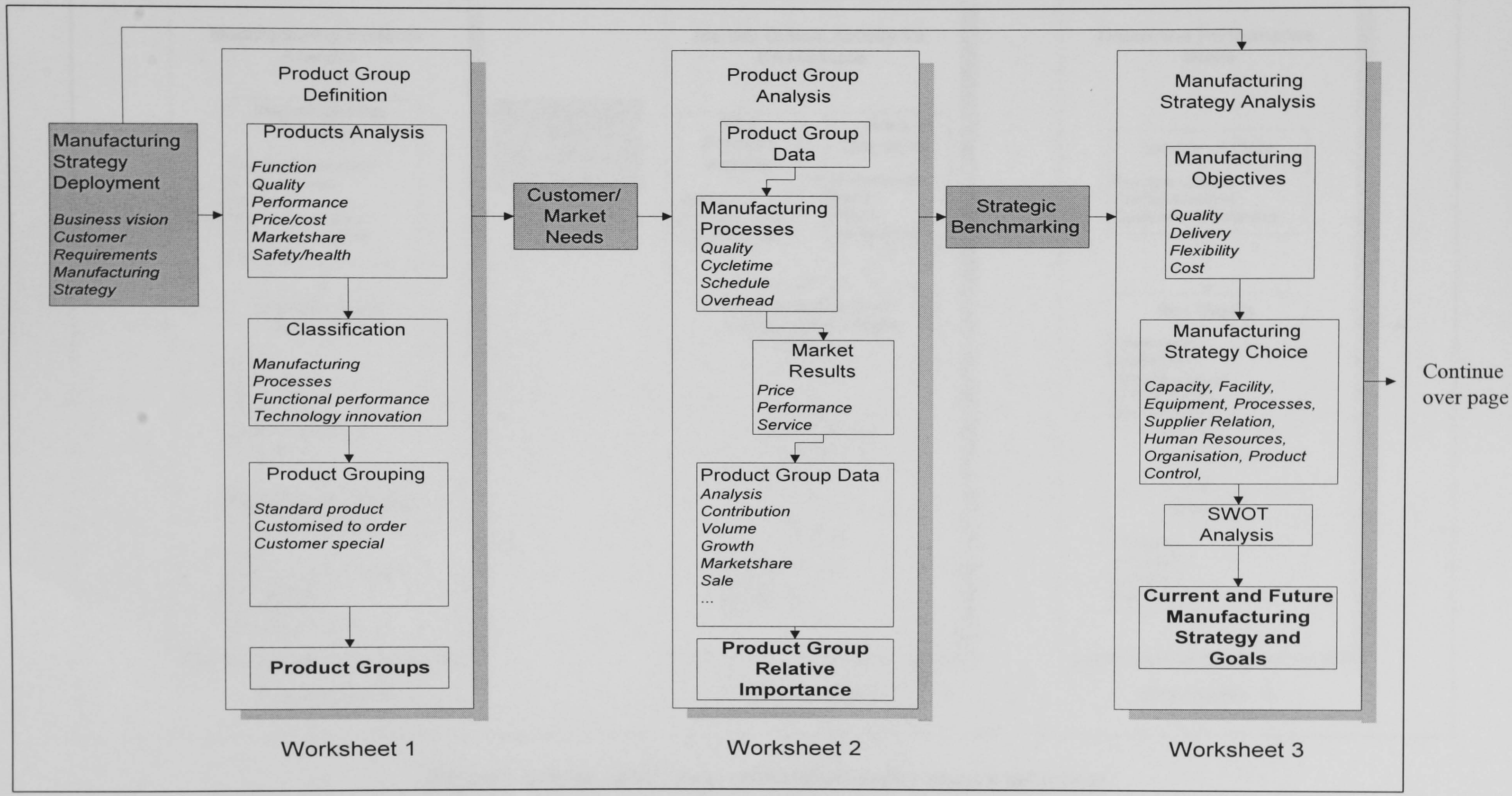


Figure 5.3 Steps of strategy-oriented performance measures *(Continue over page)*

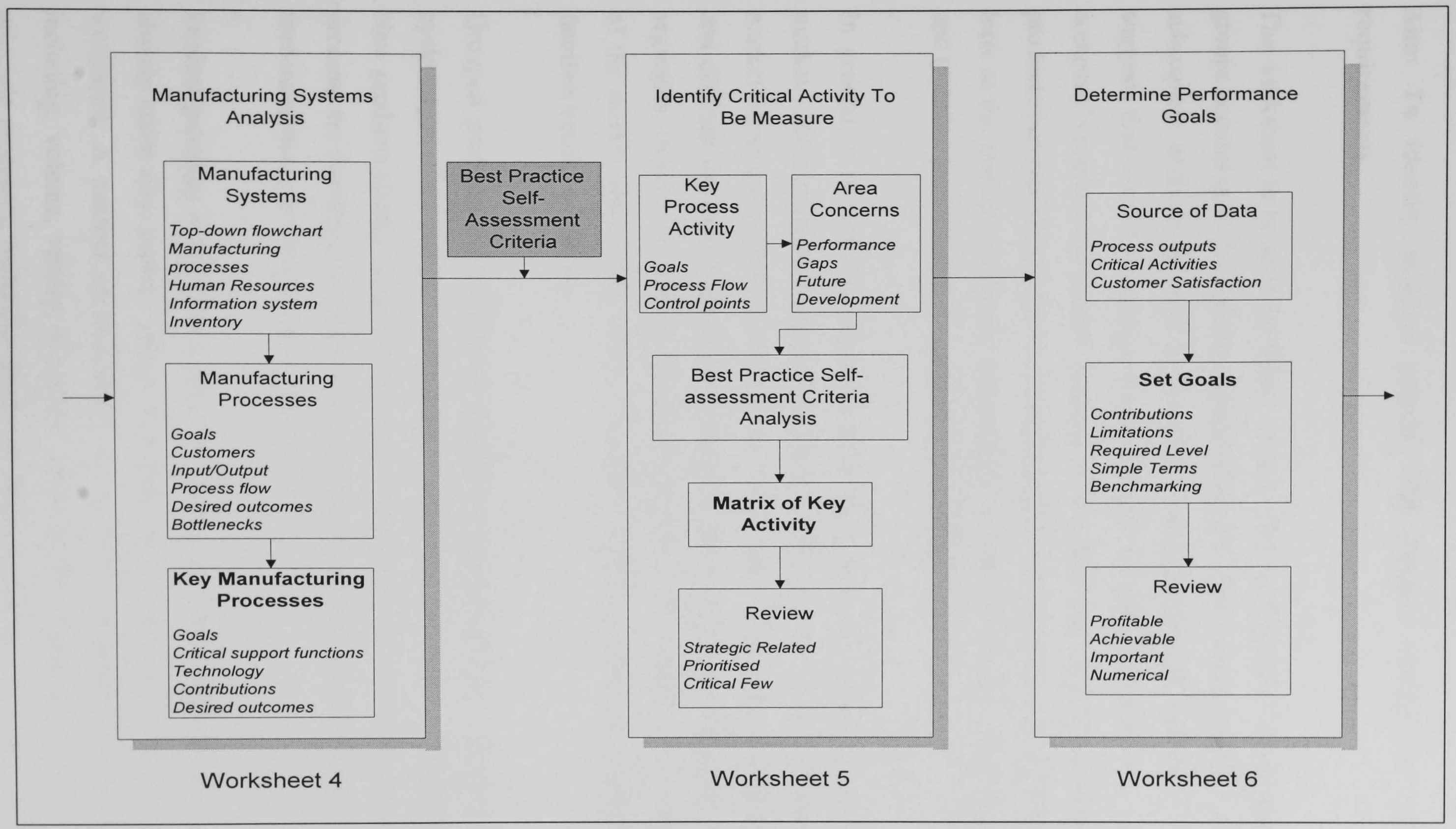


Figure 5.3 Steps of strategy-orientated performance measures

5.3.1. Step 1 – Identify product groups

Aim: To identify product groups with distinct competitive and market requirements

The worksheet to be used for Step 1 of this stage is to identify a company's product groups according to their distinct competitive and market requirement, so as to allow subsequent analysis focused on the most important product families. Hill (1993) suggests that when developing a manufacturing strategy it is essential to understand a company's product and market. Maskell (1991) states that manufacturing strategy and product characteristics define the manufacturing task. Therefore, it is necessary to first look at the markets, products, and strategy in order to identify manufacturing tasks and to define performance measurement specifications.

In general, it is rare for companies to produce only one product to compete in a market. Most companies produce different products, and compete in more than one market where competitive circumstances are different. However, it would be complex and difficult for most companies to analyse their product's performance and market segments. Also, it is unlikely that all the products will compete in the same segment of the market place (Hill, 1993). The identification of different product groups or families becomes crucial.

Grouped products normally share similar competitive criteria, similar product life cycle stages or are grouped as the result of product performance analysis (Hull, 1998). New products should identify product performance and the associated manufacturing process; the existing product should focus on product functions, performance, and the associated manufacturing processes (Hill, 1993).

Product grouping is normally a relatively easy task. Often manufacturing companies already know their product groups and hence need to do little work to complete the worksheet. A number of parameters are available to specify the product groups including: volume, variety, functions, costs, profits, competing criteria, resources, principle processes, materials, degree of standardisation, and market position (Hull 1998).

In identifying product groups, a preliminary analysis of products or services is involved, by breaking the total range of products down into groups or families, which form the basis for analysis. Then, an analysis of understanding "what are the products or services produced?" and "who are the customers?" is conducted in order to identify product groups with distinct competitive requirements (Neely et al. 1996). According to this, an understanding of an individual product's physical and functional performance and from the customer perspective is of critical importance. To assist in this process Pareto Diagrams can be applied. A detailed description of the Pareto analysis is illustrated in Appendix B.

The information required to assist the definition of product groups is recorded in Worksheet 1 of the performance measurement and evaluation worksheet shown in Appendix A. The result of this step is to obtain a sufficiently detailed picture of a company's product performance and grouping of products.

5.3.2. Step 2 – Analyse product group

Aim: To identify the importance of various criteria for each product group, and a relative ranking of the product groups

Once the product groups have been defined, the next step is to provide an in-depth analysis of each of the product groups. Hayes and Schmenner (1978) state that "product group analysis helps to identify a company's current and future product group decisions for manufacturing by considering what type of focus would best meet customers' expectations." Product group analysis represents an assessment of a company's position in the market, its products and the competitive requirements of the market (Neely ey al. 1996). In this step, the product group analysis is to take each previously defined product group in turn and ask the analysts to enter relevant information with which to compare the product groups. The aim is to allocate a measure of the relative importance of each of these product groups to the operation of the company. Typically, these criteria include those parameters shown in Table 5.2.

However, it is probable that not all product groups are of equal value to the company. Take product life cycle for instance, some may be mature products subject to intense

price competition and increase the stability of the manufacturing process. Others may be in a strong growth phase requiring a quality image change and shift toward mass production (Porter, 1980). It is therefore essential to allocate a measure of the relative importance of each of these product groups to the operations of the company. A means of recording such information can be found in Worksheet 2. Each criterion should be assigned a relative ranking based on the company's assessment of its importance. Once all the product groups have been assessed, a relative importance can be assigned to each group. The end result is a series of tables dealing with the various importance criteria for each product group and a relative ranking of the product groups.

Parameter	Product Group A	Product Group B	Product Group C	Product Group D
Cost				
% Sale				
% Contribution				
Profits				
Volume				
Growth opportunity				
Degree of innovation				
Market share				
SWOT analysis				
Relative importance				

(Source: modified from Neely et al 1996)

Table 5.2 Product group relative importance determination

5.3.3 Step 3 – Identify manufacturing strategy and objective

Aim: To understand the overall manufacturing strategy as well as individual product group objectives and strategic choices

Clark and Zirner (1993) state that a company wishing to set up a performance measurement system must identify its strategy for improving performance. When deciding on what to measure, it should start with the manufacturing purpose: its strategy and objectives. Manufacturing objectives might not seem very definitive. However they are very important because they set the direction for all processes in the manufacturing system. They are the statements of customers' needs and expectations.

They are the driving force for the selection of performance measures (Brown, 1996). As manufacturing strategy comes directly from business objectives, the purpose of this step, similar to Balanced Scorecard and other integrated performance measures methodologies, is to understand and review the mission, vision, and strategy of the manufacturing company. Clear mission and vision statements are necessary guidelines for the success of performance measurement system design (Lynch and Cross, 1991; Kaplan and Norton, 1994).

Hayes and Wheelwright (1984) argue that developing a manufacturing strategy requires addressing several decision areas. The manufacturing choices can help to identify and plan the functional nature of the manufacturing strategy, as shown in Figure 5.4. As manufacturing strategy drives manufacturing performance and must focus on competitive objectives, in this step it is necessary to conduct a strategic review by analysing each decision area, to understand its activity and task. Through the analysis, the aim is to answer the questions "Where are we?" "Where do we want to go?" and "How do we get there?"

Strategic decisions	Representative Issues
Capacity	Throughput (amount, timing, type), New purchases
Facility	Factory (size, location, specialisation)
Technology	Automation, fabrication methods
Vertical integration	Make-or-buy (direction, extent, balance), in-house dedicated, contract assembly
Human resources	Direct labour cost, skill levels, training
Organisation	Integrating design and manufacturing
Quality system	Definition, role, responsibility
Production control	Work flow, Just-in-time, component souring, storage/retrieval, material handling

(Source: Hayes and Wheelwright, 1984)

Figure 5.4 Strategic manufacturing decisions

Worksheets 3-1 and 3-2, current and future manufacturing strategy analysis, which are based on a matrix of manufacturing strategy choice and competitive criteria, record the assessment of operations and infrastructure of the manufacturing system and of the current and future manufacturing strategy in order to identify manufacturing strategies, performance gaps, and performance requirements. The performance

measurement questionnaire (PMQ) can be applied to capture relevant information and structure the approach, including:

- Mission and vision statement
- Situation analysis
- Purpose of measurement
- Customers/market expectations
- Competitor/Best practice performance

For a clear understanding of the manufacturing strategy, a situation analysis should also be conducted and reviewed (Brown, 1996). A situation analysis is used to investigate factors that can help the organisation reach its vision (Weihrich, 1982). Strengths, weaknesses, opportunities, and threats (SWOT) of the manufacturing systems as well as the manufacturing competitors have to be analysed. SWOT analysis includes the assessment of the current manufacturing policy decisions and the future manufacturing policy decisions. It serves as a means of identifying the strengths and weaknesses of a manufacturing system and the opportunities and threats facing it, with respect to both the internal and external environment (Greenhalgh, 1992). SWOT analysis is a simple generic analytical tool that examines the following aspects of the manufacturing function (Weihrich, 1982):

- **Strengths**: activities, systems, technologies, procedures etc., which the manufacturing function performs well.
- **Weaknesses**: activities, systems, technologies, procedures etc., which the manufacturing function does not perform to an acceptable standard.
- **Opportunities**: activities, systems, technologies, procedures, events, potential events etc., which the manufacturing function could exploit.
- **Threats**: activities, systems, technologies, procedures, events, potential events etc., which may prevent the manufacturing function achieving its aims.

Through SWOT analysis, and based on knowledge of the current market share, competitive position and manufacturing performance, a vision of where the manufacturing system could be in the near future can be formulated. The vision

forms the basis of the manufacturing objectives and therefore a current and future manufacturing strategy can be identified. At the end of this step, a list of short and long term goals of the manufacturing strategy and the importance of policy areas and their objectives and approaches will be identified. This ensures that the manufacturing performance measures developed in each of the architectures (e.g. manufacturing process, human resources and organisation, and information and control system) support the accomplishment of strategic objectives. It also helps to understand the links between performance measures and strategic goals. This can be satisfied using Worksheet 3, as shown by the example given in Table 5.3.

Manufacturing Strategy Choice	**Strategic Planning Objectives**	**Key activity**	**Competitive Criteria**					
			Q	**DL**	**DR**	**DF**	**VF**	**C**
.....								
Quality System	Reduce reject rate	Employ TPM	X	X		X		X
		Training	X					X
		New equipment	X				X	X
		Supplier quality	X		X			
.....								

(where Q: quality; DL: delivery lead-time; DR: delivery reliability;
DF: design flexibility; VF: volume flexibility; C: cost)

Table 5.3 Example of Worksheet 3 – Identify manufacturing strategy

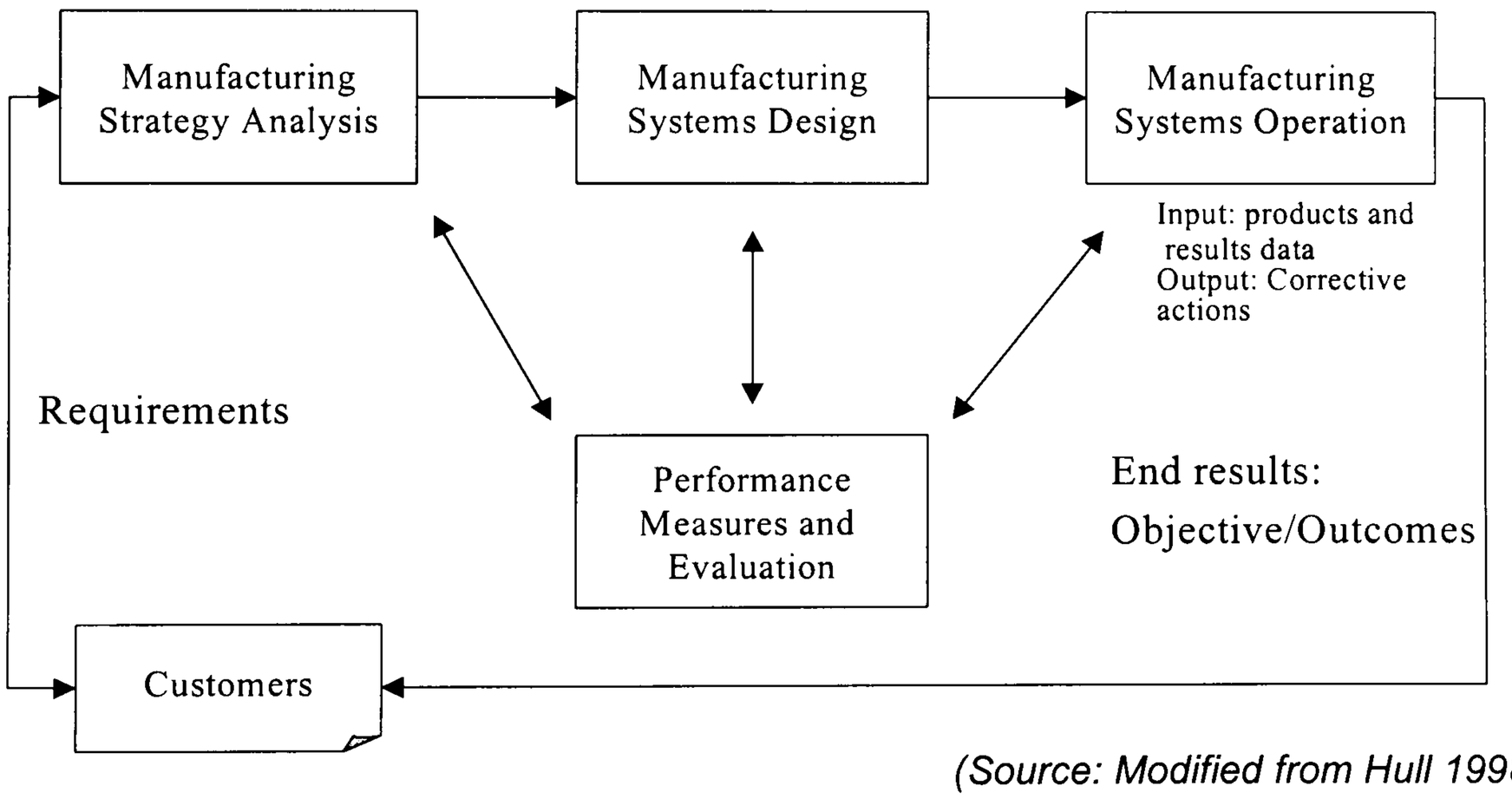
5.3.4. Step 4 – Identify manufacturing systems and processes

Aim: To conduct a manufacturing system input/output analysis to understand manufacturing processes and key processes

It is generally accepted that in order to truly understand and improve an organisation, one must focus on its processes. The understanding of manufacturing processes is to identify the necessary activities to structure the overall performance measurement systems. Hronec (1993) states that a process is a series of activities that consume resources and produce a product or service. Bourne and Wilcox (1998) argue that manufacturing companies can optimise the results of the processes and the whole organisation by focusing attention simultaneously on quality, delivery, flexibility, and cost. Therefore, in this step, the manufacturing processes in relation to the strategic

objectives within the strategic policy areas should be identified and the relevant competitive criteria to those key processes should be highlighted.

The creation of an input/output analysis for the manufacturing process is an essential step in understanding manufacturing systems. The suppliers, inputs, key processes, outputs, and customers have to be identified and defined (Miller and Roth, 1988). In identifying manufacturing systems, it is helpful to start with a simplified chart as illustrated in Figure 5.5. A manufacturing system starts and ends with customers. In between are identifiable processes that transform inputs into progressively more useful items. In Figure 5.5, these are represented by the two way arrows between manufacturing system analysis and customers, and next to the "performance measures and evaluation" process. These indicate important give-and-take interactions, implying that the inputs and outputs involved are dynamic. For example, the price that customers are willing to pay is variable. This factor will influence the measures to be selected later.



(Source: Modified from Hull 1998)

Figure 5.5 A generic manufacturing systems diagram

Brainstorming and flow diagrams are the two effective tools to identify manufacturing processes. The former is a group technique for generating new, useful ideas, the latter is a method of graphically describing the activities and sequences that produce some output in a process. In the accomplishment of Worksheet 4 the following questions should be answered (Neely et al 1996):

- What are the products or services produced?
- What are the inputs and their sources?
- What are the outputs (e.g. products and services)?
- Who are the customers (e.g. the users of the products and services)?
- What are the desired outcomes for each manufacturing process?
- What are the critical support functions (e.g. resource management)?

In identifying the manufacturing process, as stated previously, an understanding of what to measure is of critical importance, but usually there are many processes and activities within manufacturing systems, each potentially needing performance measures. The secret of a successful performance measurement, according to Ghalayini et al. (1997), is to clearly identify the "key" processes, that is, those having the most impact on the success or failure of the business, and select those processes that are most important to the customer both internal and external. In addition, the number of key processes should be kept at a manageable yet useful level. Too many can lead to a great many number of measures and resulting data. Too few can lead to inadequate information on which to support decisions (Harbour, 1993). At the end of this step, a list of manufacturing processes, key processes, and flow diagrams for these key processes can be developed.

5.3.5. Step 5 - Identify critical success factors to be measured

Aim: To clearly define performance measures areas and control points

Once the manufacturing strategies have been determined and manufacturing processes have been considered, the next step is to identify the critical activities of the manufacturing processes. The aim of this step is to examine each activity in the key manufacturing processes derived from Step 4 and to identify specific critical activities to set up control points.

Ganapathy and Goh (1997) point out that critical activities are those that significantly impact on efficiency, effectiveness, or productivity of a manufacturing process. They are the areas in which "good" performance is necessary to ensure attainment of the

goals defined by the manufacturing company's strategic objectives (Martin 1997). They are the manufacturing attributes that will have the greatest impact on product performance and manufacturing time, cost, and quality. The identification of critical activities is the process whereby the key cost, schedule, and performance drivers are identified and their importance defined (NAVSO, 1999). Therefore, it is important to choose only the critical activity to be measured, and the measure of these factors is to control them. As critical success factors determine how manufacturing objectives will be met, this step also needs to clearly address key issues and outcomes needed about the factors to be measured. Without this knowledge, there is no basis for making measurements (Tsang et al, 1999).

In identifying the critical activities, some of the most commonly asked questions are (Hodgetts, 1998):

- How do we know about our company's critical activity?
- What do our customers buy from us?
- What makes our company what it is?
- Why would our customers recommend our services?

The answers help highlight the critical activities and link them to manufacturing strategy policy areas.

The process of identifying critical activities is first to clarify those critical factors that are directly related to the ultimate goal of customer satisfaction (Hronec, 1993). Then use quality tools such as the Pareto principle, brainstorming, or examining data to help prioritise the critical factors. The next step is to confirm that the selected factors are critical. Many questions should be answered to help with the assessment (Neely et al. 1996): Does this factor need to be watched closely if its performance is less than desirable? Is it something that should be continuously improved? Does the benefit exceed the cost of taking the measurement?

If the answer is "no" to any of these questions, it is necessary to re-evaluate why the selected factor is critical. Finally, the competitive advantages that the company has to

focus on to differentiate itself from its competitors must be identified (Brown 1996). Examples for these areas of competitive advantages or key success factors are quick product development, new equipment, strong distribution system, information system, workforce, and technology (Hull, 1998). The end of this step is a list of the critical success factors of the key manufacturing processes, shown as in Worksheet 5 of Appendix D.

5.3.6. Step 6 – Determine performance goals

Aim: To agree performance measures specifications

For each critical activity selected for measurement, it is essential to establish a performance goal, to be achieved at the end of the monitoring period. Otherwise, there is no logical basis for choosing what to measure, what decisions to make, or what action to take (Kaplan and Norton 1996a). Performance goals can be a management directive or can be set in response to customer needs (Eccles, 1991). In identifying manufacturing performance goals, the first step is to determine the baseline for each of the measures selected. The baseline is an essential element of performance measurement. Without a baseline, goals are mere guesses (APQC, 1993). The next step is to determine performance goals for each measure after these baseline data are collected.

There are several ways to determine goals for future performance such as statistical analysis techniques as well as benchmarking. One of the methods is to take the customer expectations and market requirements of each of the product groups listed in Step 1 and 2 into consideration. Also, manufacturing companies can benchmark other internal processes, external competitors, and best practice. Benchmarking provides an effective technique whereby manufacturing companies compare themselves to world-class manufacturers. It is a systematic examination to locate and investigate other organisations' practices, processes and results in order to make a comparison (Zairi, 1996). Using this technique, a manufacturing company can learn what customers expect in terms of quality, what competitive goals are, and how to achieve them.

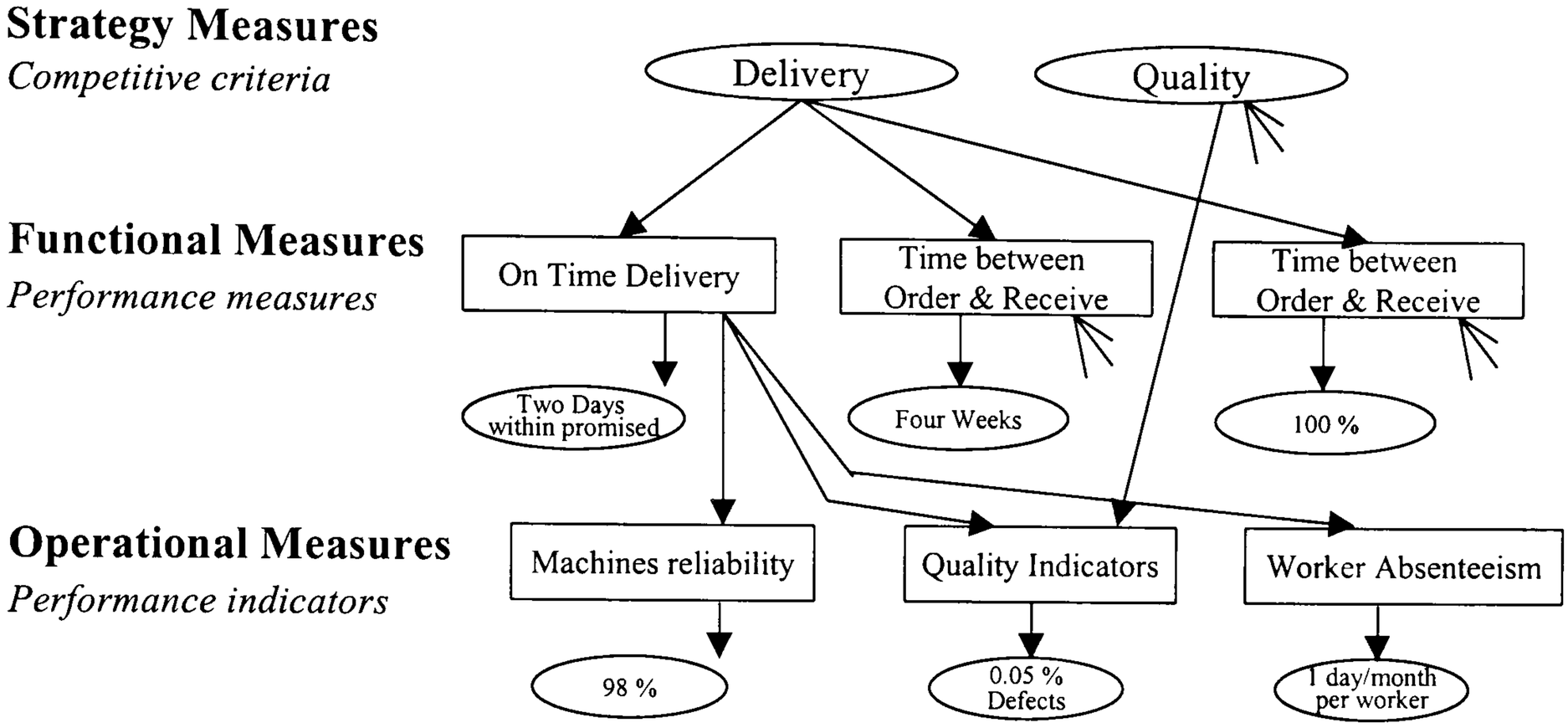
The establishment of performance goals can best be specified when they are developed in a hierarchical approach that shows a clear linkage to the manufacturing company's strategic policy areas and objectives (Cross and Lynch, 1988/1989). An example of the establishment of performance goals within a performance measures hierarchy is given in Figure 5.6, which is defined in three levels of measures:

- Strategy measures: These generally reflect the end goals based on the mission of a function.
- Functional measures: specific areas of accomplishment that satisfy major divisions of responsibility within a function.
- Operational measures: metrics designed to drive improvement and characterise progress made under each criterion. These are specific quantifiable goals based on individual expected work outputs.

The goal should be stated in simple terms using numbers, such as "Deliver 10,000 engines with fewer than three errors by the end of the month," or "Improve first pass yield to a minimum of 99.98% within six months." Good performance goals should be (NPR, 1999):

- Attainable: Should be met with reasonable effort under the conditions that are expected to prevail.
- Applicable: Should fit the conditions under which they are to be used. If conditions vary they should contain built-in flexibility to meet these variables.
- Consistent: should help to unify communication and operations throughout all functions of the company.
- Measurable: should be able to be communicated with precision.
- All-inclusive: should cover all interrelated activities.
- Understandable: should be expressed in simple, clear terms, so as to avoid misinterpretation.
- Customer focused: should address areas important to the customer (internal/external) such as cycle time, quality, cost schedule performance, and customer satisfaction.

The end of this process is a list of goals for each critical success factor within the manufacturing process, as shown in Worksheet 6.



(Source: Modified from Ghalayini et al. 1997)

Figure 5.6 Performance measures hierarchy example

5.4 Stage 2 - Overall system status monitoring

Once performance goals have been set, appropriate measures must be developed that monitor manufacturing progress towards achieving these aims. Without these appropriate measures there can be no progress towards becoming a world class manufacturer (Burcher and Stevens, 1996). The second stage in this framework is to determine what types of performance-related information are actually needed to better run and manage a manufacturing system. Knowing such performance–related information can help to identify which measures to collect. It can also help to identify who the right people are to receive the information and when it is required.

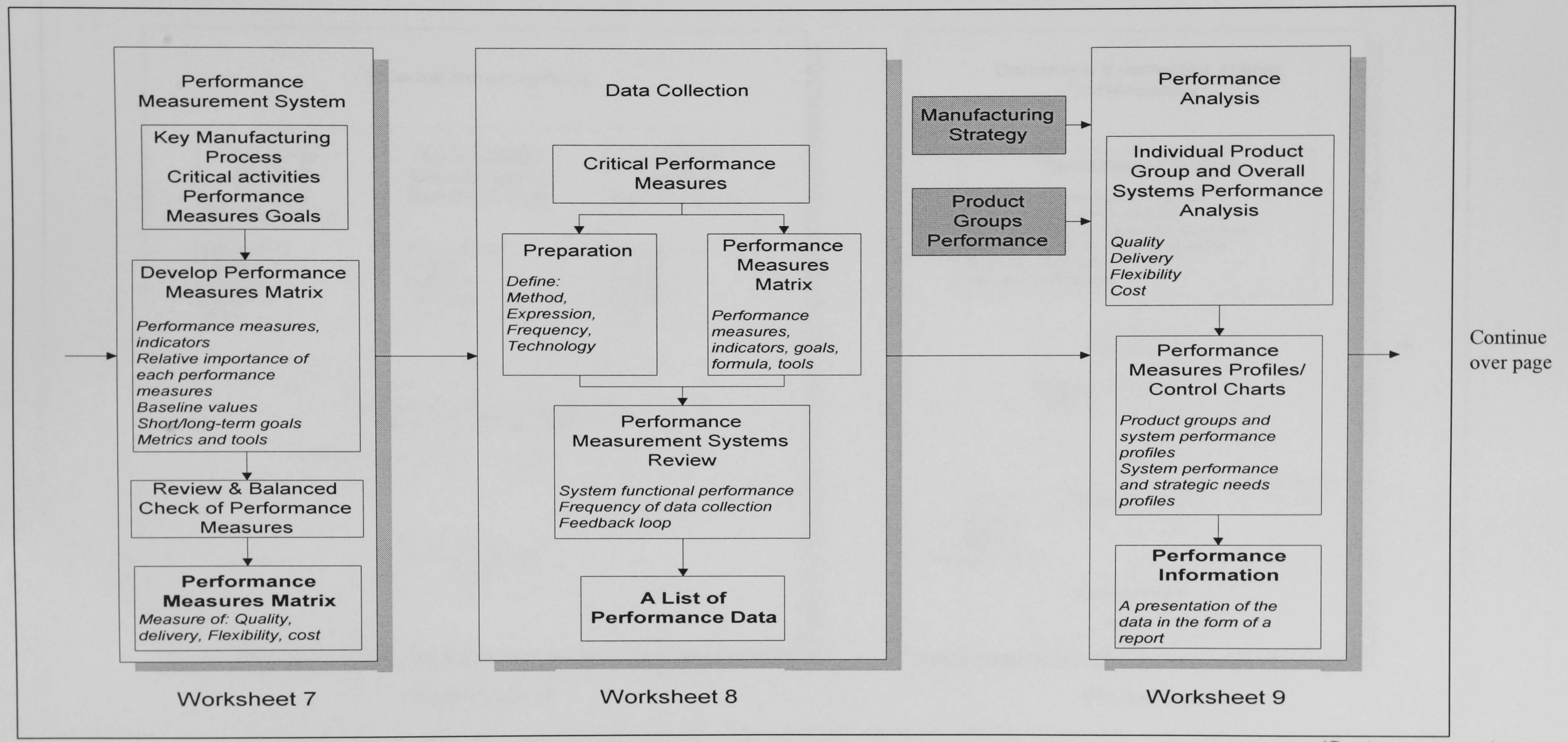


Figure 5.7 Steps of the overall system status monitoring

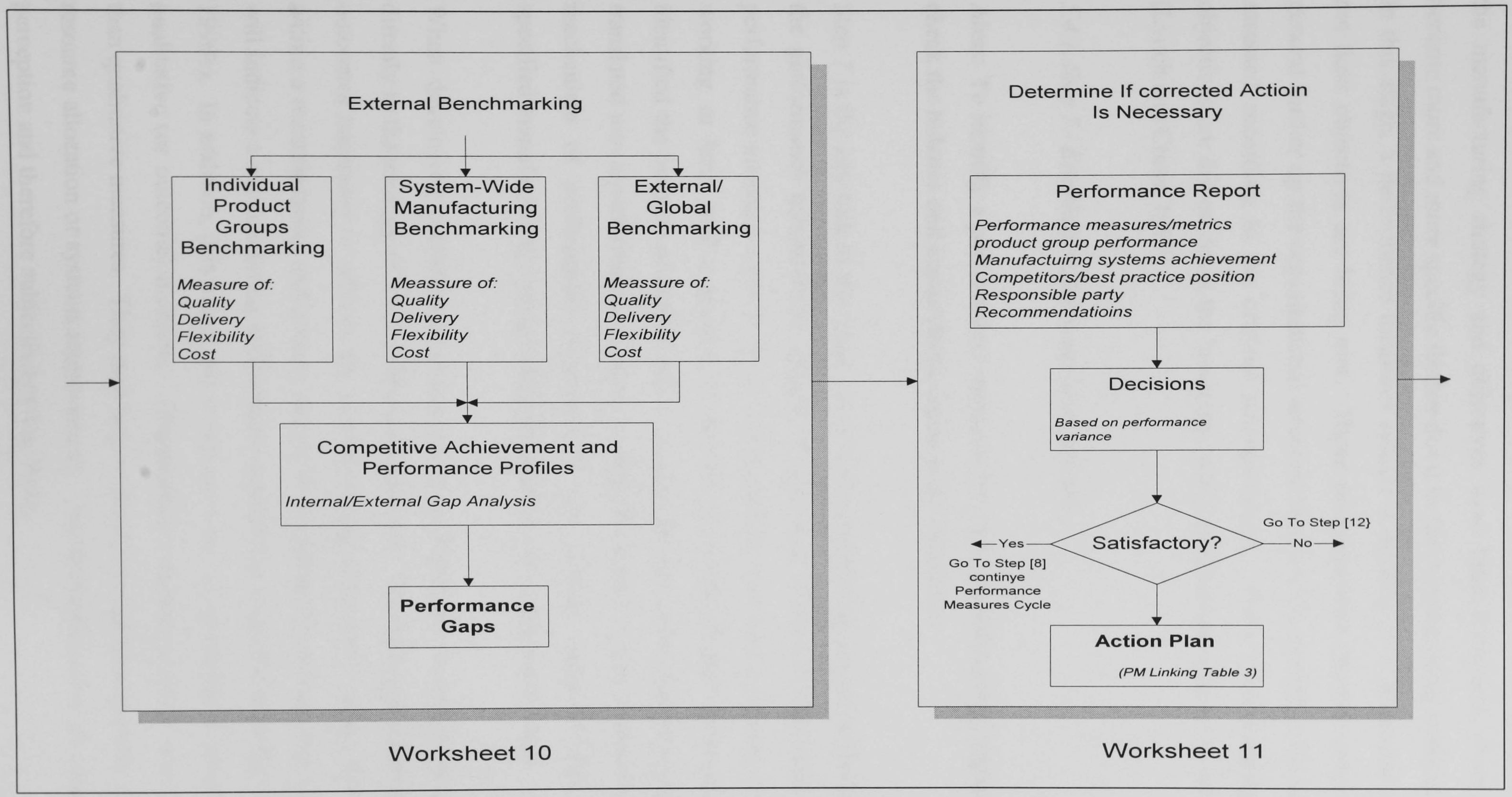


Figure 5.7 Steps of the overall system status monitoring

This stage consists of a number of steps as shown in Figure 5.7. In the previous stage, the manufacturing strategy and objectives have been identified, these objectives become more and more specific further down in the manufacturing systems hierarchy. In this stage, a performance measures system is developed to determine whether or not their objectives are being met. These measures then become more and more general further up the organisational structure to allow the system performance to be assessed according to the original strategic goals. Thus, manufacturing strategic objectives are driven down the hierarchy, while performance measures are driven up (Lynch and Cross, 1991).

5.4.1. Step 7 - Establish performance measurement

Aims: To identify a performance measure for each manufacturing objective and to check the balance and comprehensiveness of the measures

Step 7 is the key task in this stage. It involves performing several activities to build the performance measurement system. Bourne and Wilcox (1998) state that good performance measures exist to aid in understanding how well a process or activity is working or how well a product or service is produced and delivered. Having identified the purpose of critical activities and key processes, this knowledge is now translated into a performance measure. Using Worksheet 7, step 7 aims to establish a mechanism of performance measurement that directly supports the previously specified manufacturing strategy and performance measures requirement.

When developing performance measures, it is important to ensure that they link directly to the strategy of the manufacturing system. The measures must focus on the outcomes necessary to achieve the manufacturing objectives. Also, each objective within a manufacturing architecture should be supported by at least one measure that will indicate a manufacturing performance against that objective (Kaplan and Norton, 1996b). In addition, it is important to include a mix of quantitative (or process) and qualitative (or outcome) measures. Quantitative measures provide more objectivity than qualitative measures. They may help to justify critical management decisions on resource allocation or systems improvement. Qualitative measures involve matters of perception and therefore subjectivity (Wu, 1994).

Measurement of the success of a manufacturing system, however, is not a simple task. There are no set rules that each organisation can apply (Dixon et al., 1990). In order to help the accomplishment of this step, a matrix of competitive criteria (e.g. quality, delivery, flexibility, cost) and manufacturing strategy choices (e.g. capacity, facility, technology, supplier, organisation, control system) is used to stimulate the discussion. This is done through the following:

Comparative criteria	Key activities	Performance measures	Performance indicators
Quality	**Training:** Training methods and materials Personnel to train … **TPM:** Preventive maintenance RCM …	**Training:** 1st month: No. of personnel actually achieved goal 2nd month: no. of personnel actually achieved goal **TPM:** 1st month: Facility down time 2nd month: Facility down time	**Training:** proportion of total relevant personnel trained and average level achieved, at the end of monitoring period. **TPM:** No. of facilities (proportion of facilities) being under TPM, at the end of monitoring period.
Delivery Lead-time	…	…	…
…			

Table 5.4 Establishing strategy performance example

- Step 1: Select overall performance measures and indicators. To help this key process, a table (PM Table 1 – Performance parameters and indicators) illustrating the generic relationships between performance parameters and performance indicators, as shown in Table 4.1 and Appendix E, is provided to provide general guidance. This cause-effect table aims to help the identification of the right indicators to use for any given strategic concerns that are related to the critical success factors to be measured. An example of the possible outcome from this strategy/measurement linking process is given in Table 5.4.
- Step 2: For each of the component performance measures and indicators, determine its relative importance. The total of the weight for the constituent performance measures/indicators must add up to 100%.
- Step 3: Establish the baseline value for each performance measure/indicator.
- Step 4: Determine a long-term goal for each performance measure. This goal should be attainable.

- Step 5: Determine a short-term goal for each performance indicator.
- Step 6: Identify required metrics/tools such as formulae, utility weightings for the individual measures, and algorithms for calculation purposes. For example, metrics for a measure of yield quality might be the number of acceptable units produced divided by total number of units produced.
- Step 7: Develop a system for scoring and displaying results. See Figure 5.6.

An example of the performance measurement system development is illustrated in Table 5.5.

Measure Of	Performance measures & goals	Performance indicator	Relative importance	Performance indicators Goals	Metrics/tools (Partial)
Quality	First pass yield (99%) Conformance to spec. (100%)	Overall equipment effectiveness, OEE Rework rate Batches scrapped Product return rate Workers skill level	0.2 0.3 0.3 0.1 0.1	95 % 0.07 % 0.05 % 0.7% 75 % level 4	OEE = Availability x quality x productivity Not right first time = quality of defective units / total quality of units supplied
Delivery Lead Time	Manufacturing cycle time Defect rate (0.5%)	Time between order and receive Material throughput time Vendor on time delivery	0.5 0.2 0.3	11 weeks 55 days 99 %	Vendor on time delivery = No. of vendor deliveries early + late / Total no. of vendor deliveries
Delivery Reliability	On-time shipment (100%)	On-time shipment Speed of set ups Packaging quality Accuracy of shipment	0.45 0.2 0.2 0.15	98% 12 days 98% 100%	Delivery schedule achievement = [no of planned deliveries – no of late deliveries] / no. of planned deliveries
Design Flexibility	Engineering change (2.5%)	Develop time for new product Engineering time Number of change in projects	0.4 0.3 0.3	On time On time 0.8%	No. of new products introduced per year or no. of patents obtained
Volume Flexibility	Reduce set-up time (5%)	Production cycle time % of work force cross training Capacity utilisation	0.4 0.3 0.4	7 % improved 85% 90%	Production delivery ratio = Total production lead time / delivery lead time
Cost	Lapse rate (1%)	Downtime Workers absenteeism Floor space utilisation, FSU	0.5 0.3 0.2	0.7% 1 day/month per worker 75%	FSU = Turnover of model area / Square metres of model area People productivity = No. of units made / No. of direct operator hours

Table 5.5 The proposed manufacturing performance measurement example

In calculating the index, the current value for each performance indicator is measured. The score for each performance indicator is determined by multiplying the value and the weight. Once this is done, the scores are added together to determine the composite results. In this case, it yields a value of (15+24+25.2+17.4) = 82.6 for the quality measures. This could be compared to a baseline value for the index of 80 (baseline), and a goal of 86.9 (short term). See Table 5.6 below.

Quality Measures	**Performance Goals**				**Calculations**	
Performance Indicator	Relative importance	Baseline	Short-term	Long-term	Value	Score
OEE	0.2	75	82	91	75	15
First pass yield	0.3	80	88	95	82	24
Batches scrapped	0.3	80	87	92	84	25.2
Rework volume	0.2	85	90	95	87	17.4
Result	1.0	80	86.9	93.3	--	82.6

Table 5.6 The performance measurement matrix example

Having identified the relevant measures, the next step is to review the measures and make necessary adjustments to them so that they stimulate purposeful action when put into use. When conducting a view of performance measures, the balanced scorecard approach that integrates three important performance aspects in one simple management report is suggested. The strengths are that it summarizes many different management reports of a company into one and it forces management to consider all the performance measures at the same time (Kaplan and Norton, 1994). For our specific purpose, Worksheet 7 is designed into three areas to check the balance of performance measures matrix in accordance with the characteristics of manufacturing systems and performance measurement required. They are:

- The manufacturing process – the series of activities that consume resources and provide a product to the company's customers, either internally or externally.
- The organisation and human resources – which encompasses a set of performance measures and outcomes at the people and process and those doing the activities across divisions.

- The information and control – represents the planning and control functions of the manufacturing system and the processes involved in decision making.

During the measurement review, the task is first to confirm what should be measured. This can be achieved by applying the performance measurement questionnaire (PMQ). This model will help to identify which important measures are currently not being used and which currently used measures fail to contribute to the generation of needed information. Then the measures identified are checked so that a balanced mix of measures is used for the actual performance monitoring, as shown by the example in Table 5.7.

Vision
Mission
Strategy ⇨

Architecture	Strategic Objective	Performance Measures
Manufacturing Process	Technology leadership Manufacturing excellence Design productivity	Time to develop next generation Unit cost yield Engineering efficiency
Human Resources & Organisation	Workforce development Health & safety	# staff by skill area % injury/weekly
Information & Control	Production control system Infrastructure availability	application software failures % computer availability

Table 5.7 An example of balanced scorecard measures

Table 5.7 is based on the balanced scorecard approach. The aim is to balance internal and external requirements as well as financial and non-financial measures. This review lets the organisation make sure that it is maintaining the right measures. When measures become obsolete, they should be discarded, and possibly replaced with something else. To complete this step, the following need to be carried out:

- List previously identified key process/measures against policy areas, so as to check the completeness of the measures from the different perspectives, using Worksheet 7 (Table 5.8).
- Specify missing items if necessary, and use these to finalise Worksheet 7.

Manufacturing system	Manufacturing Strategy Choice	Objectives	Measures	Targets	Projects (Action plans)
Manufacturing Process	Capacity				
	Facility				
	Process & Technology				
	Product & Scope				
	Vertical Integration				
	Supplier Relations				
Human Resources & Organisation	Human Resources				
	Organisation				
Information & Control	Production & Control				
	Quality System				

Table 5.8 Worksheet 7 - balanced check

The actual system output can then be measured against this set of balanced measures, and recorded in Worksheet 7. After measurement review, if the system includes all the necessary measures, it can move to the next step, data collection (Step 8). If not, it must eliminate redundant measures and identify which additional measures are needed.

5.4.2. Step 8 – Collect Performance data

Aims: To collect performance data in accordance with defined table and to provide a basis for analysis

In this step, performance data that need to be collected depend on the indicators that are chosen. Step 8 is a natural progression from the previous steps where performance measurement systems are developed and performance measures are defined. It provides a systematic approach to the process involved in data collection. Performance data are a group of facts presented in quantitative or descriptive form. Having data is fundamental, for even the best of measurement systems have failed because of poor data collection (Clark and Zirner, 1993). Therefore, after the final set of critical performance measures has been determined, for each measure it has to be decided:

(1) How data should be tracked and collected (Brown, 1996).
(2) How data can be expressed in relative terms such as a rate or percentage to make reporting more meaningful and to allow comparison with results from other sources (Brown, 1996).

(3) How frequently data should be collected (Brown, 1996).

(4) What technology is needed (Provost, 1993).

(5) How measurement information will be communicated (Provost, 1993).

It should determine what data should be tracked, how they will collect it, and how measurement information will be communicated. In addition, data collection is much more than simply writing things down and then analysing everything after a period of time. A detail analysis is needs to be conducted to determine if the measurement system is functioning as designed, that the frequency of data collection is appropriate, and to provide feedback to the data collection when performance measurement has been changed. (Chang and Young, 1995).

The selection of tools for data collection depends on the data requirements. These tools may range from highly sophisticated computer applications to simple tables like the one represented in Worksheet 8 which is a list of performance data

5.4.3. Step 9 – Analyse current performance

Aims: To transform performance data into useful performance information and to identify performance gaps and a feasible solution, if possible

Performance data or results seldom provide meaningful information by themselves (Lebas 1995). After collecting the data it is essential to conduct measurement analysis to determine how well the indicators worked and how the results contributed to performance goals. The purpose of data analysis is to convert raw data into performance information and knowledge. Companies can then compare the actuality to what they had expected to happen, decide why there might be a variance, and determine what corrective action might be required (NPR 1999). Many tools are available for effective performance analysis. Off-the shelf software packages such as SAP III can perform statistical analysis, trend analysis, charting, quality, process cost analysis, and forecasting. Again, to help this process, a table (PM Table 2 – Strategic performance and causes) illustrating the generic relationships between strategic concerns and system considerations, as shown in Figure 4.3 and Appendix E, aims to

provide a general guidance to establish performance gaps and identify reasons for under performance.

The next step in analysing performance data is deciding how to present or display the data. The data is grouped in a form that makes it easier to draw conclusions. This grouping may take several forms: tabulation, graphs, or statistical comparisons (NPR 1999). However, at this step, the presenting or displaying of the performance data is intended to be a status transfer of information to the responsible decision-maker for the process. Therefore, the displaying of the performance data will consist of a set of profiles that track the performance measures, supplemented with basic conclusions. The worksheet to be used for Step 9 is to draw performance profiles and conduct gap analysis in accordance with the results of worksheet 8. Performance profile is used to aid the process of performance analysis. Using these values, a visual representation is provided indicating the different competitive criteria performance of both internal (individual product and the overall manufacturing system) and external (market requirements).

After summarising measured data, it is important to conduct measurement reviews to determine how well the indicators worked and how the results contribute to manufacturing objectives. The purpose of the measurement review at this step is to improve the measures for the next measurement cycle; to look for ways to improve the performance and effectiveness of manufacturing systems; and to make meaningful conclusions from the results. Several questions should be answered to complete this review (Clark and Zirner, 1993):

- Were the objectives met? If not, why not?
- Were the products acquired within budget and on-time? If not, why not?
- Did the indicators adequately measure the results intended? If not, why not?
- Were the objectives realistic?
- Did the results differ from what was expected or provide the information intended?
- What lessons were learned?
- What adjustments should be made to the measures?

- What actions or changes would improve performance?

On completion of step 9, the individual product group profile can be drawn, the overall manufacturing systems profile and manufacturing strategic planning profile can also be identified. Also, a "control chart" indicating product group and the overall system performance are developed to identify stability, capabilities, and trends of the manufacturing systems within different time periods, as shown in Figure 5.8.

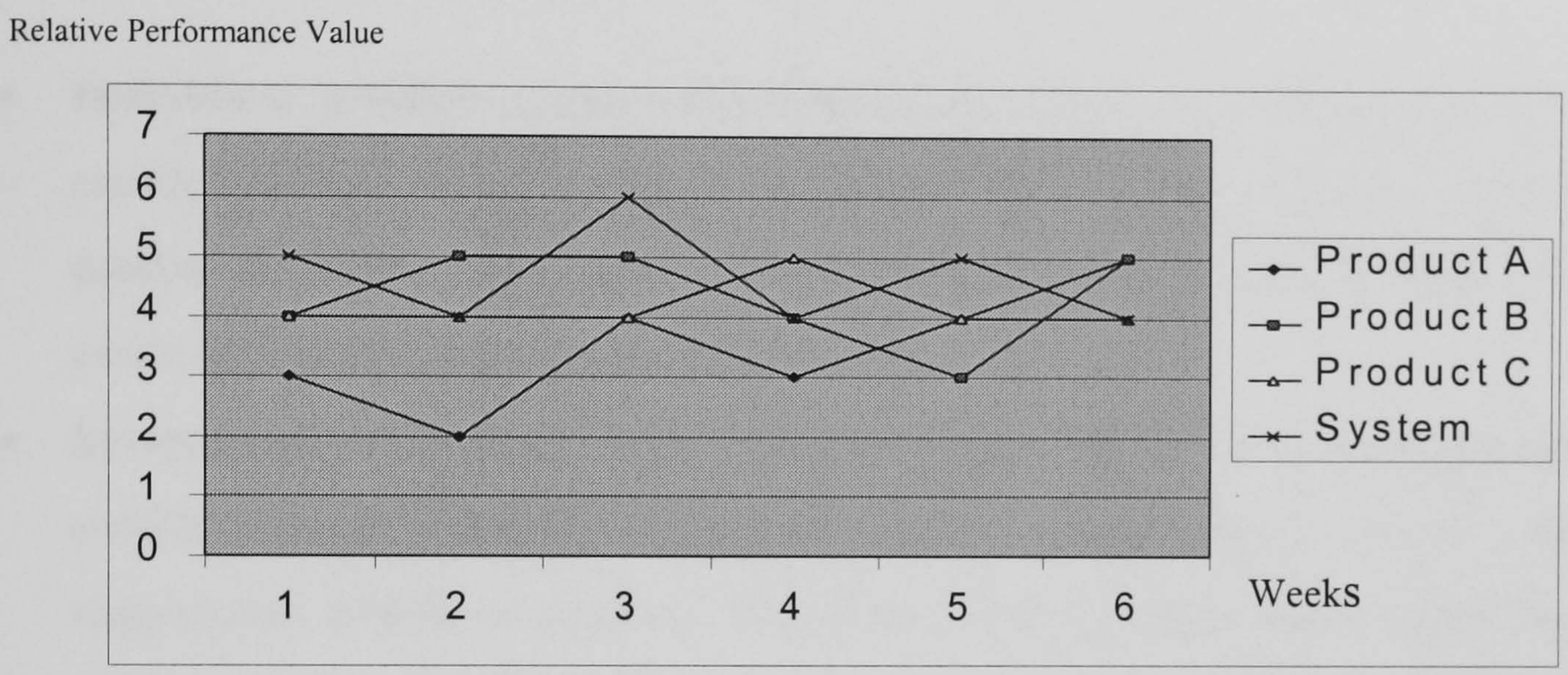


Figure 5.8 Progress chart – results of action plan performance

5.4.4. Step 10– Internal/External benchmarking

Aim: To identify external/best practice performance and to provide a basis for continuous improvement efforts

The gap analysis provides a simple comparison of the requirements and competitive performance of the manufacturing system for each of the product groups and of the system as a whole. However, it is necessary here to distinguish between the internal and external system performance gaps. The difference between these two is illustrated in Figure 5.8 – Different measures for manufacturing performance comparison, section 5.4.3. Whereas the internal gap helps a company identify the difference between its market requirement and its current systems performance, the external gap is based on the current best-practice through benchmarking, both providing an indication of future requirements.

Benchmarking is the process by which companies compare performance, in order to search and implement the best practices. It involves the systematic and continuous process to compare the performance of an organisation against the performance of the business leaders around the world. Therefore, benchmarking is a useful approach that can be adopted at this step, with the aim not only to identify manufacturing systems effectiveness, in terms of achieving a critical success factor based objective, but to help clarify probable reasons why the primary measure achieved or failed to achieve a particular value. Step 10 includes three areas of benchmarking. They are:

- **Individual product groups benchmarking,** based on individual performance profile of key product groups, compared with current strategic requirement profile, to identify the gaps, analyse their occurrence, and provide the most promising solutions to supplement the gaps.
- **System-wide manufacturing benchmarking:** based on overall performance profile, through utilisation values, compared with the current system's strategic requirement profile to identify their deficiencies, analyse and suggest the most promising solutions if needed.
- **External/global benchmarking:** the same as above, but focused on comparing with global expectation and/or industrial best practice to identify manufacturing systems' future direction.

When conducting external benchmarking, an AHP-based benchmarking process, developed by Korpela and Tuminen (1996), which integrates the Alcoa's 6-step benchmarking model and Analytic Hierarchy Process approach is relevant and can be applied in this research. The modified framework is based on the manufacturing requirements of the customers of the company performing the benchmarking process, which involves the following steps:

(1) Apply competitive criteria for benchmarking (deciding what to benchmarking). Competitive criteria (i.e. quality, delivery, flexibility, and cost) form the basis for the benchmarking process as they are the key variables on which companies' performances are compared.
(2) Identify the companies to be included in the analysis (Planning the benchmarking project). The companies to be included in the benchmarking process should not

be limited to the industry they are in. However, the key competitors should be included in the analysis.

(3) Analyse competitors/best practices performance (Studying others). The aim is to determine the importance of the competitive criteria and to analyse the performance of the companies with regard to each competitive criterion. Through the analysis, the companies having the best practices with respect to each competitive criterion can be identified and the gaps between the performance levels of different companies can be spotted.

(4) Define best approaches for the competitors/best practices (Learning from the data). The aim is to identify the processes, methods, or practices that have helped a company to achieve an outstanding performance level on a certain competitive criteria. AHP can be used to analyse and prioritise those processes or methods of each benchmarked company with respect to the competitive criteria.

(5) Analyse the company's situation and identify developmental actions (Using the findings). After defining the processes or methods for superior performance, the next step is to identify feasible actions that the company can apply to improve its own performance. The AHP hierarchy used for analysing the processes or methods provides the basic framework for analysing the strengths and weaknesses. The importance of the potential actions can also be determined by using AHP.

(6) Develop action plan. Based on the analysis, the action plan for improving the manufacturing performance is defined.

The AHP-based benchmarking process forms a logical framework for planning developmental actions as the potential actions can be linked to both customer's requirements and to the best company's processes or methods. The results of this step of the benchmarking process form the basic input for finalising the action plan for improvement, if any.

5.4.5. Step 11 – Determine if corrective action is necessary

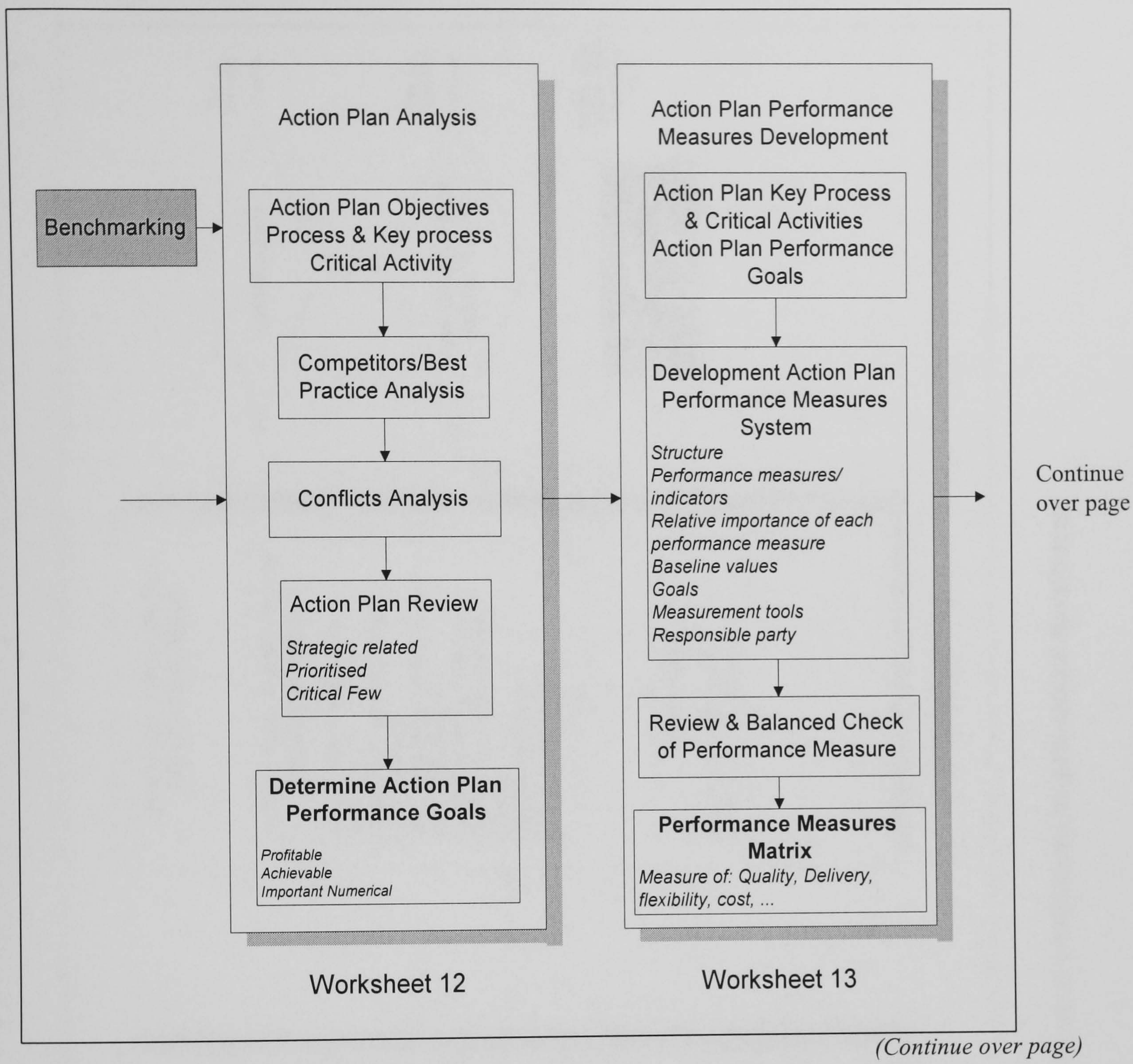
Aim: To develop a successfully implemented plan

Measurement only provides management with data. If the data are not used to make good decisions and to drive improvement efforts, a good measurement system is of little value (Brown, 1994). Step 11 is a decision step. It can either change the process or change the goal. If the variance is large, there may be a problem with the manufacturing process and corrections will need to be made to bring the performance back into line with the desired goal. If the variance is small, the manufacturing system is probably in good shape, but re-evaluating performance goals should be considered to make them more challenging. In addition, if management do make changes to the process, it will need to re-evaluate goals to make sure they are still viable. Once the comparison against the goal is initially established, there are three alternatives available for possible actions: (1) forget it (variance is not significant), (2) fix it, and (3) challenge the goal.

To help this process, a table (PM Table 3 – Strategic concerns and action plans) illustrating the generic relationships between strategic concerns and general actions, as shown in Figure 4.4 and Appendix E, provides a general guide to relate strategic aims to improvement programmes that may be initiated accordingly. The primary objectives of improvement are:

1. Remove manufacturing/product defects.
2. Remove the cause of manufacturing defects. Dependent upon the defect cause.
3. Develop a new manufacturing process to prevent defects from happening.
4. Maintain or enhance the efficiency and effectiveness of the process. This is an essential condition for continuing process improvement and ultimately increasing the competitiveness of the manufacturing system.

The output of this process is decisions based on performance variance. If there is no significant variance, then continue the data collection cycle step (8-11). If there is a variance between the goal and the performance measure, look at the magnitude. If it is significant, report to the decision-maker. If a decision to implement a corrective action is warranted, go to step 12 – continuous improvement cycle.



(Continue over page)

Figure 5. 9 Steps of continuous improvement monitoring

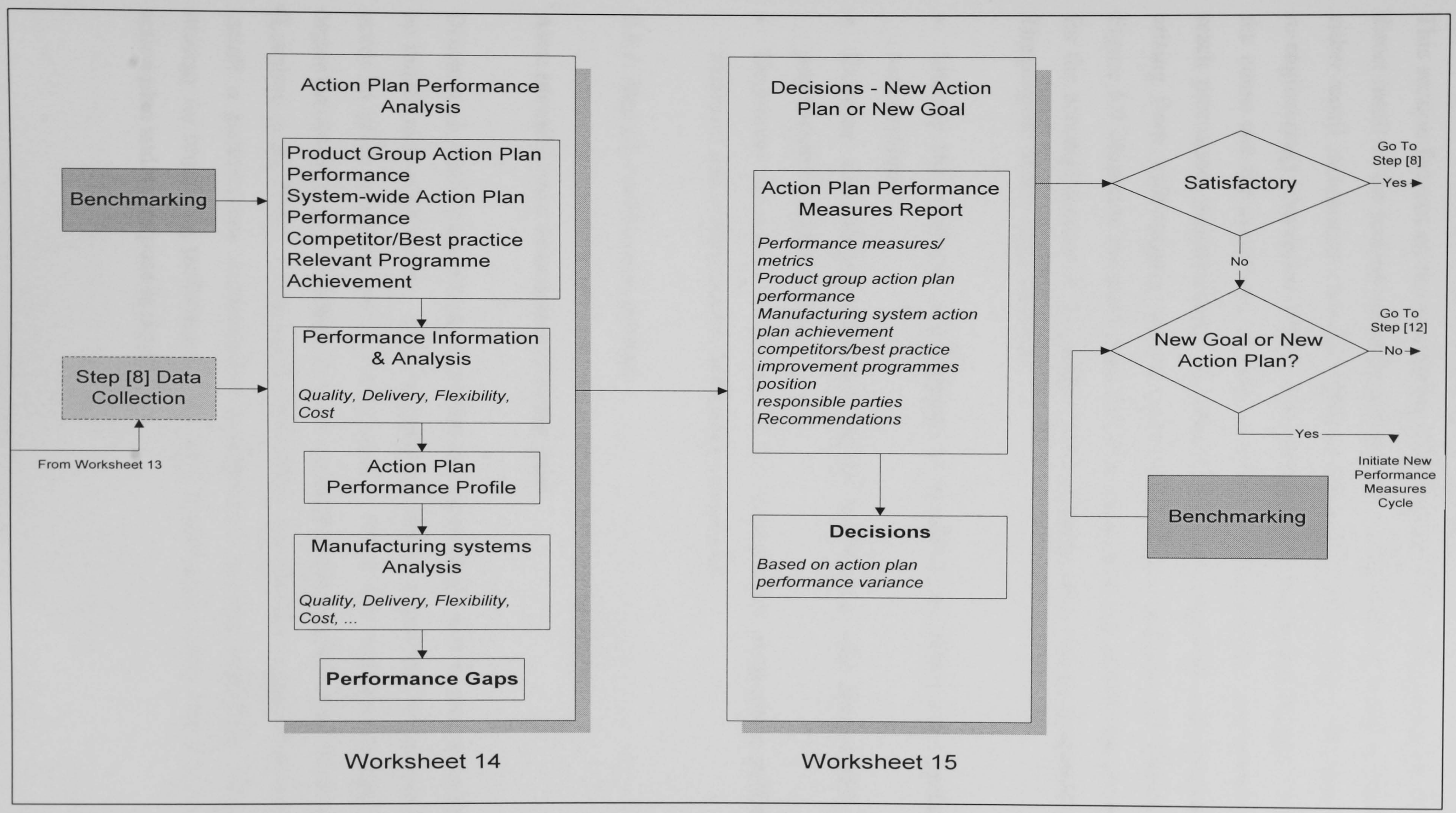


Figure 5.9 Steps of continuous improvement monitoring

5. 5 Stage 3 - Continue improvement monitoring

This section focuses on the monitoring of the system performance improvement as a direct result of the actions currently put in place. Improvement can be categorised as either small incremental change (TQM) or innovative step change (business process re-engineering) (Davenport 1993). The aim of small incremental change is to correct the cause not the symptoms in order to eliminate the problem permanently and to reach permanent improvement. In contrast BPR is concerned with breakthroughs arising from wide-ranging, radical questioning of the "big picture" (Bond, 1999). Figure 5.9 illustrates the main steps and their associated key points that are essential for the accomplishment of this stage. Each of these steps will be discussed in turn. The purpose of this stage includes:

- Identify the necessary requirements to complete the action plan performance measurement.
- Examine and eliminate conflicts of the action plan and the overall system performance measurement.
- Determine the necessary change of the improvement programme performance measures and overall system performance measures.

5.5.1. Step 12 – action plan analysis

Aim: identify what to measure of action plan

Dixon et al., (1990) argue that alignment among strategy, action, and measures must be maintained at all times. When a company makes improvements in one area, it needs to place emphasis on the other areas. When this strategic change occurs, organisations need new measures that are aimed at measuring the new critical activity (Lakshmi et al., 1998). Clark and Zirner (1993) state that the organisation wishing to install a performance improvement measurement system must first identify its strategy for improving performance. As such, the purpose of this step is to know the action plan and its purpose in detail.

The process and technique used in this step is the same as Step 3 - Manufacturing strategy analysis, needing therefore little explanation. Shown as in Worksheet 12, the key processes involved in this step include:

- Identify action plan's strategy and objectives.
- Know action plan's process and key process, if any.
- Define action plan critical activity (or improvement areas) in terms of manufacturing choices (e.g. capacity, facility, technology, organisation, etc.).
- Narrow down critical activity into vital few measures.
- Allocate vital few measures into the six areas of competitive criteria for future analysis.

At the end of this step, the action plan strategy and the importance of policy areas and their goals and approaches will be identified. Once the strategy, process, and factors necessary to achieve the action plan's goals have been defined, it becomes fairly easy to begin to identify important measures.

5.5.2. Step 13 – Define action plan performance measurement requirement

Aim: Determine action plan performance measures' goal, key performance indicators, and metrics/tools

This is the same table framework as Worksheet 7 - Performance measurement system development, but specifically focuses on action plan performance measures. The objective is to identify action plan performance in order to measure it. It is to define each of the six competitive criteria (quality, delivery lead-time, delivery reliability, design flexibility, volume flexibility, and cost) in terms of the target action plan's own performance strategy and measures. It is to determine what measures are necessary to provide the users with the information they need. The key processes involved in this step include:

- Identify the importance of factors that the current action plan(s) are concerned with.

- Use performance measures hierarchy techniques to develop action plan performance indicators/drivers and their goals.
- Select tools/formulae for the accomplishment of those measures
- Assign improvement programme responsibility, milestones, and frequency of measures

Once the action plan performance measures have been identified, the next step is to check the completeness of the improvement programme, including action plan performance measure, performance indicators and goal, and process concerned. However, although the action plan can be measured through its operation, it is less important to measure it individually (Hill 1993). As the action plan is regarded here as an integral part of the manufacturing system activities, it is difficult to measure individual performance but the overall product and system performance should reflect the effects of the action plans currently executed.

Therefore, after the action plan performance measures have been confirmed, it is essential to convey them into Step 7, together with the established system performance measures to check their completeness and balance as a whole. The overall manufacturing system performance measures review should especially focus on:

- Identifying conflicts between the new (action plan) and the old performance measures (existing system).
- Determining if there is a need to change the new added and/or the existing performance measures.
- Balancing checks of the overall performance measurement system.

After the overall system performance measures (including improvement programme action plan performance measures) have been reviewed from Step 7, the next step is data collection. Action plan performance data is collected from Step 8 of system performance monitoring stage and recorded in Worksheet 13. The output of this step is a list of action plan performance data prepared for analysis in the next step.

5.5.3. Step 14 – Action plan performance Analysis

Aim: Transfer action plan performance data into performance information and perform gap analysis

The objective of this step is two-fold: (1) to draw and compare an action plan performance profile with established goals to identify performance gaps, and (2) to conduct a gap analysis to identify performance variance. Once the action plan performance data are collected, in this step performance data is first transferred those data into performance information. It is then to analysing action plan performance gap. This can be achieved by using utility function and relative importance techniques to identify the action plan performance of individual product groups as well as the overall manufacturing system. The results of the action plan performance information can be recorded in Worksheet 14.

The next step is to draw the action plan performance profile. Two types of performance profile should be considered in this step:

(1) Radar diagrams, which indicate the action, plan performance gap of actual performance and pre-determined goals of the six areas of competitive criteria.
(2) Run charts, which help management to identify action plan performance trends and shifts in the manufacturing process over a specific period of time.

Action plan gap analysis should place equal emphasis on target achievement and performance improvement. As shown in Figure 5.10, with the multiple method applied here, it is possible the overall system performance declines, while the individual action plan performance still increases. It means another action plan should be initiated. In contrast, if the overall performance increases and the action plan performance decreases, it means the action plan strategy has less influence on the overall performance (less contribution). A new action plan is needed. On completion of Step 14, the individual product group action plan profile can be drawn, and the overall manufacturing systems action plan profile can also be identified. A control chart indicating product group and the overall system action plan performance are

developed to identify stability and trends of the improvement programme within different time periods.

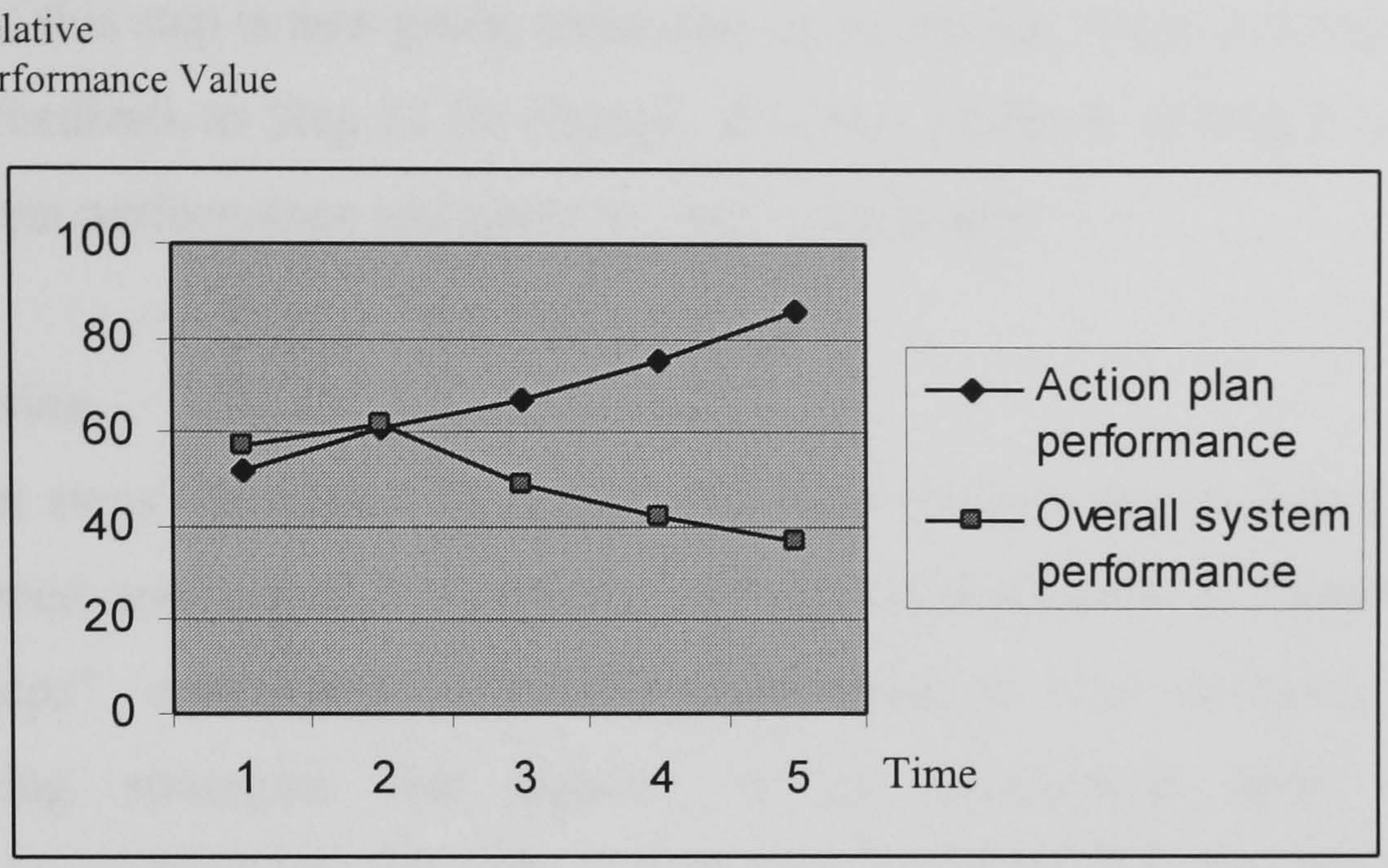


Figure 5.10 The contribution of action plan performance and the overall system performance measures

5.5.4. Step 15 Make decision

Aim: Determine if new action plan performance goals or measures are needed

The final step of this process is a decision-making process. Step 14, Action plan performance analysis, focuses on gap analysis and provides performance information for management to determine if any further corrective action(s) is necessary. Step 15 evaluates the established action plan performance measures and goals. It is to determine whether a new action plan or new goals are needed or not in accordance with performance variance. If previously set goals are difficult to attain, or not reached at all, then it may be reasonable to re-adjust expectations. This also applies to goals that are easily met.

The decision to create new performance measures or goals depends on two major factors:

- The degree of success in achieving previous goals.
- The extent of changes to the manufacturing processes.

The result of this step is new goals, measures, or no change. Once a decision has been made, it is feedback to Step 12 for change. It is also feedback to Step 3 to change the overall system performance and goals to meet congruency.

5.6 Conclusion

The "fifteen steps" discussed in this chapter showed how the proposed framework was developed and linked it to existing theory (as discussed in Chapter 2). The "fifteen steps" constituted a measurement process that includes translating manufacturing strategies into actions at the operational level; developing measurement mechanisms; measuring, analysing and communicating the results; and finding ways to improve performance. The fifteen-step approach is a logical sequence of tasks. In practice, some steps can be combined. Because performance measurement is an iterative process, it is expected that manufacturing companies can apply the fifteen steps repeatedly to obtain effective performance measures and improve performance. The following chapter is concerned with the evaluation of the proposed framework and the implementation process.

CHAPTER 6 EXAMPLE AND CASE STUDIES

6.1 Introduction

Chapters 4 and 5 showed how the proposed framework was developed and linked it to the existing theory. Chapter 6 describes the testing of the proposed framework. Three Taiwanese military plants, which were the sponsor companies of this research, were involved with the intention to use the proposed framework practically and demonstrate its usefulness.

Throughout the course of case studies, three UK manufacturing companies were also involved with respect to the investigation of the wider applicability of the proposed framework. These were accomplished by interviewing management of the three selected UK companies to seek their comments and suggestions. The selection of these companies was because they were the only companies that would accept interviews, after a total of 122 UK manufacturing companies selected from the FAME database. The objective was to identify data, which could be compared with the results of the three Taiwanese cases, and to identify specific characteristics of the proposed framework, which improved the chances of successful application. A summary of the case companies is illustrated in Table 6.1.

Company	Products	Number of Employee	Turnover (£ Million)	Interviewee(s)	Location
A	Missiles and ground support equipment	500	N/A	Plant manager Shop managers	Taiwan
B	Utility vehicles/trucks	950	N/A	Plant manager Shop managers	Taiwan
C	Armour/combat vehicles	1350	N/A	Plant manager Shop managers	Taiwan
D	Nylon, Polymer	500	160	Production control manager Human resources manager	UK
E	Products for the isolation, identification and enumeration of bacteria	377	64.5	Manufacturing Director	UK
F	Colour TV, Monitor Telephone/Fax machine	538	80	R&D Director Manufacturing manager Mfg. Engineer	UK

Table 6.1 Summary of case companies

The structure of the chapter is divided into three sections. It first provides an example of the proposed framework process using a conceptual company, the Firepower Company, with features reflecting a combination of factors from the three Taiwanese military plants. The results from the three Taiwanese case companies using the framework are summarised in the subsequent section. Then, it seeks the wider application of the proposed framework through the UK case studies. Finally, it focuses on an analysis of the findings and lessons learned from the total six cases of Taiwanese and UK companies.

6.2 Example application

The purpose of the following example is to illustrate how the proposed framework's key features were applied in a practical sense. However, due to the similarity between system status monitoring and continuous improvement monitoring, the relevant information will merely be given rather than derived in step to step detail.

6.2.1 Company background

Firepower has been in business for 25 years. It is a company involved in the design, manufacture, and marketing of electrical and electronic power equipment and technology for the defence industry. Manufacturing capabilities include fabrication, assembly, and test of magnetic components and systems, welding and sheet metal. In addition, Firepower has extensive capabilities and facilities for engineering and production testing to meet military specification requirements.

Firepower follows a manufacturing strategy in which programmes are selected based on market needs. Emphasis is placed on internally funded research and development programmes to ensure high product performance and quality, efficient product producibility, and consistent cost improvements. It focuses on customer satisfaction and provides a full spectrum of support services, including total integrated logistics support, training, field service, and depot repair capability. The Firepower management is committed to TQM and to developing a world class manufacturing capability.

However, with the end of the Cold War, the Firepower Company is under intense pressure to improve its operations and deliver its products and services more

efficiently and at the least cost to the taxpayer. In understanding their situation, the management of the Firepower Company felt that developing a new performance measurement for the manufacturing system would be beneficial. Why?

- To ensure that customer requirements are being met.
- To ensure an understanding of the process by all employees.
- To ensure an effective and efficient manufacturing system.
- To ensure decisions are based on fact, not on emotion.
- To show where improvements need to be made.

6.2.2 Stage 1 – Strategy-oriented performance measures

(1) Products and product group

The first step (see section 5.3.1, worksheet 1) is to obtain basic product data to identify the most important product groups. Firepower products can be identified into four groups:

- Product group #1: Equipment for generation and distribution of all types of military electrical power for data acquisition and electrical control systems.
- Product group #2: Ground based products including inverters and converters for use in unmanned air vehicles and command shelters, radar site generator sets and distribution equipment for battle tank use.
- Product group #3: Accelerometers, frequency converters, inverters, rectifiers, sensors, and transducers for aviation applications.
- Product group #4: AC and DC motor drivers, adjustable speed drives, line power conditioners, generators, power distribution systems, and sonar power supplies for surface ship applications.

The product group analysis (see section 5.3.2, worksheet 2) gives the following indicators of the relative importance of each product group to the business: Product group #1: 35%, Product group #2: 30%, product group #3: 20%, Product group #4: 15%.

(2) Identify manufacturing strategy

Manufacturing strategy and the associated policies are typical within a company's strategic plans. Firepower's manufacturing objectives are two fold: (1) increasing product quality, and (2) decreasing delivery lead-time. The manufacturing policies can be captured and reviewed (sees section 5.3.3, worksheet 3) in order to identify their goals, critical activities and further develop performance measures. Table 6.2 illustrates Firepower's manufacturing strategic goals and shows how these goals are related to the company's competitive criteria.

Manufacturing Policy Area	Policies	Goals	Competitive Criteria					
			Q	DL	DR	DF	VF	C
Manufacturing process architecture								
Capacity Facility Processes & technology Vertical integration Supplier relationship Scope & new product	•Rationalise material flow •Development of Kanban control with suppliers •Low ownership integration •Increase capacity through new facilities and qualified workforce •More strategically oriented make/buy structure –subcontract volume and easy components, and keep more demanding parts and processes in house	•Adjust capacity rapidly within a short period •Handle variations in customer delivery schedule •Minimum economic floor space •Run equipment at peak efficiency •Reduce manufacturing lead time •Handle changes in the product mix quickly •Ensure consistency in manufacturing	X	X X X	X X	X	X X	 X X X
Human resources and organisation architecture								
Human resources Organisation	•Recruit qualified staff •Further enhance existing on-job-training programme •Decentralised decision making •Flat organisation	•Effective and efficient organisation •Improve labour productivity	X	X			X	X X
Information and control architecture								
Planning & control Quality system	•Establish effective system and adopt useful techniques to reduce inventory and improve production planning and control •Maintain the high standard that has so far been achieved	•Ensure conformance of final product to design specifications •Control production within minimum costs •Meet delivery dates •Ensure accuracy in manufacturing	X X		X	X		X

(Q: quality, DL: delivery lead time, DR: delivery reliability, DF: design flexibility, VF: volume flexibility, C: cost)

Table 6.2 Worksheet 3 - Identify manufacturing strategy for Firepower

(3) Identify manufacturing processes

Typically an integrated manufacturing systems process can be categorised into three stages: product design, process planning, and implementation (Hitomi, 1994a). In the example case, it primarily focuses on the "implementation" stage of the manufacturing system. This is because in a real situation, the three Taiwanese military plants act as the 'pure' production entity, while R&D is supported by other institutions. The Firepower Company's manufacturing process is identified (see section 5.3.4, worksheet 4) and shown in Figure 6.1.

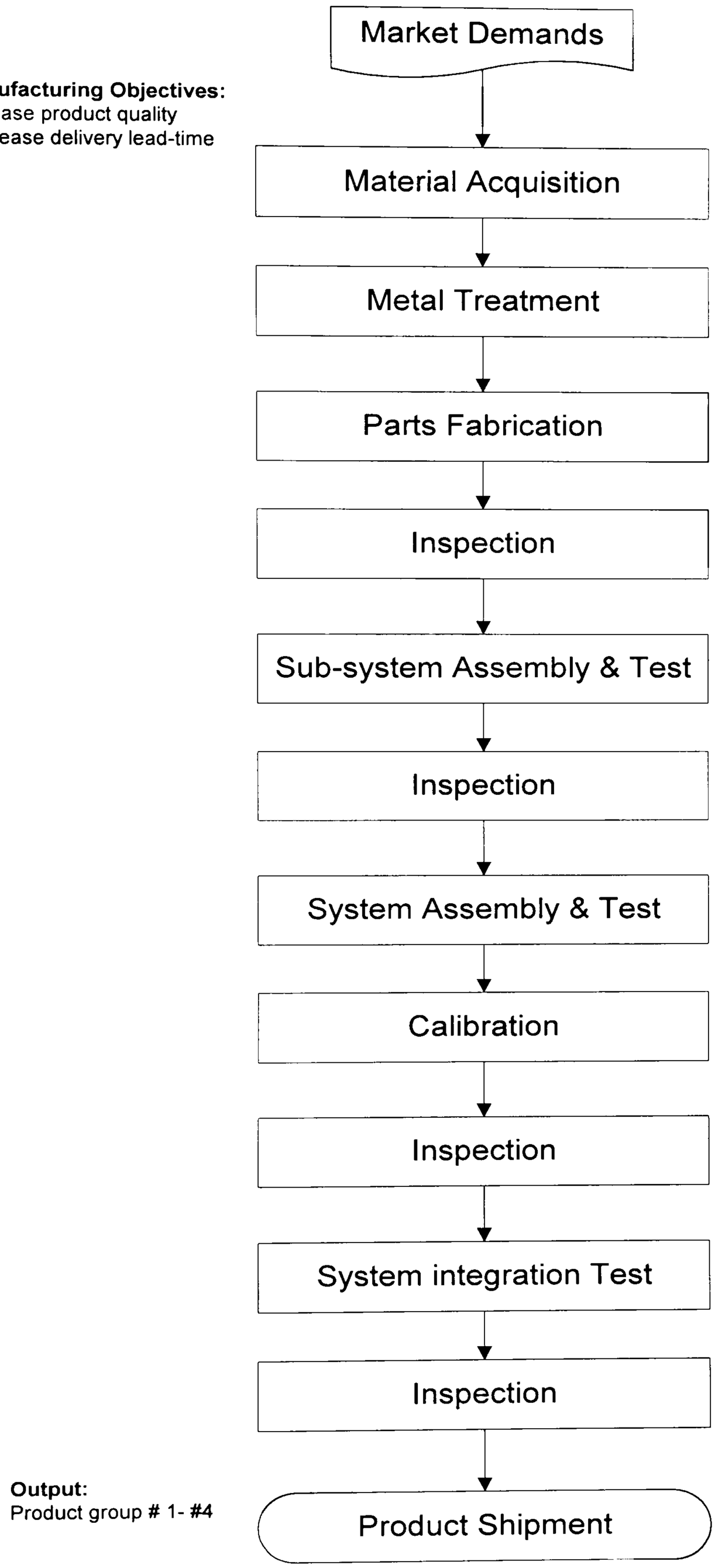


Figure 6.1 Step 4 - Identify manufacturing process

(4) Identify critical activity to be measured

The next step is to determine how Firepower's manufacturing objectives and the associated policies goals will be met. As discussed in Chapter 4 and 5, the critical activities are those that directly or indirectly relate to the ultimate goal of customer satisfaction. Therefore, it is essential to examine each activity in the process and identify those that significantly impact total process efficiency and effectiveness, with the purpose of identifying specific critical activities being to set up the control points. The Firepower Company's critical activities are captured (see section 5.3.5, worksheet 5) and shown in Figure 6.2. There are four sets of critical activities that need to be watched closely and acted on if performance is less than the desired goal. The reason that these were considered critical is that they are the sets of activities that produce the outputs.

- Control point 1 is when to produce the parts.
- Control point 2 is when to assemble and test the sub-systems.
- Control point 3 is when to assemble and test the systems.
- Control point 4 is when to perform a system integration test.

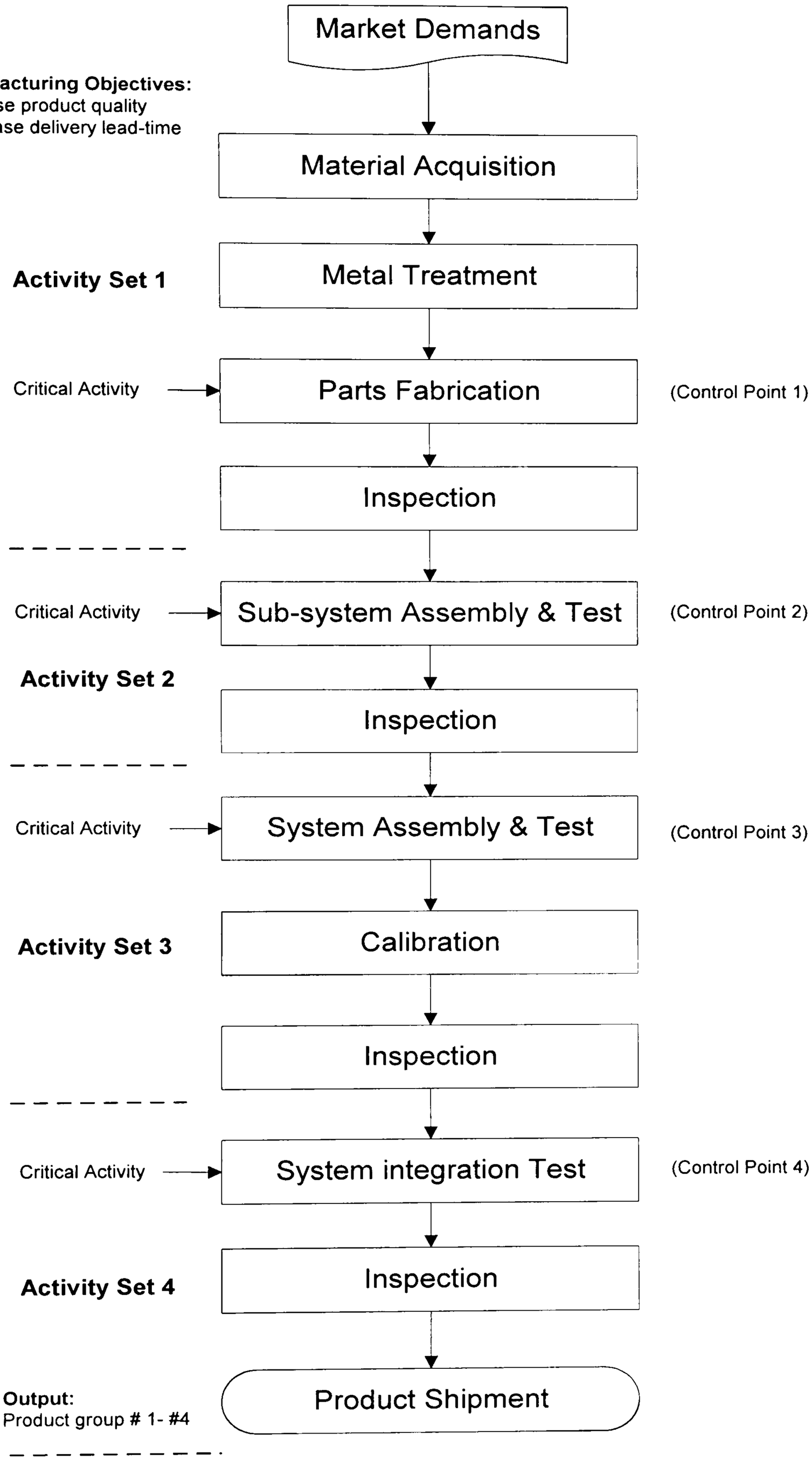


Figure 6.2 Step 5 – Identify critical activity for Firepower

(5) Establish performance goals

For each control point selected for measurement, it is necessary to establish a performance goal. Performance goals are an "aimed-at" target. Without a goal, there is no logical basis for making a decision or taking action (BMP, 1995). Recalling Chapter 5, the basis for the performance goal chosen is based on the review of manufacturing strategy, objectives and policies. Looking at the critical activities identified in Step 5, Firepower's performance goals are established (see section 5.3.6, worksheet 6) and shown in Figure 6.3.

The performance goals of each critical activity are summarised below:

- Critical Activity 1, parts fabrication: (1) 99% first pass yield, (2) 5% reduce set-up/change over time.
- Critical Activity 2, sub-system assembly and test: (1) 1% lapse rate, (2) 0.5% defect rate.
- Critical Activity 3, system assembly and test: (1) 1% assembly line defect rate, (2) manufacturing cycle time, (3) 10% reduce manufacturing lead time.
- Critical Activity 4, system integration test: (1) 0.5% systems return rate, (2) 100% conformance to specification, (3) 100% on time shipment.

After the performance goals have been identified, the next stage is to identify specific performance measures for the four critical activities.

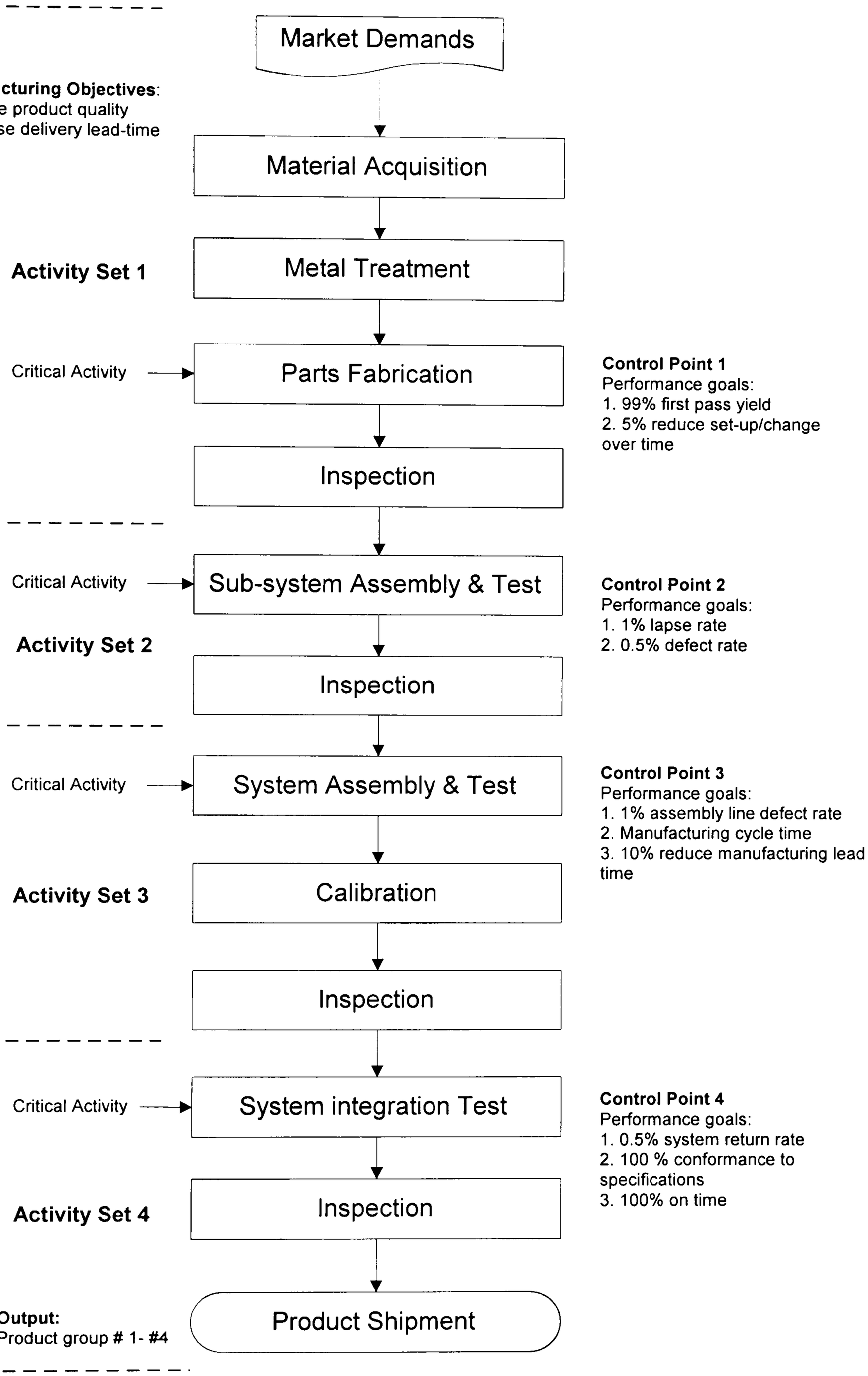


Figure 6.3 Step 6 – Establish performance goals for Firepower

6.2.3 Stage 2 - Overall system status monitoring

(1) Establish performance measurement

Table 6.3 (see section 5.4.1, worksheet 7) shows how Firepower's current manufacturing strategy objectives can be related to a set of balanced measures. The PM Linking Table 1 - Performance parameters and indicators, as discussed in Chapter 4 and shown in Appendix E, can help with the selection of performance indicators. At the end, the identified performance goals and performance indicators in each control point should be re-assessed and allocated into the competitive criteria of quality, delivery, flexibility, and costs to be measured, shown in Figure 6.4.

Measure Of	Performance measures & goals	Performance indicator	Relative importance	Performance indicators Goals	Metrics/tools (Partial)
Quality	First pass yield (99%) Conformance to spec. (100%)	Overall equipment effectiveness, OEE Rework rate Batches scrapped Product return rate Workers skill level	0.2 0.3 0.3 0.1 0.1	95 % 0.07 % 0.05 % 0.7% 75 % level 4	OEE = Availability x quality x productivity Not right first time = quality of defective units / total quality of units supplied
Delivery Lead Time	Manufacturing cycle time Defect rate (0.5%)	Time between order and receive Material throughput time Vendor on time delivery	0.5 0.2 0.3	11 weeks 55 days 99 %	Vendor on time delivery = No. of vendor deliveries early + late / Total no. of vendor deliveries
Delivery Reliability	On-time shipment (100%)	On-time shipment Speed of set ups Packaging quality Accuracy of shipment	0.45 0.2 0.2 0.15	98% 12 days 98% 100%	Delivery schedule achievement = [no of planned deliveries – no of late deliveries] / no. of planned deliveries
Design Flexibility	Engineering change (2.5%)	Develop time for new product Engineering time Number of change in projects	0.4 0.3 0.3	On time On time 0.8%	No. of new products introduced per year or no. of patents obtained
Volume Flexibility	Reduce set-up time (5%)	Production cycle time % of work force cross training Capacity utilisation	0.4 0.3 0.4	7 % improved 85% 90%	Production delivery ratio = Total production lead time / delivery lead time
Cost	Lapse rate (1%)	Downtime Workers absenteeism Floor space utilisation, FSU	0.5 0.3 0.2	0.7% 1 day/month per worker 75%	FSU = Turnover of model area / Square metres of model area People productivity = No. of units made / No. of direct operator hours

Table 6.3 Worksheet 7 – Establish performance measures for Firepower

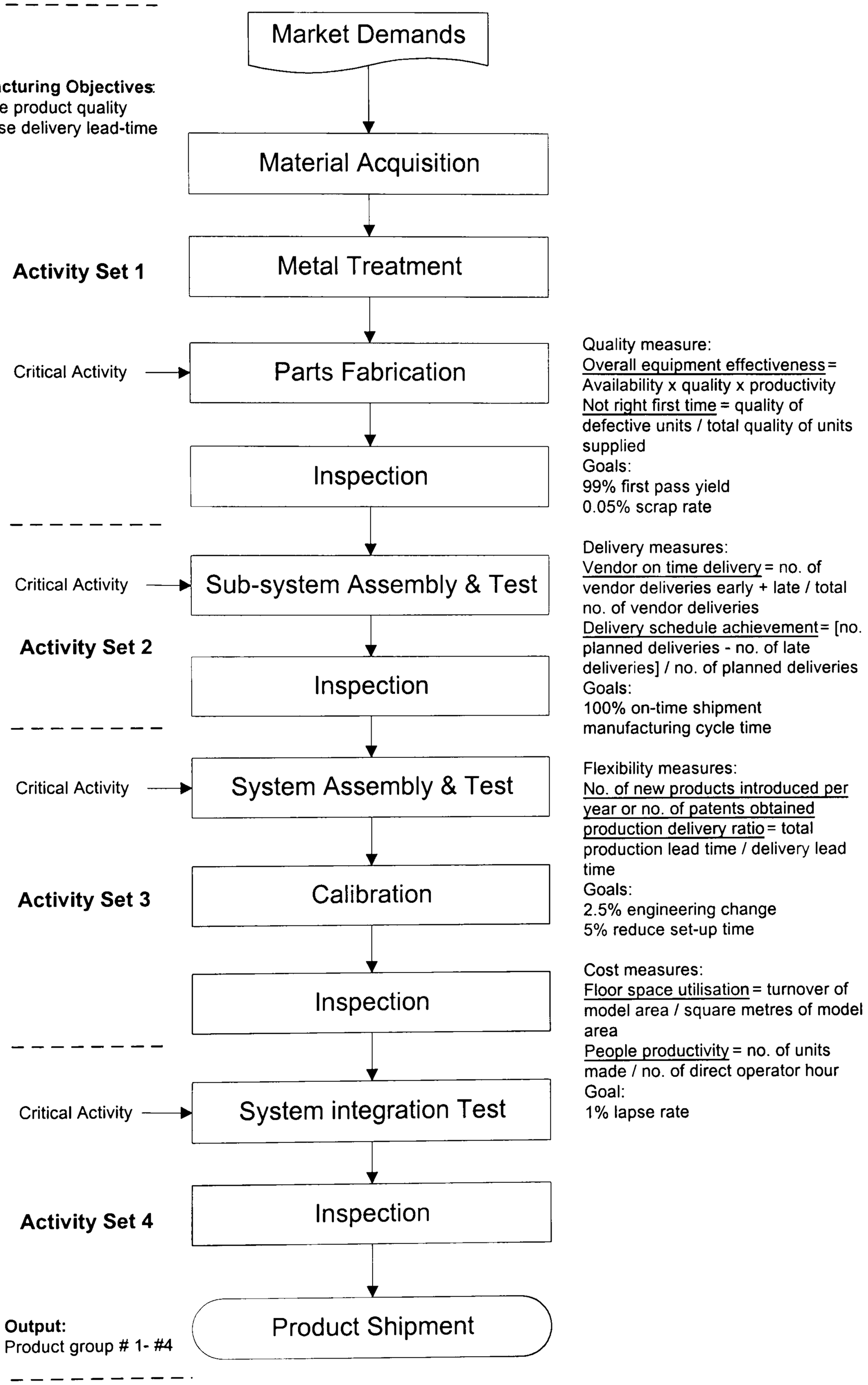


Figure 6.4 Step 7 – Establish performance measures for Firepower

(2) Analyse actual performance

After the performance measurement system has been developed and the data has been collected, the next step is to analyse actual performance. The analysis of Firepower's manufacturing strategy, current performance of the individual product groups and the overall manufacturing system are summarised in Tables 6.4 and 6.5 respectively.

Requirements	Group 1	Group 2	Group 3	Group 4	System (Σ)
Importance	35%	30%	20%	15%	100%
Quality	95	90	90	95	92.5
Delivery Lead-time	90	85	95	90	89.5
Delivery Reliability	90	90	95	90	91
Design Flexibility	65	70	75	65	68.5
Volume Flexibility	70	75	65	70	70.5
Cost	70	70	65	65	68.25

Table 6.4 Summary of requirement analysis for Firepower

Measure of	Group 1	Group 2	Group 3	Group 4	System (Σ)
Importance	35%	30%	20%	15%	100%
Quality	90	80	80	85	84.25
Delivery Lead-time	90	90	90	90	90
Delivery Reliability	90	85	90	90	88.5
Design Flexibility	70	75	70	70	71.5
Volume Flexibility	80	85	75	85	81.25
Cost	55	60	50	55	55.5

Table 6.5 Summary of current performance analysis for Firepower

The gap analysis profile in relation to the above two tables is given in Figure 6.5. The requirement/performance gap values are calculated and produce the results as shown in Table 6.6.

Measure of	Group 1	Group 2	Group 3	Group 4	System (Σ)
Importance	35%	30%	20%	15%	100%
Quality	-5	-10	-10	-10	-8.25
Delivery Lead-time	-	5	-5	-	0.5
Delivery Reliability	-	-5	-5	-	-2.5
Design Flexibility	5	5	-5	5	-3
Volume Flexibility	10	10	10	15	10.75
Cost	-15	-10	-15	-10	-12.75

Table 6.6 Summary of gap analysis for Firepower

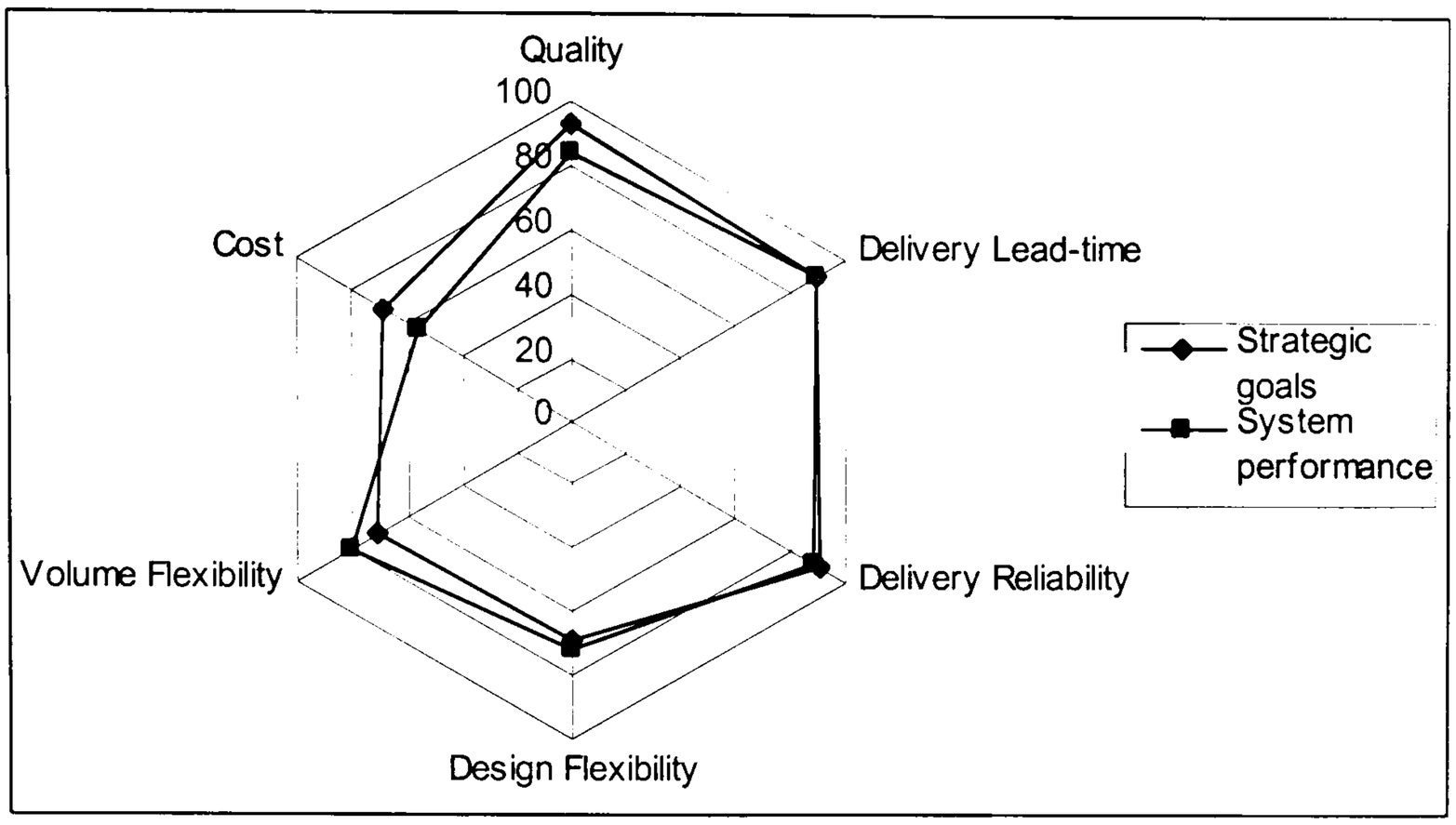


Figure 6.5 Firepower's manufacturing systems performance profile

As explained in Chapter 4 and 5, the gap analysis profiles provide the basis for a relatively extensive evaluation of the overall manufacturing performance situation. In this example, the gap analysis (Table 6.6 and Figure 6.5) reveals that Firepower's manufacturing systems quality and cost are behind accepted levels and could still be improved.

- Low quality: It reveals that the product quality and/or product functional performance cannot meet customer's requirements. The possible problem areas may be related to unreliable supplier quality, too old plant and equipment, yield problem, and work environment (see section 5.4.3 and Appendix E).
- High cost: This is the most common problem that appears in the public sector. The possible problem areas include too large and complex plant, low productivity, high employee turnover, ageing workforce, labour motivation, and high overhead cost (see section 5.4.3 and Appendix E).

A summary of the gap analysis for the individual product groups and the overall manufacturing system performance is illustrated in Table 6.7 (see section 5.4.3, worksheet 9).

Measure of	Group 1	Group 2	Group 3	Group 4	System (Σ)	Comments	Improvement Priority
Importance	35%	30%	20%	15%	--	--	--
Quality	-5	-10	-10	-10	**-8.25**	Improved. The possible problem areas include yield problems, too old plant and equipment, unreliable supplier quality, working environment.	**3**
Delivery Lead-time	-	5	-5	-	0.5	Target achieved.	--
Delivery Reliability	-	-5	-5	-	-2.5	Target achieved.	--
Design Flexibility	5	5	-5	5	-3	Target achieved.	--
Volume Flexibility	10	10	10	15	**10.75**	Target achieved but needs to be improved. The possible problem areas include excess manufacturing capacity, excess workers, excess equipment.	**2**
Cost	-15	-10	-15	-10	**-12.75**	Improved. The possible problem areas include too large and complex plant, low productivity, falling behind in information technology, high employee turnover, ageing workforce, labour motivation.	**1**

Table 6.7 Worksheet 9 - Summary of internal gap analysis for Firepower

(3) External benchmarking

The next step is to compare Firepower's manufacturing performance with competitors/best practice (see section 5.4.4, worksheet 10) in order to provide a basis for continuous improvement efforts. In this example, the external benchmarking can either be the individual product group or the overall manufacturing system performance comparison, or both. The results are illustrated in Table 6.8 and Figure 6.6 respectively.

Measure of	Firepower	Competitor A (difference)	Competitor B (difference)
Quality	84	95 (11)	90 (6)
Delivery Lead-time	90	80 (-10)	75 (-15)
Delivery Reliability	90	75 (-15)	85 (-5)
Design Flexibility	70	85 (15)	80 (10)
Volume Flexibility	80	90 (10)	85 (5)
Cost	55	80 (25)	70 (15)

Table 6.8 Summary of external gap analysis for Firepower

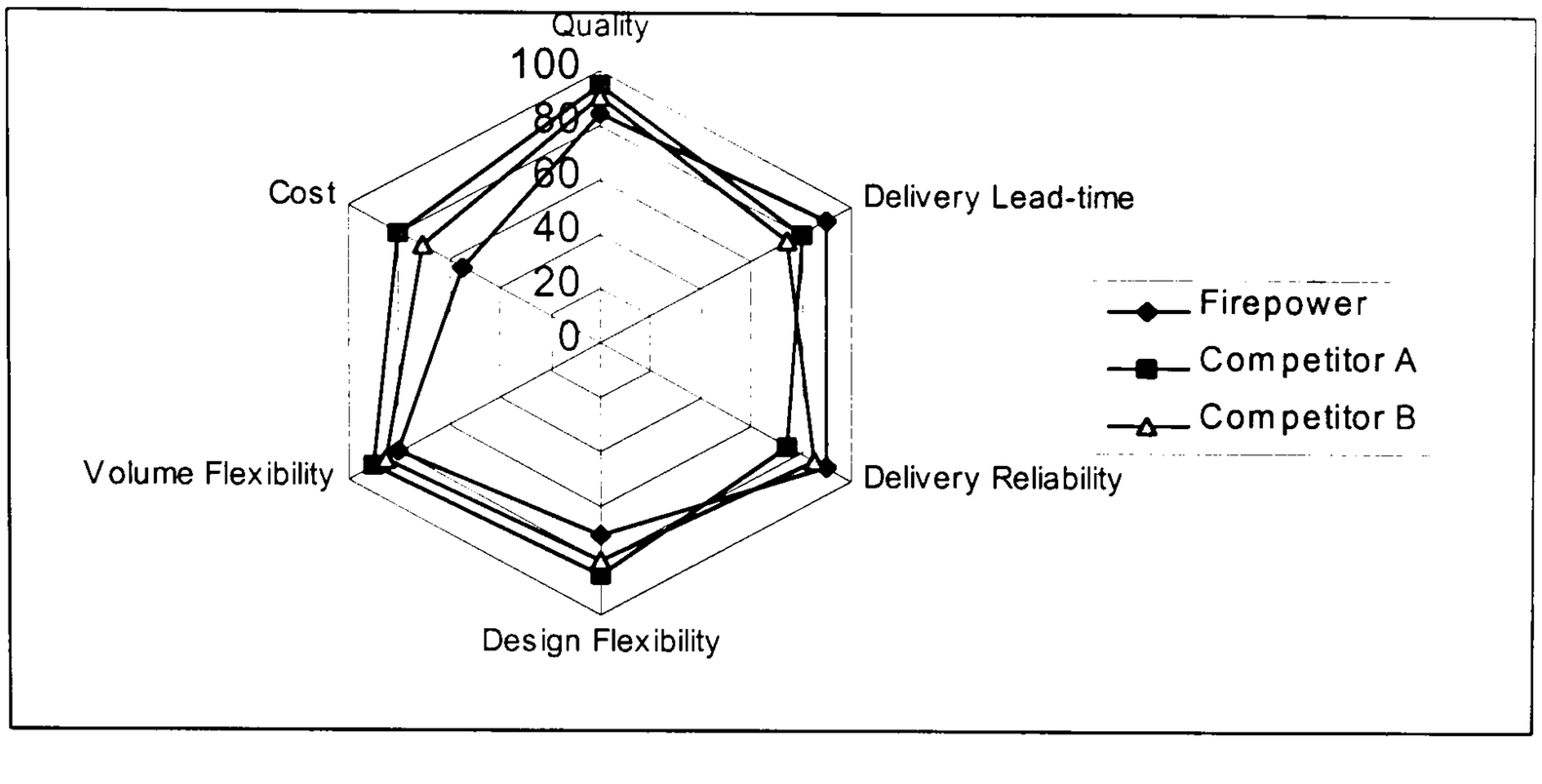


Figure 6.6 An example of Firepower's external gap analysis profile

From Figure 6.6, it is obvious that Firepower, in comparison with their competitors, has strong points in delivery lead-time and delivery reliability. The other factors such as quality, design flexibility, volume flexibility, and cost are relatively low and need to be improved in order for them to become more competitive. A summary of Firepower's external benchmarking is illustrated in Table 6.9.

Measure of	Firepower	Competitor A (difference)	Competitor B (difference)	Comments	Improvement Priority
Quality	84	95 (11)	90 (6)	Improved. The possible problem areas include yield problems, too old plant and equipment, unreliable supplier quality, working environment.	3
Delivery Lead-time	90	80 (-10)	75 (-15)	Maintained	--
Delivery Reliability	90	75 (-15)	85 (-5)	Maintained	--
Design Flexibility	70	85 (15)	80 (10)	Improved. The possible problem areas include too many engineering changes, getting behind using new information technology.	2
Volume Flexibility	80	90 (10)	85 (5)	Improved. The possible problem areas include falling behind in process technology, voluntary direct labour turnover, too old plant and equipment.	4
Cost	55	80 (25)	70 (15)	Improved. The possible problem areas include too large and complex plant, low productivity, falling behind in information technology, high employee turnover, ageing workforce, labour motivation.	1

Table 6.9 Worksheet 10 - Summary of external benchmarking for Firepower

(4) Corrective action necessary

Once a comparison against the strategic goals and the competitors/best practice is completed, it is time to determine "are corrective actions necessary?" Based on Table 6.10 (see section 5.4.5, worksheet 11), the results of system status monitoring, managers can make their decision. If the answer is yes, they would need to take the necessary action to bring their performance back into line with their goals. The possible improvement programmes and their priorities are given below:

1. Reconditioning physical plant.
2. Giving workers more responsibility.
3. New processes for new and/or old products.
4. Total quality management.
5. Downsizing.

Measure of	Internal Analysis (priority)	External Benchmark (priority)	Problem Areas	Strategic Concerns	Action plan (Priority)
Quality	Improve (3)	Improve (3)	Too old plant and equipment, work environment.	Improve environmental safety and protection Procure new equipment and renew plant facility	Total quality management (5) Plant modernisation programme (1)
Delivery Lead-time	Maintain	Maintain	None		
Delivery Reliability	Maintain	Maintain	None		
Design Flexibility	Maintain	Improve (2)	Getting behind using new information technology.	Evaluate new process technology, CAM, …	New processes for new/old products (4)
Volume Flexibility	Improve (2)	Improve (4)	Excess old equipment, excess technicians and operators.	Phasing out old equipment Reduce workforce	Plant modernisation programme (1) Downsizing (6)
Cost	Improve (1)	Improve (1)	Too large and complex plant, low productivity, high employee turnover.	Re-evaluate plant capacity Change culture of manufacturing system Improve labour relation	Reconditioning physical plant (1) Giving workers more responsibility (2) Work environment improvement (3)

Table 6.10 Worksheet 11 – Summary of system status monitoring for Firepower

6.2.4 Continue improvement monitoring

The worksheets to be used for this stage are similar to those used in the previous steps for the same purposes, that is to establish a mechanism of performance measurement that directly supports the manufacturing strategy/action plan requirements. Having already presented in detail many relevant aspects of the example company, including the processes and relevant company data for the analysis, it is necessary here only to summarise the details and possible findings as follows:

- Example worksheets 12 and 13 (see sections 5.5.1 and 5.5.2) illustrate how Firepower's action plan strategic aims can be related to a set of balanced action plan performance measures.
- Example worksheet 14 (see section 5.5.3) illustrates the way in which the immediate system results associated with the current action plan can be assessed, which provides a basis for the assessment of the successfulness of the current improvement programme, and for the selection of future improvement actions.
- Additionally, Figure 6.7 illustrates the benefits of action plans to the overall manufacturing system performance.

The other processes and analysis involved would be similar to the relevant system performance monitoring processes for the analysis and identification of necessary future directions.

Action Plan	**Goals**	**Performance Measures**	**Competitive Criteria**					
			Q	*DL*	*DR*	*DF*	*VF*	*C*
Reconditioning physical plant	Reduce operational cost	Unit manufacturing cost						X
Giving workers more responsibility	Improve labour productivity	Direct/indirect labour productivity		X				X
Work environment improvements	Focus on health and safety	Incidence rate	X					
New processes for new and/or old products	Increase manufacturing response time	Manufacturing cycle time		X				
Total quality management	Effective and efficient organisation	Customer satisfaction	X	X	X	X	X	X
Downsizing	Cut waste	Overhead cost						X

(Q: quality, DL: delivery lead-time, DR: delivery reliability, DF: design flexibility, VF: volume flexibility, C: cost)

Table 6.11 Worksheet 12 - Action plan analysis for Firepower

Measure of	Performance Measures	Performance Indicators	Metrics/Formula (example)
Quality	Incidence rate Customer satisfaction	% of injuries and/or illness Product return rate	No. of man hours lost due to accidents/Total available man hours
Delivery Lead-time	Manufacturing cycle time Customer satisfaction	Set up time, lead time, machine down time Delivery schedule achievement	No. of projects undergoing unnecessary process time/Total no. of main procedures and routine projects
Delivery Reliability	Customer satisfaction	Accuracy of shipment	No. of orders delivered on time/No. of orders delivered for the period
Design Flexibility	Customer satisfaction	New product introduction	Number of new products introduced per year
Volume Flexibility	Customer satisfaction	Ability to respond to demand increase	Process through time
Cost	Labour productivity Overhead costs Customer satisfaction Unit manufacturing cost	Value added per person Manufacturing cost Customer return rate Overall equipment effectiveness	Output value – Input value / Number of employees

Table 6.12 Worksheet 13 – Establish action plan performance measurement

Measure Of	Product Group 1		...		System Performance				Action plan performance (c x d)
					Previous (a)	Current (b)	Difference (c = a-b)	Importance (d)	
Importance	35%								
Quality	History	Current			84.25	90	5.75	20%	1.15
Delivery Lead-time					90	92	2	5%	1.00
Delivery Reliability					88.5	91	2.5	5%	0.13
Volume Flexibility					71.5	76	4.5	10%	0.45
Design Flexibility					81.25	87	5.75	25%	1.44
Cost					55.5	66	10.5	35%	3.68
System performance					72.56	79.6	6.04	1	7.85

Table 6.13 Action plan performance analysis for Firepower

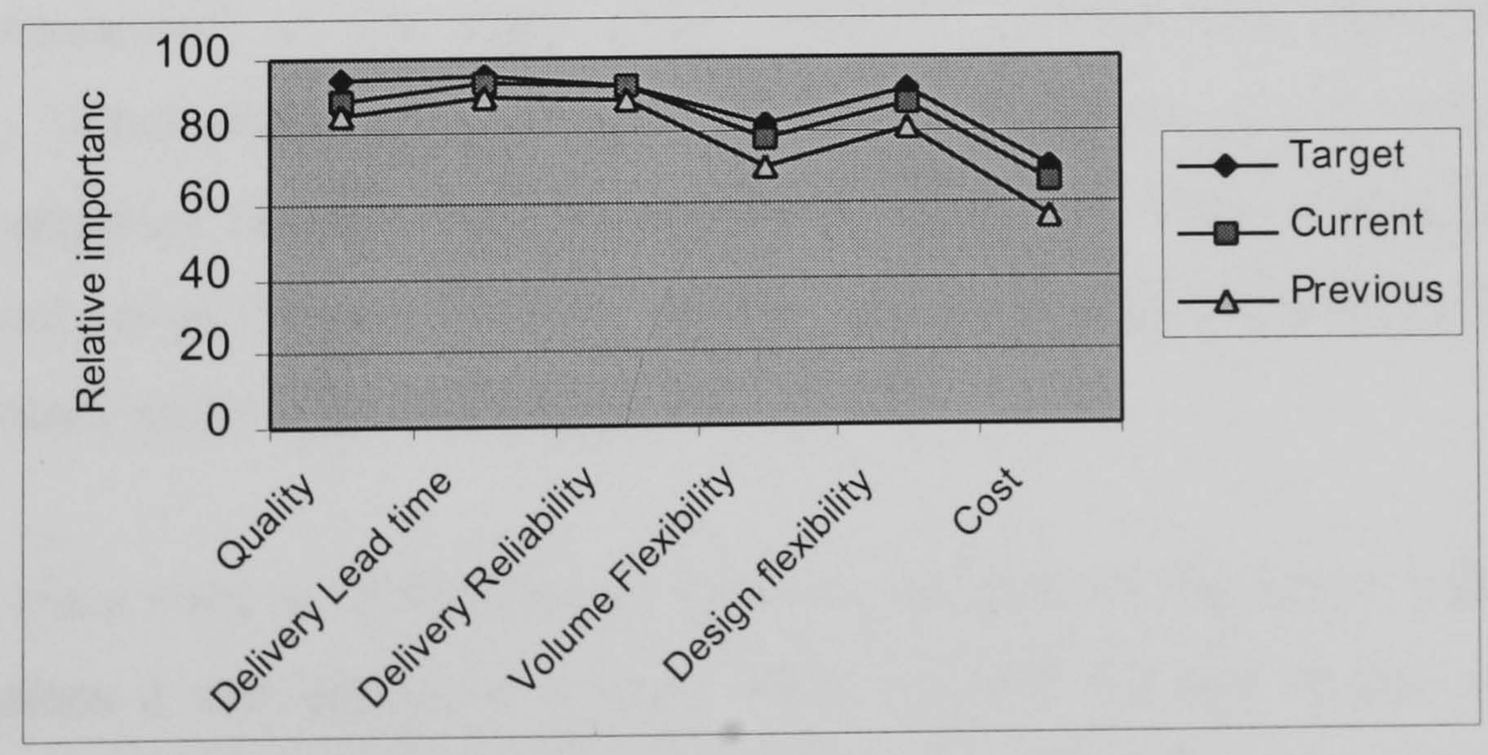


Figure 6.7 The contribution of action plans to overall system performance

To conclude, the above example has clearly demonstrated the logic and value of the proposed framework for performance measures and evaluation. That is, combining these techniques will help a company identify manufacturing performance gaps through the overall system status monitoring and continuous improvement monitoring that would not be recognised by other techniques on their own.

6.3 Case study results – lessons learnt from the Taiwanese cases

This section looks across the three cases of the Taiwanese military plants and considers the activities at each stage in the proposed framework. In order to perform the assessment, the three criteria of feasibility, usability, and utility developed by Platts (1990) were used. Feasibility refers to the practicality of using the approach, usability refers to the user-friendliness of the approach, and utility refers to the overall usefulness of the approach (Platts, 1990). Accordingly, the testing of feasibility involved checking that the proposed framework could be followed, the testing of usability included identifying common problems and suggesting solutions where possible, and the testing of utility considered the results of the approach.

6.3.1 Evaluate the feasibility and usability of the proposed framework

(1) Stage 1 – Strategic-oriented performance measures

This section consists of a number of steps with the objective being to identify the context of the proposed framework in order to help a company align performance measurement with its manufacturing strategy. The concerns when developing the proposed framework at this stage were: "Would the worksheet data be easily obtained?", "What problems would be encountered for the use of the worksheet?", "Would companies find the concept of process approach useful in specifying the critical activity to be measured?", and "Would there be enough information to enable the performance goals to be identified?".

Generally, there were no difficulties in obtaining the data in this stage, although in some occasions it was necessary to think about the data required as they were not always available from the expected source. The key results of this stage from the case studies are summarised in Table 6.14. A short discussion on each of the worksheets is provided below.

- Worksheet 1 – Identify product. No problems were experienced in the identification of products in companies A, B, and C. Actually, in all the three case companies, Worksheet 1 mainly served as a checklist rather than a tool to define products. This is because that the companies had already recognised their products defined by product function.
- Worksheet 2 – Analyse product. No problems were experienced in Worksheet 2 to identify the relative ranking of the products. During the case studies, one interesting finding was that the relative importance of products has a close relationship with product orders. If a company had stable product orders like company A, its relative ranking of the products was also stable, and *vice versa,* such as companies B and C.
- Worksheet 3 – Identify manufacturing strategy and objectives. All the three case companies' manufacturing strategy and objectives could be identified easily from the existing strategic plan. However, one difficulty experienced in the completion of the worksheet was how to link the identified manufacturing strategy and objectives with the competitive criteria of quality, delivery, flexibility, and cost to be measured. To solve this problem, many techniques such as work breakdown structure, analytical hierarchy process (AHP), and brainstorming were applied to the case companies. Surprisingly, most of the managers preferred the brainstorming technique, although the result of brainstorming was the most subjective one. One possible explanation is that brainstorming allowed for management involvement and was easy to use.
- Worksheet 4 - No problem was experienced in the identification of manufacturing systems and processes. This is because the three factories were all in the mature stage of the life cycle and their manufacturing systems and processes had seldom been changed. Four basic questions "what do we do?", "how do we do it?", " what starts our process?", and "what ends our process?" were applied to help identify the case company's manufacturing processes.
- Worksheet 5 – Identify critical activity to be measured. No major problems were experienced in choosing the critical activity of manufacturing processes. Some questions such as "does it relate, directly or indirectly, to the ultimate goal of customer satisfaction?" were used to confirm that the activity was critical. The brainstorming technique was also applied in this step to clarify the linkage

between the identified critical activity and the competitive criteria of quality, delivery, flexibility, and cost.

- Worksheet 6 – Determine performance goals. No problems were experienced in choosing the short-term performance goals. However, in long-term performance goal selection, all three companies had difficulties. Therefore, a table for checking good performance goals, as shown in Appendix E, was developed and provided for the case companies to accomplish of Worksheet 6.

Generally, this stage of the framework was feasible and the initial problems were overcome. One important finding was that the three case companies' current performance measurement systems were in an unbalanced state, that is they were mainly focused on quality and cost measures, other measures such as delivery lead-time, delivery reliability, and volume flexibility had their deficiencies. According to the case companies suggestion, one change was made to Worksheet 1, that is to take product functional performance as a key factor in the definition of products. Some checklists and techniques were also applied to the framework to help accomplish this stage. Other positive responses for stage 1 from the case companies can be concluded into two aspects:

- It provided them with a clear picture of manufacturing strategy and processes to enable them to specify their performance measurement specifications.
- It enabled them to identify critical activities and to define the performance measurement goals.

Table 6.14 Summary of problems experienced in Stage 1 - Strategic-oriented performance measures

Step	Objectives	Areas of Concern	Comments	Outputs
1. Identify product	Identify product with distinct competitive and market requirements.	1.General: • Could the worksheet data be easily obtained? • What problems would be encountered form the use of the worksheet? 2. Specific: There were no specific concerns in the identification of product groups.	• All three companies had already recognised their products defined by product function. Therefore, Worksheet 1 was mainly used to check the definition of products. • Because of the complexity of weapon systems, it was difficult to clearly define material needed for each product as specified in Worksheet 1. This was especially obvious at companies A and C. • Generally, there were no difficulties in the identification of products in companies A, B, and C. However, all three companies suggested that Worksheet 1 should be expanded to include product characteristics and functions in defining products.	A list of products that the manufacturing company produces.
2. Analyse product	Identify the importance of various criteria for each product, and a relative ranking of the products.	1. General: As above 2. Specific: Would there be enough information to enable the relative importance of product groups to be identified?	• The relative ranking of products at companies A and C was greatly influenced by the order size, and was changeable. Company B had a stable annual order, and the relative ranking of products was also stable. • Generally, no problems were experienced in using Worksheet 2 to analyse products and identify relative ranking of the products.	A list of product performance and a relative ranking of the products
3. Identify manufacturing strategy and objective	Understand the overall manufacturing strategy as well as individual product group objectives and strategic choices.	1. General: As above 2. Specific: • How could data be best obtained? • What problems would be experienced in determining manufacturing policy areas and goals?	• Companies A, B, and C had a clear manufacturing strategy and objectives. It was no problem to identify each company's strategic policy areas and goals. However, one problem was experienced in allocating the goals of identified manufacturing policy area into the competitive criteria of quality, delivery, flexibility, and cost to be measured. To solve this problem, the brainstorming technique was applied in the middle level management of each company in order to identify the necessary data for further analysis.	A list of manufacturing strategy in terms of competitive criteria and manufacturing strategy choice.

Continue over page

Step	Objectives	Areas of Concern	Comments	Outputs
4. Identify manufacturing systems and processes	Conduct manufacturing system's input/output analysis to understand manufacturing processes and key processes.	1. General: As above 2. Specific: What problems would be experienced in the identification of manufacturing processes and key processes?	• Generally there was no problem in identifying the manufacturing systems and processes. This is because all three companies were in the mature stage of the plant life cycle. • Four basic questions "what do we do?", "how do we do it?", " what starts our process?", and "what ends our process?" were applied to help identify the case company's manufacturing processes.	A list of manufacturing processes, key processes, and flow diagrams for these key processes.
5. Identify critical activity to be measured	Clearly define performance measures areas and control points.	1. General: As above 2. Specific: Would companies find the concept of process approach useful in specifying critical activity to be measured?	• No major problems were experienced in choosing the critical activity. Some questions such as "does it relate, directly or indirectly, to the ultimate goal of customer satisfaction?" were asked to confirm that the activity is critical. • However, one difficulty was encountered from the use of critical activity to specify competitive criteria of quality, delivery, flexibility, and cost. The way to solve this problem was the same as in step 3, that is the brainstorming technique. Other techniques such as Analytical hierarchy process (AHP) and Fishbone diagram can also be applied to solve the problem.	A list of the critical activity areas for the key processes.
6. Determine performance goals	Agree performance measures specifications.	1. General: As above 2. Specific: Would there be enough information to enable the performance goals to be identified?	• No problems were experienced in choosing the short-term performance goals. However, in long-term performance goal selection, company A had difficulties. There is one possible explanation for this, that there is only pass and fail of missile systems in manufacturing, with no other alternative. • A checklist of good performance goals was provided for the case companies to accomplish Worksheet 6.	A list of goals for each critical activity within the key manufacturing processes.

Table 6.14 Summary of problems experienced in Stage 1 – Strategic-oriented performance measures

(2) Stage 2 – Overall system status monitoring

The objective of this stage was to determine what types of performance-related information were actually needed to run and manage a better manufacturing system. The concerns when developing the proposed framework were: "Could the worksheet data be easily obtained?", "What problems would be encountered in the use of the worksheet?", "Could a common set of performance measurements be defined based on current manufacturing criteria of quality, delivery, flexibility, and cost?", "Would there be sufficient information to enable managers to make decisions?".

It was during this stage of the framework that most difficulty was generally experienced. Five worksheets were used during this stage. The key results of this stage from the case studies are summarised in Table 6.15. A short discussion on each of the worksheets is provided below.

- Worksheet 7 – Establish performance measurement system. Two problems were experienced in the establishment of the performance measurement system. (1) Choosing performance indicators. In company A, the researcher found that the selection of performance indicators was not an easy job and was time consuming. Many aspects of performance measures should be concerned during this process, especially the selection of performance indicators, which should be confined to a limited number, but represent the most important factors of the manufacturing to be measured. According to company A's experience, a linking table that linked performance parameters and indicators was then developed and tested in companies B and C (see Appendix E). The results show that the linking table was beneficial for the selection of performance indicators. (2) Determining the goals of performance indicators: Again this involved calculation of performance indicators and their priority. Although many techniques such as fishbone diagram, probability theory, and AHP were applied to help the determination of performance indicator goals, the process still was complex and it was not easy to reach the desired goal.
- Worksheet 8 – Collect performance data. No major problems were encountered in the measurement of quality, delivery, flexibility, and cost. The majority of the data from the three companies were collected from existing records, not directly

measured from operations. Other data were collected through interviews with shop managers and operators.

- Worksheet 9 – Analyse current performance. There were no problems in analysing system performance and drawing performance profiles.
- Worksheet 10 – External benchmarking. It was expected that there would be some difficulty in conducting external benchmarking but the extent of this was underestimated. One possible explanation is that the defence industry is confidential. It is difficult to acquire sufficient information from competitors to benchmark manufacturing performance.
- Worksheet 11 – Determine if corrective action is necessary. No problems were experienced in choosing the improvement programmes. Two linking tables (PM 2 - Strategic performance and causes table and PM 3 - Strategic concerns and action plans table, discussed in Chapter 4 and shown in Appendix E) were provided to help accomplish action plan selection. However, in making decisions, managers from the three case companies said that although the result from the above performance measurement analysis was logical and relevant, it could only serve as one of the key factors for improvement. Other factors such as national security strategy, potential threads, tactical considerations, and budgets should also be taken into account when making decisions.

To conclude, this stage of the framework was generally feasible. Although many problems had been encountered, they were all solved eventually. Further, all the three case companies agreed that the performance profiles provided them with a clear picture of performance gaps to enable them to specify areas to be improved. As this research was mainly focused on the development of a set of manufacturing performance measurement and evaluation framework, other external factors that might influence management decisions such as government policy, national security strategy, potential threads, tactical considerations were purposefully neglected.

Table 6.15 Summary of problems experienced in Stage 2 - Overall system status monitoring

Step	Objectives	Areas of Concern	Comments	Outputs
7. Establish performance measurement system	Identify a performance measurement for each manufacturing objective and check the balance and comprehensiveness of the measures.	1. General: • Could the worksheet data be easily obtained? • What problems would be encountered from the use of the worksheet? 2. Specific: Could a common set of performance measures be defined based on the used manufacturing performance criteria of quality, delivery, flexibility, and cost?	• The problems experienced with the completion of Worksheet 7 can be grouped into two categories: (1) Choosing performance indicators. In company A, the researcher found that the selection of performance indicators was time consuming and not an easy job, it should not only be concerned with the interrelationships between performance measures and indicators but also involve the determination of their priority and number. A linking table that linked performance parameters and indicators was then developed and tested in companies B and C. The results proved that the linking table was beneficial in the selection of performance indicators. (2) Determining performance indicator's goal: Again this involved calculation of performance indicators and priority. Although the probability theory was applied to aid the determination of performance indicator goals, the results were subjective. • The results of Worksheet 7 revealed that according to strategic concerns, different companies had different focuses in performance measures and performance indicators: company A placed more emphasis on quality and test, company B focused on quality and scheduling, company C focused on delivery reliability.	The performance measures matrix and their components.
8. Collect data	Collect performance data in accordance with defined table and provide a basis for analysis.	1. General: As above 2. Specific: How could the data best be obtained?	• No major problems were encountered in the measurement of quality, delivery, flexibility, and cost. The majority of the data from the three companies were collected from existing records, not directly from the operations. The other data were collected through interviews with operators and management. • Since most of the required data were available in existing records, it can be said that the design of the performance measures metrics was relevant.	A growing list of performance data.

Continue over page

Step	Objectives	Areas of Concern	Comments	Outputs
9. Analyse current performance	Transform performance data into useful performance information and identify performance gaps and feasible solutions.	1. General: As above 2. Specific: Would there be enough performance information to enable the performance profiles and gaps to be identified?	Generally there was no problem in analysing system performance and drawing performance profiles.	A list of performance information and profiles of individual product as well as the overall system can be drawn.
10. External benchmarking	Identify external/best practice performance and provide a basis for continuous improvement efforts.	1. General: As above 2. Specific: • What problems would be experience in the identification of external performance measures? • What are standards for comparison?	It was expected that there would be some difficulty in conducting external benchmarking but the extent of this was underestimated. This can be categorised into two aspects: 1. Internal benchmarking. This mainly refers to the comparison between military plants in Taiwan. However, since all the military plants are public and follow the same regulations, and because of their unique functionality with one another, the effect of internal benchmarking is limited. 2. Competitive benchmarking. Because of the high security of the defence industry, it is difficult to acquire sufficient information from other competitors. This is especially true in the comparison of technology aspects such as R&D and manufacturing processes.	A presentation of performance information in the form of a report.
11. Determine if corrective action is necessary	Develop a successfully implemented plan.	1. General: As above 2. Specific: Would there be sufficient information to enable managers to make decisions?	• No problems were experienced in choosing the improvement programme. Two linking tables (Strategic performance and causes and Strategic concerns and action plans) were developed to help accomplish of Worksheet 11. • However, in making decisions, managers from all three case companies stated that although the result from the above performance measurement analysis was logical and relevant, it could only serve as one of the key factors for improvement. Other factors such as national security strategy, potential threads, tactical considerations, and budgets should also be taken into consideration.	Action plan to implement change or re-evaluate goals.

Table 6.15 Summary of problems experienced in Stage 2 – Overall system status monitoring

(3) Stage 3 – Continue improvement monitoring

The basic structure and objective of this stage is similar to the previous one. However, it focuses on the monitoring of the system performance improvement as a direct result of the actions currently put in place. The concerns when developing the proposed framework at this stage were: "Could the worksheet data be easily obtained?", "What problems would be encountered for the use of the worksheets?", "How could the data be best obtained?", "Would there be enough information to enable the performance goals to be identified?", "Would there be sufficient information to enable managers to make decisions?".

Four worksheets were used during this stage. The key results of this stage from the case studies are summarised in Table 6.16. As many relevant aspects of the problems experienced in performance measurement and evaluation have already been presented, including the selection of performance indicators and determination of their goals, it is necessary here only to summarise the details and possible findings as follows:

- Ideally, action plans used in this stage should be based on the results of system status monitoring identified in the previous stage. However, it was impossible for the case companies to adopt the identified action plan(s) directly in order to improve their current situation. Therefore, for test purposes, action plan(s) selected in this stage were mainly based on two criteria: (1) they should directly relate to the results of system performance monitoring, and (2) they should be relevant to the case company's current practice. Accordingly, the action plan selected for each case company was as follows: Company A – outsourcing, Company B – work environment improvement, and Company C – inventory automation.
- Managers from the three case companies remarked that the action plan performance profile, see Figure 6.7, provided a way in which the immediate system results associated with the current action plan can be assessed, which provided a basis for the assessment of the successfulness of the current improvement programme, and for the selection of future improvement targets and actions.

Table 6.16 Summary of problems experienced in Stage 3 - Continue improvement monitoring

Step	Objectives	Areas of Concern	Comments	Outputs
12. Action plan analysis	Identify what to measure of the action plan.	1. General: • Could the worksheet data be easily obtained? • What problems would be encountered from the use of the worksheet? 2. Specific: What problems could be experienced in the analysis of action plan?	• The action plans selected in this stage were based on the results of system performance monitoring identified previously. For test purposes, each case company applied only one action plan, which was the most relevant to the case company's current practice. Company A – outsourcing, company B – work environment improvement, company C – inventory automation. • According to the above, there was no problem in identification of the selected action plan.	A successfully implemented action plan.
13. Establish action plan performance measurement	Determine action plan performance measurement goals, key performance indicators, and metrics/tools.	1. General: As above 2. Specific: What problems would be experienced in determining action plan performance?	No major problems were encountered in the development of action plan performance measurement.	Action plan performance measures matrix and their components.
14. Analyse and benchmark action plan performance	Transfer action plan performance data into performance information and perform gap analysis.	1. General: As above 2. Specific: • How could the action plan performance information be best obtained? • What problems would be experienced in the analysis and benchmarking of current practice?	The same as in Worksheet 8, there was no problem in analysing performance gap and drawing performance profiles.	A lost of action plan performance variance identified through gap analysis
15. Decision making – new action plan or new goal	Determine if new action plan performance goals or measures are needed.	1. General: As above 2. Specific: Would there be sufficient information to enable managers to make decisions?	The same as in Worksheet 11, no problems were experienced in determining "if new goals or measures are needed?"	New goals, measures, or no change

6.3.2 Evaluate the utility of the proposed framework

In this section, two methods presented by Platts (1990) were adopted to test the utility of the proposed framework: (1) looking at the results obtained, and (2) obtaining the reactions of users.

- Results: The case studies presented in the previous section have been valuable for proving the logic and potential usefulness of the proposed framework. In all three case companies the procedure resulted in a clear definition of manufacturing performance measurement specification requirements and an identification of the performance gaps and major problems with the existing manufacturing practices. In addition, the results also highlighted where improvements had been made and which areas still need to be improved. The proposed framework has therefore met its original objective of providing a useful way to help Taiwanese military plants to establish their future manufacturing performance measurement and evaluation system.
- User reactions: All the three companies found the exercise useful, providing a closed-loop mechanism of for both the monitoring and the continuous improvement of the manufacturing system. Therefore, although the proposed framework is still in its early stages of development and the structure and procedures reported in this thesis can only be regarded as a well specified prototype, it has been proven to be conceptually logical, and overall well structured.

The basic concepts of the proposed framework of manufacturing performance measurement and evaluation have been shown to be both feasible and effective when applied within the three Taiwanese military plants. However, due to its generic nature, there seems to be no logical reason why the same framework can not be applied to the private sector or other manufacturing industries to solve their performance measurement and evaluation problems. Therefore, the next section focuses on a wider application of the proposed framework.

6.4 Wider application of the proposed framework – the UK cases

The purpose of this section is to achieve the second objective of the research – to investigate whether the proposed framework can apply to other societies or industries. The investigation involved three UK manufacturing companies. The selection of these companies was because they were the only companies that would accept interviews to discuss the validity of the proposed framework. These companies are described as companies D, E, and F. Although the number of case companies was limited, each company had shown its unique characteristics that were beneficial for the accomplishment of this research, see Table 6.17.

Company	Manufacturing Type (Sweeney, 1996)	Products	Comments
D	Caretaker	Nylon Polymer	The company used to be part of UK ICI (Group), and was sold to America two years ago. The transition of this company from the UK to the USA and the change of performance measurement were the interest for this research.
E	Innovator	Products for the isolation, identification and enumeration of bacteria	This manufacturing company has currently applied SAP/R3 into the performance measurement system. Also the company has relied on benchmarking in performance measures
F	Caretaker	Colour TV, Monitor, Telephone/Fax machine	This is a Taiwanese invested company. This company provided the researcher with an opportunity to identify the difficulties and conflicts of the proposed framework applied into different cultured companies, this is Western and Eastern.

Table 6.17 Summary of the UK case companies

The results of this stage of the investigation are intended to be compared with the results of the Taiwanese cases. Therefore, the assessment criteria of feasibility, usability and utility used in the Taiwanese case studies are also appropriate in this section. The feasibility criterion was met as the proposed framework had been followed in the Taiwanese military plants. This analysis will concentrate on the assessment of usability and utility and be divided into three areas:

- Company's view on the overall proposed framework. It investigated the structure, processes, and characteristics of the proposed framework at system level.
- Company's view on the individual worksheet design. It focused on the assessment of the design, specification, and processes of the worksheet within the proposed framework.
- The use of the proposed framework. Whether the proposed framework can develop a set of manufacturing performance measures and evaluation scheme that are usable and actionable.

A summary of the interviews is illustrated in Table 6.18. A short discussion of the analysis is provided below:

(1) Company's view on the proposed framework and worksheets

The purpose of this section was to establish that the proposed framework was understood and that it was clear how the worksheets should be completed.

Generally, no communication problems were experienced during the interviews. This was because many manufacturing performance measurement theories and techniques applied to the proposed framework were also relevant or recognised by the three companies and their management.

A positive response from the case companies was that the proposed framework was logical and it was clear how the worksheets should be filled in. Many interviewees suggested that the proposed framework provided a good coverage of all the elements required for the development of a set of manufacturing performance measures and evaluation. However, one or two interviewees were concerned with the complexity of the framework either due to its steps or processes. The explanation given by the interviewees was that it was time consuming to complete the worksheets. However, this is not a comment on the structure and processes of the proposed framework but a comment on the difficulty of completing the worksheets.

(2) Company's view on the individual worksheet design

This section focused on the identification of limitation and credibility of the worksheets within the proposed framework.

All the three companies agreed that performance measures should initiate from product (group) analysis. However, one problem which was not experienced in the Taiwanese cases was that some interviewees said that in worksheets 1 and 2 (product groups define and analysis) the major problems with data collection might be in defining the market requirements and obtaining competitive criteria data of quality delivery, flexibility, and cost to be measured. Many interviewees also agreed that these difficulties could be solved through team discussions.

No problems were experienced in the identification and collection of data in worksheet 3 (identify manufacturing strategy and objective). However, although the three case companies agreed that manufacturing performance measurement should be derived from manufacturing strategy, only company E had currently applied strategic performance measurement, companies E and F mainly focused on short-term target oriented performance measures. This provides us with the view that strategic performance measurement has potential in industry.

Companies D and E agreed that the establishment of manufacturing performance measurement systems should take manufacturing processes and key processes into consideration (worksheet 4). However, company F disagreed with this criterion. One possible explanation is that the company was satisfied with its current manufacturing performance measurement system and that system did not take manufacturing processes into account.

The design and development of worksheet 5 (identify critical activity to be measured) was based on the concept of vital few measures (see section 4.4.1). However, only company F agreed this criterion. Harbour (1993) suggests the number of critical few measures should not exceed 20, depending on the complexities of the organisation. In the investigation of the number of critical few measures applied to each of the case company, the result was surprisingly. Company D used 28 measures, company E

used 32 measures, and company F used 21 measures. Accordingly, the result from companies D and E was obvious.

No problems were experienced in the identification and collection of data in worksheet 6 (determine performance goals).

All the case companies agreed that manufacturing performance measurement system should provide a balanced set of measures (worksheet 7). They also agreed that the three principal manufacturing architectures of manufacturing processes, human resources and organisation, information and production control provided by the proposed framework were relevant and useful for the design and development of manufacturing balanced measures (see section 4.3.1).

Most of the interviewees had shown their interests in the performance profile (worksheet 8 and 9, also see section 4.3.4). They also agreed the performance profile was a useful tool that could not only identify manufacturing performance gap but also provide management with a one-shot picture to know their current situation and where they need to improve.

It was unexpected that external benchmarking (worksheet 10) which had experienced many difficulties in the Taiwanese cases, experienced no major problem in the UK cases. One possible explanation is that the private sector considered benchmarking as a powerful tool in specifying competitor/best practice performance in order to become more competitive. In contrast, because there is no competition in the public sector, by nature they are reluctant to use benchmarking.

Only company E agreed that the manufacturing performance measurement should not only place emphasis on the performance data collection and gap analysis but also provide the most promising solution to supplement the gap (worksheet 11). Company D was not sure about the criterion, whilst company F showed its disagreement. According to the above, it is obvious the need to move from performance measurement (data collection and gap analysis) to performance management (the ability to use performance information to improve performance and support decision-making) should be encouraged (see section 4.5).

Worksheets 12-15 were concern with the continuous improvement monitoring. Again there were no problems experienced in the identification and collection of data. However, only one company agreed the design of improvement programme performance measures should be part of the overall performance system, not just another "new" measurement system. On the contrary, company D showed its disagreement. Whilst company F was not sure about the criterion. This provides us with the view that the integrated manufacturing performance measurement has potential in industry.

(3) The use of the proposed framework

It was to determine whether the proposed framework was usable and actionable.

This was to assess whether the proposed framework could develop a set of manufacturing performance measures and evaluation scheme that were usable and actionable. Throughout the interviews, no objections were experienced to this statement. Therefore, the conclusion was that the proposed framework was useful and actionable.

To conclude, the worksheets were found to be easy to use and to provide a valuable way of structuring the information required in developing a set of performance measures and evaluation framework. Although no single company had considered applying the proposed framework, all the three companies agreed that the proposed framework could be serve as an educational aid to increase general awareness of manufacturing performance measurement and evaluation. The major problems encountered were with the collection of data for specifying the competitive position of the company in the market and obtaining competitive criteria data of quality delivery, flexibility, and costs to be measured. In the three UK companies the researcher studied, leadership commitment to the development and use of performance measures was a critical element in the success of the performance measurement systems. In addition, one unexpected finding was that the more profitable, high technology company like company E showed an interest in the proposed framework. Whilst the company with mixed culture and/or struggling with profits showed less interest in it.

Question	Company D	Company E	Company F
Do you agree performance measurement system design should initiate from the identification of product group and market requirement?	Agree	Agree	Agree
Do you agree performance measures should clarify manufacturing processes and key processes?	Agree	Agree	Disagree
Do you agree the development of performance measures hierarchy, that is to align manufacturing strategy and functional performance is important?	Agree	Agree	Agree
Do you agree manufacturing performance measurement should derive from strategy and provide a balanced set of measures?	Agree	Agree	Agree
Do you agree the performance measurement should not only place emphases on the performance data collection and gap analysis but also provide the most promising solution to supplement the gap?	Not sure	Agree	Disagree
Do you agree manufacturing performance measurement should focus on the critical few measures?	Not sure	Not sure	Agree
Do you agree performance measures benchmarking is essential to help increasing competitiveness?	Agree	Agree	Agree
Do you agree the design of improvement programme performance measurement should be part of the overall performance measurement system, not just another "new" measurement system?	Disagree	Agree	Not sure
Do you agree performance measures should not only identify customer requirement has been met but to show where improvement need to be made?	Agree	Agree	Agree

Table 6.18 Summary of the interviews

6. 5 Conclusions

This chapter has performed an evaluation of the manufacturing performance measurement and evaluation framework developed in Chapters 4 and 5. This was achieved through six manufacturing company case studies in both Taiwan and the UK. The feasibility and utility of the proposed framework were demonstrated by the successful application of the approach at the three Taiwanese military plants. The analysis of the usability of the approach focused on identifying the problems that occurred at each stage and suggesting improvements, where possible. Through interviews with the three UK companies, it was demonstrated that the proposed framework could also be applied to other societies and industries to solve their performance measurement and evaluation problems. The next chapter concludes this programme of research by evaluating how the research objectives have been addressed, and recommends future work.

CHAPTER 7 DISCUSSION AND CONCLUSION

This chapter discusses and concludes the findings of the research. Discuss research process as well. The strengths and weaknesses of the proposed framework are indicated and areas for further work are recommended.

7.1 Summary of the research

The objective of this research was to develop a set of generic manufacturing performance measures and an evaluation methodology that can not only meet the Taiwanese military plant's requirements but can also be applied to other industries, either public or private. In order to provide a basis for the development of the concepts of an approach to be suggested, this research has been executed by first reviewing the relevant and current techniques to measure manufacturing performance and identifying to what extent a gap between the theory and practice exists (Chapter 2).

The research then focused on the justification of the research requirements and specifications, and developed a logical and actionable research approach that could be applied in the course of the research (Chapter 3). A mix of case study and survey methods was adopted which can be viewed as a more suitable approach for investigating manufacturing performance measurement and evaluation methodologies, because it is not only concerned with the practical success of the case under investigation, but also with addition to knowledge.

The review of current manufacturing performance measurement literature together with the specific requirements of the project identified in Chapter 3 found evidence that an extended framework for the purpose of manufacturing performance measurement and evaluation is beneficial. Therefore, an extended measurement scheme which, compared to the existing approaches, provides a more comprehensive way of monitoring not only the overall system performance but also continuous improvement performance was developed (Chapters 4 and 5). The proposed framework has been divided into three stages with fifteen steps. It is a logical sequence of tasks with the aim of closing the gap between the theory and practice specified in Chapters 2 and 3.

From the proposed framework that has been given an overview and development of procedure in Chapters 4 and 5, the appropriate research methods as given in the research approach in Chapter 3, were carried out. The research then set out to test the proposed framework. Three Taiwanese military plants were involved with the intention to use the framework practically and demonstrate its usefulness. Throughout the course of case studies, three UK manufacturing companies were also involved with respect to the investigation of wider applicability. The results and findings of the research were then used to generate amendments to the proposed framework (Chapter 6).

7.2 The strengths of the proposed framework

The case studies presented in the previous chapter have been valuable for proving the logic and potential usefulness of the proposed framework for the purpose of helping industry to develop a set of performance measures and evaluation framework

Bond (1999) states that a performance measurement system should have the characteristics of: (1) providing an early warning detection system indicating what has happened, (2) diagnosing reasons for the current situation, and (3) indicating what remedial action should be undertaken. The proposed framework has met the above three requirements, that is to define an early warning detective system by conducting strategy-oriented performance measures to know "where we are", to diagnose reasons for the current situation by developing system status monitoring to know "where we want to go", and to indicate what action should be taken by implementing continuous improvement monitoring to specify "how we can achieve it".

The proposed framework for manufacturing performance measurement and evaluation is fundamentally different from other popular models designed to provide a conceptual approach. It not only shows what to do but provides a step by step procedure to show how to do it. The proposed framework is a strategically driven performance control system and, therefore, it provides a systematic approach to continuous improvement efforts and benefits the manufacturing company by:

- Providing a framework that ties efforts together.
- Providing a vehicle for identifying and comparing best practices/competitors manufacturing performance.
- Improving the ability to measure the overall systems performance and improvements by documenting processes and results.
- Involving the company in continuous improvement toward world-class manufacturing.

In addition, the application of radar diagrams to identify and further analyse performance profiles proved to be beneficial. Radar diagrams provide a certain extent of equilibrium to the competitive criteria of quality, delivery reliability, delivery lead-time, design flexibility, volume flexibility, and cost to be measured. The equilibrium here means to place equal emphasis on the competitive criteria either in manufacturing strategy planning or in performance measurement. Other advantages of radar diagrams include:

- Being used to identify performance gaps.
- Providing management with an overall picture of performance progress.
- Being a diagnostic tool to assist in analysing performance gaps.
- Indicating "learning by doing" with each measurement. As the performance measures are periodically implemented, it can create a favourable environment to facilitate the establishment of a learning organisation.

7.3 Findings against the research objective

The basic concepts of the proposed framework were proved to be both feasible and effective. Therefore, the initial aim of the research, the development of a manufacturing performance measurement and evaluation framework, has been achieved. In addition, during the course of the research there were many findings which can be categorised in the following three areas. They are:

- The findings during the design and development of the proposed framework (from literature review and practitioner interviews),

- The findings during the direct application of the approach (from the Taiwanese case studies), and
- The findings from the wider application of the proposed framework (from the interviews with the UK cases).

7.3.1 The findings during the design and development of the proposed framework

Six needs were identified for the design and development of a more extensive and adaptive manufacturing performance measures framework.

(1) The need to develop a performance measurement and evaluation framework that encompasses both financial and non-financial measures, and is simple to use.
(2) The need for a more structured way to link manufacturing strategy to the process of performance measurement and evaluation.
(3) The need to take both the present performance requirements and predicted future requirements into consideration.
(4) The need to provide a closed-loop mechanism for both overall system status monitoring and continuous improvement monitoring
(5) The need to provide both internal measures and external benchmarking to evaluate manufacturing strategic concerns.
(6) The need to provide help and guidelines which provide an in-depth balance of measures across manufacturing strategy choice of capacity, facility, technology, vertical integration, human resources, production and control system, etc.

These findings were used in the initial design of the project. They were the requirement specifications of the proposed framework. The proposed framework has attempted to tackle all six requirements, and illustrated conceptually their feasibility.

Regarding requirements (1) and (2), it applies the SMART concept to link the measurement of organisational performance to the strategic planning process so as to integrate both financial and non-financial measures and to concentrate the measurement system design on satisfying customer needs. As to requirements (3) and (6), it uses the balanced scorecard approach to translate manufacturing strategy into a set of perspectives (financial, customer, internal business process, and learning and

growth), which provide a balanced picture of current operating performance as well as the drivers of future performance.

For requirement (4), it uses utility functions to integrate different product groups to show the current situation in the company level which provides a comprehensive consideration compared with other methods, many of which have focused on company level strategy or product group oriented consideration alone. As a result performance gap analysis can be conducted in a flexible way dependent on the specific needs: product-related requirements/system gap analysis, factory-wide requirements/system gap analysis, and the overall system/competitors gap analysis. Concerning requirement (5), it applies benchmarking to measure and compare one's manufacturing processes against comparable processes in leading companies in order to obtain information that will help the organisation identify and implement improvement.

7.3.2 The findings during the direct application of the approach

Generally, there were no difficulties in obtaining the data during the case studies, although on some occasions it was necessary to think about the data required as they were not always available from the expected source. For instance, during product analysis, since all three case companies used product characteristics and functional performance to specify product families, worksheet 1 mainly served as a checklist rather than a tool to define products.

The "transformation from the identified manufacturing strategy and objective to the competitive criteria of quality, delivery, flexibility, and cost to be measured" was found to be difficult, though it provides a useful way of determining "what to measure" in qualitative terms. The introduction of the brainstorming technique, which specifies the acceptable level of performance measures, was found to be beneficial.

In specifying long-term goals of performance measures, all three companies had difficulties. One possible explanation is that long-term goals of performance measures are not so rigid and tangible as short-term ones, whilst the latter are easier to define.

All three companies had little factual data about their competitors. This is because the defence industry is more concerned with security than any other industry. Therefore, it is difficult to acquire accurate data from competitors to benchmark manufacturing performance.

In addition, although all three companies agreed that the exercise was useful, in the first stage of the case studies, the researcher encountered many difficulties, not because of the proposed framework itself, but because managers from the case companies were reluctant to involve themselves in the case studies. From this lesson, it has been learnt that in order to ensure the success of implications for testing of framework, or any other new project, management commitment and communication are key.

7.3.3 The findings from the wider application of the approach

In the three UK companies, only one had currently applied strategic performance measurement, the other two were measuring short-term performance from the costs/profits perspective. This provides us with the view that strategic performance measures have, to some extent, potential in industry. Also, with the deficiency of financial performance measures, the measurement system currently used by industry, even though it will facilitate their short-term success, theoretically and practically it will harm their health in the long term.

Although the three Taiwanese companies had some difficulties in performing external benchmarking, no problem was found in the UK cases. Instead, one UK case company had already used benchmarking to establish performance targets as part of a continuous improvement process.

No single company has considered applying the proposed framework, though all three companies agree that the proposed framework is useful and can be used for educational purposes. One interesting finding was that the most profitable of the UK companies showed an interest in the proposed framework, whilst the companies with mixed culture struggling with profits showed less interest in it.

7.4 Weakness and Limitations

It should also be made clear that, in its present form, there are weaknesses and limitations related to both the research method and content of the proposed framework.

(1) Weakness of the proposed framework

The proposed approach does not include after sales service in its framework, particularly those related to maintenance and logistic support. Maintenance and logistic support are especially important for defence products and some commercial products such as machinery, automobile, aeroplane, and ships. The U.S. Department of Defence (DoD) has estimated that for every $12 that DoD puts into R&D, $20 are needed for production and $60 for operation and support (DoD, 1994). Therefore, the omission of performance measures for maintenance and logistic support may be criticised because the proposed framework is only capable of monitoring manufacturing systems performance itself, and restricting product availability and modification.

It may be argued that policy and decisions related to maintenance and logistic support should have a place of their own within the hierarchy of business strategies, and hence are not within the scope of manufacturing strategies and the associated manufacturing performance measurement. Indeed, a few of the existing approaches including some of those reviewed in Chapter 2 seem to have followed this argument. They do not include maintenance and logistics support issues in the manufacturing strategy and manufacturing performance measurement, and hence assume that performance measurement of maintenance and logistic support should be made elsewhere within the organisation. However, they should be treated as the manufacturing strategy policy area and input for the design and development of manufacturing performance measurement.

(2) Weakness of the research method

Due to the limitation of time available, only a certain number of case studies and interviews (three Taiwanese companies and three UK companies) could be carried out in this research, which limits the confidence in the conclusions. For example, since the three Taiwanese companies were all military plants, they shared similar

characteristics of policy and culture with one another. Whilst the companies in UK who were invited to take part in the evaluation test could only offer a limited amount of time to interview users. Therefore, if the researcher had the opportunity to start the project again, the researcher would first follow the process of research methodology developed in Chapter 3, because it is logical and has been proved useful. However, in the validation stage, the researcher would have to get more companies involved. For instance, the number of companies should not be limited to the three sponsor companies. It should be expanded to other industries, either public or private, as long as time is available. This is because the more the companies involve in the research, the more the usefulness of the conclusions will be.

Also, in order to get more UK manufacturing companies involved, the researcher will first search for companies which have relations with Cranfield University, either currently or in the past. In the meantime, the researcher will also use database to select more target companies to extend sampling sources. After the companies have been selected, the next step is to send questionnaires to specify the structure and procedures of the proposed methodology. Then, a face to face interviews could be conducted with those companies that allow the researcher in to further validate/refine the proposed method, and to improve practice. With this effort, it is believed that more UK companies will be involved, and a more useful conclusion could have been drawn as a result.

(3) Limitations related to the case studies

Due to limitations such as time and companies available, only a certain number of case studies and interviews could be carried out within the scope of this research. Consequently one cannot claim that the proposed framework and its new techniques have been completely proven. The positive results thus obtained have only demonstrated their usefulness in a practical sense.

In addition, because of the nature of case studies and interviews, and the fact that companies differed from case to case, certain aspects of the results were difficult to interpret in a general sense. Only a few features of the new approach could be validated with relative confidence (e.g. the overall structure of the framework (section 4.3), the manufacturing performance measures balanced scorecard (section 4.3.1), and

the usefulness of the performance measures metrics (section 5.41) and performance measurement profiles (section 5.43)).

7.5 Lesson learnt from the research

Some lessons learnt from the research, which are important for the design and development of a successful manufacturing performance measurement system, that is:

(1) A conceptual framework is needed for manufacturing performance measurement systems. A review of the literature in Chapter 2 found evidence that every manufacturing company needs a clear and cohesive performance measurement framework that supports objectives and the collection of results. The proposed framework used a balanced set of measurement methodologies to organise performance measures and align them with the business/manufacturing goals and objectives. It includes the use of:

- A balanced set of measures,
- Matrix systems,
- Target setting,
- Benchmarking, and
- The manufacturing strategy policy criteria of capacity, facility, technology, supplier relations, human resources, organisation, production control and so on.

(2) Manufacturing performance measurement systems should place equal emphasis on performance measures and evaluation. According to Dhavale (1996) and GAO (1998) a performance measurement system involves determining what to measure, identifying data collection methods, and collecting the data, whilst evaluation comprises assessing progress towards achieving performance expectations, usually to explain the relationships that exist between programme activities and outcomes. However, from the UK case study results, only one company agrees that performance measurement should not only focus on performance measures but also concentrate on gap analysis in order to provide the most promising solution to supplement the gap. The other two companies were not sure about the

criteria. Also, recalled the Chapter 2 literature review, although current performance measurement models provide a comprehensive structure or process in performance measures, seldom have them take evaluation into consideration. Therefore, the need to place equal emphasis on performance measures and evaluation should be encouraged.

(3) Manufacturing performance measurement systems must provide valid information for management, not just collect data. Kaplan and Norton (1996) argue that performance should focus on the vital few measures. Therefore, manufacturing performance measures should be limited to those that relate to strategic goals and objectives, and that provide timely and relevant information for use by management to assess progress toward achieving predetermined goals. These measures should produce information on the efficiency with which resources are transformed into products and services, on how well results compare to the intended purpose, and on the effectiveness of manufacturing activities in terms of their specific contributions to the objectives.

(4) The case study result has also highlighted some issues regarding the need to develop a quick version of performance measures and evaluation framework. This is because single company has considered applying the proposed framework, though all three companies agree the proposed framework can be used for educational purposes. Also some interviewees were concerned with the complexity of the framework either due to its steps or processes. Although this is not a comment on the structure and processes of the proposed framework, it is a comment on the difficulty and time consuming of completing the worksheets. Accordingly, a more extensive and adaptive performance measures and evaluation scheme should be developed.

7.6 Future works

Some further work has been identified as a result of the lessons learnt from the research, the weakness of the proposed framework, and the suggestions from the case studies and interviews. They are:

- The proposed framework for manufacturing performance measurement and evaluation as presented here is only a prototype, specifying the concepts, logical structure and overall procedures. Further enhancement and refinements are needed: (1) the maintenance and logistic support issue should be taken into consideration, and (2) more tests should be carried out to validate the detailed procedures involved (3) future development of the proposed framework should take the quick version into consideration.
- The procedures of the framework should be made more technically complete and self-explanatory, so that they can be easily understood and effectively applied by the manufacturing managers and engineers.
- Computer-aided tools should be developed to help with the actual application of the proposed framework in practice.

7.7 Contribution to Knowledge

This research has made three main contributions. They are:

(1) Placing emphasis on the integration of manufacturing performance measurement.

As discussed previously in Chapters 2 and 4, a manufacturing performance measurement system is to help develop and maintain a competitive advantage through monitoring of both individual units as well as the whole, and motivating behaviour leading to continuous improvement. However, although the theory of performance measurement or more specifically manufacturing performance measurement is well documented, no one has dealt with the integration of manufacturing strategy, overall system status monitoring, and continuous improvement monitoring. In order to explore this area, the proposed framework is a method of assessing performance that consists of three main sections: specification of strategy-oriented performance measures, overall system status monitoring, and continuous improvement monitoring. The method is for managers to apply to a manufacturing system to assess the current competitive position with respect to the current strategic direction, the competitors and market demands of the market. It also monitors the system's progress towards its strategic objectives and identifies avenues for continuous improvement.

(2) Specifying areas of manufacturing performance measures.

Researchers such as Skinner (1974), Harbour (1993), Brown (1994), and Kaplan and Norton (1996) indicate the importance of vital few measures for the success of performance measurement system implementation. Harbour further suggests the number of vital few measures should not exceed 20, depending on the complexities of the organisation. However, among them, no one has provided us with a guideline regarding how to select those critical few measures. In order to accomplish this task, a matrix of competitive criteria (e.g. quality, delivery flexibility, cost) and manufacturing architectures (e.g. manufacturing processes, human and organisation issues, and information and product control system) is used to stimulate the discussion. The matrix allows management to focus on and develop the critical few measures that balance manufacturing architectures, in a way that matches manufacturing strategies and goals in terms of quality, delivery, flexibility, and cost (see sections 4.4.1 and 5.4.1).

(3) Providing a logical process for manufacturing performance measurement and evaluation.

Again, from the Chapter 2 literature review, it is obvious that there is still no "accepted" process for manufacturing performance measurement and evaluation. Researchers such as Clark and Zirner (1993), Rose (1995), and Neely et al. (1995) place emphasis on the design and develop of the performance measurement process. However, they fail to provide a detailed description of when and how to conduct performance measures. In order to prevent the above deficiencies, this research provides the proposed manufacturing performance measurement and evaluation process in great detail. Also, as discussed previously, although the current prototype still has some deficiencies and needs to be modified, it has been proven to be conceptually logical, and overall well structured. As a process, the proposed framework is not simply concerned with collecting data associated with a predetermined performance goal. It involves prevention and detection of performance variance with the aim of achieving conformance of the products or services to the customer's requirement. In addition, it is concerned with process optimisation

through the increased efficiency and effectiveness of the manufacturing system or product produced, in a continuous cycle (see Chapters 5 and Appendix D).

7.8 Conclusions

The study presented within this thesis represents an advancement in the approach to manufacturing performance measurement and evaluation in terms of academic study and practical application. This research has adapted the relevant and current techniques to measure performance, including their theory, processes, approaches, and criteria to provide a new approach for the design and development of manufacturing performance measurement and evaluation. This research has developed a proposed framework to link strategy-oriented performance measures, overall system status monitoring, and continuous improvement monitoring. The proposed framework not only shows what to do but provides a step by step procedure to show how to do it, which is fundamentally different from other popular models designed to provide a conceptual approach. In addition, this research has highlighted some theoretical and practical problems associated with the design and development of a manufacturing performance measurement framework.

The results of the case studies revealed that the proposed framework was logical and met the original objective of providing a useful way to help Taiwanese military plants establish their future manufacturing performance measurement and evaluation system. Also, since the structure, contents and techniques of this framework are generic, throughout the interviews with the three UK case companies, it demonstrated that the proposed framework has the potential of being adopted and implemented in a flexible way to suit the needs of manufacturers within different industrial sectors to solve their performance measurement and evaluation problems.

References

Ahmed, P.K. and Montagno, 1996, Operations strategy and organisational performance: an empirical study, *International Journal of Operations & Production Management,* 16(5), 41-53.

Ahmed, P.K., Lim. K.K., and Zairi, M, 1999, Measurement practice for knowledge management, *Journal of Workplace Learning: Employee Counselling Today,* 11(8), 304-311.

Akao, Y., 1990, *Quality Function Deployment*, Productivity Press, Cambridge, MA.

Allen, D.J., 1993, Developing an effective performance measurement system, *APICS Annual International Conference Proceedings,* Falls Church, VA, USA.

Alreck, P.L. and Settle, R.B., 1985, *The Survey Research Handbook,* Richard D Irwin Inc., USA.

Andersen, B., and Pettersen, P.G., 1996, *The Benchmarking Handbook: Step-by-step Instructions*, Chapman & Hall, London.

APQC (American Productivity & Quality Centre), 1993, *Basics of Benchmarking*, Houston, USA.

Baldrige Award Web Site, http://www.baldrige.com, September, 2000

Balkcom, J.E., Ittner, C.D., and Larcker, D.F., 1997, Strategic performance measurement: lessons learned and future directions, *Journal of Strategic Performance Measurement,* April/May, 22-32.

Ballantine, J. and Brignall, S, 1995, *A taxonomy of performance measurement frameworks*, Warwick Business School Research Papers, University of Warwick, No. 135.

Basu, R. and Wright, N., 1996, Measuring performance – against world class standards, *IIE solutions,* December, 32-35.

Beamon, B.M., 1999, Measuring supply chain performance, *International Journal of Operation & Production Management*, 19 (3), 275-292.

Bemowski, K., 1991, The benchmarking bandwagon, *Quality Progress*, 24(1), 19-24.

Benbasat, I, Goldstein, D.K., and Mead, M., 1987, The case research strategy in studies of information systems, *MIS Quarterly*, September, 369-386.

Berliner, C. and Brimson, J.A., 1988, *Cost Management for Today's Advanced Manufacturing,* Harvard Business School, Boston, USA.

Bititci, U.S., 1994, Measuring your way to profit, *Management Decision*, 32(6), 16-24.

Bititci, U.S., Carrie, A.S., McDevitt, L., 1997, Integrated performance measurement systems: an audit and development guide, *The TQM Magazine,* 9(1), 46-53.

Black, J.T., 1991, *The Design of Manufacturing Systems: Axiomatic Approach, Design, Analysis, and Control of Manufacturing Cells*, (ASME, New York).

Blaxter, L. Hughes, C., and Tight, M., 1996, *How to Research*, Open University, Press, Buckingham.

Blazey, M.L., 1997, Achieving performance excellence, *Quality Progress*, 30(6), 61-64.

Bohoris, G.A., 1995, A comparative assessment of some major quality awards, *International Journal of Quality & Reliability Management,* 12(9), 30-43.

Bolden, R., Waterson, P., Warr, P., Clegg, C., 1997, A new taxonomy of modern manufacturing practices, *International Journal of Operations & Production Management*, 17(11), 1112-1130.

Bond, T.C., 1999, The role of performance measurement in continuous improvement, *International Journal of Operations & Production Management*, 19(12), 1318-1334.

Bourne, M. and Wilcox, M, 1998, Translating Strategy into Action, *Manufacturing Engineer*, June, 109-112.

Bourne, M., 1999, Designing and Implementing a Balanced Performance Measurement System, *Control*, July-August, 21-24.

Boxwell, R.J., 1994, Benchmarking for Competitive Advantage, Mcgraw-Hill, New York

British Quality Foundation, 1994, *UK Quality Award: Guide to Self-Assessment*, London.

British Quality Foundation, 1995, *Guide to Self-Assessment*, London.

Brown, M.G., 1994, Is your measurement system well balanced? *Journal for Quality and Participation*, October/November, 6-11.

Brown, R. Mark, 1996, *Keeping Score: Using The Right Metrics to Drive World Class Performance*, Quality Resources, New York.

Buffa, E.S, 1984, *Modern Production/Operations Management*, 7th edition, John Wiley & Sons, Chichester.

Burcher, P and Stevens, K., 1996, Measuring up to world class manufacturing, *Control,* 22(1), 17-21.

Butler, A., Letza, S.R., and Neale, B., 1997, Linking the balanced scorecard to strategy, *Long Range Planning*, 30(2), 242-253.

Camp, R.C., 1989, *Benchmarking: The Search for Industry Best Practices That Lead to Superior Performance*, ASQC Quality Press, Milwaukee, WI.

Camp, R.C., 1993, Benchmarking: the search for best practices in industry, *Manufacturing Europe*, 24-28.

Caplice, C and Sheffi, Y., 1995, A review and evaluation of logistics performance measurement systems, *International Journal of Logistics Management*, 6(1), 61-74.

Chang, R.Y. and Young, P.D, 1995, *Measuring Organisational Improvement Impact*, Richard Chang Associates, Inc., California.

CIMA, 1995, *Performance Measurement in the Manufacturing Sectors Research Studies*, The Chartered Institute of Management Accountants.

Clark, L.A. and Zirner, U., 1993, How to design, develop, & implement successful performance measurement systems, *Quality and Productivity Management Journal*, 10, 61-80.

Cohen, L. and Manion, L., 1989, *Research Methods in Education*, 2nd Edition, Routledge, London.

Corbett, L.M., 1998, Benchmarking manufacturing performance in Australia and New Zealand, *Benchmarking for Quality Management & Technology, 5(4), 271-282.*

Crawford, K.M., Cox, J.F., 1990, Performance measurement systems for just-in-time operations, *International Journal of Production research,* 28(11), 2025-2036.

Cross, K.F. and Lynch, R.L., 1988/1989, The SMART way to define and sustain success. *National Production Review, 8(1), 23-33.*

Czuchry, A.J, Yasin, M.M., and Dorsch, J.J., 1995, A review of benchmarking literature: a proposed model for implementation, *International Journal of Materials and Product Technology*, 10(1/2), 27-45.

Davenport, T.H. & Short, J.E., 1990, The new industrial engineering: information technology and business process redesign," *Sloan Management Review*, Summer, 11-27.

Davenport, T.H., 1993, *Process Innovation*, Harvard Business School Press, Boston, MA.

Davies, J., Khodabocus, F., and Obray, C., 1996, Self-assessment: a path to business excellence, *Quality World Technical Supplement,* March, 4-11.

De Meyer, A., Nakane, J., Miller, J.G., and Ferdows, K., 1989, Flexibility: the next competitive battle: the manufacturing futures survey, 1989, *Strategic Management Journal*, 10, 135-144.

Deming, W.E., 1982, *Quality, Productivity, and Competitive Position, Massachusetts Institute of Technology*, Centre for Advanced Engineering Study, Cambridge, MA.

Dhavale, D.G., 1996, Problems with existing manufacturing performance measures, *Journal of Cost Management (USA),* winter, 50-55.

Dixon, J, Nanni, A.J. and Vollmann, T.E., 1990, *The New Performance Challenge: Measuring Operations for World-Class Competition*, Homeweed, Irwin, US.

DoD, 1994, *Integrated Logistics Support Guide*, Defence systems management college Press, Fort Belvoir, VA, USA.

Dooley, K.J., Bush, D., Anderson, J.C., and Rungtusanatham, M., The US Baldrige Award and Japan's Deming Prize: two guidelines for total quality control, *Engineering Management Journal,* September, 2(3), 9-16.

Douwe, S., Flapper, P., Fortuin, L., and Stoop, P.M., 1996, Towards consistent performance management system, *International Journal of Operations & Production Management,* 16(7), 27-37.

DTI (Department of Trade & Industry), 1990, *Managing into the '90s – Aiming for World Class Manufacturing*, London.

DTI (Department of Trade & Industry), 1992, *Competitive Manufacturing: A Practical Approach to the Development of a Manufacturing Strategy*, London.

DTI (Department of Trade & Industry), 1998, *Quality Cost Delivery: Seven Measures for Improved Competitiveness in Manufacturing Industry*, London.

Eisenhardt, K.M., 1989, Building theories from case study research, A*cademy of Management Review,* 14(4), 532-550.

Elliot, J., 1991, *Action Research for Educational Change*, Open University Press, Buckingham.

Ferdowns, K. and De Meyer, A., 1990, Lasting improvements in manufacturing performance: in search of a new theory, *Journal of Operations Management* 9(2), 168-184.

Fine, C.H. and Hax, A.C., 1985, Manufacturing strategy: a methodology and an illustration, *Interfaces*, 15(6), 28-46.

Fisher, J., 1992, Use of non-financial performance measures, *Cost Management*, Spring, 31-38.

Fitzgerald, L., Johnston, R, Brignall, S., Silvestro, R., and Voss, C., 1991, *Performance Measurement in Service Business*, The Chartered Institute of Management Accountants, UK.

Flynn, B.B., Schroeder, R.G., and Flynn, E.J., 1999, World class manufacturing: an investigation of Hayes and Wheelwright's foundation, *Journal of Operations Management,* 17, 249-169.

Fortuin, L., 1988, Performance indicators-why, where and how?, *European Journal of Operational Research,* 34, 1-9.

Foster, R.N., 1986, *Innovation: The Attacker's Advantage*, Macmillan, London.

Fry, T.D., 1995, Japanese manufacturing performance criteria, *International Journal of Production Research,* 33(4), 933-954.

Ganapathy, B.K. and Goh, C.H., 1997, A hierarchical system of performance measures for concurrent engineering, *Concurrent Engineering: Research & Applications*, 5(2), 137-143

GAO, 1998, GGD-98-26, *Program Measurement and Evaluation: Definitions and Relationships*, US Government Accounting Office Report, Washington DC.

Garvin, D.A., 1991, How the Baldrige Award really works, *Harvard Business Review,* November-December, 80-93.

Gershwin, S.B., 1994, *Manufacturing Systems Engineering*, Prentice-Hall, London.

Ghalayini, A.M., and Noble, J.S., 1996, The changing basis of performance measurement, *International Journal of Operations & Production Management*, 16(8), 63-80.

Ghalayini, A.M., Noble, J.S., and Crowe T.J., 1997, An integrated dynamic performance measurement system for improving manufacturing competitiveness, *International Journal of Production Economics*, 48, 207-225.

Ghobadian, A. and Woo, H.S., 1996, Characteristics, benefits and shortcomings of four major Quality Awards, *Internal Journal of Quality & Reliability Management*, 13(2), 10-44.

Gibson, P., Greenhalgh, G., and Kerr, R., 1995, *Manufacturing Management: Principles and Concepts,* Chapman & Hall, London.

Greenfield, T., 1996, *Research Method*, ARNOLD, London.

Greenhalgh, G.R., 1992, *Manufacturing Strategy, Formulation and Implementation*, Addison-Wesley, Wprlomgjam.

Gregory, M.J., 1993, Integrated performance measurement: a review of current practice and emerging trends. *International Journal of Production Economics,* 30/31, 281-296,

Gupta, D. and Buzacott, J.A., 1996, A 'goodness test' for operational measures of manufacturing flexibility, *The International Journal of Flexible Manufacturing Systems,* 8, 233-245.

Hacker, M.E. and Brotherton, P.A., 1998, Designing and installing effective performance measurement systems, *IIE Solutions*, August, 18-23.

Hakes, C, 1996, *The Corporate Self-assessment Handbook for Measuring Business Excellence*, 3rd Edition, Chapman & Hall.

Hammer, M. and Champy, J, 1993, *The Reengineering Corporation: A manifesto for business revolution*, Harper Business, NY.

Harbour, J.L., 1993, *The Basics of Performance Measurement*, Quality Resources, New York.

Harrington, H.J., 1991, *Business Process Improvement: The Breakthrough Strategy for Total Quality, Productivity, and Competitiveness*, ASQC, McGraw-Hill.

Hayes, R.H. and Schmenner, R.W., 1978, How should your organisation manufacturing? *Harvard Business Review,* January-February, 105-118.

Hayes, R.H., and Wheelwright, 1984, *Restoring Our Competitive Edge: Competing Through Manufacturing*, Wiley, New York.

Hayes, R.H. and Clark, K.B., 1986, Why some factories are more productive than others, *Harvard Business Review,* September-October, 67-73.

Heim, J.A. and Compton, W.D., 1992, *Manufacturing Systems: Foundations of World-Class Practice,* National Academy of Engineering, Washington DC.

Hendricks, J.A., Defreitas, D.G., and Walker, D.K., 1996, Changing performance measures at caterpillar, *Managing accounting* (US), December, 18-22, 24.

Heizer, J. and Render, B., 1996, *Production & Operations Management*, Prentice Hall.

Hill, T.J., 1987, Teaching and research directions in production/operations management: the manufacturing sector, *International Journal of Operations and Production Management*, 7(4), 5-12.

Hill, T.J., 1993, *Manufacturing Strategy, Text and Cases*, Macmillan, Basingstoke.

Hinnels, M., 1993, Environmental factors in products: how to gather the evidence?, *Design Studies,* 14 (4), 457-474.

Hitomi, K., 1994a, *Analysis and Design of Manufacturing Systems, in Dorf, R.C. and Kusiak, A, Handbook of Design, Manufacturing and Automation*, John Wiley & Sons, Inc., USA.

Hitomi, K. 1994b, Manufacturing systems: past, present and for the future, *International Journal of Manufacturing System Design*, 1(1), 1-17.

Hodgetts, R.M., 1998, *Measures of Quality & High Performance: simple tools and lessons learned from America's most successful corporations*, AMACOM, American Management Association.

Hronec, S.M., 1993, *Vital Signs: Using Quality, Time, and Cost Performance Measurements to Chart Your Company's Future*, Arthur Andersen & Co., USA.

Hughes, M., 1996, *Interviewing, in Greenfield, T., Research Methods: Guidance for Postgraduates,* ARNOLD, London.

Hull, R.S., 1998, *An Investigation into the Structure of a Manufacturing Strategy Analysis/manufacturing systems design interface within an integrated CAMSD environment*, PhD thesis, Cranfield University.

Hutton, P., 1990, *Survey Research for Managers: How to Use Surveys in Management Decision-Making*, 2nd Edition, Basignstoke, Macmillan.

Internal Business Excellence and Awards Models wet site: *www.nbs.ntu.ac.uk*

Ishikawa, K, 1989, How to apply company wide quality control in foreign countries, *Quality Progress*, September, 70-74.

Jonsson, P. and Lesshammar, M., 1999, Evaluation and improvement of manufacturing performance measurement systems – the role of OEE, *International Journal of Operations & Production Management,* 19 (1), 55-78.

Kaplan, R.S., 1984, Yesterday's accounting undermines production, *Harvard Business Review*, July-August, 52-59.

Kaplan, R.S., 1990, *Measures for Manufacturing Excellence*, Harvard Business School Press, USA.

Kaplan, R.S., 1991, New systems for measurement and control, *The Engineering Economist,* 36(3), 201-218.

Kaplan, R.S., Norton, D.P., 1992, The Balanced Scorecard – measures that drive performance, *Harvard Business Review,* January-February, 47-54.

Kaplan, R.S. and Norton, D.P., 1996a. Linking the Balanced Scorecard to strategy. *California Management Review*, Vol. 39 (1), 53-79

Kaplan, R.S., Norton, D.P., 1996b, Using the Balanced Scorecard as a strategic management system, *Harvard Business Review,* January-February, 75-85.

Kaplan, R.S., Norton, D.P., 1996c, *The Balanced Scorecard: Translating Strategy into Action, Harvard Business School Press.*

Kaydos, W., 1991, *Measuring, Managing and Maximising Performance*, Productivity Press.

Kaye, M. and Andersson, R., 1999, Continuous improvement: the ten essential criteria, *International Journal of Reliability Management*, 16(5), 485-506.

Keegan, D.P., Eilar, R.G., and Jones, C.R., 1989, Are your performance measurements obsolete? *Management Accounting,* Vol. 71, June, 45-50.

Korpela, J. and Tuominen, M., 1996, Benchmarking logistics performance with an application of the Analytic Hierarchy Process, *IEEE Transactions on Engineering Management*, 43(3), August, 323-333.

Lakshmi, U., Tatikonda, C.M., and Rao, J.T., 1998, We need dynamic performance measures, *Management Accounting (US)*, 80(3), 49-53.

Langrish, J., 1993, Case studies as a biological research process, *Design Studies*, 14 (4), 357-364.

Lebas, M.J., 1995, Performance measurement and performance management, *International Journal of Production Economics*, 41, 23-35.

Leong, G.K, Snyder, D.L., and Ward, P.T., 1990, Research in the process and content of manufacturing strategy, *OMEGA, International Journal of Management Science*, 18(2), 109-122.

Lingle, J.H. and Schiemann, W.A., 1996, From Balanced Scorecard to strategic gauges: is measurement worth it? *Management Review*, March, 56-61.

Lockammy III, A., 1998, Quality-focused performance measurement systems: a normative model, *Internal Journal of Operations and Production Management*, 18(8), 740-766.

Lockammy III, A. and Cox III, J.F., 1995, An empirical study of division and plant performance measurement systems in selected world class manufacturing firms: linkages for competitive advantage, *International Journal of Production Research*, 33(1), 221-236.

Lynch, R.L. and Cross, K.F., 1991, *Measure Up! Yardsticks for Continuous Improvement*, Cambridge, MA. US.

Manoochehri, G., 1999, The road to manufacturing excellence, *Industrial Management*, 41(2), 7-13.

Mansell, G., 1991, Action research in information systems development, *Journal of Information Systems,* 1, 29-40.

Mapes, J., New, C., and Szwejczewski, 1997, Performance trade-offs in manufacturing plants, *International Journal of Operation and Production Management*, 17(10), 1020-1033.

Martin, R., 1997, Do we practise quality principles in the performance measurement of critical success factor? *Total Quality Management*, 8(6), 429-444.

Mashall, C., Rossman, G.B., 1989, *Designing Qualitative Research*, Sage Publications, Newbury Park, CA.

Maskell, B.H., 1989, Performance measurement for world class manufacturing, M*anagement Accounting*, May, 32-33; June, 32-33; July/August, 48-50; September, 64-66.

Maskell, B.H., 1991, *Performance Measurement for World Class Manufacturing: A Model for American Companies*, Productivity Press.

McCutcheon, D.M., Meredith, J.R., 1993, Conducting case study research in operations management, *Journal of Operations Management*, 11, 239-256.

Mcmann, P and Nanni, A.J., 1994, Is your company really measuring performance? *Management Accounting* (US), 76(5), 55-58.

McNair, C.J., Lynch, L., and Cross, K.F., 1990, Do financial and non-financial performance measures have to Agree? *Management Accounting (NAA)*, 72(5), 28-36.

Meyer, C., 1994, How the right measures help teams excel, *Harvard Business Review*, May-June, 95-103.

Miller, J.G. and Roth, A.V., 1988, *Manufacturing Strategies,* Boston University Manufacturing Roundtable, Boston, USA.

Miller, J.G., Amano, A., De Meyer, A., Ferdows, K., Nakane, J., and Roth, A., 1989, *Closing the Competitive Gaps*, Boston University Manufacturing Roundtable, Boston, USA.

Miller, J.G. ,De Meyer, A., and Makane, J., 1992, *Benchmarking: Global Manufacturing*, Business One IRWIN.

Miller, J.G. and Roth, A.V., 1994, Taxonomy of manufacturing strategies, *Management Science,* 40 (3),

Moore, N., 1987, *How to do Research*, 2nd Edition, Library Association, London.

Najarian, G., 1993, Performance measurement: measure the right things, *Journal of Manufacturing Systems, September,* 54-57.

Nakhai, B. and Neves, J.S., 1994, The Deming, Baldrige, and European Quality Awards, *Quality Progress*, April, 33-37.

Nanni A.J., Dixon, J.R., and Vollmann, T.E., 1990, Strategic control and performance measurement, *Jouirnal of Cost Management*, Summer, 33-42.

Nanni A.J., Dixon, J.R., and Vollmann, T.E., 1992, Integrated performance measurement: management accounting to support the new manufacturing realities, *Journal of Management Accounting Research*, Fall, 1-19.

NAVSO P-3689, 1999, *Producibility System Guidelines For Successful Companies*, US Navy, Washington DC.

Neely, A., Gregory, M., Platts, K., 1995, Performance measurement system design, *International Journal of Operations & Production Management*, 15(4), 80-116.

Neely, A.S., Mills, J.F., Gregory M.J, Richards, A.H., Platts, K.W., and Bourne, M., 1996, *Getting the Measure of Your Business*, Findlay, London.

Neely A., Richards, H., Mills, J., Platts, K., and Bourne, M., 1997, Designing performance measures: a structured approach, *International Journal of Operation and Production Management,* 17(11), 1131-1152.

NPR (National Partnership for Reinventing Government), 1999, *Balancing Measures: Best Practices in Performance Management,* Washington DC.

Platts, K.W., 1990, *Manufacturing Audit in the Process of Strategy Formulation*, PhD Thesis, University of Cambridge.

Platts, K.W. and Gregory, M.J., A Manufacturing Audit Approach to Strategy Formulation, in Voss A. C., 1992, "*Manufacturing Strategy: Process and Content*", Chapman & Hall, U.K.

Porter, M.E., 1980, *Competitive Strategy: Techniques for Analysing Industries and Competitors*, Free Press, New York.

Prasad, B., 1999, A model for optimising performance based on reliability, life cycle costs and other measurements, *Production Planning & Control*, 10(3), 286-300.

Rich, A.B., 1997, Continuous improvement: the key to future success, *Management Progress*, 30(6), 33-36.

Richardson, P.R., Taylor, A.J., and Gordon, J.R.M., 1985, A strategic approach to evaluating manufacturing performance, *Interfaces*, 15(6), 15-27.

Republic of China Annual Defence Report, 2000, Ministry of National Defence, Taipei, Taiwan (*www. mnd. gov.tw).*

Rose, K.H., 1995, A performance measurement model, *Quality Progress*, February, 63-66.

Roth, A.V. and Miller, J.G., 1992, Success factors in manufacturing, *Business Horizons*, July-August, 73-81.

Santori, P.R. and Anderson, A.D., 1987, Manufacturing performance in the 1990s: measuring for excellence, *Journal of Accountancy*, 164(5), 141-147.

Schmenner, R.W. and Vollmann, T.E., 1994, Performance measures: gaps, false alarms and the 'Usual Suspects', *International Journal of Operations and Production Management,* 14(12), 58-69.

Simons, R, 1995, *Level of Control: How Managers Use Innovative Control Systems to Drive Strategic Renewal*, Harvard Business School Press, Boston.

Sink, S.D., and Tuttle, T.C., 1989, *Planning and Measurement in your Organisation of the Future*, Industrial Engineering and Management Press, Georgia, US

Skinner, W., 1969, Manufacturing - missing link in corporate strategy, *Harvard Business Review,* May-June, 136-145.

Skinner, W., 1974, The focused factory, *Harvard Business Review,* May-June, 113.

Spendolini, M.J., 1992, *The Benchmarking Book*, AMCOM, New York.

Stivers, B.P., Covin, T.J., Hall, N.G, and Smalt, S.W., 1998, How non-financial performance measures are used, *Management Accounting,* February, 44-49.

Sweeney, M.T., 1993, Benchmarking for strategic manufacturing management, *International Journal of Operations & Production Management*, 14(9), 4-15.

Sweeney, M.T., Szwejczewski, M., 1996, Manufacturing strategy and performance, I*nternational Journal of Operations & Production Management*, 16(5), 25-40.

Swink, M., Way, M.H., 1995, Manufacturing strategy: propositions, current research, renewed directions, *International Journal of Operations and Production management,* 15(7), 4-26.

Tatikonda, L.U., 1998, We need dynamic performance measures, *Management Accounting (US)*, September, 49-53.

Taylor, L. and Convey, S. 1993, Making performance measurements meaningful to the performers, *Canadian Manager*, Fall, pp22-24.

Thomas, R., 1996, Survey, in Greenfield, T., *Research Methods*, ARNOLD, London.

Troxler, J.W. and Blank, L., 1989, A comprehensive methodology for manufacturing system evaluation and comparison, *Journal of Manufacturing Systems,* 8(3), 175-183.

Tsang, A.H.C., Andrew, K.S., and Harvey, K., 1999, Measuring maintenance performance: a holistic approach, *International Journal of Operations & Production Management*, 19(7), 691-715.

Vaziri, H.K., 1992, Using competitive benchmarking to set goals, *Quality Progress,* October, 81-85.

Voss, C.A., 1992, *Manufacturing Strategy: Process and Content*, Chapman & Hall, London.

Walsh, P., 1996, Finding key performance drivers: some new tools, *Total Quality Management*, 7(5), 509-519.

Walleck, S.A, O'Halloran, D.J., and Leader, C.A., 1991, Benchmarking world-class performance, *The McKinsey Quarterly,* No. 1, 3-24.

Ward, P.T., Keong Leong, G., and Snyder, D.L., Manufacturing Strategy: An Overview of Current Process and Content Models, in Ettlie, J.E., Burstein, M.C., and Fiegenbaum, A, 1990, *Manufacturing Strategy: The Research Agenda for the Next Decade*, Kluwer Academic Publishers, Ma. USA.

Ward, A., 1996, Measuring the product innovation process, *Engineering Management Journal*, 6(5), 242-246.

Webster's American English Dictionary, 1990, Collins, London.

Weihrich, H., 1982, The SWOT matrix – a tool for situational analysis, *Long Range Planning*, 15(2), 54-66.

Westbrook, R., 1995, Action Research: A new paradigm for research in production and operations management, *International Journal of Operations and Production Management,* 15(12), 6-20.

Wheelwright, S.C., 1984, Manufacturing strategy: defining the missing link, *Strategic Management Journal,* 5, 77-91.

White, G.P., 1996, A survey and taxonomy of strategy-related performance measures for manufacturing, *Internal Journal of Operations & Production Management,* 16(3), 42-61.

White, G.P., 1996, A survey and taxonomy of strategy-related performance measures for manufacturing, *Internal Journal of Operations & Production Management,* 16(3), 42-61.

Wisner, J.D. and Fawcett, S.E., 1991, Linking firm strategy to operating decisions through performance measurement, *Production and Inventory Management Journal,* 3rd Quarter, 5-11.

Wu, B., 1994, *Manufacturing Systems Design and Analysis*, 2nd Edition Context and Techniques, Chapman & Hall, London.

Wu, B. and Hull, R.S., 1997, A task centred methodology to support an integrated and open computer aided manufacturing systems design environment, *Proceedings of International Conference on Manufacturing automation,* Volume 1, edited by Tan, S.T., Wong, T.N., Gibson, I., Hong Kong.

Yin, R., 1989, *Case Study Research*, Sage Publications, New York.

Yin, R., 1993, *Application of Case Study Research*, Sage Publications, Newbury Park, CA.

Zairi, M., 1994, *Measuring Performance for Business Results*, Chapman & Hall, UK.

Zairi, M, 1996, *Benchmarking for Best Practice: Continuous Learning Through Sustainable Innovation*, Buttterworth-Heinemann, Oxford.

Appendix A Glossary of Manufacturing Performance Measurement Terms

The following terms used in this thesis are defined as they apply to manufacturing performance measurement.

Balanced Scorecard: A management instrument that translates an organisation's mission and strategy into a comprehensive set of performance measures to provide a framework for strategic measures and management. The scorecard measures organisational performance across several perspectives: financial, customers, internal business processes, and learning and growth.

Benchmarking: A process of comparing and evaluating products or processes in order to identify best practices and/or opportunities for improvement.

Business Process Reengineering: A methodology for radical, rapid change in business processes achieved by redesigning the process from scratch and then adding automation. Aimed at cost reductions of 70% or more when starting with antiquated processes, but with a significant risk of lower results.

Check Sheet: A form specially designed so that results can be readily interpreted from the form itself.

Effectiveness: (a) Degree to which a strategy is successful in achieving the vision (outcome); (b) degree to which activities of a unit achieve the unit's mission or goal faster, better (as defined by the customers), and cheaper.

Efficiency: (a) Degree of productivity of a process, such as the number of cases closed per year; (b) degree to which a functional unit accomplishes its mission faster and cheaper.

Continuous Improvements: The ongoing improvement of products, services, and processes through incremental and measurable enhancements.

Core Process: The fundamental activities, or group of activities, so critical to an organisation's success that failure to perform them in an exemplary manner will result in deterioration of the organisation's mission.

Critical Activity: Activity that significantly impacts total process efficiency, effectiveness, quality, timeliness, productivity, or safety. At the management level, they impact management priorities, organisational goals, and external customer goals.

Feedback Loop: a systematic series of steps for maintaining conformance to quality goals by feeding back performance data for evaluation and corrective action. This is the basic mechanism for quality control.

Key Performance Indicator: Measurable factor of extreme importance to the organisation in achieving its strategic goals, objectives, vision, and values that, if not implemented properly, would likely result in a significant decrease in customer satisfaction, employee morale, and effective financial management.

Life-Cycle Cost: the total cost for development, operation, maintenance, and disposal of product over its full life and a value that is often used in design trade-off studies. A model can be used to optimise product costs and predict future costs of maintenance, logistics, and warranties.

Metrics: The elements of a measurement system consisting of key performance indicators, measures, and measurement methodologies.

Outcome Measure: An assessment of the results of a program activity as compared to its intended purpose.

Output Measure: Tabulation, calculation, or recording of activity or effort.

Pareto Analysis: A method, using vertical bar graphs, to display occurrences in a prioritised order. Occurrences are taken for a specific time frame of the event measured.

Performance Goal: A target level of performance expressed as a tangible, measurable objective, against which actual achievement can be compared.

Performance Indicator: A particular value or characteristic used to measure output or outcome.

Performance Measures: Performance measures are quantitative/qualitative evaluations of the products or services of a process or system. (A metric used to quantify the efficiency and/or effectiveness of action).

Performance Measurement: A process of assessing progress toward achieving predetermined goals

Performance Measurement System: The set of metrics used to quantify the efficiency and effectiveness of actions.

Performance Objective: This is a critical success factor in achieving the organisation's strategy. If it is not achieved, it would likely result in a significant decrease in customer satisfaction

Products/Service: Products and services are treated alike – they are simply the output of a process such as computer boards (products) or training modules (services).

Quality Function Deployment: an iterative process used to identify and define customer requirements and their effective on the design attributes.

Self-Assessment: The continuous process of comparing performance with desired objectives to identify opportunities for improvement.

Strategic Goal: A long-range change target that guides an organisation's efforts in moving toward a desired future state. Strategic objective: A broad time-phased measurable accomplishment required to realise the successful completion of a strategic goal.

Strategic Planning: A continuous and systematic process whereby guiding members of an organisation make decisions about its future, develop the necessary procedures and operations to achieve that future, and determine how success is to be measured.

Strategy: Hypotheses that propose the direction a company should go to fulfil its vision and maximise the possibility of its future success.

Statistical Process Control (SPC): The use of statistical tools and techniques to identify, analyse, and control variation in manufacturing processes.

Statistical Quality Control (SQC): the use of statistical methods to analyse, monitors, and control the quality of the product and the production processes.

Total Quality Management: A methodology for continuous monitoring and incremental improvement of a supply-line process by identifying causes of variation and reducing them.

Variance: In quality management terminology, any non-conformance to specification.

Vision: An idealised view of a desirable and potentially achievable future state where or what an organisation would like to be in the future.

Appendix B Measurement Methods and Decision Support Tools

Benchmarking

Benchmarking is the continuous process of measuring one product or process against another similar product or process to identify best practices. It is a starting point for initiating change within a company or organisation. The most common reasons an organisation will benchmark are to determine where they stand amongst the competition and whether value can be added by incorporating the practices of others. Benchmarking can be used by organisations for comparison of internal operations, competitor-to-competitor products, industry standing, and generic business functions or processes. The goal of benchmarking is to identify the best practices of industry and to adapt and/or incorporate those practices that are beneficial to the organisation.

In benchmarking, it is always best to start with a known problem that can be defined or one that has the potential to provide the maximum benefit to the organisation. When applied to producibility, benchmarking can result in the identification of processes that will reduce cost, improve quality, and result in more desirable products for the customer.

Benchmarking within an organisation can be used for the setting of goals and spurring creativity and innovation. It can also be employed to identify solutions for product or process problems. Benchmarking is an effective means of identifying improvements within an organisation by raising the standard of quality and efficiency in a product or process. The standard of quality is elevated when comparison via benchmarking identifies opportunities and methods that can improve upon the item, process, or procedure being benchmarked.

When a company decides that it will strive to have the best product or process, benchmarking is used to determine its current status in the industry and to identify and steps necessary to reach its goal of becoming or remaining the best. In many cases, companies form benchmarking partnerships to permit the exchange of data. The benchmarking partner can be either a primary competitor, an internal organisation, or, ideally, a world-class organisation, which may be more likely to share information than a primary competitor.

There are four primary phases of benchmarking. The first phase is the planning phase during which the product or process to be benchmarked is identified and the companies to be used for comparison sleeted. The type of data to be gathered is identified, and the data is collected. One method to gather data is through a questionnaire to the benchmarking company that specifically addresses the area being benchmarked.

The second phase is data analysis. In this phase, all aspects of the identified competition or benchmarking company are analysed to determine variations between the two similar products or processes. The information is compared for similarities and differences to identify improvement areas. This is where the current performance gap between the two benchmarking companies is determined.

The third phase, integration, is where the findings are communicated, goals are established, and a plan of action is defined.

Implementation, the fourth phase, consists of initiating the plan of action and monitoring the results. The product or process that was benchmarked continues to be monitored for improvement and should be benchmarked often to ensure the improvement is continuous.

Quality Function Deployment

Quality function deployment (QFD) is a team-based systematic and iterative process used to address and fine tune the requirements and needs of customers. The primary goal is satisfying the customer's requirements. Once the customer's requirements are identified, they are then translated into specifications for product planning, design, process and production. QFD is a team approach to determine objectives, the best method to accomplish the objectives, the process to be used, and the resources needed.

A major benefit of QFD is that communication is enhanced throughout the product development process. This enhanced communication leads to a more effective decision-making process. Short-term benefits include reducing cross-functional barriers associated with product development teams and aiding changes in corporate culture. Long-term benefits include reduced development costs, reduced overall cycle time, and increased productivity.

The QFD process is a structured procedure that begins with identifying the qualities desired by the customer and then the steps and means necessary to provide the product. It enables a great deal of information to be summarised in the form of easy-to-interpret charts. The process used a series of interrelated matrices to convert customer needs to process steps. QFD matrices relate the data produced in one stage to the decision that must be made at the next process stage. The QFD House of Quality (Figure B-1) shows the process for developing these matrices.

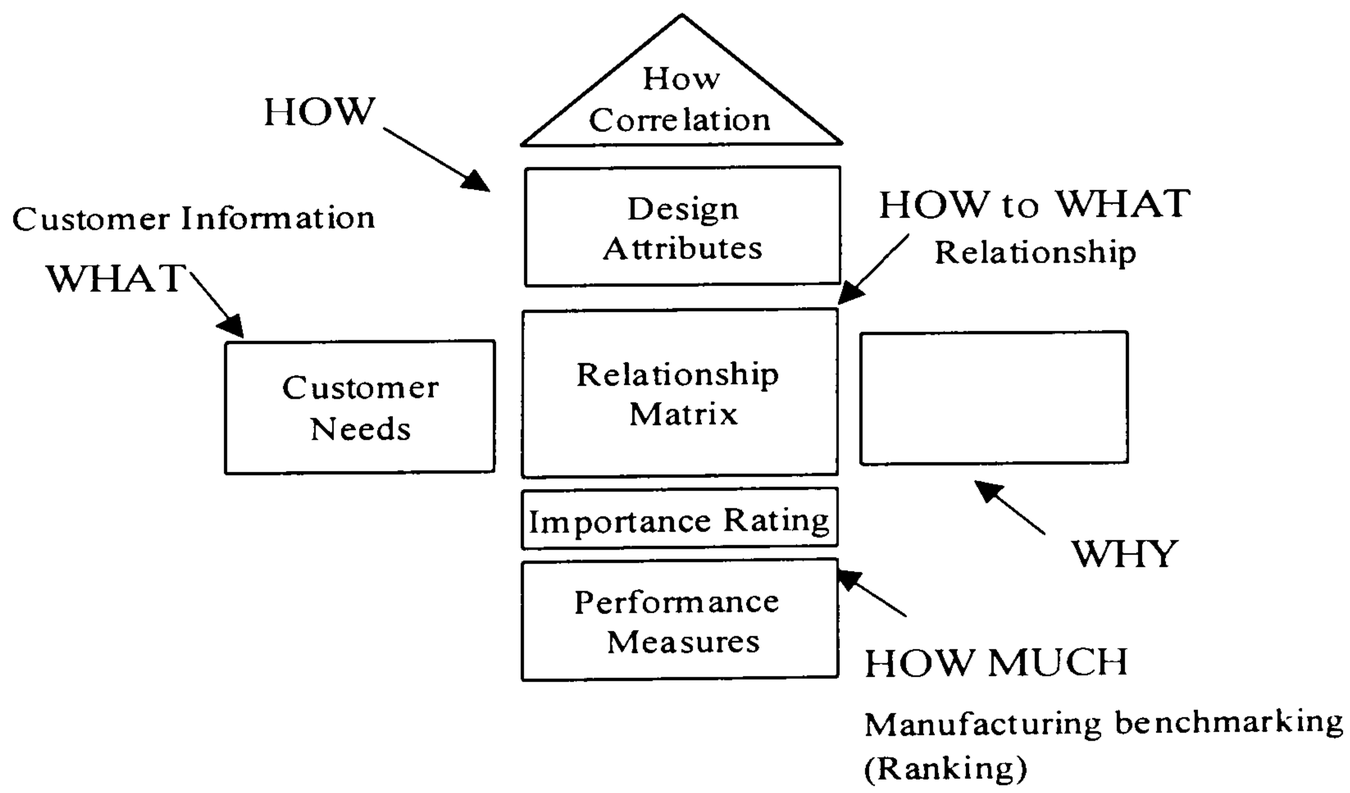


Figure B-1 QFD house of quality (source: Akao, 1990)

The "What"s are the product characteristics, function, or level of performance wanted by the customer. The "How"s are the ways to accomplish the "What"s. The "How to What" is the relative strength relationship between the two. The "importance rating" denotes the importance of each "How." Through this process, input from all team members is considered to develop an overall recommendation on how to proceed to meet customer requirements.

Brainstorming

Brainstorming is a method for developing creative solutions to problems. It works by focusing on a problem, and then deliberately coming up with as many deliberately unusual solutions as possible and by pushing the ideas as far as possible. During the brainstorming session there is no criticism of ideas - the idea is to open up as many possibilities as possible, and break down preconceptions about the limits of the problem. Once this has been done the results of the brainstorming session can be analysed and the best solutions can be explored either using further brainstorming or more conventional solutions.

Advantages of brainstorming:

- Produces many new and novel ideas
- Defers judgement hence encourages participation
- Fosters creativity and it's fun

Disadvantages of brainstorming:

- Not as useful where trial and error is required
- Many of the ideas are superficial
- Works best with simple or specific problems
- Often limits individual recognition for idea.

The following rules are important to brainstorming successfully:

- A leader should take control of the session, initially defining the problem to be solved with any criteria that must be met, and then keeping the session on course. He or she should encourage an enthusiastic, uncritical attitude among brainstormers and encourage participation by all members of the team. The session should be announced as lasting a fixed length of time, and the leader should ensure that no train of thought is followed for too long. The leader should try to keep the brainstorming on subject, and should try to steer it towards the development of some practical solutions.
- Participants in the brainstorming process should come from as wide a range of disciplines with as broad a range of experience as possible. This brings many more creative ideas to the session.

- Brainstormers should be encouraged to have fun brainstorming, coming up with as many ideas as possible, from solidly practical ones to wildly impractical ones in an environment where creativity is welcomed.
- Ideas must not be criticised or evaluated during the brainstorming session. Criticism introduces an element of risk for a group member in putting forward an idea. This stifles creativity and cripples the free running nature of a good brainstorming session.
- Brainstormers should not only come up with new ideas in a brainstorming session, but also should also 'spark off' from associations with other people's ideas and develop other people's ideas.
- A record should be kept of the session either as notes or a tape recording. This should be studied subsequently for evaluation. It can also be helpful to jot down ideas on a board, which can be seen by all brainstormers.

Pareto Analysis

The Pareto principle suggests that most effects come from relatively few causes. In quantitative terms: 80% of the problems come from 20% of the causes (machines, raw materials, operators etc.); 80% of the wealth is owned by 20% of the people etc. Therefore effort aimed at the right 20% can solve 80% of the problems. Double (back to back) Pareto charts can be used to compare 'before and after' situations. General use, to decide where to apply initial effort for maximum effect.

Pareto Analysis is a simple method for separating the major causes (the 'vital few) of a problem, from the minor ones ('trivial many'). It can help to prioritise and focus resources where they are most needed. It can also help to measure the impact of an improvement by comparing before and after. When giving presentations, Pareto Diagrams are a visually effective means of displaying the relative importance of causes, problems or other conditions.

Eight steps to construct a Pareto diagram:

- Assemble the data to be analysed. You may need to design a check sheet to collect it.
- Add up the total of each item under analysis.
- List the items in order of magnitude, starting with the largest.
- Calculate the total of all the items, and the percentage that each item represents of the total. Beside each item write the cumulative total and cumulative percentage.
- Draw a bar chart. Use the y-axis (vertical) to show the volume of what you are comparing (frequency, cost , time etc.); list the items from left to right in the x-axis (horizontal), arranged according to size, with the largest on the left. If there are a lot of items, you may group together those containing the fewest number into an 'Other' category placed on the far right as the last bar. Above each item draw a bar to a height that matches its frequency or count on the y-axis. The bars should all be the same width and not have gaps between them. Under the horizontal axis label each of these bars.
- Draw in the cumulative curve. To do this, draw a line from where the axes start to the upper right-hand corner of the first bar. Place a dot here and nest to it write the

percentage calculated for that item. Make a second dot directly above the top-right hand corner of the second bar to represent the cumulative total (i.e. the total of the first an second item added together). Join it to the first dot and write the cumulative percentage beside it. Continue until the last cumulative total has been plotted. On the right-hand side of the diagram, next to the last bar, draw in a second vertical axis, which starts at zero and has 100%, aligned with the end of the cumulative curve.

- Label the diagram with a title and any other necessary items; the date it was drawn, the source of the data, etc.
- Interpret the diagram. In general, the items requiring priority action, the 'vital few', will appear on the left of the diagram where the slope of the curve is steepest. When comparing before and after, if the improvement measures are effective either the order of the bars will change or the curve will be much flatter.

Analytical Hierarchy Process

The analytic hierarchy process (AHP) is a comprehensive, logical and structural framework, which allows to improve the understanding of complex decisions by decomposing the problem in a hierarchical structure. The incorporation of all relevant decision criteria, and their pairwise comparison allows the decision-maker to determine the trade-offs among objectives. Such multicriteria decision problems are typical for R&D project selection. The application of the AHP approach explicitly recognises and incorporates the knowledge and expertise of the participants in the priority setting process, by making use of their subjective judgements, a particularly important feature for decisions to be made on a poor information base. However AHP also integrates objectively measured information (e.g., yields) where this information is available.

AHP involves building a hierarchy (Ranking) of decision elements and then making comparisons between each possible pair in each cluster (as a matrix). This gives a weighting for each element within a cluster (or level of the hierarchy) and also a consistency ratio (useful for checking the consistency of the data). The AHP is based on three principles:

1. Decomposition of the decision problem,
2. Comparative judgement of the elements, and
3. Synthesis of the priorities.

The first step is for the team to decompose the goal into its constituent parts, progressing from the general to the specific. In its simplest form, this structure comprises a goal, criteria and alternative levels. Each set of alternatives would then be further divided into an appropriate level of detail, recognising that the more criteria included, the less important each individual criterion may become.

Next, assign a relative weight to each one. Each criterion has a local (immediate) and global priority. The sum of all the criteria beneath a given parent criterion in each tier of the model must equal one. Its global priority shows its relative importance within the overall model.

Finally, after the criteria are weighted and the information is collected, put the information into the model. Scoring is on a relative basis, not an absolute basis, comparing one choice to another. Relative scores for each choice are computed within each leaf of the hierarchy. Scores are then synthesised through the model, yielding a composite score for each choice at every tier, as well as an overall score.

Appendix C: The Proposed Framework Flowchart

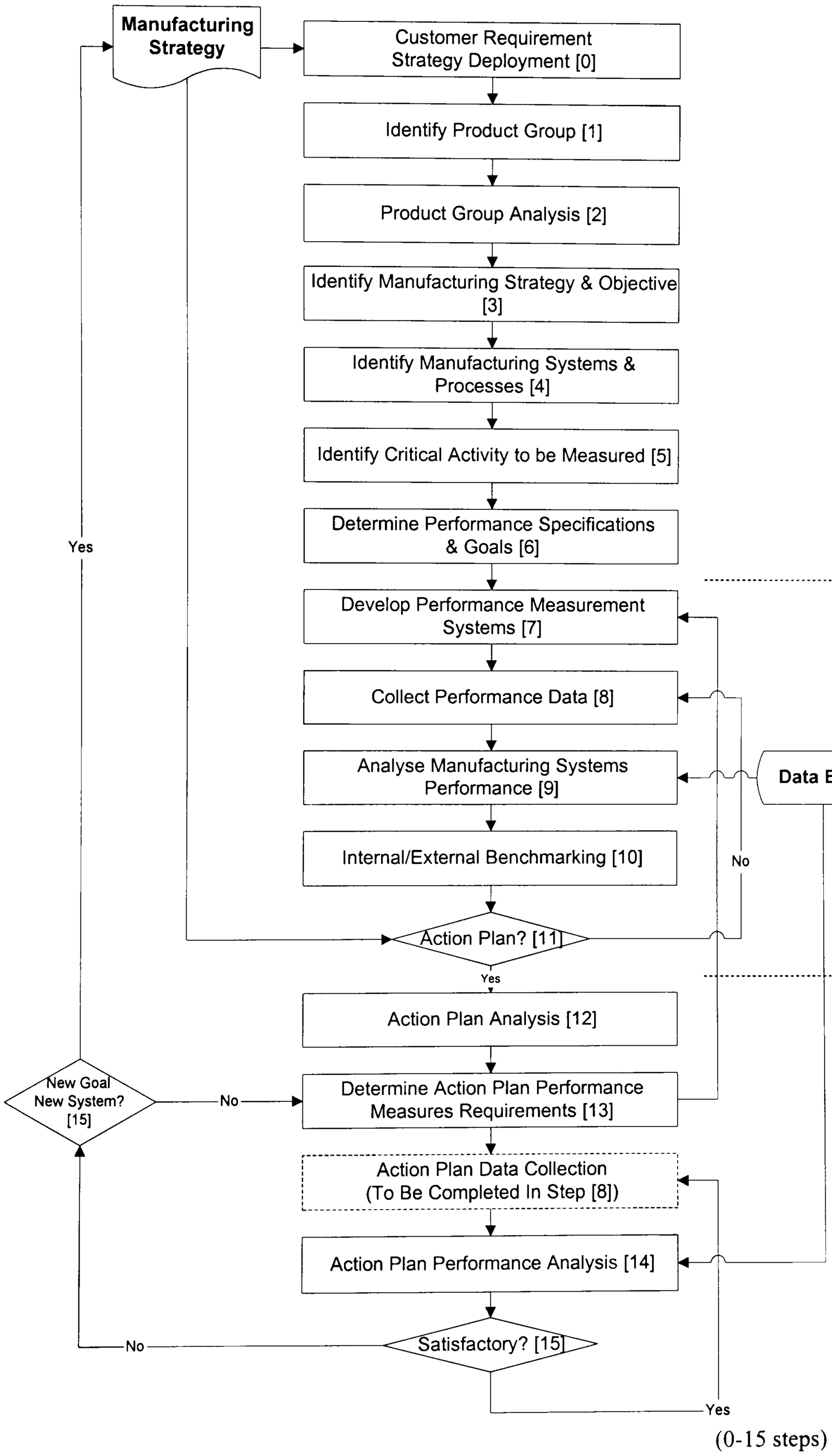


Figure C-1 The performance measurement process

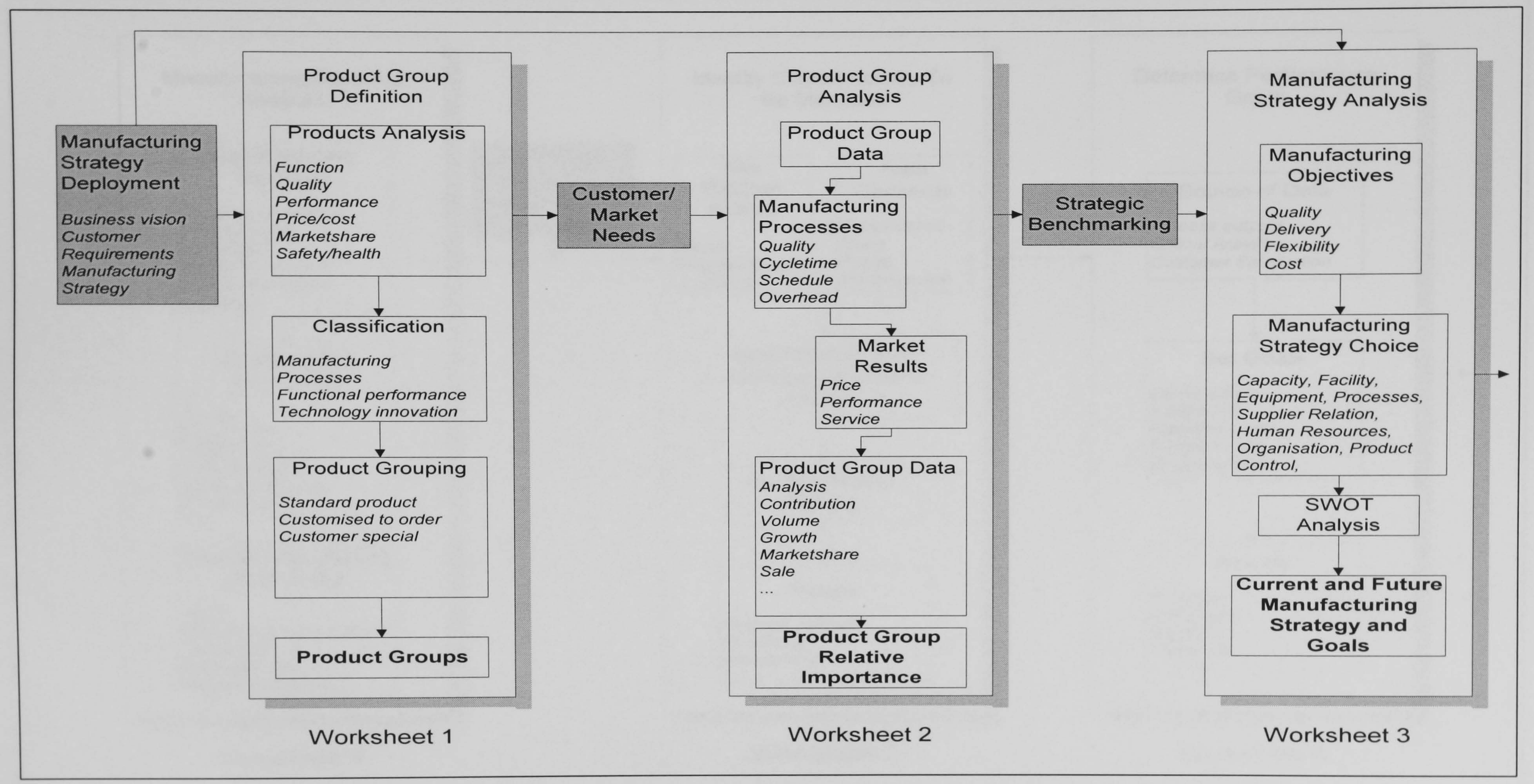


Figure C-2 Strategy-oriented performance measures

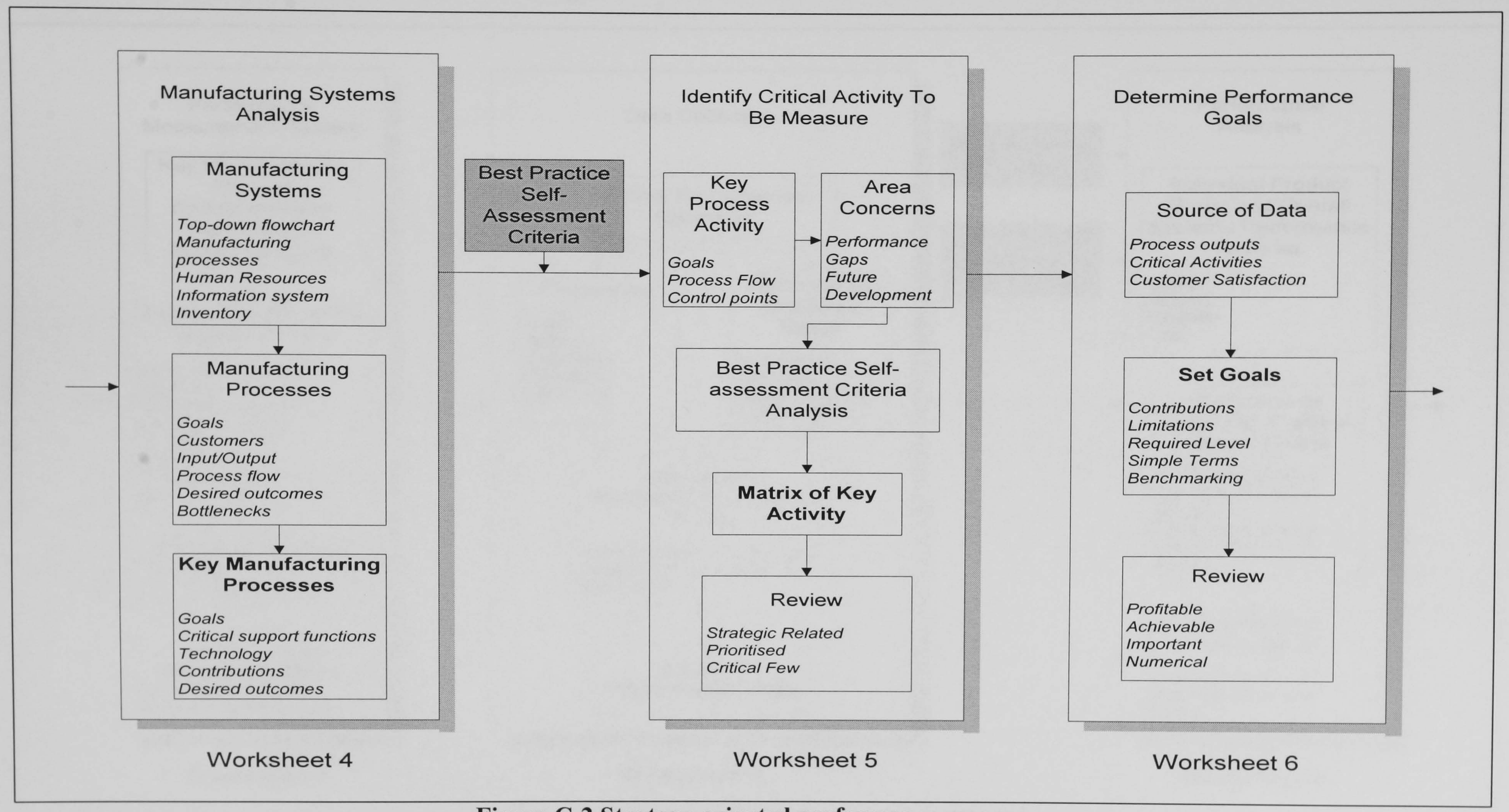


Figure C-2 Strategy-oriented performance measures

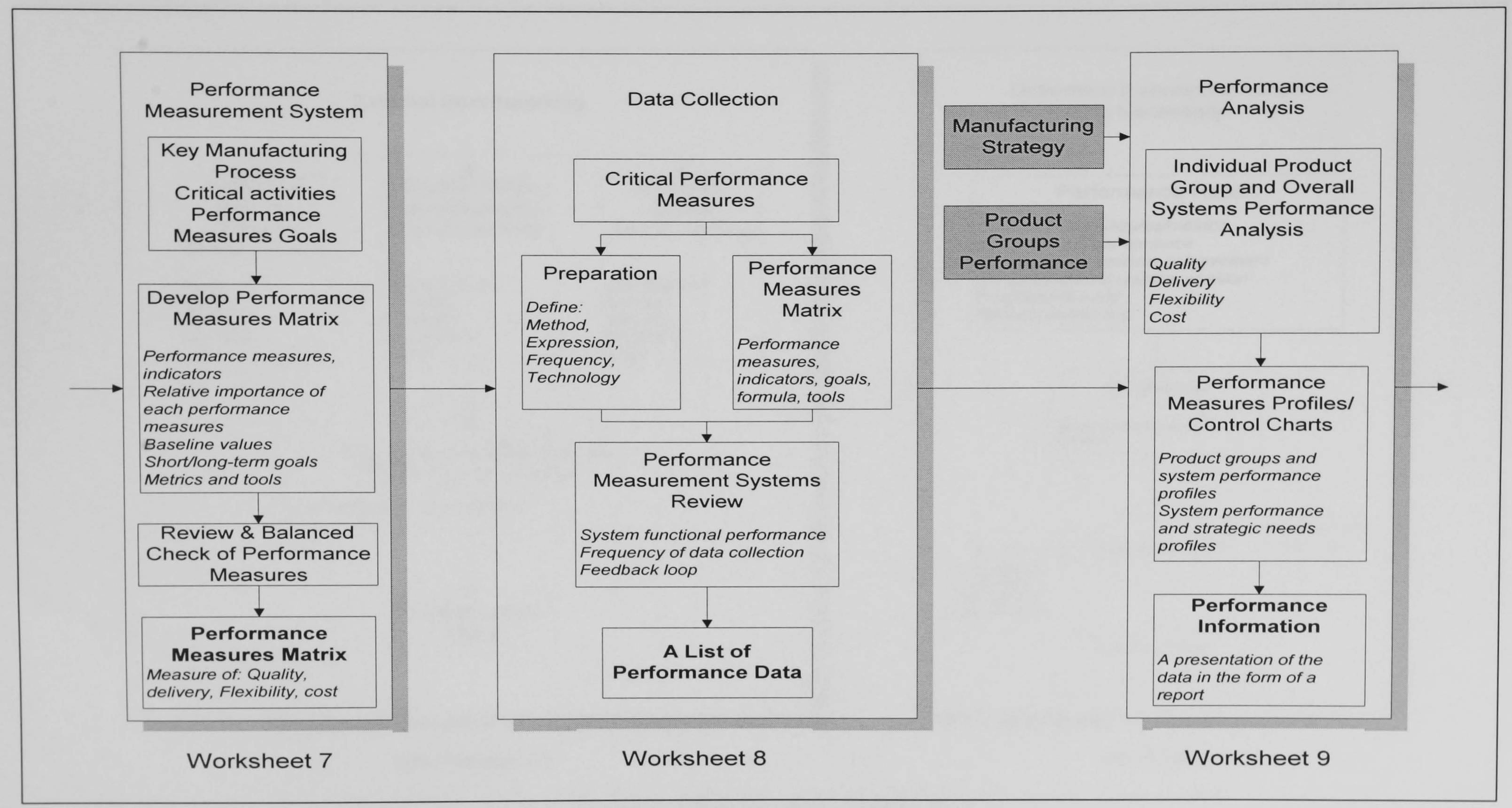


Figure C-3 System status monitoring

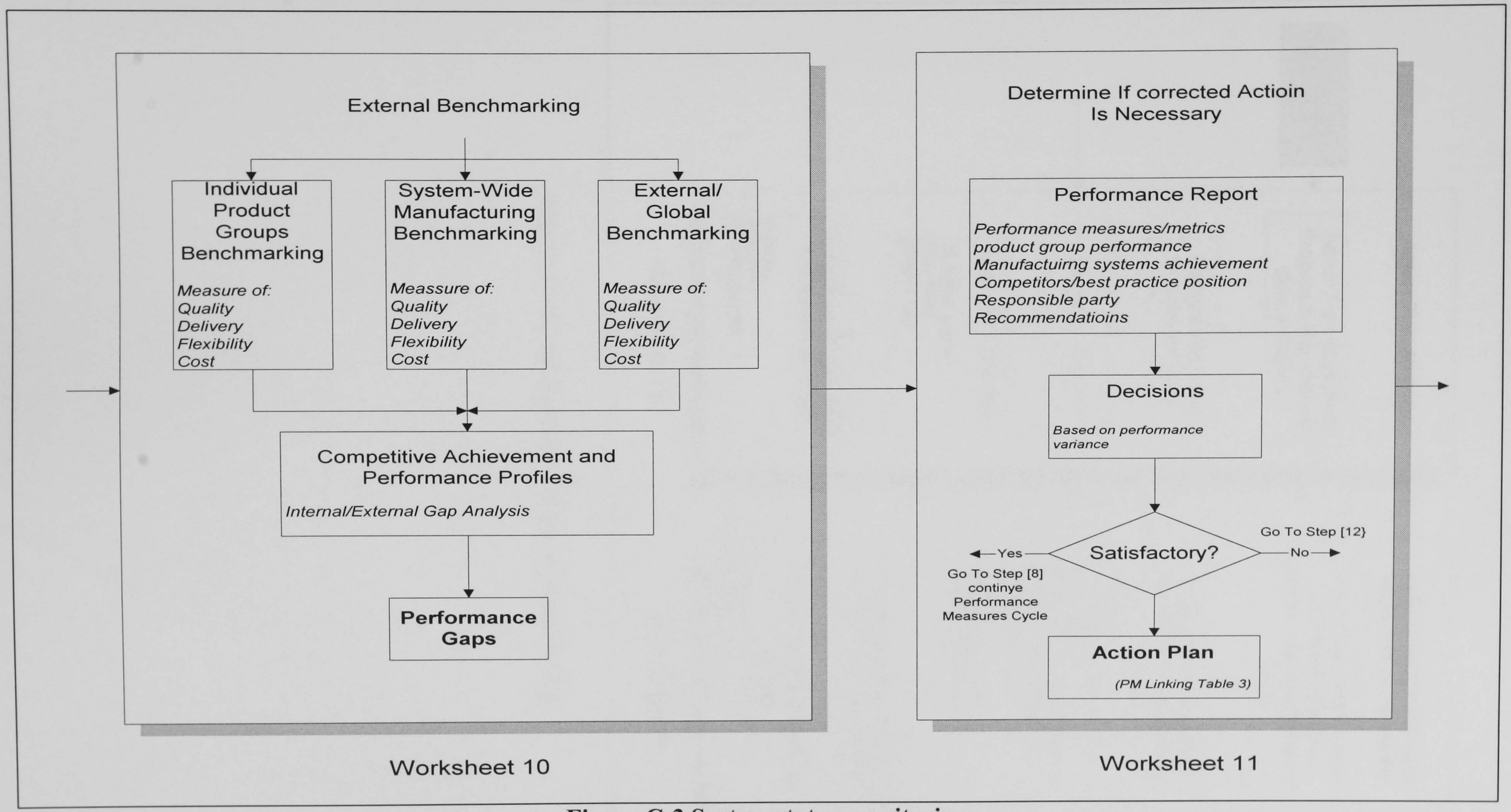


Figure C-3 System status monitoring

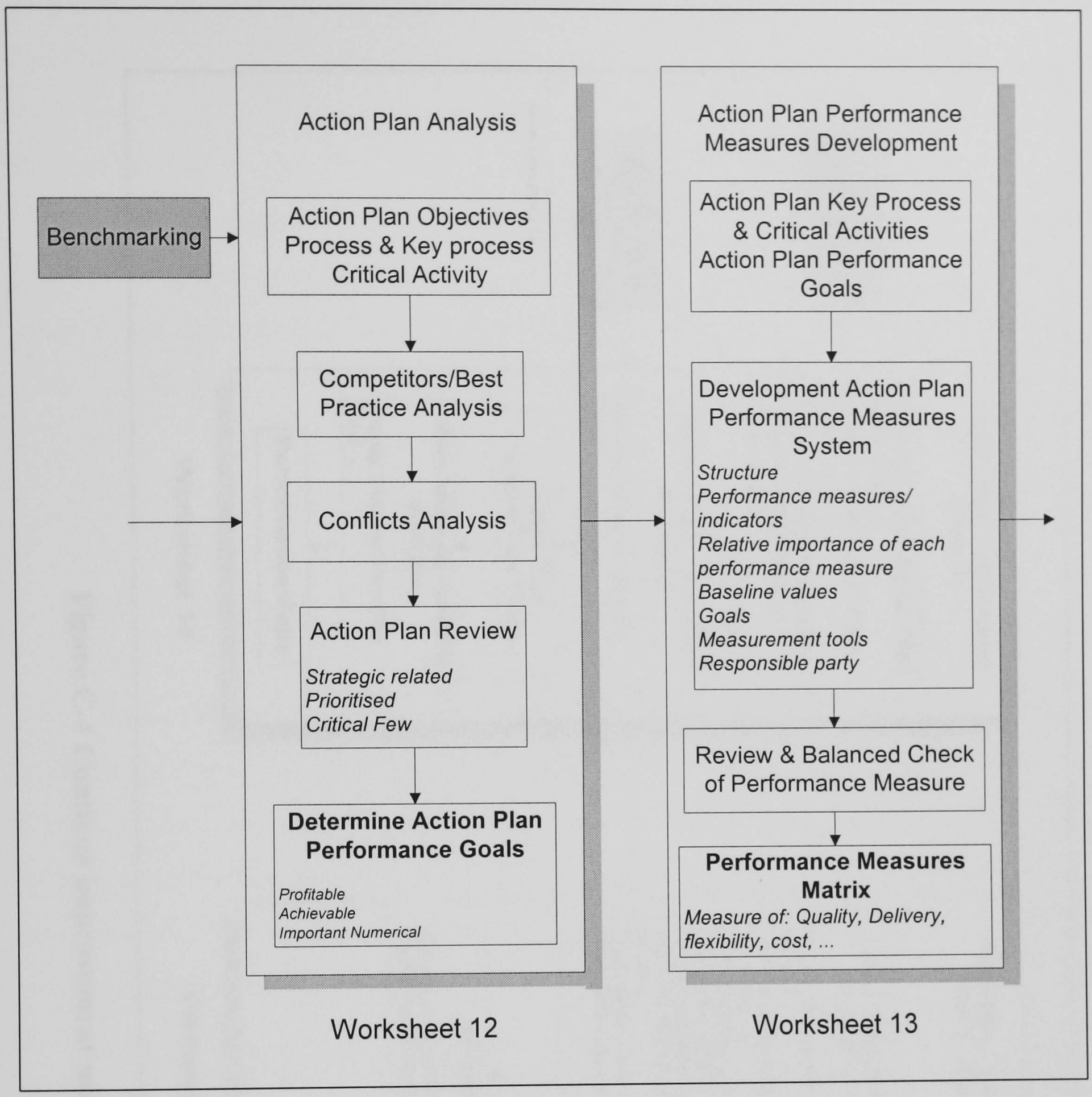


Figure C-4 Continue improvement monitoring

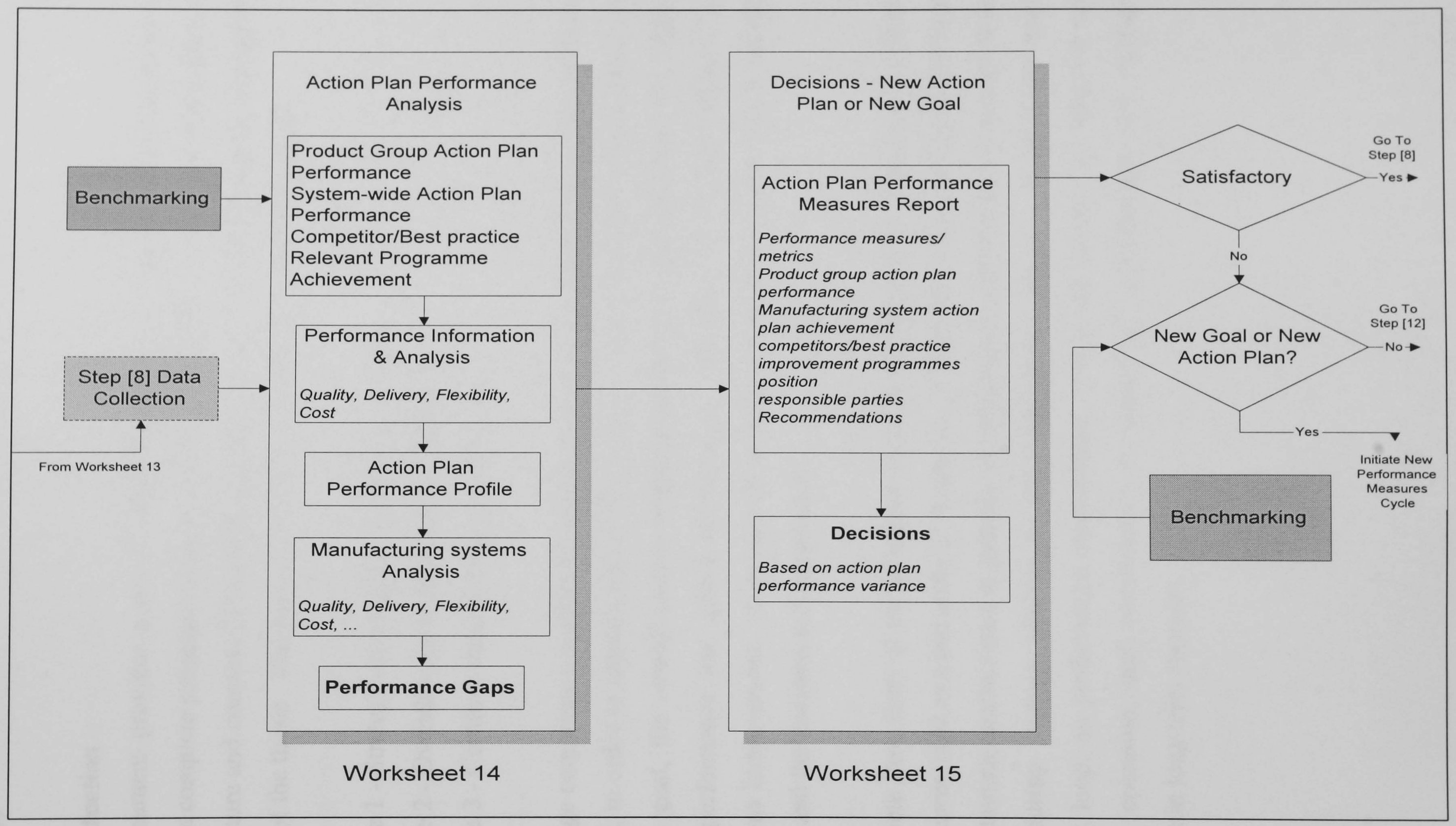


Figure C-4 Continue improvement monitoring

Appendix D: Manufacturing Performance Measurement and Evaluation Processes

1. Introduction

This document provides a set of worksheets that are logically linked together to provide a complete processes of the proposed framework. The detailed explanation of the structure and contents of the proposed framework have been discussed in chapters 4 and 5 of the thesis. The proposed framework consists of three main stages:

- Stage 1 - Strategic-oriented performance measures,
- Stage 2 - Overall system status monitoring, and
- Stage 3 - Continue improvement monitoring.

Each stage comprises a number of tasks with a series of questions and data collection methods, in order to identify performance gap between individual product group and strategic goal, the overall system performance and strategic goal, and the overall system performance and global performance, and assist for the development of continuous improvement. A number of analytical tools are also provided to aid the analysis and the decision-making process.

A complete flow chart of the procedure is given in Figure C-1. The overall process can be represented as a hierarchy of measures. It presents a systematic series of steps for maintaining conformance to goals by communicating performance data back to the manufacturing strategy analysis to take appropriate action. Without the basic feedback loop, no performance measurement system can measure an effective and efficient operation, and conformance to customers' requirements and strategic objective in long term survival.

2. Stage 1 - Strategy-oriented performance measures

This section consists of a number of steps as shown in Figure C-2, with the main aim being to define the overall context of the proposed framework in order to help a company align performance measures with its manufacturing strategy. As an integral part of the manufacturing system, the performance measures here should always be tied to the system's current goals or objectives. Therefore it is important that the performance measurement of the monitoring function is based on the identification of the manufacturing system's key processes, which have the most impact on the success or failure of the organisation's goals. The following key points in this stage include:

- Focus on customer needs,
- Measure only what is important, and
- Involve employees in the choice and implementation of the measures.

There are a number of sources that should be examined as the first stage in establishing a set of meaningful and integrated performance measures:

- Outputs of the strategic planning process: to specify the company's mission and what directions the company should move to achieve those objectives.
- Analysis of key processes: the processes that have the most impact on the success or failure of the organisation's goal.

Thus a performance measurement system enables the organisation to ensure its progress along an appropriate path as it moves from its current state to a future state. Therefore, the vision and mission statements for the manufacturing strategy should be treated as the foundation of the system status monitoring function. With such a foundation to provide the direction and reason, quantitative objectives can be defined to assess the progress toward the vision.

Worksheet 1 Identify products

- Aim: Identify product groups with distinct competitive and market requirements
- Description: The definition of product groups depends very much upon the company, and its business and markets. The following table provides a number of variables to investigate when defining product groups. However, it is probably easiest to consider a product family as a grouping of products, which compete in the market in identical ways. Other useful indicators include the product life cycle concept and the manufacturing operations and production processes that are required for the constituent parts.
- Output: The individual product group, overall manufacturing system, and manufacturing strategic profiles can be drawn.

PRODUCT						
Variants						
Volume						
Life cycle stage						
Principle processes						
Materials						
Profit/cost/sales						
Typical order size						
Standardisation						
Production introduction rate						
Market						
Competing criteria ***Quality***						
Competing criteria ***Delivery lead-time***						
Competing criteria ***Delivery reliability***						
Competing criteria ***Design flexibility***						
Competing criteria ***Volume flexibility***						
Competing criteria ***Cost/Price***						
Customers						
Other						
….						
Product Group						

Worksheet 2 Analyse product groups

- Aim: Identify the importance of various criteria for each product group, and a relative ranking of the product groups.
- Description: This is to perform an in-depth analysis of product groups previously defined in order to provide a broad understanding of their performance and situation among competitors and to identify the product groups which are the most important to the company.
- Output: A list of product performance and groping of products.

PRODUCT GROUP						
Sales growth						
Sale as a % of total sales						
Market growth						
Market share						
Product group life cycle						
Contribution as a % of product group sales						
Contribution as a % of total contribution						
Product group introduction rate						
Growth opportunities						
Vulnerabilities						
Standardisation						
Degree of innovation						
Other						
….						
Relative Importance						

Worksheet 3 Identify manufacturing strategy and objectives

- Aim: Understand the overall manufacturing strategy as well as individual product group objectives and strategic choices, and provide an approach to show how manufacturing tasks in cope with competitive criteria in a matrix.
- Description: It is to identify business objectives and manufacturing short/long term strategic goals and key factors necessary to achieve the goals. Once the goals and key factors have been classified, it becomes easy to start identifying importance measures.
- Output: A list of manufacturing strategy in terms of competitive criteria and manufacturing strategy choice.

MANUFACTURING ARCHITECTURE		**POLICIES**	**GOALS**	**COMPETITIVE CRITERIA**					
				Q	***DL***	***DR***	***DF***	***VF***	***C***
Manufacturing Process	Capacity								
	Process and Technology								
	Facility								
	Vertical Integration								
	Supplier Relations								
	Product Scope								
Information & Production Control	Information System								
	Quality System								
Human Resources & Organisation	Human Resources								
	Organisation								
.....									

(Q: quality, DL: delivery lead-time. DR: delivery reliability, DF: design flexibility, VF: volume flexibility, C: cost)

Worksheet 4 Identify manufacturing systems

- Aim: Conduct manufacturing system's input/output analysis to understand manufacturing processes and key process.
- Description: The purpose of this step is to know existing manufacturing policies, activities, and core processes in specifying how the systems' operations will produce the desired outputs and outcomes, and distinguishing what are the critical activities to be measured and their priority.
- Output: A list of manufacturing processes, key processes, and flow diagrams for these key processes.

MANUFACTURING ARCHITECTURE		**MANUFACTURING POLICY**	**MANUFACTURING FLOW (MANUFACTURING PROCESS & GOALS)**
Manufacturing Process	Capacity		
	Process and Technology		
	Facility		
	Vertical Integration		
	Supplier Relations		
	Product Scope		
Information and Production Control	Information System		
	Quality System		
Human Resources and Organisation	Human Resources		
	Organisation		
…			

Worksheet 5 Identify critical activities to be measured

- Aim: Clearly define performance measures areas and control points.
- Description: The critical activity is that culminating activity where it makes the most sense to locate a sensor and define an individual performance measure within a process.
- Output: A list of the critical activity areas for the key processes.

MANUFACTURING STRATEGY POLICY AREA	MANUFACTURING PROCESSES	CRITICAL ACTIVITY	COMPETITIVE CRITERIA					
			Q	DL	DR	DF	VF	C
Capacity								
Process & Technology								
Facility								
Vertical Integration								
Supplier Relation								
Product Scope								
Information System								
Quality System								
Human Resource								
Organisation								
…								

(Q: quality, DL: delivery lead-time, DR: delivery reliability, DF: design flexibility, VF: volume flexibility, C: cost)

Worksheet 6 Determine performance goals

- Aim: To agree manufacturing performance measures specifications.
- Description: All performance measures should be tied to a predefined goal, even if the goal is at first somewhat subjective. Having goals is the only way to meaningfully interpret the results of measurements and gauge the success of the manufacturing systems.
- Output: A list of goals for each critical activity within the key manufacturing processes.

MEASURE OF	CRITICAL ACTIVITY	PERFORMANCE MEASURES	PERFORMANCE GOALS
Quality			
Delivery Lead-time			
Delivery Reliability			
Design Flexibility			
Volume Flexibility			
Cost			
…			

3. Overall system status monitoring

Once performance goals have been set, appropriate measures must be developed that monitor manufacturing progress towards achieving these aims. Without these appropriate measures there can be no progress towards becoming a world class manufacturer. The second stage in this framework is to determine what types of performance-related information are actually needed to better run and manage a manufacturing system. Knowing such performance–related information can help to identify which measures to collect. It can also help to identify who the right people are to receive the information and when it is required.

This stage consists of a number of steps as shown in Figure C-3. In the previous stage, the manufacturing strategy and objectives have been identified, these objectives become more and more specific further down in the manufacturing systems hierarchy. In this stage, a performance measures system is developed to determine whether or not their objectives are being met. These measures then become more and more general further up the organisational structure to allow the system performance to be assessed according to the original strategic goals. Thus, manufacturing strategic objectives are driven down the hierarchy, while performance measures are driven up.

Worksheet 7 Establish performance measurement

- Aim: Identify performance measures for each manufacturing objective and to check the balance and comprehensiveness of the measures.
- Description: In this step, a performance measurement system is built by identifying individual measurement. Two major tasks are involved in this step: to specify quantifiable, readily measurable performance indicators and drivers; and to develop performance measures systems to assess strategic progress.
- Output: The performance measures matrix and their components.

MEASURE OF	PERFORMANCE MEASURES	GOALS	PERFORMANCE INDICATORS	RELATIVE IMPORTANCE	GOALS	METRICS TOOLS
Quality						
Delivery Lead-time						
Delivery Reliability						
Design Flexibility						
Volume Flexibility						
Cost						

The following is a catalogue of manufacturing performance measures

Quality measures	**Speed measures**
Perceived relative quality performance	Lead time
Quality relative to competitors	Cycle time
Product reliability relative to competitors	Order processing time
Customer satisfaction reputation	Response time
Expected product life	% on-time for rush jobs
Number of complaints	Paperwork throughout time
Service call rate	Material throughput time
Retention rate	Value added as percent of total elapsed time
Renewal rate	Decision cycle time
Value of returned merchandise	Time lost waiting for decisions
Field failure	New product introduction vs. competition
Mean time between failures	Development time for new products
Uptime percentage pass rate	Break-even time
% conform to targets	Time from idea to market
% with no repair work	Number of changes in projects
% repair reduction	Engineering time
% scrap value reduction	Time from customer need recognition to delivery
Flexibility measures	**Cost measures**
Production cycle time	Cost relative to competitors
Set-up time	Manufacturing cost
Perceived relative volume flexibility	Total product cost
How well plant adapts to volume change	Direct labour
Smallest economical volume	Indirect labour
Lot size	% improvement in labour
Ability to perform multiple tasks efficiency	Relative labour cost
Number of job classifications	Labour productivity
% programmable equipment	Labour efficiency
% multipurpose equipment	% reduction in employee Turnover
% of slack time for equipment, labour	Materials cost
% products using pull system	Inventory cost
WIP	Scrap cost
Vendor lead-time	Repair or rework
	Cost of quality
	Design cost
	R&D cost
	Overhead
Delivery measures	
Perceived relative reliability	% of orders with incorrect amount
Reliability relative to competitors	Schedule attainment
% on-time delivery	Average delay
due date adherence	% reduction in lead-time per product line
% increase in portion of delivery promises met	% improvement in output
	% reduction in purchasing lead-time

Examples of manufacturing performance measures

(1) Performance measures in quality

$$\text{Not Right First Time} = \frac{\text{Quality of defective units}}{\text{Total quality of units supplied}}$$

$$\text{Accepted shipments} = \frac{\text{No. of shipments received accepted}}{\text{No. of shipments received}}$$

$$\text{Customer satisfaction} = \frac{\text{No. of customer complaints}}{\text{No. of million units sold}}$$

$$\text{Supplier certification} = \frac{\text{No. of suppliers certified}}{\text{Total no. of supplier}}$$

(2) Performance measures in delivery:

$$\text{On time delivery} = \frac{\text{No. of products delivered to customers on schedule}}{\text{Total no. of planned deliveries}}$$

$$\text{Stock turns} = \frac{\text{Sales turnover of product}}{\text{Value of raw material + WIP + finished goods}}$$

$$\text{Delivery schedule achievement} = \frac{\text{No. of planned delivery} - \text{No. of late delivery} + \text{No. of part delivery}}{\text{No. of planned deliveries}}$$

$$\text{Vendor-on-time delivery} = \frac{\text{No. of vendor deliveries early + late}}{\text{Total no. of vendor deliveries}}$$

$$\text{On time and complete Delivery performance} = \frac{\text{No. of orders delivered on time and completed}}{\text{No. of orders delivered for the period}}$$

(3) Performance measures in flexibility:

$$\text{Raw materials flexibility} = \frac{\text{No. of different raw materials used}}{\text{No. of different finished products made}}$$

$$\text{Packing material flexibility} = \frac{\text{No. of different packing material components used}}{\text{No. of finished goods items produced}}$$

Production process time (Hrs) = Time first raw material is introduced into production process until finished product made with that raw material

$$\text{Rate of new product introduction} = \frac{\text{\% of sales derived from new products}}{\text{Total amount of sales}}$$

$$\text{Cycle time} = \frac{\text{No. of projects undergone unnecessary queues/process time}}{\text{Total no. of main procedures and routine projects}}$$

$$\text{Resource allocated to R\&D} = \frac{\text{\% of expenditure on R\&D}}{\text{Total amount of expenditure}}$$

$$\text{R\&D Productivity} = \frac{\text{Improvement in performance of product/process}}{\text{Incremental investment in R\&D}}$$

$$\text{R\&D Yield} = \frac{\text{\% Profit generated by amount of R\&D investment}}{\text{Total amount of profit}}$$

$$\text{New product development} = \frac{\text{Sales amount of new product in a given period}}{\text{Net sales amount in a given period}}$$

(4) Performance measures in cost:

$$\text{People productivity} = \frac{\text{Number of units made}}{\text{Number of direct operator hours}}$$

Overall equipment effectiveness = Availability % X Productivity % X Quality %

$$\text{Value added per person} = \frac{\text{Output value} - \text{Input value}}{\text{Number of employees}}$$

$$\text{Floor space utilisation} = \frac{\text{Turnover of model area}}{\text{Square metres of model area}}$$

$$\text{Raw materials days on hand} = \frac{\text{Tonnes of raw materials on hand}}{\text{Average tonnes produced}}$$

$$\text{Finished goods days on hand} = \frac{\text{Tonnes of finished goods on hand in plant}}{\text{Average tonnes produced}}$$

$$\text{Absence rate performance} = \frac{\text{No. of working days lost}}{\text{Total no. of working days}}$$

$$\text{Safety} = \frac{\text{Cost of poor safety}}{\text{Total cost of all projects}}$$

$$\text{Mean time between failure (MTBF)} = \frac{\text{Loading time}}{\text{Total no. of stoppages}}$$

The following questions serve as a checklist to determine the quality of the performance metrics that have been defined:

- Is the metrics objectively measurable?
- Does the metric include a clear statement of the end results expected?
- Does the metrics support customer requirements, including compliance issues where appropriate?
- Does the metric focus on the effectiveness and/or efficiency of the system being measured?
- Does the metric allow for meaningful trend or statistical analysis?
- Have appropriate industry or other external standards been applied?
- Does the metric include milestones and or indicators to express qualitative criteria?
- Are the metrics challenging but at the same time attainable?
- Are assumptions and definitions specified for what constitutes satisfactory performance?
- Have those who are responsible for the performance being measured been fully involved in the development of this metrics?

Worksheet 8 Collect data

- Aim: Collect performance data in accordance with defined table and to provide a basis for analysis.
- Description: The data that needs to be collected depends on the indicators that are chosen. In addition to writing down the numbers, it is necessary to perform an assessment to determine the quality of data. For accurate data is more important than precision.
- Output: A list of current manufacturing performance data.

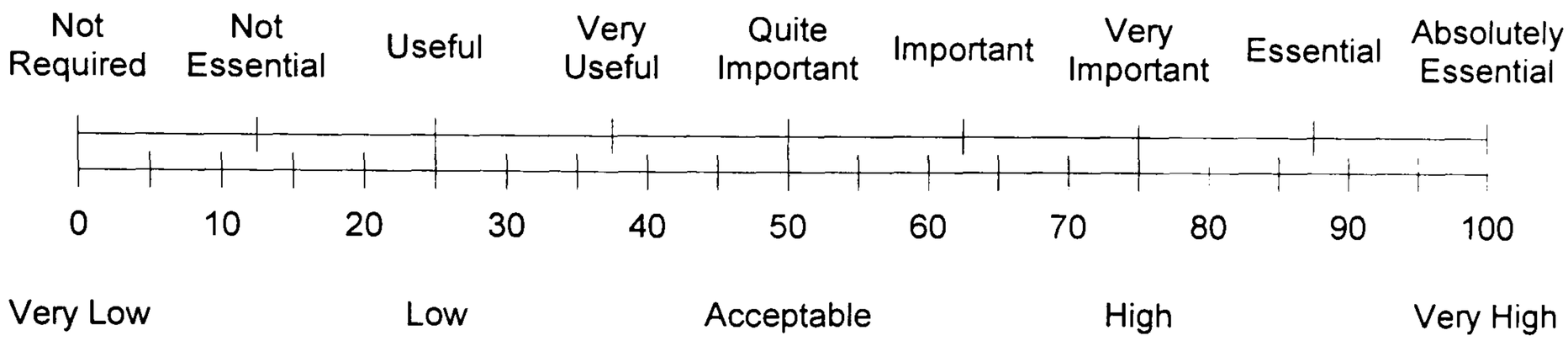
MEASURE OF	**(PRODUCT NAME) PERFORMANCE MEASURES RECORD**							
	Milestone 1		***Milestone 2***		***Milestone 3***		...	
	Target	Actual	Target	Actual	Target	Actual		
Quality								
Delivery Lead-time								
Delivery Reliability								
Volume Flexibility								
Design Flexibility								
Cost								
...								

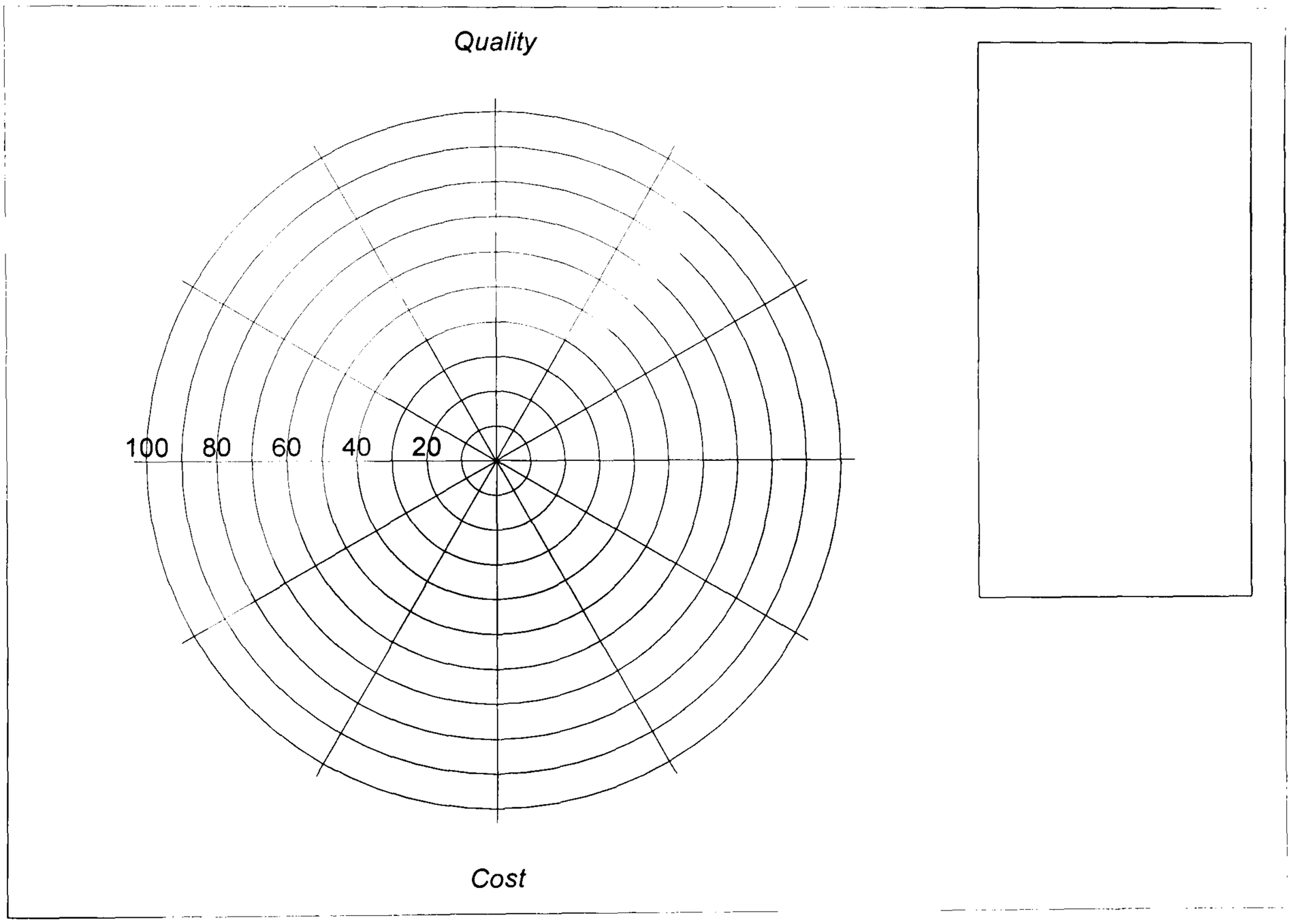
Worksheet 9 Analyse actual performance

- Aim: Transform performance data into useful performance information and to identify performance gaps and feasible solutions, if possible.
- Description: In this step, the raw data are formally converted into performance measures, displayed in an understandable form, and disseminated in the form of a report. Gap analysis provides a realistic picture of the total resources required to meet customer requirements both current and in the future.
- Output: The individual product group, overall manufacturing system, and manufacturing strategic profiles can be drawn.

MEASURES OF	PRODUCT (GROUP) 1	PRODUCT (GROUP) 2	...	SYSTEM PERFORMANCE	IMPROVEMENT PRIORITY
Importance					
Quality					
Delivery Lead-time					
Delivery Reliability					
Volume Flexibility					
Design Flexibility					
Cost					
....					
Product Mfg. Performance					

Product and systems performance profiles, competitors product and systems performance profiles





PRODUCT GROUP							
Relative Importance							
Quality							
Delivery Lead-time							
Delivery Reliability							
Design Flexibility							
Volume Flexibility							
Cost / Price							
.....							

Worksheet 10 External benchmarking

- Aim: Identify external/best practice performance and to provide a basis for continuous improvement efforts.
- Description: It is to compare manufacturing performance with competitors/best practice in order to provide a basis for continuous improvement. Understanding external industry of operational environment is an important step in helping to decide the future direction of a company, and the choice of manufacturing process.
- Output: A presentation of the performance information in the form of a report.

MEASURES OF	CURRENT PERFORMANCE	COMPETITOR A	COMPETITOR B	...	IMPROVEMENT PRIORITY
Importance					
Quality					
Delivery Lead-time					
Delivery Reliability					
Volume Flexibility					
Design Flexibility					
Cost					
....					
Product Mfg. Performance					

List of manufacturing problem areas

Yield problem, reject
Tool old plant and equipment
Unreliable supplier quality
Availability of qualified workers
Availability of qualified supervisors
Work environment
Producing to quality standard
Inability to respond to rush orders
Too old plant and equipment
Ineffective material handling systems
Excess manufacturing capacity
Too many different products
Too many engineering changes
Inability to delivery on time
Inability to manage expediting orders
Inability to deliver schedule
Getting behind using new information technology
Too wide range of products
Too large and complex plants
Low productivity
Falling behind in information technology
Too broad a product line
High employee turnover
Low motivation to work among direct personnel
Ageing workforce
Personnel absenteeism
Impact of government regulations
High overhead cost
Unavailable forecast
Labour motivation
Incorrect inventory information
Unreliable supplier lead times
Long lead time
Problems to response to fast orders
Communication with top management
Communication with other functions
Ineffective material control systems
Poor sales forecasts
Inability to manage expediting orders

Worksheet 11 Determine if corrective action is necessary

- Aim: Develop a successfully implemented plan.
- Description: This is a decision step. If the variance is large, corrections will need to be made to bring the performance back into line with the desired goal. If the variance is small, the process is probably in good shape. However, re-evaluating performance goals should be considered to make them more challenging.
- Output: Action plan to implement change or re-evaluate goals.

MEASURE OF	INTERNAL RESULTS	EXTERNAL RESULTS	PROBLEM AREAS	STRATEGIC CONCERNS	ACTION PLAN
Quality					
Delivery Lead-time					
Delivery Reliability					
Design flexibility					
Volume Flexibility					
Cost					
…					

List of manufacturing improvement programme (Action plan)

Giving workers a broad range of tasks
Giving worker more planning responsibility
Changing labour management relationships
Manufacturing reorganisation
Worker safety
Worker training
Management training
Supervisor training
Preventive maintenance
Zero defects
Manufacturing lead-time reduction
Vendor lead-time reduction
Computer-aided manufacturing
Computer-aided design
Reducing set-up/changeover time
Value analysis/product redesign
Group technology
Capacity expansion
Reducing size of manufacturing units
Plant relocation
Developing new processes for new products
Developing new processes for old products
Narrowing product lines/standardising
Defining a manufacturing strategy
Integrating information systems between manufacturing and other functions
Integrating information systems within manufacturing
Vendor quality
Reconditioning of physical plants
Just-in-Time
Robots
Flexible manufacturing systems
Closing plants
Statistical quality control (product)
Statistical quality control (process)
Improving new product introduction capability
Quality circles
Automating jobs
Production/inventory control systems
Reducing the size of manufacturing work force (including hourly and salaried)

4. Continue improvement monitoring

The basic structure and aim of this section is similar to the previous one. However, it focuses on the monitoring of the system performance improvement as a direct result of the actions currently put in place. Improvement can be categorised as either small incremental change (TQM) or innovative step change (business process re-engineering). The aim of small change is to correct the cause not the symptoms in order to eliminate the problem permanently and to reach permanent improvement. In contrast BPR is concerned with breakthroughs arising from wide-ranging, radical questioning of the "big picture". Figure C-4 illustrates the main steps and their associated key points that are essential for the accomplishment of this stage. Each of these steps will be discussed in turn. The purpose of this stage include:

- Identify the necessary requirements to complete action plan performance measurement.
- Examine and eliminate conflicts of the action plan and the overall system performance measurement.
- Determine the necessary change of the improvement programme performance measures and overall system performance measures.

Worksheet 12 Action plan analysis

- Aim: Identify what to measure of the action plan.
- Description: This step only occurs if corrective action is expected to be necessary. The actual determination of the corrective action is part of the quality improvement process, not the performance measurement process. This step is primarily concerned with improvement of the manufacturing system. By studying the action plan's objectives, processes, and critical success factors, the aim is to identify performance measures requirements and goals in response to the improvement programme. The internal/external factors that could affect goal achievement should also be identified.
- Output: A successfully implemented action plan.

ACTION PLAN	GOALS	PERFORMANCE MEASURES	COMPETITIVE CRITERIA					
			Q	DL	DR	DF	VF	C

Worksheet 13 Establish action plan performance measurement

- Aim: Determine action plans performance measures goal, key performance indicators, and murices/tools and their components.
- Description: The process is the same as in step 7 but focuses on the development of improvement programme performance measures including: performance goals, indicators, tools, etc.
- Output: Action plan performance measures matrix.

MEASURES OF	PERFORMANCE MEASURES	GOALS	PERFORMANCE INDICATORS	GOALS	METRICS/ TOOLS
Quality					
Delivery Lead-time					
Delivery Reliability					
Design Flexibility					
Volume Flexibility					
Cost					
…					

Worksheet 14 Analyse and benchmark action plan performance

- Aim: Transfer action plan performance data into performance information and performance gap analysis.
- Description: It is to examine the effectiveness of the chosen indicators by comparing performance data with the goals. The purpose is to improve the measures for the next measurement cycle, and to look for ways to improve the performance and effectiveness of action plan(s).
- Output: A list of action plan performance variance identified through gap analysis.

MEASURE OF	PRODUCT (GROUP) 1	...	SYSTEM PERFORMANCE				ACTION PLAN PERFORMANCE
			Previous	Current	Difference	Importance	
Quality							
Delivery Lead-time							
Delivery Reliability							
Design Flexibility							
Volume Flexibility							
Cost							
...							

Worksheet 15 Decision making – new action plan or new goal

- Aim: Determine if new action plan performance goals or measures are needed.
- Description: The final step is to describe action plan(s) for meeting unmet goals or to explain why a goal should be modified. If previously set objectives were attained with great difficulty, then it may be reasonable to re-adjust expectations, and vice versa.
- Output: New goals, measures, or no change.

***MEASURE* OF**	**MANUFACTURING PERFORMANCE**			**GAPS**	**PROBLEM AREA**	**MANUFACTURING STRATEGY POLICY AREA**										
	Plans	Actual	Competitor			C	F	P	V	S	P	Q	H	O	P	..
Quality																
Delivery Lead-time																
Delivery Reliability																
Volume Flexibility																
Design Flexibility																
Cost																
…																

(C: capacity, F: facility, P: process and technology, V: vertical integration, S: supplier relation, P: product scope, Q: quality system, H: human resources, O: organisation, P: product control)

MANUFACTURING POLICY AREA	PROBLEM AREA	SUGGESTED STRATEGY		SUGGESTED ACTION PLAN	
		Short-term	Long-term	Short-term	Long-term
Capacity					
Facility					
Process technology					
Product scope					
Vertical integration					
Supply relations					
Human resource					
Organisation					
Quality system					
Production & ctrl.					
…					

Appendix E Performance Measurement Linking Tables

Performance Indicators / Performance Measures		Quality																
		Rework rate	Scrap rate	Pass rate	Field failure	Reject rate	Packaging quality	Material yield	Supplier quality	No. of complaints	Warranty claims	Service call rate	Supplier certification	Process capability	% conform to targets	% with no repair work	Assembly line defects rate	Lapse, renewal, retention rate
Quality	Incoming quality	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X
	First pass yield	X	X	X				X	X	X		X	X	X	X	X	X	X
	Not right first time	X	X	X		X			X	X		X		X	X	X	X	X
	Reject rate		X	X		X			X	X			X	X	X	X	X	X
	Supplier quality	X	X	X	X					X		X	X		X	X	X	X
	Process waste yield	X	X	X				X		X	X			X	X	X	X	X
	Customer complaints	X	X	X	X		X			X	X	X	X		X		X	X
Delivery Lead time	Time between order and delivery	X	X	X			X	X					X	X		X	X	X
	Vendor lead times							X					X		X			
	Manufacturing cycle time	X	X	X			X	X				X		X		X	X	X
	No. of change in project	X	X	X	X		X	X		X	X	X			X	X	X	X
Delivery	% on time deliveries	X	X	X			X					X	X		X	X	X	X
	Speed of set ups													X				X
	Inventory accuracy																	X
	Forecast accuracy	X	X	X	X		X					X	X	X	X	X	X	X
	No of days of late shipments		X				X											X
Volume Flexibility	Response to demand increase													X				
	Lot size													X				
	Worker flexibility													X				
	Capacity imbalance												X	X				X
	Smallest economic volume			X				X			X			X				X
Design Flexibility	Proportion customised	X	X	X	X		X								X			
	Variety flexibility																	
	Labour skill			X	X		X			X	X	X			X	X	X	X
	Design change per year																	
	Ability to introduce new product																	
Cost	Unit manufacturing cost	X	X	X						X		X					X	X
	Overhead cost					X												
	Cost of quality																	
	Cost of cycle times																	
	Labour productivity																	
	Finish goods inventory turnover																	
	Absenteeism																	

Table E-1 PM Linking Table Number 1 – Performance parameters and indicators

									Delivery Lead time												Delivery Reliability							
Quality relative to competitors	Mean time between failures	Conformance to specifications	% processed material effective	Delivery inspection reject rate	Defect improvement	% process failure	No. of engineer change	Hours of training per worker/year	Lead times through department	Response time	% on time for rush jobs	Paperwork throughput time	Material throughput time	Decision cycle time	Time lost waiting for decision	Breakeven time	Hours of overtime	Time from idea to market	Average time between innovations	Non-manufacturing lead time	Lead times for raw materials	Reliability relative to competitors	% of orders with incorrect amount	Schedule attainment	Due date adherence	Average age of equipment	% improvement in output	Overall equipment effectiveness
X	X	X	X	X		X			X				X	X		X	X	X			X	X		X	X			
X		X				X	X	X		X			X			X	X					X		X		X	X	X
X		X	X	X		X		X	X	X	X					X	X	X						X	X	X		
X		X	X			X	X	X														X		X	X	X		X
X		X	X	X		X					X					X	X					X		X	X			
X			X	X		X		X	X		X		X											X	X	X		X
X	X	X	X	X		X				X	X			X	X	X		X	X				X	X	X		X	X
	X			X		X	X	X	X			X	X	X	X					X	X			X	X	X		X
										X	X					X	X			X	X			X	X			
	X		X	X		X	X	X	X			X	X	X	X			X		X	X			X		X		X
	X		X	X		X	X					X				X	X						X				X	X
	X		X	X		X	X		X		X	X	X		X					X	X	X	X	X	X			
								X	X	X				X	X	X	X							X				
	X	X		X			X			X	X	X	X	X	X					X	X		X	X			X	
	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X				X		X	X	X	X	X	X
			X	X																					X			
	X																	X	X									
																												X
					X			X																				
	X						X	X																		X		X
	X																									X		X
											X													X				
										X																		
	X	X	X			X		X	X	X	X	X	X			X											X	
																			X									
	X		X	X		X	X									X												

(Restate the title from the previous page)

		Volume Flexibility																					Design Flexibility								
% of items delivered on time	No of suppliers	Set-up time	Lot size	Job classification	Capacity utilisation	% of slack time for labour	% multipurpose equipment	% of programmable equipment	% increase in direct labour skills	Volume flexibility relative to competitors	Process flexibility relative to competitors	Time to replace tools, change tools	Perceived relative volume flexibility	Workforce cross -trained	Schedule change ability	Ability to response to demand increase	Strategic control system	Product shelf life	Seasonal demand variation	Random demand variation	Frequency of schedule change	Effect on delivery lead-time	Perceived design flexibility	Perceived relative product flexibility	No. of material part number	Speed of new product introduction	No of product types produced	Ability to cope with product change	Design change per year	Customisation ability	No. of new product introduced
X	X									X			X		X	X		X	X	X		X		X							
X			X		X	X			X	X	X		X	X		X	X					X									
X									X					X		X					X	X								X	X
X									X	X			X		X	X	X		X	X	X				X						
X															X	X	X	X										X		X	
									X					X		X									X						
X		X	X		X	X			X			X			X	X		X	X	X		X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X			X	X	X		X	X		X	X		X			X	X		X			
X	X														X	X			X	X											
X		X				X	X	X	X			X		X			X														
					X	X																				X		X	X		
X	X	X	X		X	X	X	X	X			X		X														X			
X		X												X		X															
X	X		X		X	X						X			X						X	X									
X		X			X	X	X	X	X			X		X												X		X			
						X						X																			
	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X			X									X			
			X		X		X	X																							
				X		X			X					X	X	X										X		X			
					X	X	X	X	X												X							X		X	
		X	X	X	X	X	X	X	X											X											
				X			X		X					X										X				X		X	X
																							X	X	X		X			X	X
X		X		X		X			X			X	X	X	X	X										X		X		X	X
																							X	X		X	X	X	X	X	X
					X						X															X			X		X
					X	X												X													
																	X														

(Restate the title from the previous page)

Cost																						
Cost of quality	Tooling cost	Overtime cost	Repair/re-work cost	Manufacturing cost	Material cost	Energy/Utility cost	Cycle time cost	Downtime cost	Absenteeism cost	Overhead cost	Cost relative to competitors	Direct labour cost	Indirect labour cost	Labour efficiency	Inventory cost	Scrap cost	Design cost	Relative R&D expenditure	Distribution cost	Maintenance expences	Funds for training programs	Warranty cost
X		X	X	X	X	X	X	X		X	X	X		X		X				X		
X		X	X	X	X	X	X	X		X	X					X						X
X		X	X	X	X	X	X	X		X						X						
X		X	X	X	X	X	X			X	X	X	X	X		X					X	
X			X	X	X		X			X	X			X		X						X
X	X	X	X	X	X	X	X			X	X	X	X	X		X					X	X
										X				X				X				X
														X							X	
		X					X			X	X											
																					X	
																		X				
	X			X				X		X											X	
																		X				
																		X				
																		X			X	
																		X			X	
																		X			X	
X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
X			X					X	X							X						X
X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
		X		X		X	X	X	X	X		X	X	X								X
		X					X			X					X				X			
X		X							X	X		X	X	X								

(Restate the title from the previous page)

Measure of	Problem Domain	Manufacturing Strategy Implementations	Manufacturing Policy Area								
			Cap	Fac	Tec	V.I.	S.R.	Org	H.R.	Prd	Inf	Qty
Quality	Yield problem, reject	Improvement conformance quality	X			X	X					X
	Too old plant and equipment	Improve safety work		X				X	X			
	Unreliable supplier quality	Improve vendor quality				X	X					X
	Availability of qualified workers	Increase environmental safety/protection						X	X			X
	Availability of qualified supervisors	Improve pre-sales service and technical support			X	X				X		
	Work environment	Improve after-sales service				X						X
	Producing to quality standard	Initiate vendor certification or qualification				X	X					X
Delivery Lead time	Unreliable supplier lead times	Reduce manufacturing lead time	X	X	X	X	X			X	X	X
	Long lead time	Reduce procurement lead time			X			X			X	
	Problems to response to fast orders	Reduce new product development cycle	X		X	X		X	X	X	X	X
	Unreliable supplier lead times	Increase throughput	X					X			X	
	Communication with top management	Increase delivery speed	X	X	X		X				X	X
	Communication with other functions	Improve inter-functional communication						X	X		X	
	Ineffective material control systems	Reduce set up times	X	X	X				X	X	X	
	Poor sales forecasts	Narrow product line	X		X					X		
	Falling behind in information technology	Rapid deliveries/meeting orders	X	X	X	X	X			X	X	X
	Inability to manage expediting orders	Shorter production lead times				X			X	X	X	X
Delivery Reliability	Too many different products	Reduce number of vendors				X	X					X
	Too many engineering changes	Increase delivery reliability	X	X	X	X				X	X	
	Inability to deliver on time	Maximise manufacturing thourghput	X	X	X				X		X	
	Inability to manage expediting orders	Minimise idle times				X			X		X	X
	Inability to deliver on schedule	Evaluate potential new suppliers and contractors					X	X			X	X
	Getting behind using new information technology	More stable production schedule				X	X				X	X

Table E-2 PM Linking Table Number 2 – Strategic performance and causes

Design Flexibility	Getting behind using new information technology	Improve ability to make rapid product mix changes	X		X						X	X
	Introducing new products on schedule	Increase product/materials			X		X	X				
	Too many engineering changes	Standardise components	X		X					X	X	X
	Too wide range of products	Narrow product lines/standardisation	X							X		X
	Inability to delivery on time	Improve new product introduction capability			X					X	X	X
	Introducing new products on schedule	Re-design products and processes								X		X
Volume Flexibility	Yield problems	Increase capacity	X		X					X	X	
	Inability to respond to rush orders	Improve ability to make rapid volume changes	X		X		X					X
	Too large manufacturing capacity	Reduce capacity	X							X	X	
	Voluntary direct labour turnover	Evaluate need to upgrade capability		X							X	X
	Too old plant and equipment	Increase products produced by existing facilities		X					X	X		
	Ineffective material handling systems	Reduce changeover/set-up time	X		X				X			
	Excess manufacturing capacity	Lower W.I.P.			X							X
Cost	Too old plant and equipment	Reduce unit costs	X		X			X	X	X		
	Too large and complex plants	Reduce material costs				X	X			X		
	Low productivity	Reduce overhead costs		X	X				X			
	Falling behind in information technology	Improve direct labour productivity							X			X
	Too broad a product line	Reduce inventory				X	X			X	X	X
	High employee turnover	Reduce breakeven points	X		X						X	
	Low motivation to work among direct personnel	Raise employee morale							X			X
	Ageing workforce	Maximise cash flow						X				
	Personnel absenteeism	Improve labour relations							X			
	Impact of government regulations	Improve white collar productivity							X	X		
	Large and complicated plants	Lower production costs							X			
	High overhead cost	Change culture of manufacturing organisation						X				X
	Unavailable forecasts	Reconditioning physical plants		X	X							X
	Labour motivation	Evaluate benefits of souring vs. multiplesourcing				X					X	X
	Incorrect inventory information	Consider need for JIT delivery	X	X	X						X	X

(Restate the title from the previous page)

Policy Area	Strategy Implementations	Action Plans	Competitive Criteri					
			Qty	DL	DR	VF	DF	C.
Capacity	Develop capacity strategy	Capacity expansion		X		X		X
	Expand existing facilities for economies of scale	Product standardisation	X			X	X	X
	Convert capacity to new products	Reconditioning of physical facilities	X					X
	Increase capacity	Automating jobs		X	X	X		X
	Increase ability to make rapid volume changes	Expand existing facilities			X	X	X	
Facility	Determine facility locations and missions on new competition	Reconditioning physical plants	X			X		
	Bottlenecks, and improve materials handling in existing facilitie	Closing and/or relocating plants						X
	Evaluate impact of new distribution patterns on facility location	Reduce size of manufacturing units						X
	Increase products produced by existing facilities	3-shifts production		X		X		X
	Reconditioning physical plants	Plant modernisation programme	X					
	Locate facilities to obtain cost advantages in labour, materials	Work environment improvement	X					
	Evaluate the need to upgrade manufacturing methods, remove	Plant relocation						X
		Automation/computerisation	X	X	X	X	X	X
Vertical Integration	Re-evaluate make/buy decisions	Vendor lead-time reduction		X				
	Evaluate opportunities for vertical integration	Rapid prototyping	X			X		X
	Negotiate volume contracts	Customer involvement in design	X				X	X
	Reduce inbound and outbound freight costs	Supply chain partnering	X		X			
	Evaluate benefits of sole sourcing vs. multiple sourcing	Outsourcing	X	X		X	X	X
	Consider need for JIT delivery	Customer feedback	X		X			X
	Reduce number of vendors	After-sales support	X		X			X
	Re-evaluate make/buy decisions	Predicting customer requirements		X			X	
Vendor Relation	Evaluate potential new suppliers	Vendor quality	X	X				X
	Initiate vendor certification/qualification	Vendor certificate	X					X
	Evaluate potential new suppliers and contractors	Single sourcing	X					X
		Vendor training	X	X	X			X
		Improve vendor/buyer relation	X	X	X			
		Vendor/buyer technical exchange/support	X					X
Process & Tech.	Re-design products and processes	Computer-aided manufacturing		X				
	Standardise components	Computer aided design				X	X	X
	Move down product-process matrix toward more efficient tech.	Value analysis/product redsign					X	
	Evaluate new prodess and automation tech. (CAD,CAM)	New processes for new products	X			X	X	X
	Address long-term manufacturign trends	New processes for old products	X			X		X
	Evaluate need to upgrade capcbility	Preventive maintenance	X					
	Reduce manufacturing lead-time	Just-in-time						X
	Reduce new product development cycle	Total productive maintenance	X					
	Modify materials handling to achieve maximum efficiency	Group technology				X		
	Increase delivery speed	Increase technical autonomy			X			
	Reduce set-up time	Process mapping				X		
	Increase delivery reliability	Business process reengingeering					X	
	Maximise manufacturing throughput	Process statictical quality control		X				
	Improve ability to make rapid product mix changes	Ergonomics					X	
	Improve new product introduction capability	Lean production						X
	Re-design products and processes	Automation				X		
	Evaluate new process technology	Manufacturing lead-time reduction		X				
	Evaluate need to upgrade capability	Reduce set up time		X	X			
	Reduce changeover/set-up time	Logistics management	X		X			
	Lower W.I.P.	Robots		X				
		Smart design				X		
		Concurrent engineering		X				
		Flexibility manufacturing systems				X		
		Design for manufacture				X	X	
		Total productive maintenance				X		
		Cellular manufacture		X				
		Rapid prototyping		X				
		Flexible manufacturing systems						X
		Computer integrated manufacturing (CIM)	X					
Human Resource	Evaluate policies concerning wage payment, hiring..	Worker training	X	X				X
	re-train workers as required by new manufacturing methods	Management training	X					
	hire additional skilled workers	Supervisor training	X					
	Improve direct labour productivity	Worker safety	X					
	Raise employee morale	Implement new wage system						X
	Improve white collar productivity	Multi-skilling	X		X	X	X	
		Appraisal	X					X
		Casual labour						X

Table E-3 PM Linking Table Number 3 – Strategic concerns and action plans

		Giving worker planning tasks		X	X			
		Employee empowerment		X				
		Downsizing, workforce						X
		Job enrichment	X					
		Derict labour motivation					X	
		Learning climate	X			X	X	
		Job rotation		X				
		Quality training	X					
Organisatio	Centralise control of strategy and insure adequate coordinatio among subsidaries	Giving workers a broad range of tasks or more responsibility		X				
	Allow subsidiaries enough autonomy to insure effectiveness	Change labour management relationships	X	X				
	facilitate sharing of technology among plants and subsidiaries	Reduce manufacturing work force						X
	Improve inter-functional communication	Manufacturing reorganisation		X		X		X
	Change culture of manufacturing organisaiton	Inter-functional work teams			X	X	X	
	Maximise cash flow	Work environment improvement	X					X
		Implement group work				X	X	
		Automating jobs		X		X		
		Specialise jobs	X					
		Cost management						X
		External environment improvement	X					X
		Timebased management		X				
		Delayering						X
		Decentralise decision-making authority		X				X
		Office automation		X	X			
		Learning climate	X					
		Team-base work		X				
		Flexible work organisation			X			
		Culture change	X					X
		Downsizing						X
		Flexble work organisatiion		X		X	X	
Product Scope	Moduleisation	Zero defects	X					X
	Develop new product	Ergonomic design	X					
	Technology advantage	Value analysis/product redesign	X				X	X
	Product modification	Customer involvement in product design					X	
	Narrow product lines/standardisation	Product rationaliosation	X			X		X
	Extend product life cycle	Develop product work shop		X			X	X
Production & Control	Coordinate aggregate production planning distribution among f	Information systems in manufacturing				X		X
	Set new stock levels as required	Information systems across functions		X				X
	Modify production planning and scheduling systems in accord	Production-inventory control systems						X
	Modify materials handling to achieve maximum efficiency	Automate storage and retrieval system	X	X				
	Consider JIT inventory control	Electronic data interchange			X			
	Reduce manufacturing lead-time	Predicting customer requirements			X			
	reduce procurement lead-time	Maintaining stock levels		X				X
	Address long-term manufacturing trends	Reduce inventory						X
	Reduce unit costs	Computer-aided process control			X			
	Reduce unit costs	Logistic management						X
	Consider need for JIT delivery	Manufacturing lead time reduction		X	X			X
		Vendor lead time reduction		X	X			X
		Just-In-Time	X	X	X	X	X	X
		Reducing setup/changeover time				X		X
		JITproduction	X	X			X	X
		Stock forecasting	X			X		X
		Process mapping		X			X	X
		Lean production		X	X			
Quality System	Implement Total Quality Control	Quality function deployument	X	X			X	X
	Certify vendors	Statistical quality control	X					X
	Consider eliminating incoming inspection	Standardise production processes	X	X	X		X	
	Use quality as a competitive weapon	Total productivive maintenance	X					X
	Stress wosrker participation	Benchmarking for quality	X					X
	Continual improvement	Conformance check	X					X
	Improvement conformance quality	Zero defects	X					X
	Improve safety record	Quality improvement teams	X					
	Improve vendor quality	Qquality cirlces	X					X
	Improvement environmental safety/protection	Total Quality Management	X	X	X	X	X	X
	Improve pre-sales service and technical support	Qualifty function deployment (QFD)	X		X			X
	Improve after-sales service	Quality award	X	X	X	X	X	X

(Restate the title from the previous page)

Appendix F: Questions for the Proposed Manufacturing Performance Measurement and Evaluation Framework Interviews

- Do you agree performance measures should be in line with business objectives and help to develop manufacturing goals?
- Do you agree performance measures should not only identify customer requirement has been met but to show where improvement need to be made?
- Do you agree performance measures should measure the effectiveness of the manufacturing process and identify opportunities for improvement?
- Do you agree performance measures should provide a mechanism tat could be used to mode, control, and improve activities at the factory shop floor?
- Do you agree performance benchmarking is essential to help increasing competitiveness?
- Do you agree performance measures should focus on in proving manufacturing competitiveness by overcoming the limitations of existing performance measurement systems?
- Do you agree performance measures should be derived from strategy?
- Do you agree performance measures should initiate from product or product groups analysis?
- Do you agree performance measures system should provide data for monitoring past and planning future performance?
- Do you agree performance measures goals should be based on customer expectations and internal and/or external requirements?
- Do you agree performance measures should be integrated over both the functions and hierarchy?
- Do you agree performance measures design should initiate from the identification of product group and market requirements?
- Do you agree performance measures should identify each manufacturing activity and task in detail?
- Do you agree performance measures should clarify key manufacturing process?
- Do you agree the development of performance measures hierarchy, that is to align strategy and measurement, is important?
- Do you agree the design of improvement programme performance measures should be part of the overall performance system, not just another "new" measurement?