A methodology for the selection of overall strategic performance measures for manufacturing business

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IN THE NAME OF ALLAH
THE BENEFICENT AND THE MERCIFUL
A METHODOLOGY FOR THE SELECTION OF OVERALL STRATEGIC PERFORMANCE MEASURE FOR MANUFACTURING BUSINESS

By

AZHARI BIN MD SALLEH
M.Sc., M.I.E.M

A Doctoral Thesis submitted in partial fulfilment of the requirements for the award of Degree of Doctor of Philosophy of the Loughborough University of Technology November 1995

Department of Manufacturing Engineering
LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY

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DECLARATION

This is to certify that I am responsible for the work submitted in this thesis, that the original work is my own except as specified in acknowledgements or in references, and that neither the thesis nor the original work contained therein has been submitted to this or any other institution for a higher degree.

Signed: ........................................................................

( AZHARI BIN MD SALLEH )

Date : ........................................................................
Dedication

To

My father and late mother whom has laid the foundation of my education and my wife, Zainab who has given me encouragement and support throughout the study and my daughters Rahimah and Nur Sabirah who has to endure testing time in new environments and my son Ahmad Munir who was born with brain damage during the period of this study.
This thesis describes the results of research analysing the utilisation of overall strategic performance measures for manufacturing business organisations in industrially developing nations. It proposes a methodology for the selection of overall strategic performance measures appropriate to a manufacturing organisation's position in the business life-cycle.

The process of deciding which overall strategic performance measures are the most likely to have the greatest impact in relation to the state of evolution of a manufacturing business organisation can be highly complex. Business managers often have to use their experience and intuitive judgement as guiding factors. The author of this research has made a study of the various factors which may influence the decision to adopt certain performance measures in a given stage of the growth of a manufacturing business organisation. Five main theoretical models namely, the life-cycle model, the competitive model, the organisational adaptation model, the phase requirement model and the business type model are used to develop the theoretical framework of the research. These models, although adopted by many major business organisations in the industrially developed world, are little understood or utilised in many small to medium scale industries in particular in the newly industrialised nations. Also, the models only indicate the characteristics exhibited by a business during its evolution and do not suggest the corresponding appropriate performance measures.
This research has identified the performance measures congruent with each model during a business life cycle.

Questionnaire surveys have also been carried out to complement and validate the theoretical models. The results of the survey generally confirm the expected measures derived from the theoretical models.

The learning process for these newer industrial business organisations can be greatly reduced if the expertise and experience of the established manufacturing business organisations is made readily available. This is the motivation for this research and the methodology which has been developed.

The research also proposes use of a knowledge based expert decision support system to encapsulate the methodology, and the wealth of expert knowledge in the domain of performance measures. A prototype knowledge based expert decision support system has been developed to test the concept.

It is hoped that this research has achieved its aim to provide a new contribution in the manufacturing business organisation strategy domain and to the improvement of managerial productivity and effectiveness through better use of performance measures.
ACKNOWLEDGEMENTS

The author wish to acknowledge and express his sincere thanks to both his supervisors, Mr John E Middle and Prof. Neil Burns for their supervision, encouragement, suggestions and help throughout this research. Their comments and suggestions have helped in the preparation of this thesis.

The author have also called upon the assistance of a large number of people both within and outside the University during the course of this study. To his Director of Research Dr Allen Hodgston and all administrative staff of Manufacturing Engineering Department, Loughborough University of Technology the author wishes to extend his thanks for their continuous support and help. To those managers of business organisations which participated in the research the author would like to express his sincere thanks and appreciation.

Thanks are also extended to University Technology Malaysia and the Malaysian Government for their sponsorships.

Lastly, the author is very grateful to his wife and children who persevered and offered their warm encouragement and help over the past four years.
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<td>A I</td>
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</tr>
<tr>
<td>BATC</td>
<td>Business Advanced Technology Centre</td>
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<tr>
<td>CAPP</td>
<td>Computer Aided Process Planning</td>
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<tr>
<td>CIM</td>
<td>Computer-Integrated Manufacturing</td>
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<tr>
<td>CIMA</td>
<td>Council Institute of Management Accounting</td>
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<tr>
<td>DN</td>
<td>Developed Nation</td>
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<tr>
<td>DSS</td>
<td>Decision Support System</td>
</tr>
<tr>
<td>DTI</td>
<td>Department of Trade and Industry</td>
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<tr>
<td>EDS</td>
<td>Expert Decision Support System</td>
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<tr>
<td>EPU</td>
<td>Economic Planning Unit</td>
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<td>ES</td>
<td>Expert System</td>
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<td>ESS</td>
<td>Expert System Shell</td>
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<td>ESSE</td>
<td>Expert System Support Environment</td>
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<td>FAME</td>
<td>Financial Analysis Made Easy</td>
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<td>FMM</td>
<td>Federation of Malaysian Manufacturers</td>
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<tr>
<td>FMS</td>
<td>Flexible Manufacturing System</td>
</tr>
<tr>
<td>JIT</td>
<td>Just-In-Time</td>
</tr>
<tr>
<td>KB</td>
<td>Knowledge Base</td>
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<tr>
<td>KE</td>
<td>Knowledge Engineer</td>
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<tr>
<td>MAMPU</td>
<td>Manpower &amp; Management Planning Unit</td>
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<tr>
<td>MIDA</td>
<td>Malaysian Industrial Development Authority</td>
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<tr>
<td>MIER</td>
<td>Malaysian Institute of Economic Research</td>
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<tr>
<td>MITI</td>
<td>Ministry of International Trade &amp; Industry</td>
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<tr>
<td>MOF</td>
<td>Ministry of Finance</td>
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<tr>
<td>MRPI</td>
<td>Material Requirement Planning</td>
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<td>MRPII</td>
<td>Manufacturing Resource Planning</td>
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<tr>
<td>NEDC</td>
<td>National Economic Development Council</td>
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<td>NIC</td>
<td>New Industrialised Country</td>
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<td>NPC</td>
<td>National Productivity Corporation</td>
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<tr>
<td>PM</td>
<td>Performance Measure</td>
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<td>PMFS</td>
<td>Performance Measurement &amp; Feedback Scheme</td>
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<td>PS</td>
<td>Production Systems Rule</td>
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<tr>
<td>SEDC</td>
<td>State Economic Development Corporation</td>
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<tr>
<td>SIRIM</td>
<td>Standard Industrial Research Institute Malaysia</td>
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<tr>
<td>SMART</td>
<td>Strategic Measurement Analysis &amp; Reporting Technique</td>
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<tr>
<td>SMI</td>
<td>Small &amp; Medium Scale Industry</td>
</tr>
<tr>
<td>SPC</td>
<td>Statistical-Process-Control</td>
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<tr>
<td>TQM</td>
<td>Total Quality Management</td>
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<td>WIP</td>
<td>Work In Progress</td>
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INTRODUCTION
CHAPTER ONE

INTRODUCTION

This chapter provides the general background and motivation for the research, and defines its scope and objectives. It describes the main areas of research and discusses the organisation of the dissertation.

1.1 The Research Background

The growth process of manufacturing business organisations has become increasingly vital and a topic of major concern of today's manufacturing management. As more and more nations throughout the world, especially the developing countries, are turning towards industrialisation as a key to economic salvation and prosperity, research efforts will increasingly be directed to the study of the characteristics and dynamic nature of the manufacturing business organisations. The objectives of industrialisation will never be achieved without a sustained and continuously successful manufacturing base. Manufacturing business organisations are the dynamic and major organ of industrialisation. However faced with the unprecedented complexity of today's manufacturing environment most manufacturing business managers are finding it hard to achieve competitive targets, and these tends to delay the process of growth towards industrialisation in developing countries.

Manufacturing business organisations, just like human beings, will pass through a number of life stages from 'birth' to 'death' [1,2]. The life-span of a business organisation may differ from that of a human being but the life-cycle image fits reasonably well. There are cases of infant mortality of businesses, just as with human beings, and businesses become established and mature in the manner of humans
attaining adulthood. From the day it is 'born' a business will encounter various challenges if it is to remain in existence. Everyday we hear of businesses closing down, ceasing to trade, taken over or 'dead' through bankruptcy. At the same time we also witness many thousands of businesses which are rejuvenated or nursed back to health by hopeful people, turning around these businesses into profitable and successful ventures. Many factors contribute to the success or failures of these businesses, not least is the understanding of how critical activities affect business performance, or how the business is performing in terms appropriate to the market and manufacturing environment in which it is operating.

Measuring the performance of an organisation, be it a service or manufacturing organisation, is not a new activity; there can be few businesses that do not measure profitability or return on investment. However the concept of using performance measures as a strategic tool for achieving continuous success in the growth of a manufacturing business organisation is quite a recent phenomena. Interest in this area of research has increased rapidly over the past few years. In the 1980s several leading researchers in the field of industrial management, both academicians and industrial manufacturing experts have shown that winning and losing in a manufacturing business organisation's battle for market shares and customer approval, relies heavily on the type of key performance measures which are installed in the business. Case studies, have shown that the 'success/failure' or the 'life/death' of a manufacturing business organisation is related to the type of performance measures deployed by management [3,4,5,6].

Spearheading this revolutionary research as described in the following paragraph are names like Schonberger [7], Porter [8], Peters [9], Ohmae [10], Deming [11], Kaplan [12], Goldratt & Fox [13], Cox [14], Cross & Lynch [15], Hiromoto [16], Lamont [17] and Maskell [3]. Their works have gained widespread publicity, and interest in the concept of strategic performance measures is growing almost world-wide in terms of how the manufacturing business organisations are to be managed today and in the years to come.
Collectively the above researchers reported that, although enormous changes had taken place in manufacturing business organisation, there had been no significant change in the development of performance measures.

Many manufacturing managers are often caught struggling to find the right formula for performance measures in various manufacturing activities. They are either too absorbed in their routine manufacturing activities, to the extend of not realising the actual movement and direction of their businesses, or they may end up taking irrelevant measures which contribute little to the continued survival of their businesses. The introduction of computer-integrated manufacturing (CIM) for example, would definitely alter the way manufacturing businesses operate. Unfortunately many manufacturing business organisations still retain the traditional ways of measuring manufacturing performance. Campbell [18] reported that the full benefit of technological change would not be realised unless accompanied by strategic reappraisal of organisational aims, structures, attitudes and practices (which includes the way performances are measured). Pollit [19] reported that most managers do not really know the actual contribution of performance measures toward the improvement of their companies. Vollman [20] mentioned that most of the known performance measures just report history to the external world rather than promote effective action inside the company. He reported that measures such as quality, skill enhancement and useful knowledge, which are real competitive dimensions and sources of added value, are ignored. Maskell [3] and many other researchers namely Goldratt & Fox [13], Kaplan [12], Sinks [21] and Lippa [22], in several detailed studies have shown that some of the existing performance measures are no longer adequate, they are costly to maintain, misleading and can be consider as outdated. They collectively agree that the collapse of many manufacturing businesses facing the global competition of the 1970s and 1980s was related in one way or the other to the continued deployment of what they termed the traditional types of manufacturing performance measures.

Lamont [17] also reported the finding of a survey which concluded that a great majority of corporate management has yet to recognise the full benefit of performance measurement. Generally, performance measures were linked to the annual review process - the normal end of the year financial and account reporting. Performance measures are also frequently seen as an imposition from top management
and as functioning primarily to provide some form of assessment of individual performance for the purpose of promotion or pay increase. Whitting [6] has suggested that there is evidence that many organisations adopt performance measures which are conventional and universal without considering other measures that may be more appropriate to suit their individual business.

A recent study on the performance measures of manufacturing business organisations in United Kingdom, which was commissioned by the Department of Trade and Industry (Manufacturing & Technology Division) and undertaken by CIMA, Cambridge University, Glasgow University, NIMTECH and Warwick University [23] has concluded that, although advocates of reforms in performance evaluation and measurement systems strongly recommend the greater adoption of non-financial manufacturing measures, most businesses, small, medium and large, have a tendency to base their decisions primarily on financial monitors of performance. However in 1990 the National Economic Development Council Engineering Industry Sector Group of United Kingdom published a report entitled 'success factors in engineering' which highlighted that success should not necessarily be quantifiable in financial terms alone [24]. Considering the recommendations which came from two such respectable and powerful bodies as DTI and NEDC it is surprising that manufacturing company managers are still reluctant to adopt a new form of performance measurement system.

The research carried out in this study has also found that most manufacturing business organisations, especially in developing countries, are still using their yearly financial report as the sole measure of success or failure [25]. This kind of phenomena is not surprising since in most developing nations many aspects of life depend on the legacy of technology and manufacturing knowledge left by their colonial masters. It is therefore not uncommon to find manufacturing businesses still employing outdated methods of measuring performance. No one should deny the central role that financial measures play in assessing the performance of a business organisation. These measures are legitimate and important indicators of how well management is utilising the assets under its control to increase share holding value. Unfortunately many business organisations fail to realise the limitations of relying exclusively on financial measures of performance in today's highly competitive
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manufacturing environment. Manufacturing management is still too slow to recognise, employ and harness the real potential of correct performance measures.

It is against the above background that this research was initiated. The main motivation behind the research is the need of a typical developing country in search of the best means of achieving success in the quest for industrialisation. Malaysia, a rapidly developing nation in South East Asia is chosen to represent the many developing nations in the world today. The country is aiming to be an efficient and competitive industrialised nation by the year 2020. This aim of Malaysia can only be achieved if her manufacturing performance reaches world class levels. It is vital that every manufacturing business organisation involved in transforming Malaysia into a developed nation by the year 2020 knows how to properly utilise and measure its performances so as to gauge their own achievement and steer their development through the growth stages. To maintain an industrialised nation's economic strength, its performance both in the manufacturing and service sectors must always be geared towards improvement. Government and private sectors wanting to stay ahead in economic development must find ways and means to improve these twin sectors. One of the ways to do this is to monitor and measure the performance of all manufacturing and service organisations. By doing so the real situation of an organisations performance will be known at any given time. Any deviation or negative performance of any department in the organisation would quickly be dealt with and remedial action be taken. This research represents an effort to accumulate as much expert knowledge as possible in the field of strategic performance measurement of manufacturing business organisations. This is incorporated in a methodology which will serve as a decision support system in the selection and use of strategic performance measures, and for which a prototype knowledge based expert decision support system has been developed to show the potential practical realisation of the methodology as a computer based management tool.
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1.2 Research Scope and Objectives

1.2.1 The scope

The scope of the research covers two fields namely the global utilisation of strategic performance measurement in manufacturing business organisations and the usage of expert system technology as a supporting tool in management decision making.

1.2.2 The main objectives

The main objectives of the research are the creation of a methodology for the selection of overall strategic performance measures for manufacturing business organisations within a developing country at any stage of their growth / life cycle, and to embody this with a knowledge based expert system.

1.2.3 The secondary objectives

The following are the secondary objectives to be achieved:

a. To understand the global problem of performance measurement utilisation.

b. To study the needs of manufacturing business organisations in a developing country in the area of performance measurement.

c. To understand the methodology of strategic performance measurement and assigning it to the various manufacturing business organisations.

d. To comprehend the factors affecting performance measurement analysis.
e. To understand the concept and techniques of designing expert systems and decision support systems, and their application in performance measurement.

f. To select the appropriate tools for the development of the expert decision support system.

1.3 The Main Areas of Research

The research addresses three major areas namely, the evolution of manufacturing business organisations in a developing country, the concept of performance measurement in manufacturing businesses and the application of expert system technology in the manufacturing management domain.

1.3.1 The role of manufacturing business organisations in a developing country.

The first area of this research is the role of the manufacturing business organisations of a developing country. Even though developing countries can be classified into several types, the manufacturing business organisation's role in each type in their endeavour to become industrialised, is almost the same. The research has concentrated on the characteristics, the dynamics, the problems, needs and requirements of the manufacturing business organisations in a developing country. It has also looked at the past, present and the vision of the future direction of these businesses as they will develop and play a role towards the establishment of the industrialised society.

Development and industrialisation have long been known to be synonymous, and the evolution of the present developed nations (DN) such as United States of America, Britain, France, Germany and Japan and the new industrialised countries (NIC) like Argentina, Brazil, Hong Kong, Singapore and South Korea emphasises this. Chenery et al [26] has shown that industrialisation is characteristic of
countries that have developed, and manufacturing business organisations are at the heart of the industrialisation process. It is therefore inevitable for a developing country striving to become an industrialised nation to concentrate on developing a successful manufacturing base.

Traditionally manufacturing business organisations in a developing country can be expected to evolve in a similar pattern to that found historically in a developed country. It is therefore essential that the experiences of the manufacturing business organisations of developed countries be carefully analysed and the positive and negative aspects be learned. Every manufacturing business organisation in a developing country need not necessarily 'reinvent the wheel'. There is a great deal to be learned from other peoples' experience. The 200 years of British experience in manufacturing for instance would contribute tremendously to the learning process of the newly developing countries of the world. Especially those countries which are adopting the philosophy and the practices of the British manufacturing establishments. This is how researchers who sometimes pursue fairly restricted specialisation can contribute to the practice of manufacturing management as a whole.

History has shown that each developing country is linked to at least one industrialised country. Normally the initial path the developing country will follow in its industrial evolution is the path followed by the industrialised country to which it is linked. In the case of this research, Malaysia is used as the developing country and Britain is the linked industrialised nation. After gaining her independence from Britain in 1957, Malaysia embarked on developing the infrastructure of the country imitating almost 100% of the British systems, from legislative to judiciary, district to federal management right to parliament and monarchy systems everything was based on British systems. Physical development like the roads and railways, postal and telecommunication networks, ports and airports are almost identical to that of Britain. Similarly with the development of manufacturing industries. Initially the practices in the manufacturing institutions tended to copy the codes of conduct of British industries. The management and worker relationships are exactly similar to that of the British ways of doing things. The link to Britain continued until the 1980s when slowly Japanese and Singaporean influence began to play a bigger role in the development of the manufacturing industries of Malaysia. Steadily the 'Look East
Policy of the Malaysian government began to gain momentum and take root in certain sectors of the manufacturing environment of Malaysia. However, many aspects, including the means of measuring performance, still remain traditional and conventional. It is in this specific area that this research had looked. Several studies have compared the various ways of measuring performance of manufacturing industries in Europe, America, and Japan [27]. Many industrialists and academicians have realized that there are strong reasons to believe that the different performance in manufacturing business organisations between the countries are due to their management ability to select proper performance measures. It is the desire of this research that the problems faced by the various manufacturing companies in those countries should be learned and not be repeated in the process of industrialization of Malaysia.

1.3.2 The concept of performance measurement in manufacturing businesses.

The concept of performance measurement in manufacturing businesses organisation is the second main area of the research. Whereas the first area defines the objective, this second area researched the philosophy, utilisation, and the theoretical aspects of performance measurement in manufacturing business organisations. The research has centred around the traditional and the current concepts of performance measures and surveyed the reasons why manufacturing business organisations were using particular measures. In the majority of cases, a performance measurement system is selected to suit a certain purpose. The purpose is normally different for internal and external users and for different levels of management within a business organisation or business group. Externally, shareholders, potential investors, lenders, and creditors will need a different measure of performance from those on the inside of the business organisation such as the directors and managers. The chief Executive Officer of a business organisation will require different measures from those needed by a shop supervisor. Needless to say, there are business organisations which select sets of measures for their organisation but without any purpose whatsoever apart from some form of window dressing. In other cases, performance measurements is nothing more than just the normal end of the year financial and account reporting ritual.
Traditionally, the great majority of performance measures of manufacturing business organisations have been based on the cost and management accounting concept which has remained largely unchanged [3]. Such measures place emphasis on cost, price and profit. On the other hand manufacturing management technology and processes have undergone numerous changes. In more recent times these manufacturing changes have reflected change in market expectations away from price alone to such as value, quality, innovation, choice and delivery lead time. To respond to these customer demands, and to increase competitiveness, various new technologies and management techniques have been introduced, even into a small manufacturing business organisation, transforming the methods of managing and producing its products. Concurrent Engineering, Just-In-Time (JIT) delivery and purchasing systems, Computer-Integrated-Manufacturing (CIM), FMS and Cellular Manufacturing, Material-Requirement-Planning (MRP-I), Manufacturing-Resource-Planning (MRP-II), Statistical-Process-Control (SPC) and Total-Quality-Management (TQM) are examples of these new techniques and technologies which have definitely altered the manner of manufacturing processes and management. As a consequence, many researchers have claimed that the way performance of various aspects of a manufacturing business organisation is measured must be reviewed and a new set of performance measures be introduced.

The shift away from cost and management accounting as the foundation of performance measurement in manufacturing business organisations happened only in recent years. New performance measurement concepts have emerged which relate directly to successful manufacturing strategy. The new concepts utilised primarily non financial performance measures. The measures will vary from location to location and are much simpler to use. From the review that was carried out in this research it is noted that in the concept of strategic performance measures the measures required change over time. Researchers have argued that the solution to the performance measurement problem lies not in the creation of new sets of measures but rather to institutionalise a process for continuously changing measures [4]. They suggest that there should not be a stable set of permanent measures in a dynamic and improving manufacturing business organisation but rather measures should change to reflect the needs of manufacturing strategy and business objectives. The process of defining performance measures appropriate for any point in a manufacturing business
organisations growth / life-cycle by using expert system technology is what this research is directed at.

1.3.3 The application of expert system technology in manufacturing

An expert system (ES) can be described as a knowledge based computer program developed to aid solution to a particular problem that requires a high level of expert knowledge, reasoning and judgement. According to Waterman [28] the computer program uses the expert knowledge to attain high levels of performance in a narrow problem area. ES typically represent knowledge symbolically, examine and explain their reasoning processes, and address problem areas that require years of special training and education for humans to master. They capture expert knowledge and make it available to the others. They bridge the gap between those who know and those who need to know. ES technology itself is not a new phenomena. ES have branched out of studies and applications in artificial intelligence (AI), which is a subject concerned with improving the application of computers to behave in a more 'intelligent manner'. Within the last decade many business or consultancy companies including government departments, have set up teams to investigate how and where ES technology could and should be employed. Today the design and construction of ES is occurring world wide and its application has been successful in various fields such as medical diagnosis, electronic circuit diagnosis, automobile engine fault diagnosis, interpretation of chemical data, mineral exploration, military defence, air-traffic control and many computer-aided instruction.

In the field of manufacturing, ES technology has been widely used in more generalised problems. Most of the current systems deal with manufacturing planning, scheduling, fault diagnosis, maintenance, design, training, control, debugging and interpretational problems. Everyday this list is steadily increasing. In 1989 alone, Alting and Zhang [29] have listed at least 150 ES developed to perform computer-aided process planning (CAPP). MADEMA, OPIS, IMACS, PTRANS and ISIS are few of the well known examples of ES developed to perform intelligent factory scheduling and planning.
In the diagnostic and maintenance fields, Majstorovic [30] has surveyed nearly 90 ES which were developed to diagnose various processes and malfunctions. FAITH and FALCON are two notable examples of the diagnostic ES type. FAITH was developed at the Jet Propulsion Laboratory as a diagnostic system for identifying spacecraft malfunction through the analysis of telemetric data stream transmitted from the spacecraft while FALCON identifies the causes of process disturbances in a chemical plant by monitoring gauges, switches, and alarms.

In the design area several ES such as ASASP, ROSCAT and EXCAST were developed. ASASP assists a quality engineer in designing a sampling plan while ROSCAT was developed for component design and the specification of ISO tolerances in the manufacture of rotational components. Besides assisting design engineers in the design of casting components, EXCAST also predicts metal casting defects.

The application of ES technology in the instructional and control fields were also gaining momentum. An example of ES which falls within the control category is GENESIS which performs real time control of public phone network while ECESIS is another developed at Boeing Aerospace Company to autonomously control the environmental life support subsystem of a manned space station. XMAN II and ESWELPD are two examples of instructional types of ES which were developed in 1990. XMAN II evaluates the data generated by an aircraft engine monitoring system and assists the mechanic in troubleshooting tasks. ESWELPD was developed at Loughborough University of Technology Manufacturing Department to recommend welding procedures to novice welders.

Examples of debugging and interpretation ES are DESPLATE and GAMMA respectively. The DESPLATE ES diagnoses abnormal shape steel plates in plate mills, identifies the underlying causes and suggests remedies. The underlying causes could be electrical failure, machine wear, machine breakdown, or prerolling conditions. The GAMMA ES helps researchers in determining the composition of unknown substances by interpreting the resulting gamma-ray activation spectra when the substance is bombarded by neutrons.
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It can be seen from the above examples that the majority of the applications of ES technology in manufacturing are mostly to perform process control or to diagnose process malfunction. Even though a survey conducted in 1990 indicated that manufacturers are among the largest group of ES developers, limited focus is seen to be given to manufacturing management applications. It is the desire of this research that the development of an expert decision support system, using ES technology to capture a methodology incorporating the best available knowledge and expertise in the use of performance measures will be a new contribution in the manufacturing management domain.

1.4 Organisation of Dissertation

This chapter has outlined the general background, scope, objectives and the main areas of the research.

The second chapter reviews the literature on the development, utilisation and current approach of the manufacturing performance measures. It also presents the general concepts of expert systems and decision support systems.

The third chapter explains the research methodology and procedure. It defines the research category, phases and the types of manufacturing business organisations involved in the research. It discusses the design of the research instrumentation which is the performance measurement survey questionnaires, and lists the knowledge acquisition main sources. The use of expert system shells and the techniques used in the representation of knowledge are also presented.

The fourth chapter introduces the theoretical framework of the research. It outlines the factors which may influence the process of reviewing and selecting the various manufacturing business performance measures. It also explains the conceptual models of manufacturing businesses, the life-stages model, the organisational adaptation model, the phase requirement model, the competitive model and the business type model. These models provide the basis and the linkages for selecting the various manufacturing business performance measures.
Chapter 1

The fifth chapter describes the development and basic principles of expert systems and decision support systems and the selection of expert decision support system type and tools. It also includes the discussion on the selection of expert system shell. The chapter ends with the presentation of the design of an expert decision support system for the selection of manufacturing business performance measures.

The sixth chapter discusses the analysis of survey questionnaires and system evaluation while the seventh presents the discussions and conclusions.

Chapter eight discusses the recommendations for future work and finally chapter nine summarises and discusses the research contribution and concludes the dissertation.

REFERENCES


Chapter 1


...introduction


CHAPTER TWO

REVIEW OF LITERATURE
CHAPTER TWO
REVIEW OF LITERATURE

This chapter introduces the historical development of manufacturing performance measures, and discusses the evolution of market demands and changing performance criteria. It describes the utilisation of performance measures in manufacturing business organisations and presents examples of the current approaches in manufacturing performance measurement. The possible utilisation of expert system-based technology in solving the manufacturing business organisation performance measurement problem is also presented and the general concepts of expert systems and decision support systems is discussed.

2.1 Historical Development of Manufacturing Performance Measures

Work on measuring performance dates back to the early history of man. It is in the human nature for man to desire to measure his performance and to compare it with others. This need to compare and contrast with others has resulted in the establishment and development for various criteria for measuring human performance. What criteria should one use to differentiate between the good and the poor performance? How should one measure success and failure in one's performance? The holy books of various religions notably the Bible and the Quran were the earliest known documents to present the criteria of human good and bad performance in all spheres of human activities. Most of the criteria in the holy books outline that anything manufactured by man must be for the good of mankind for it to be really considered as good performance. Later man began to be more materialistic and material gain or loss began to take over as the main criteria for human success or failure, irrespective of the means of achieving it - the end justified the means. Slavery and under-age factory workers were familiar features of manufacturing business organisations. Success or failure of manufacturing business organisations depended
solely on the owner, or 'the boss', who ran the business in an authoritarian or 'iron-handed' way.

The Industrial Revolution which took place in Britain about 230 years ago saw the first change in the way manufactured goods were produced and hence the first change in the way manufacturing performance was measured. Before the industrial revolution, individual craftsmen measured their manufacturing performance based on the number of people willing to buy their wares [1]. The Industrial Revolution created a new environment in the factory for both man and machine. It imposed new forms of labour by bringing together many workers under one roof to operate machines driven by power. Employees were incorporated into an organised system of division of labour in which they performed only a small part of the total production labour. Very little interest was shown or given to the social needs and contribution of the workers. Performance of the business was solely in the hands of the industrialists whom had invested the capital outlay and expected only to obtain a profitable return [2]. These capitalist industrialists were the only people in the manufacturing world at that time who could make the necessary business decisions and judgement to solve all business problems and tell the shop-floor workers what to do. Shop-floor workers were expected only to use their physical strength and not their brains.

As the Industrial Revolution of the nineteenth century started to spread its wings from Britain through Europe to America, creating new urban environments and societies, the world of manufacturing business management also grew, expanded and developed in many ways. The Encyclopaedia of Management [3] describes Frederick Taylor's scientific management which was introduced around 1911, where it was argued that, "division and specialisation of labour would lead to greater productivity ". Workers were considered as a standard extension to machines doing routine and tightly controlled jobs. Standard production methods were used and standard costing techniques applied. Various other organisational concepts and systems were developed and perfected, among which were the management accounting techniques to meet the requirements of new type of entrepreneurs [4]. Maskell [5] reported that the techniques of management accounting were developed over a period from the late nineteenth century until the 1920s and 1930s. During this
time theoretical and practical methods of management accounting became established, and these standard techniques were widely taught and applied. Maskell termed these techniques the traditional management accounting techniques. These techniques became the accepted method of measuring the performance of a manufacturing business.

Since the 1930s, there have been few significant changes in the fundamental principles of management accounting [5] & [6]. In contrast, manufacturing business has changed enormously. Automation and new product development have changed the cost distribution and structure of production. Similarly, customer demands and requirements of the market have also changed [7]. As a result of the above changes many researchers have argued that management accounting measurement techniques such as efficiency and utilisation measures have become irrelevant for supporting internal business decisions and have been wrongly equated as measures that would bring about successful performance of the manufacturing business organisation [8]. Throughout the 1980s many researchers have highlighted the importance of reviewing the use of traditional management accounting techniques. Kaplan [9] and Edwards [10] were among the early researchers whom pointed out the shortcomings of the traditional accounting ways of measuring manufacturing performance in today's dynamic manufacturing environment. Later Goldratt [11], Finch & Cox [12], Sink [13] and Lippa [14] showed that these measures are no longer adequate, and that they are costly to maintain. In addition they challenged the assumption that inventory was an asset and illustrated how this assumption misrepresented manufacturing plant and business performances. Zairi [15] wrote that, in today's global competitive environment, manufacturing business organisations compete in terms of product quality, value, delivery, reliability, after-sale service and customer satisfaction in addition to price. Almost all of these performance measures are not considered by the traditional financial measures, despite the fact that they are among the main objectives of a manufacturing business organisation. Dixon et al. [16] and Drury [17] also expressed their concern about the limitation of the existing traditional financial measures and argue that they are not compatible with modern management concepts such as just-in-time (JIT), statistical process control (SPC), computer integrated manufacturing (CIM), manufacturing resource planning (MRP II) and total quality management (TQM). All of the above
researchers concluded that for continued effectiveness a good performance measurement system needs to be able to change in response to changes in the manufacturing environment in order for a business to remain competitive.

2.1.1 The changing performance criteria and market demands

Figure 2.1 shows the changing performance criteria and market demands from 1960s to 1990s [18]. The change in the demand of the market is one of if not the most important factor which has caused the need for continually changing performance measures inside the manufacturing business organisation. The literature survey reveals that until the 1960s, the market was characterised by the pursuit of quantitative growth [8]. Anything that was produced in the 'good old days' could easily be sold as demand out-stripped supply. The market showed all the characteristics of a seller's market. As such, the main effort was directed toward increasing production and the increase in turnover was paramount. Turnover was noted to be one of the most important measures of business success.

In the 1960s the market environment changed as manufacturing businesses began to search for lower manufacturing cost and moved their manufacturing bases to newly emerging industrial nations and to countries having low wage rates and easy access to raw material. Products manufactured in one country can now easily be distributed throughout the world. Price then became an important criterion for success in the market [19]. Customers could for the first time select on price. Products made in various parts of the world were compared by consumers. Before the 1960s, customers paid the price for whatever was available from the limited sources of supply i.e., Britain, Europe or America. During the 1960s the market started to be filled with more choice as cheap Japanese, Taiwanese and South Korean products began to penetrate the market, and resulting from the greater choice the price war begun. Price then becomes a very important factor in the performance of manufacturing businesses.

With price as an all important market requirement, logically, manufacturing business organisations had to become extremely efficient to keep in...
phase with it. Efficiency then became a very important performance criterion of manufacturing business organisations. The activities of transferring their factories to different parts of the world, restructuring their business organisations, and procurement of easy access raw material and cheap labour were clear evidence of the effort made to improve the cost efficiency of their business.

In the early 1970s international and local markets were flooded with products manufactured in various parts of the world. The price variation for similar products often became a confusing issue for the customers as well as retailers. For household equipment such as radios, television, refrigerators, cookers and washing machines price was not necessarily a measure of quality. This phenomena was a natural outcome of the price war which happened in the 1960s. Some governments increased subsidies and introduced new tariffs, incentives and regulations and manufacturers tended to compete by bringing down the price at the expense of quality. Affluent customers started to select more critically and paid more attention to the quality, specification, value and price of the products they chose to buy. They began to react against poor quality products delivered by many agents of manufacturing businesses. Poor quality products with low initial cost could be very costly in the long term. Also 'nuisance cost' became an important factor due to breakdown and the repair work which was frequently required. Customers started to give more attention to product quality. Realising the change in market demand the Japanese, largely as a result of the contributions of Deming [20], Juran [21] and others to their industrial reconstruction, made a clear-cut strategic choice to bring out high quality but with competitively priced products. The success of this strategy was evident as Japanese manufacturing businesses captured and swept the world market relentlessly in the 1970s. Quality measure was added to price and became another major factor in the performance of manufacturing businesses.

The subsequent focus of performance criteria onto quality was the direct result of changes that occurred in the market demand. As the market demanded quality products, manufacturing businesses had to make quality a very important performance criterion to ensure their business survival. Business which did not give due attention to quality in the 1970s soon found themselves unable to compete. For years Deming and Juran pointed out that quality improvement is ultimately the way to

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22 ...review of literature
increase efficiency of manufacturing business organisations. Quality measures can therefore be seen as an extension of efficiency measures, encompassing and reinforcing it in facing the competitive environment of the manufacturing business world.

By the end of the 1970s and into the 1980s another market requirement came into the picture. The market had turned from a sellers' market into a buyers' market in which production capacity exceeded demand. Competition intensified as the Japanese began to introduce new products in a shorter time interval. New models of cars, engines, household equipment and various other utensils were delivered onto the market on a regular short-time cycle basis. The development process time began to get shorter and manufacturing businesses started to produce an array of new products with up-to-date design. The market became more fashion conscious as more and more quality and reasonably priced products were paraded for the customers to choose from. Flexibility of product range increasingly became an essential factor for manufacturing business success. As a result, production lines had to be modernised, and advanced technology and machines which are more flexible were adopted. Flexibility becomes another important measure adding to the already existing quality and price measures in the manufacturing business.

In the 1980s the manufacturing businesses had to compete not only in term of price and quality but also on the ability to provide a wider range of up-to-date products [8]. Again, the Japanese were the initiator in introducing a variety of products on to the market. Various types and ranges of audio-visual, cameras, electrical appliances, cars and motorcycles could be found. In America for instance, by 1984 there were more than 250 different car models on sale [23]. This new market requirement demanded most manufacturing business organisations to produce a wider product range to remain competitive. In other words production processes had to be more advanced and flexible in order to produce a wider range of products. Flexibility then had become a very important performance criterion in manufacturing businesses. However it could not be achieved unless the manufacturing business was efficient and had the quality aspects of the business and product under control. Flexibility is thus an extension of efficiency and quality requirements. Researchers began to appreciate that
efficiency and quality are the prerequisite for flexibility to be operable. In the long term flexibility is seen to support and enhance efficiency and quality.

Bolwijn, Van Ham & Kumpe [22] have suggested that the market requirement of the 1990s would be that the product must be clearly superior and stand out from those of competitors. This they term product uniqueness. They quoted several examples of products such as the 'Volkswagen Beetle', 'Swatch Watch', 'CD Player', flat screen television and 'Walkman' which fell into this unique category. New technologies such as fibre-optic cables, micro-electronics, industrial ceramics, micro lasers and many more will have to be utilised to the maximum to achieve uniqueness in new products. Manufacturing management will have to implement the best possible management techniques and tools to facilitate the introduction of new technologies and superior products to the market. The lesson from the past decade is that technological advancement alone does not ensure success unless accompanied by management willingness to upgrade management tools, facilities and techniques. Thus uniqueness becomes the fourth market requirement with innovativeness as the associated performance criterion.

As shown in Figure 2.1, each new market requirement and corresponding performance criteria was in addition to rather than a replacement for the existing requirement.
From 1990 onward successful manufacturing businesses have been competing on price, quality, and flexibility as their major business objectives. In late 1992 a survey was carried out on 858 small to medium-sized UK manufacturing companies by Neely et al. [23]. Among the questions asked was how the businesses competed and what they measured. It was not surprising to find that quality, price and...
flexibility came out as the top three competitive business objectives adopted by the majority of the businesses that responded to the survey. The other competitive stance was 'time', which involved manufacturing lead time and on-time delivery performance measures.

Another report published by National Economic Development Office of UK in July 1990 showed that the 10 most highly successful manufacturing businesses in UK adopted quality, products and production processes as among the most important business success factors as shown in Figure 2.2

<table>
<thead>
<tr>
<th>Number</th>
<th>Success Factor</th>
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<tbody>
<tr>
<td>1</td>
<td>A committed, long-term management philosophy</td>
</tr>
<tr>
<td>2</td>
<td>An emphasis on the product and its quality</td>
</tr>
<tr>
<td>3</td>
<td>Continuous improvement of production processes</td>
</tr>
<tr>
<td>4</td>
<td>Close relations with suppliers</td>
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<tr>
<td>5</td>
<td>Valuing people</td>
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<td>6</td>
<td>Financial strength</td>
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</table>

Figure 2.2 Important Business Success Factor Reported By NEDC

As we move into the twenty-first century, most researchers and industrialist are emphasising product uniqueness [8]. This is based on the line of reasoning that each new market requirement is an extension of the previous ones. In all probability manufacturing businesses over the decades will have mastered the art of managing price, quality and flexibility. Consequently, the next natural stage will be that manufacturing businesses will have to make their products really superior and stand out in the market so as to remain competitive. Manufacturing businesses must be innovative. It thus seems highly likely that innovation will be the new important performance criteria of the 1990s and into the twenty-first century.
2.2 Utilisation of Performance Measures in Manufacturing Businesses

Traditionally performance measures were seen as an accounting report prepared to explain what has happened to the business and how it was being controlled. Pollit [24] reported that little was known of the real contribution of performance measures towards the actual improvement of departments in various organisations. Similarly, Vollman [7] mentioned that most of the performance measures used by manufacturing business just report history to the external world of manufacturing rather than promote effective action inside the business. In 1988 Lamont [25] reported that a great majority of corporate management has yet to recognise the full benefit of performance measurement. In his book Whitting [26] suggests that there is evidence that many organisations adopt performance measures which are conventional and universal without considering other measures that may be more appropriate and useful.

It is only in recent years that Western manufacturing business management has appreciated that there is real potential in the proper utilisation of performance measures. They began to realise that to be competitive in any or all of the current market requirements (price, quality, flexibility, time, innovation) it is necessary to measure corresponding performance criteria.

Study by Bhimani [27], (funded by DTI and CIMA) on the utilisation of performance measure and the rationale for their use in UK manufacturing business organisations had the following conclusions;

- although advocates of reforms in performance evaluation and measurement systems recommend the greater adoption of non-financial manufacturing measures, most companies (small, medium and large) have a tendency to base their decisions primarily on financial monitors of performance.

- board members, bankers, investors and other lenders place overwhelming reliance on financial indicators such as profit, turnover, cash flow and return on capital, and in many cases do so exclusively.
executives tend to be more receptive to the internal use of non-financial measures.

there appears not to be an optimal mix of specific financial and non-financial indicators applicable to all manufacturers. Rather, each business must find a balance of measures which it views as sufficient for the management of its operational activities. Nevertheless, broad guidelines as to which dimensions of performance may be appropriate can be developed. Thus for financial measures, a company may develop its own measures in relation to the following: working capital, capital market, financial return and lender security. Likewise, for non-financial measures, the business could adopt the following broad categories: quality, delivery, process time and flexibility.

The study also concluded that performance measures are seen to constitute an important element of decision-making and manufacturers are increasingly of the opinion that adoption of performance measures, both financial and non-financial, is a step in the right direction.

Studies in Europe by Andersin & Laaksob [28] have also shown that manufacturing business organisations are beginning to make real use of performance measures such as quality and delivery. They show that French manufacturing businesses are using performance measurement as a tool for problem spotting and problem solving. Managers from all parts of a manufacturing business meet monthly to review the performance measures used and decide on actions.

The study shows that in Germany performance measures are used for process control while in Sweden the main areas are cost and quality. In Finnish manufacturing business organisations Andersin & Laaksob found that performance measures are extensively use in the area of delivery, productivity, quality and inventory levels.

Overall, critics of performance measurement systems in use in manufacturing business organisations have pointed out the existence of a trend towards fundamental changes in the way in which manufacturing processes now take
place and the traditional performance measures being used in many manufacturing businesses.

Maskell reported that many manufacturing managers are beginning to respond and recognise the value of performance measures and are actively seeking to identify the measures which will help managers to manage more effectively. Eccles & Pyburn [29] also reported that many manufacturing business organisations in response to the changing market requirements have begun to create new performance measurement systems that supplement and extend the more traditional financial measures of corporate performance. Several researchers have undertaken studies and have developed and tested performance measurement systems. Some of these developments will now be discussed.

2.3 Current Approaches in Manufacturing Performance Measures

2.3.1 Integrated performance measurement.

Nanni et.al [16] with a team of accountancy and operations experts used a questionnaire-based approach to 'audit' and prioritise performance measures as they relate to manufacturing strategy. They suggested in their field research report that the solution to the performance measurement problem lies not in creating some totally new system of measurement but in institutionalising a process for continuously changing measures. They argue that there is not and never will be a stable optimal set of performance measures in dynamic and improving manufacturing business organisations. The approach adopted by Nanni et.al. concentrated on eliciting information from key managers as to the most important improvement areas for the manufacturing business, requiring responses on a 1-10 scale. It then uses a similar format to identify current performance measures and their significance in influencing improvement. Figure 2.3 gives an example of the questionnaires used by the team.
## PERFORMANCE MEASUREMENT QUESTIONNAIRE 2

### PART I: FINANCIAL FACTORS

<table>
<thead>
<tr>
<th>Importance of Performance Factor</th>
<th>PERFORMANCE FACTOR</th>
<th>Firm's Emphasis on Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>None &gt;&gt;&gt;&gt;&gt;&gt;&gt;&gt; Great</td>
<td>None &gt;&gt;&gt;&gt;&gt;&gt;&gt;&gt; Major</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1 2 3 4 5 6 7 8 9 10</th>
<th>COST OF QUALITY</th>
<th>1 2 3 4 5 6 7 8 9 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>INVENTORY TURNOVER</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>TRAINING BUDGET</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>COST REDUCTION</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>CAPITAL INVESTMENT</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>R &amp; D COST</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>UNIT MATERIAL COST</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>UNIT LABOUR COST</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>RETURN ON INVESTMENT</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>DEPARTMENT BUDGET CONTROL</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
</tbody>
</table>

(Please add if there is any other financial performance measure, Thank you)

<table>
<thead>
<tr>
<th>1 2 3 4 5 6 7 8 9 10</th>
<th>.................................................</th>
<th>1 2 3 4 5 6 7 8 9 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>.................................................</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
</tbody>
</table>

Figure 2.3  A Sample of the Performance Measurement Questionnaire
2.3.2 Strategic measurement analysis and reporting technique (SMART)

Cross & Lynch [30] developed an approach called the Strategic Measurement Analysis and Reporting Technique (SMART). Figure 2.4 shows the basic structure of this approach. SMART is developed with a hierarchy of objectives and measures. At the top of the structure is the corporate vision. Below the vision are goals for the market place and finance. These goals are the strategic manufacturing business objectives. The next step down in the hierarchy involves the business system objectives of customer satisfaction, flexibility and productivity. The last level in the hierarchy is the departmental and work centre performance criteria. These are quality, delivery, process time and cost. For each of these goals, objectives or criteria a measure or measures of performance are required.

![The SMART Performance Measurement Pyramid](image)

Figure 2.4 The SMART Performance Measurement Pyramid

...review of literature
2.3.3 Hierarchical performance measurement systems

An example of a hierarchical performance measure approach is shown in Figure 2.5. This approach is developed by Keegan et.al [31]. The objective of this approach is to develop a system that fosters constant evaluation - both in terms of what is important and how the business is to be measured. The approach also integrates both financial and non-financial reporting, linking manufacturing strategic goals, and developing a measurement system that will satisfy customers' needs. Inherent in the approach is that all the measures will be improved over time to assure success and survival of the manufacturing business organisation.

Figure 2.5 Example of Hierarchical Performance Measurement System
2.3.4 Other approaches

Performance Measurement and Feedback Scheme' (PMFS) developed at General Motors [32] and the approach provided by ALCOA [33] are examples of effort made to design new performance measurement systems which link manufacturing strategy to actions. The framework of PMFS and ALCOA are shown in Figure 2.6 and Figure 2.7 respectively and the details of which are given in the Appendix 2.1. Recent work by Kaplan & Norton [33] also produced a new approach for performance measurement systems which incorporate financial, operational and strategy links. The approach termed as 'Balanced Scorecard', was based on an intensive and practical research programme involving 12 major manufacturing companies in the United States. An example of the balanced scorecard approach is shown in Appendix 2.2.

![Figure 2.6 Performance Measurement and Feedback Scheme](image-url)
2.4 Characteristics of Current Performance Measures

Miller, [34] in a survey of manufacturing business organisations with consistent record of success in terms of sales, profits, innovation and market acceptance in Europe, America and Japan has shown that all of these businesses are currently using a new approach to performance measures. One of the most remarkable aspects of the survey report is that these businesses are found to fully utilise the performance measures established in their system. Figure 2.8 shows the performance measures, listed in order of importance, used by these manufacturing businesses in Europe, America and Japan. The survey findings also stated that...
although the performance measures used by the businesses vary considerably, several common characteristics could be identified.

Maskell in his work identifies seven common characteristics of the new performance measures, as follows:

(1) **The performance measures change over time as the needs change.**

   It is evident from the literature discussion in 2.1.1 and 2.1.2 that performance measures have to change over time as the market requirement changes. Measures also have to change when manufacturing processes change and need a different kind of assessment of its performance. At the heart of this basic change is the concept of continuous improvement. The concept of continuous improvement is an important aspect of many of the new manufacturing techniques such as JIT and TQM.

(2) **The performance measures vary between locations.**

   One of the notable characteristic of the new performance measures is that they vary from one business to another and from one location to another within the same manufacturing business organisation. Performance measures may differ significantly between locations because different aspects of manufacturing may be more important in one location than another. Additionally different types of technology used in different manufacturing departments may require different performance measures.

(3) **Non-financial performance measures are primarily used.**

   The new performance measures which are chosen by today's successful manufacturing business are primarily non-financial measures. Financial measures are still required for external reporting, however, the day-to-day control of manufacturing and distribution operations is handled better with non-financial measures. As an example, the appropriate measure for reduction in WIP inventories and increase in production flexibility would include set-up time rather...
than the traditional financial report of labour cost, tooling costs and WIP inventory values.

(4) The performance measures are simple and easy to use.

Examples of measures which are used in successful manufacturing business are reject rates, SPC charts, inventory level, production rate, customers service level, absenteeism, safety records and set-up times. These measures are simple and easy to comprehend and are often displayed continuously throughout the day on boards, charts or graphs.

(5) The performance measures provide a fast feedback

New performance measures are able to detect variance from target such that operators can then resolve specific problems on the spot as they occur. In most cases fast feedback is provided by the use of visual signals.

(6) The performance measures are intended to improve rather than to monitor.

The concept of traditional performance measures are based on monitoring worker's work so that they can be assessed, rather than providing information that will help the worker to improve. This practice leads to fear and nervousness, rather than to innovation and improvement. The new performance measures show clearly where improvement has been made and where more improvement is possible. Psychologically, people are motivated more by seeing the results of their improvement as an increase in the measurement, rather than seeing a reduction of their error.

(7) The performance measures are directly related to manufacturing strategy.

The new performance measures, directly measure the success or failure of the manufacturing business strategy. The business needs to know how well it is
achieve the goals laid down in the strategy. The choice of performance measures must enable the business managers to assess progress constantly and ensure that the business is steered in the right direction. Measures that relate to strategy would give a clear signal to all employees in the business about the priorities that are important to management.

<table>
<thead>
<tr>
<th>Order</th>
<th>EUROPE</th>
<th>AMERICA</th>
<th>JAPAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Outgoing Quality</td>
<td>Incoming Quality</td>
<td>Manufacturing Leadtimes</td>
</tr>
<tr>
<td>2.</td>
<td>Unit Manufacturing Costs</td>
<td>Inventory Accuracy</td>
<td>Direct Labour Productivity</td>
</tr>
<tr>
<td>3.</td>
<td>Unit Material Costs</td>
<td>Direct Labour Productivity</td>
<td>WIP Turnover</td>
</tr>
<tr>
<td>4.</td>
<td>Overhead Cost</td>
<td>Manufacturing Leadtimes</td>
<td>Incoming Quality</td>
</tr>
<tr>
<td>5.</td>
<td>On Time Delivery</td>
<td>Vendor Leadtime</td>
<td>Vendor Leadtime</td>
</tr>
<tr>
<td>6.</td>
<td>Incoming Quality</td>
<td>Set-Up Times</td>
<td>Indirect Productivity</td>
</tr>
<tr>
<td>7.</td>
<td>Direct Labour Productivity</td>
<td>WIP Turnover</td>
<td>Material Yield</td>
</tr>
<tr>
<td>8.</td>
<td>Material Yield</td>
<td>Material Yield</td>
<td>Finish Goods Inventory Turnover</td>
</tr>
<tr>
<td>9.</td>
<td>Unit Labour Cost</td>
<td>Outgoing Quality</td>
<td>Inventory Accuracy</td>
</tr>
<tr>
<td>10.</td>
<td>Forecast Accuracy</td>
<td>Indirect Labour Productivity</td>
<td>Absenteeism</td>
</tr>
</tbody>
</table>

Note: Performance Measures Listed in order of Importance

Figure 2.8 Performance Measurement in Europe, America & Japan as Reported By Miller
From Figure 2.8 it can be seen clearly that the Japanese performance measures are very much in line with the seven characteristics mentioned above. The listed order of importance of performance measures clearly reflect the current approach and appreciation of the subject. The Japanese focus their performance measures on manufacturing strategy because they have already addressed the basic issues of quality, delivery reliability, inventory accuracy and reduction of set-up times. It is also reported in the survey by Miller [34] that many Japanese manufacturing businesses are expected to be concentrating on price, quality, production flexibility and innovation over the next couple of years. Most of these performance measures have been used before. What is new, however is the importance attached to them.


Weinshall [35] reported that manufacturing business organisations were of relatively small size in the nineteenth century. The operating business rarely exceeded several hundred people, and the dependent suppliers and customers were likewise limited in number. Today there are businesses whose operating personnel may reach many thousands; their suppliers, advertising agencies, management consultants, and transportation companies and customers may run into millions. The institutions and people that a present day manufacturing business have to deal with are also numerous. The list including individuals such as managers, workers, directors, shareholders, and customers up to government officials could be endless. Then there are institutions such as banks, other creditors, competitors and government ministries with which manufacturing business has to be in constant touch. Keeping up with manufacturing technological development is another headache requiring the full attention of the management. The factors involved in running today's successful manufacturing business is therefore enormous and sometimes is not only confined to local or national boundaries but spreads further into the international and global stage.

Given the nature of the manufacturing environment outlined above, it would appear that a manager in today's successful manufacturing business would have
to be a super person to be able to handle problems arising from all the business dealings and developments. It is here that expert system technology can contribute in helping to solve many manufacturing business problems. The application of expert systems was initially in the domains of chemistry, geology, mathematics, accountancy and medicine, but now it has moved well into manufacturing. Tom Peters [36] in his foreword to an expert system book wrote that any manager in any business of almost any size who is not at least learning about expert systems is simply out of step, and dangerously so. Stoddard [37], stated that since 1985 it has been within the means of any manufacturing business of any size to apply expert system technology in their businesses.

The nature of manufacturing process has changed tremendously. Without doubt the changes in manufacturing process has resulted in the development of a new paradigm of how to effectively manage a manufacturing business organisation. The introduction of expert system technology is among the latest contributions towards improving the manufacturing process and manufacturing management. Expert systems have already been in place in manufacturing processes, designed to perform process control, to diagnose process malfunction and for planning activities such as computer aided process planning (CAPP). Few such systems have been developed to assist the strategic decision making process in manufacturing business management. This research is aimed at filling this important gap.

The literature has revealed that in today's competitive manufacturing business environment the area of performance measurement is a very crucial and important aspect of manufacturing management. Several studies have shown that the difference in performance of manufacturing business can often be attributed to the way in which the manufacturing performance measures are deployed. Manufacturing experts and academicians alike are convinced that the solution to the problem of adopting the best possible performance measures is to institutionalise a process for continuously changing measures. The evolution of the manufacturing business itself is known to effect the type of measures adopted by the business. New small businesses, for example, with limited resources compared to established companies which may have hundreds of employees and sophisticated machinery will definitely have to use different kinds of performance measures. From the literature it is clear that different
performance measures will be employed depending on the objective, nature and position of the business organisation. The process of deciding which performance measures are the most likely to have the greatest impact in relation to the state of evolution of a manufacturing business organisation can be highly complex. Business managers often have to use their experience and intuitive judgement as guiding factors. It is for this reason that expert system technology will be useful for embodying a performance measurement system.

2.6 Expert Systems (ES) and Decision Support Systems (DSS)

ES are a product of artificial intelligence-based technology. Barr & Feigenbaum [38] defines artificial intelligence as that field of computer science concerned with designing intelligent computer systems, that is, a computer system that exhibits the characteristics associated with intelligence in human behaviour. Sprague and Carlson [39] defines DSS as computer-based systems that help decision makers confront ill-structured problems through direct interaction with data and analysis models. Artificial intelligence-based technology is well advanced, and it is possible to develop a combined expert system (ES) and decision-support system (DSS) for manufacturing business management. The combined ES and DSS is called Expert Decision Support System (EDSS). A DSS only assists a human in making critical decisions, while a combination of DSS with ES will create a system which will be able to some extent to replicate human reasoning in making decisions. The combined system would be able to store a knowledge base incorporating decision rules as compared to a DSS which will have only a data base. Through their capabilities to integrate heterogeneous knowledge processes, EDSS could offer a highly useful tool for decision making in manufacturing business management. Gaines [40] explained that the critical technologies to EDSS application are the expert system support environment (ESSE) providing tools for interfacing with and validating the knowledge base, and knowledge acquisition tools for transferring knowledge from established knowledge sources (human experts, textual form, etc.) to the knowledge base. For the purpose of this research the tool for interfacing with and validating the knowledge-base provided by the use of an expert system shell called Leonardo. The details of Leonardo and the selection of the tool is discuss in section 5.5.2. The
knowledge acquisition tools in the form of questionnaires are designed based on the work of Nanni et.al. The details of which is discuss under research instrumentation in section 3.3.

Established expert knowledge in the performance measurement domain, is in abundance in textual form. Each and every single manufacturing business organisation, has in one way or another, experience in implementing a performance measurement system in their business. The only difference is that some businesses may have failed whilst others prospered and continued to be successful. Published experience and knowledge of performance measurement systems used in businesses has been accumulated for storage in a knowledge-base. The number of manufacturing business organisations from various parts of the world that were involved in surveys, researches and studies mentioned in the literature and reported in this research are well over 2000. More than 50% of the businesses are classified as successful manufacturing business ventures and all the case-studies reported in the literature were on the successful manufacturing businesses.

REFERENCES


Chapter 2


...review of literature


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Chapter 2


...review of literature

44


CHAPTER THREE

THE RESEARCH METHODOLOGY AND PROCEDURE
CHAPTER THREE
THE RESEARCH METHODOLOGY AND PROCEDURE

The contribution of this research is in its effort in assembling and analysing knowledge of performance measures which have been applied in various successful manufacturing business organisations and developing this into a simple and useful management decision making methodology, and a tool for the selection of the most appropriate performance measures to suit different business organisation in given situations. In particular the methodology is aimed at emerging and growing business organisations as typically found in industrially developing areas, and their need for changing performance measures to suit the dynamics of growth and development. The management decision making tool is in the form of a knowledge based expert decision support system.

This chapter explains the research design and procedure. It defines the research category, phases and the types of manufacturing business organisations involved in the research. The status of the manufacturing businesses based on conceptual models used in the research are introduced. It also discusses the design of the research instrument which is the performance measurement survey questionnaire and lists the main sources of knowledge acquisition. The use of an expert system shell and the technique used in the representation of knowledge are also presented.

3.1. Defining The Research Category

It is vital that the research methodology should be clearly specified so as to avoid any misunderstanding at the later stage. The basis for classifying research can either be by its 'objective' or by the 'method' it employs. The diagram in Figure 3.1 shows the different types of research based on 'objective' and 'method'. 'Objective',

46 ...research methodology
research is normally classified into three types, the pure or basic type of research, applied research and action-oriented research. Pure or basic research is normally exploratory in nature looking more into the theoretical derivation of specific models, while 'applied research' refers to the application of known and proven theory to current problems or observable phenomena and often involves a survey on current practices. Action-oriented research refers to research which produces results which can be materially utilised. Based on these definitions this research would fall within the applied research category.

Figure 3.1 - Types of research
On the basis of 'method', research can be classified as historical, correlational, ex-post facto, experimental and descriptive. The classification is normally characterised by the techniques employed in collecting and analysing data. Categorising this research by method, it can be classified as historical and descriptive. Historical because the research involves arriving at conclusions concerning trends, causes or effects of past occurrences which help to explain present events and anticipating future events. Historical research does not involve much manipulation of variables. It is also descriptive in nature because the study deals with collecting data and answering questions concerning the current status of the subject of study, performance measures, in various performance measurement systems of manufacturing business organisations. Another aspect of descriptive research is that data collection is either done through asking questions from individuals in the study domain (through questionnaires or interviews) or by textual reports and observations.

3.2 The Research Process Design and Procedure

The research design and procedure specification is based on the standard process for developing an expert system. The process involves five fundamental phases, namely the concept formulation, initial development, prototyping, final implementation and operation and maintenance phases as discussed in 3.2.1 below. Figure 3.2 below illustrates the phases involved.
<table>
<thead>
<tr>
<th>Phases</th>
<th>Sub-Phases</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Formulation</td>
<td>Pre-Planning</td>
<td>Initial conceptualisation and application selection</td>
</tr>
<tr>
<td>Initial Development</td>
<td>Project planning and initiation</td>
<td>Project initiation</td>
</tr>
<tr>
<td></td>
<td>Requirement Definition</td>
<td>Initial environment analysis and role conceptualisation.</td>
</tr>
<tr>
<td></td>
<td>First Stage</td>
<td>Knowledge elicitation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Initial Knowledge modelling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concept demonstration</td>
</tr>
<tr>
<td>Prototyping</td>
<td>Requirement Definition</td>
<td>Prototype mobilisation</td>
</tr>
<tr>
<td></td>
<td>Second stage</td>
<td>Expanded knowledge modelling</td>
</tr>
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<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Specification of system deliverables</td>
</tr>
<tr>
<td>Final Implementation</td>
<td>Design and building Phase</td>
<td>Technical system design</td>
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<td></td>
<td>System prototyping</td>
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<tr>
<td></td>
<td>Operational Testing</td>
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</tr>
<tr>
<td></td>
<td>Transfer to user</td>
<td>Implementation of system in the field</td>
</tr>
<tr>
<td>Operation and maintenance</td>
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</tr>
<tr>
<td></td>
<td>Maintenance</td>
<td>Maintenance of the system</td>
</tr>
</tbody>
</table>

![Figure 3.2 - The Expert System Development Phases and Task](image)

3.2.1 Phase 1.0 - Concept formulation

In the concept formulation phase several activities were carried out. Firstly the description of the project and the area of its application have to be identified.
This project is described as the development of a methodology and an expert decision support system for the selection of manufacturing business performance measures. The area of application would be in the management sector of manufacturing business organisations with particular references to manufacturing businesses in developing countries. The example developing country chosen is Malaysia, a country of 20 million people situated in South East Asia where manufacturing business organisations are growing at a very fast average rate of 15.5% a year and which has a strategic plan to become a major manufacturing nation within 25 years [1]. The scope and objectives of the project were determined as shown in Section 1.2.1 to 1.2.3 of Chapter One and the project justification is discussed in section 5.1 of Chapter Five.

3.2.2 Phase 2.0 - Initial development

The initial development phase consisted of project planning and initiation activities. These included work on the development and implementation planning of the project and the selection of various tools for the initial project development. It was estimated that the time required for knowledge acquisition would be very long, hence a large amount of the project time was allocated to that area. At this stage the first of three parts of a survey questionnaires was developed and mailed to selected manufacturing business organisations in the United Kingdom.

The use of an expert system shell for the project eliminated the necessity to allocate time for the development or construction of the means for representing knowledge, the inference mechanism and the user interface. The expert system shell is a ready-made software tool for developing and executing the expert decision support system. Several shells were investigated and the shell initially adopted for this project was NEXPERT Object. Later it was decided to change to LEONARDO due to reasons discussed in 5.5.2 of Chapter Five. At this stage the procurement of appropriate computer hardware to enable early development of an initial prototype of the EDSS was made. The procurement of the PC would also act as a useful tool for recording the initial knowledge elicited from various sources. The minimum
PC configuration for NEXPERT Object was an 80486 processor, 5 Mbytes RAM and 100 Mbytes of hard disc storage.

### 3.2.3 Phase 3.0 -Prototyping

Several types of prototype can be used in the development of an expert system application, to accelerate the process and as communications media for reviews, and knowledge elicitation, and for verification. The five major prototypes are the demonstration prototype or proof-of-concept prototype, interactive prototype, development prototype, system prototype and operational prototype.

It was estimated that the demonstration prototype of this project could be built in three months after the initial domain knowledge was available and this would then be used as a building block for an interactive prototype. The interactive prototype typically follows the proof-of-concept prototype and is an expansion of it. The interactive prototype is used to elicit additional knowledge. The targeted period of completion of the interactive prototype was two months after the demonstration prototype was ready. The initial development prototype was expected to be built over a period of three months after the interactive prototype was available and then it would continue to be expanded over many months until a stable and proper system prototype took shape.

### 3.2.4 Phase 4.0 -Final implementation

The final implementation phase is one of the most important phases in the development of the expert system. This is where the actual design and building of the expert system takes place. Four major activities are carried out: the technical system design, the final system prototyping, the operational testing and the transfer to the actual user were involved. During the technical system design, various aspects of the technical framework are defined and further expansion of the knowledge base undertaken. The final system
prototyping involves the design of training material and the operating and maintenance procedures. The training of trainers and system maintainers would be carried out when the system is ready for operational testing. It is during this period that the verification and validation processes are further carried out. Preparation of the sites for the installation of the system in the field must be conducted before the system is finally transferred to the user, who may be a business strategies, IT managers or other senior managers reporting to the decision making executive. From then on the users are then trained to operate the system.

3.2.5 Phase 5.0 - Operation and maintenance

In the case of this project the actual operation and maintenance will be conducted in several manufacturing businesses in Malaysia. Several small to medium scale manufacturing business organisations have been earmarked for the installation of the system. The activities involved in this phase will be the evaluation of the operation and the recording and feedback of proposals for change and reporting of errors. The maintenance aspects will involve the elicitation of new knowledge, analysis of that knowledge and the correction of errors.

3.3 Research Instrument

The major instruments used in this research were a series of survey questionnaires. The main objective of the questionnaires was to obtain information regarding manufacturing business organisation performance measurement practices and to compare them with best practice. The survey questionnaires were divided into several parts and each part would provide specific information for the research. Part I of the questionnaires deals with the respondents understanding of the business organisation vision and measures of success. Information on the business type and location were also obtained using this part of the questionnaire. It also describes the
level of management occupied by the respondent and the functional areas where the respondent works. Appendix 3.1 illustrates Part I of the survey questionnaires.

Part II of the survey questionnaires stresses the business organisation's emphasis of performance measures. There are four sub-sections namely, the financial performance measures, the business performance measures, the production performance measures and the operational performance measures. Respondents were asked to record their perception of the most important measures against their business organisation emphasis of those measures. The respondents were requested to indicate on a scale from 1 to 10 the importance of the performance measures and similarly the business organisations emphasis of the same measures as shown on Appendix 3.2.

Part III of the survey questionnaires concentrated on the characteristics and evolution process of the manufacturing business. The aim of this part was to obtain information on the types of performance measures used at the different life-stages of the manufacturing business organisation and to compare them with the theoretical measures developed by this research. As shown in Appendix 3.3 the respondents were asked to indicate the current status of the manufacturing business organisation based on the given life-stage graphs and to state the type of performance measures that the business organisation was using. The respondents were also asked to state the measures which in their opinion, from their experience, are the most important for the various life-stages of the manufacturing business organisation. In each of the sections a brief explanation of the terms used was given so as to avoid any misinterpretation prior to answering the actual questions.

3.4 Defining the Manufacturing Business Organisation Category

The manufacturing businesses that were involved in the research were specifically targeted to suit the environment of a developing nation although the types and classes of manufacturing businesses do not differ very much from one country to another. The variation is only in the unit of operating capital or turnover. Manufacturing business organisations are normally categorised into small, medium or large businesses. Certain countries use the term small-to-medium as a class in classifying their manufacturing businesses. For Malaysia large manufacturing businesses are termed as heavy manufacturing businesses. Manufacturing businesses
in America which employ up to 500 employees or with annual turnover of less than US$3.5 million dollars are considered as small-to-medium scale businesses. Small-to-medium manufacturing businesses in Taiwan are those with operating capital of less than US$1 million dollars.

Small scale manufacturing businesses in Malaysia have less than 50 employees or the business turnover is less than 2.5 million Malaysian Ringgit (£1 = 4MR ). Medium scale business has more than 50 but less than 250 employees or turnover of between 2.5 million and 10 million Malaysian Ringgit. Large or heavy manufacturing businesses have more than 250 employees or the turnover is more than 10 million Malaysian Ringgit.

Whitting [2] in his work categorised 13 different types of businesses that exist in the United Kingdom. The following are the categories of business organisations he outlined,

1. Single business public company
2. Single business private company
3. Business division of company
4. Small Businesses
5. New Businesses
6. Old Businesses
7. Sales-oriented businesses
8. Production-oriented businesses
9. Capital-intensive businesses
10. Labour-intensive businesses
11. Co-operatives and co-partnerships
12. Nationalised businesses
13. Charities and non-profit-making businesses

The Whitting category of business organisations was used in Part I of the survey questionnaire which was conducted in the United Kingdom. All the categories were offered to the respondents but this research only concentrated on manufacturing related business categories. Questionnaires were sent to 100 manufacturing business organisations of which 35 responded. The 35% response was
considered as relatively good for a mailed type of survey questionnaire. Normally a 15 to 20% response would be considered as a workable sample. Appendix 3.4 lists the respondents.

3.5 Defining the Status of Manufacturing Business Organisation Life-Cycle

Three different approaches to define the status of the manufacturing business organisation life-cycles or life-stages were investigated and used in this research. The most common of the three methods is the s-curve life-cycle as shown in Figure 3.3 below. Several authors, notably Porter [3], Twiss [4], Plant [5], Kotler [6], Polli and Cook [7] and Pedler, Burgoyne and Boydell [8] discuss the s-curve life-cycle. Porter, Kotler and Polli and Cook, divide the s-curve into four main stages, namely introduction, growth, maturity and decline as Figure 3.3.

![Figure 3.3 - The Common S-Curve Business Life-Stages](image-url)

Figure 3.3 - The Common S-Curve Business Life-Stages
Twiss divided it into five stages, incubation, diversity, sustained growth, maturity and the decline stages. Figure 3.4 illustrates the Twiss version of the s-curve. Pedler, Burgoyne and Boydell divided the s-curve into seven different stages, namely the infant, pioneer, rational, established, wilderness, dying, and transforming stages as illustrate in Figure 3.5. It is this version of classification, which is the most recent version, that this research adopted and used in the survey questionnaires as shown in Appendix 3.3. A brief on the various stages is also given in the same appendix.
Figure 3.5  The S-Curve Developed By Pedler, Burgoyne & Boydell

The second aspect of the status of the manufacturing business is seen through the evolution model developed by Kumpe and Bolwijn [9]. Figure 3.6 illustrates the model which shows that manufacturing businesses will have to go through the various stages to maintain competitiveness and success. Kumpe and Bolwijn used the evolution of market requirement and performance criteria to develop the model. They believe that manufacturing business organisation has to be efficient before looking into quality, and quality should come before flexibility, and finally comes innovativeness. Further stages would be developed as the market requirement expands. Details of the model development has already been discussed in section 2.1.1 of Chapter Two of this work.
The third useful aspect concerned with the status of the manufacturing business organisations is based on the model developed by Miles and Snow [10]. In their intensive investigation Miles and Snow classified organisations according to their strategic orientation and predicted with some reliability the structural and process characteristics associated with a chosen strategy. They classified organisations into four strategic types namely defender, prospector, analyser or reactor. Organisations which are suited to one of the strategic types, would continue to be successful over a considerable period of time if the management designed the organisation accordingly. Appendix 3.3 gives the details of the various strategic types of organisations.
3.6 Knowledge Acquisition Main Sources

Levine et al [11] stated that knowledge acquisition is the process of identifying, extracting, documenting and analysing the knowledge and information processing behaviour of domain experts in order to define an expert system's knowledge base and it is one of the most difficult developing areas of AI research. The accuracy and consistency of the knowledge is paramount importance. It is therefore necessary that an effective process of knowledge acquisition be developed. The process of translating knowledge from its sources to the expert system is performed by a knowledge author or knowledge engineer. The knowledge engineer normally uses expert system tools to create the expert system.

The knowledge engineer can source the domain knowledge from several locations namely, human experts, textual materials such as empirical data, technical references, books, records, encyclopaedias, other data or knowledge bases and audio-visual references. Abu Bakar [12] discussed four possible approaches that an author developing an expert systems may adopt:

(1) The author acts as both knowledge base engineer and domain expert, using a tool to encode knowledge he already possess.
(2) The author acts as knowledge base engineer and must elicit the domain knowledge from other sources, such as other persons, textual material, data base, etc.
(3) The author is the domain expert and acts as the knowledge base engineer, but require the services of a software engineer to build an interface between the expert system and other applications.
(4) The author is the domain expert and someone else acts as the knowledge base engineer because he lacks the time and resources.

For this work, the development of an expert system to select manufacturing business organisation performance measures, the author adopted approach (2) and acted as the knowledge base engineer. Further details of the knowledge acquisition is shown in the analysis of survey questionnaires in Chapter Six.
The following are the main sources for knowledge acquisition used by the author of this thesis:

(1) Knowledge from the authors own questionnaire survey of 35 UK manufacturing business organisations (from 100 contacted).

(2) Knowledge from 30 Successful UK Companies - Research Work by Dinah Bennett Durham University Business School. (Appendix 3.5)

(3) Knowledge from report on 10 most successful manufacturing businesses by National Economic Development Council, United Kingdom [13].

(4) Knowledge from the survey result Fry on performance measurement systems of 8 successful Japanese Manufacturing businesses [14].

(5) Productivity Improvement Manual By Alan Lawlor [15].

(6) Competitive Strategy- Technique For Analysing Industries & Competitor by Michael E Porter [3].

(7) Knowledge from work on performance measurement by Edwin Whitting from Manchester Business School [2].

(8) Knowledge from work on performance measurement for World Class Manufacturing by Brian H Maskell [16]

(9) Knowledge from work on performance measurement By Dixxon, Nanni & Vollmann - Boston University USA.[17].

(10) Knowledge from survey by David Sumanth on productivity indicators used by USA manufacturing businesses [18].

(11) Knowledge from work on 84 private businesses by Raymond E Miles University of California, Berkeley & Charles C Snow, Pennsylvania State University [10].

(12) Knowledge from work by Mike Pedler, John Burgoyne & Tom Boydell on the learning company [8].

(13) Knowledge from work by Bolwjin and Kumpe on the evolution of market requirement and performance criteria [9].

(14) Knowledge from work by Andy Neely et.al on the performance of 800 small and medium sized firms in the United Kingdom, Manufacturing Engineering Group, University of Cambridge, UK [19].
(15) Knowledge from work by Dr Al-Bhimani on the performance measures of 21 manufacturing companies in United Kingdom, London School of Economic. (Appendix 3.6)

(16) Knowledge from interviews with the Executive Officers or their representatives of the following institutions:
Malaysian Institute of Economic Research
National Productivity Corporation Of Malaysia
Federation Of Malaysian Manufacturers
Standard Industrial Research Institute Of Malaysia.
Malaysian Industrial Development Authority
National Corporation Limited, Malaysia
Irshad Management Institute, Malaysia
Manpower and Management Planning Unit, Malaysia
Johor State Economic Development Commission, Malaysia
Economic Planning Unit - Malaysian Prime Minister Department.
Ministry of International Trade & Industry, Malaysia
Ministry of Finance, Malaysia
Business Advance Technology Centre, Kuala Lumpur, Malaysia.

3.7 Knowledge Representation in the Adopted Expert System Shell

Knowledge representation is a term used in AI to describe how the knowledge is structured in a computer program. A representation is a set of syntactic and semantic conventions that make it possible to describe objects, relations and/or procedures. Knowledge representation also includes a set of operations for manipulating the described items.

An expert system shell is software that provide the facilities for knowledge representation structure inferencing and other features for expert system development. Many expert system shells are available. Each has different combinations of features and capabilities. The four most popular knowledge representation techniques are production rules, frames, semantics net and hypothesis and test.
Production rules which were advocated by Newall and Simon [20] are a natural way of expressing heuristics because they utilise the simple IF \textit{condition} Then \textit{action} format. The IF and the Then parts of a production rule respectively represent an antecedent i.e some pattern containing several clauses linked by logical connectives and a consequent that specifies an action. The IF part of the production rule is called the conditions and describes the required conditions for the particular production rule to be applicable, or 'fired'. The THEN part is called the actions. They describe what are the actions to be taken is a particular production rule is fired. A production rule will be fired when the current situation matches the condition of the IF part. Successive rule firings produce an inference chain. The set of rules, the knowledge, are held in the knowledge base of the expert system shell. Operation of the rules requires specific data from the user and is held in a data-base or obtained via interactive input from the user.

The expert system shell used in this research adopted the production rules formalism to code its domain knowledge. The rules shown below are examples of the production rules used in this research,

Generally a production rule is a statement cast in the following form:

" IF this condition(s) holds, 
    THEN do this action(s) "

An example of a production rule in the research domain is,

" IF business\_turnover < 2.5 (million pounds) 
    OR business\_employees < 100 (persons) 
THEN 
    business is Small\_Scale "
Following the example above could be another production rule such as shown below:

```
" IF  business is Small_Scale
     and Life.Stage is Infant
     and Status is defender

THEN

Recommended Measures are

'1 - operating profit
'2 - profit after tax
'3 - operating cash flow
'4 - earning per share
'5 - leadership ability
```

In this research the production rules are represented in a modular knowledge based allowing greater flexibility of the knowledge base than most other schemes. The advantage of this method is that rules in one module can be deleted, modified or added without effecting other modules.

REFERENCES


...research methodology


CHAPTER FOUR

THE DEVELOPMENT OF THEORETICAL FRAMEWORK
This chapter presents the theoretical framework of the research. Firstly, it outlines the general factors which may influence managers of manufacturing business organisations to start the process of reviewing and selecting the various manufacturing business performance measures. The chapter then proceeds to describe the foundations upon which the theoretical framework of the research is built. These are the conceptual models of the business type, the competitive, the 'life-stages', the manufacturing business organisational adaptation and the phases requirement of the manufacturing business. It then discusses how these models provide the basis and the linkages, the methodology, for selecting the various manufacturing business performance measures. A complete theoretical framework is shown in flow-chart form, Figure 4.10 at the end of the chapter.

4.1 Factors Influencing the Selection of Performance Measures

There are several factors, each with a varying degree of effect, which could influence the selection of manufacturing business performance measures. Geanuracos and Meiklejohn [1] in their research report on non-financial performance measurement indicators referred to these factors as the catalyst for re-examining and redefining manufacturing business performance measures.

The author of this research has made a study of the various factors which may influence the decision to adopt certain performance measures at a given stage of the growth of a manufacturing business organisation. The following are the 9 most common factors reported by various researchers [1,2]:

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- Type of business
- Competitive environment and stance
- Phases in manufacturing business life-stages
- Business organisational adaptation
- Customers demand
- Financial crisis
- New management
- New technology
- New government regulation

The study of these factors provide the basis for the development of the theoretical framework.

4.1.1 Type of business

The first and possibly most influential factor that managers have to examine to determine in the selection of performance measures for a manufacturing business organisation is the type of business it is involved in. The major differences between each type of manufacturing business is often to be found in their objectives. The objectives are often strongly influenced by the country culture and legislative processes. Most countries in the world would legalise and classify businesses by either its ownership, size, technology utilised or/and customer's function or group served.

A new manufacturing business can be an example of a type of business. Setting up a new manufacturing business would call for the development of a brand new set of performance measures. The 'new' business could be a new division of the parent manufacturing business organisation perhaps requiring application or extension of existing measures. On the other hand it could be a totally new venture in a new type of business requiring measures to be established appropriate to the early phases of the business organisation life cycle. The discussion and details of the type of business is given in section 4.2.1.
4.1.2 Competitive environment and stance

The choice of performance measures is also greatly influenced by the competitive environment facing the manufacturing business organisation. A manufacturing business must establish a clear picture and understanding of the activities of its competitors and develop its own competitive stance. A different competitive stance would require a different set of performance measures. To develop a competitive stance one has to study the market competition. The full details of the competitive model [3,4] adopted by this research is given in section 4.2.2.

4.1.3 Phases in manufacturing business life-stages

Manufacturing businesses are seen by many researchers as dynamic organisms [5]. They not only grow or shrink in size but also move from one organisational phase to another. Different sizes and phases would create different kinds of challenges and demand different actions. In facing the challenges, for every action there exists certain specific performance measures which are congruent with the action. Numerous studies [6], [7] & [8] have been carried out on the structure, functioning and performance of manufacturing business organisations and the behaviour of groups and individuals within them as the business moves from one phase to another. Some of the researchers [3,9] have developed conceptual models which are universally accepted to be useful in analysing business situations and planning business strategy. The discussion on the life-stage and phase requirement models are given in section 4.2.3 and 4.2.4 respectively.

4.1.4 Business organisational adaptation

When a manufacturing business changes and adapts itself to a new strategy, structure or process, the whole performance measurement system of the business has to be reviewed. Miles & Snow [9] have developed a conceptual model of the adaptive process and examined empirically the behaviour employed by the business organisation as it adjusts to new environments. The complex adaptation process was simplified and reduced by Miles & Snow to sub-divisions of three specific areas
namely the entrepreneurial, engineering and administrative areas as shown in Figure 4.1 below. The entrepreneurial function seeks to look into the development and projection of the business image which defines its product and market orientation and remains a top-management responsibility. The engineering function involves the creation of a system which puts into actual operation management solutions to the entrepreneurial problems. The creation of such a system requires management to select an appropriate technology for producing and distributing the chosen products or services, forming new information, communication, and control linkages to ensure proper operation of the technology. The administrative function is designed or required to rationalise and stabilise those activities which successfully solve problems faced by the business during the entrepreneurial and engineering phases. It also involves formulating and implementing those processes which will enable the business organisation to continue to evolve. Miles and Snow's overall theoretical framework contain two major elements namely,

- a general model of the process of adaptation that describes the decisions needed by the business organisation to maintain an effective alignment with its environment, and

- an organisational typology that portrays the different patterns of adaptive behaviour used by the business organisation in a given industry.
The author of this research has concentrated more on the second element of the theoretical framework which touches on the four different strategic types of business organisation. These Miles & Snow described as the Defender, Analyser, Prospector and Reactor types. For each of the strategic types different types of performance measures are needed, based on the salient characteristics and major strengths and weaknesses inherent in the pattern of adaptation. Detailed
discussion of the four strategic types of manufacturing business organisation is given in section 4.2.5.

4.1.5 Customers demands

Recent studies [10], & [11] have shown that the most effective performance measures of manufacturing businesses are those that are developed based on the feedback obtained from customers. Almost every survey on manufacturing business performance indicates that customers demand is one of the most important factors influencing the selection of performance measures [12]. In recent years it has become clear that successful manufacturing business organisations are those that meet customer needs in terms of quality, variety, delivery and price. Increasingly, delivering customer satisfaction is seen as vital to corporate survival.

Newell [13] reported,

"...It used to be that we could compete on the basis of our product innovation alone. We dictated to the customer what they needed and what was good for them. We could actually rope in the customer via our unique product capabilities and operating standards. But those days are gone. Open standards and more competitors means that we have to listen to the customer and satisfy their needs at every level."

The recent trend of shortening product life cycles is a strong indicator of how customer demand is influencing the way manufacturing business operates [1]. Today it is very rare for a manufacturing business to produce a product that will remain marketed for more than 20 years compared to for example, in the automotive market, the Morris Minor or VW Beetle which were sold for more than 30 years. Today most manufacturing businesses design their products for at best up to only 5 years market life. In some cases especially in the electronic businesses the product may only be marketed for a couple of months. The effect of a shorter product life cycle means that manufacturing business has to adjust the performance measures not only in the product development areas but also the technology involved in the manufacturing and the type of market where it will have to compete.
4.1.6 Facing financial crisis

Geanuracos & Meiklejohn [1] point out that facing a financial crisis is among the catalysts for senior executives in manufacturing businesses to re-examine and redefine their business organisation performance measures. Despite the increasing interest in non-financial measures of success, most business directors and bankers or shareholders who provide the capital, would tend to agree that one of the major objectives of a business is to create value for its shareholders. It is important, therefore, that performance measures should be able to track changes in shareholder value. This means that short-term measures such as earnings per share must not be neglected. The financial world of today is so volatile that it could easily trigger the need for changes in measures of performance of manufacturing businesses. For example, in a sudden shift of the currency values the competitive advantage of a manufacturing business could be overturned overnight and new measures would therefore need to be introduced.

4.1.7 New management

The principles of business operation such as the control and style of business management normally have a strong influence on the measurement used. New management can arrive as a result of an acquisition, buyout, mergers or disposal. New management is often the catalyst for new thinking about the business and about the way it is measured. Cook [14] reported that when the new CEO of National Westminster Bank took over the post, he wanted a much better vision of where the business was going. He wanted to know the underlying causes for the numbers which, every day, were put on his desk, not just the numbers themselves. That soon led them to begin a wholesale investigation of their performance measurement system.

New management also tends to alter the existing business organisational structure. The recent rise of a new form of organisational structure incorporating the concept of continuous change sees businesses constantly reforming themselves to seize new opportunities, counter new threats, and meet changing market requirement. As a result businesses have to look for new key factors which must be measured and tracked.
4.1.8 New technology

The influence of new technology on changing business organisations can be seen almost daily. From the administrative to the production floor, roles and relationships have to be altered and readjusted due to technological change. The implication for performance measurement is very clear, the introduction of new technology frequently means the introduction of new performance measures.

The changes in communication and information technology has brought about phenomenal changes in the way performance is or can be measured. Eccles [15] in his paper "The Performance Measurement Manifesto", explains that,

"... Information technology has played a critical role in making a performance measurement revolution possible. Thanks to dramatically improved price-performance ratios in hardware and to breakthroughs in software and database technology, organisations can generate, disseminate, analyse and store more information from more sources, for more people, more quickly and cheaply than was conceivable even a few years ago. The potential of new technologies, such as hand held computers for employees in the field and executive information systems for senior managers, is only beginning to be explored. Overall, the range of measurement options that are economically feasible has radically increased."

4.1.9 New government regulation

The introduction of new government regulation such as privatisation would definitely effect the way performance is measured in manufacturing businesses. Candelot [16] commented:

"... There is no doubt that the recent privatised businesses in the United Kingdom - such as the power and water companies - are more likely to develop performance measurement systems from scratch. They have nothing to lose because their old performance measurement systems are entirely inappropriate for their new operating environment."
The following Figure 4.2 summarised the nine factors which may influence the selection of manufacturing business organisation performance measures.

Figure 4.2 - Factors Effecting The Selection Of Performance Measures.
4.2 The Theoretical Framework

The theoretical framework used to develop the methodology and decision support system for selecting pertinent performance measures in this research is drawn from a number of concepts and models developed by several notable current manufacturing management thinkers such as Porter [3], Vollmann [17], Kaplan & Norton [18], Nanni et al [19], Maskell [20], Bolwijjn & Kumpe [21], as well as those long and well-established manufacturing organisational researchers such as Druckers [22], Chandler [23], Mintzberg [24], Grinyer [25], Miles & Snow [9], Miller [26], Galbraith [27], Ansoff [28] and several others to be cited later. The conceptual models, particularly the phases in the manufacturing business life-stage, Porter's generic competitive model and the business organisational adaptation model have been researched and discussed extensively and are universally recognised. These models can easily be understood and effectively employed by small to medium size manufacturing business organisations in the developing world which are the targeted users of this research.

The following discussion concentrates on the various contributors to the development of the theoretical framework. Porter [3] for example, contributes the generic competitive model which is used in the framework to analyse the competitive situation facing the manufacturing business organisation. Vollmann [17] presented the concept that one of the fundamental attributes of an effective performance measurement system is that it should 'encourage actions congruent with the business strategy.' Kaplan & Norton [18], Nanni et.al [19] and Maskell [20] provided the basic concepts of developing new state-of-the-art performance measures and the foundation and techniques used in the development of the research instrument which is the research questionnaire.

Mintzberg [24] pointed out that manufacturing business strategies are realised through consistency of decision making and action, and that the correct selection of performance measures provides one means of inducing this.
Drucker [22], Chandler [23], Grinyer [25], Miller [26], Galbraith [27], and Ansoff [28] in their separate works, in general collectively agree that business strategy should consist of a set of management guidelines which specify the following:

- the manufacturing business's product-market position;
- the direction in which the firm seeks to grow and change;
- the competitive tools it will employ;
- the means by which it will enter new markets;
- the manner in which it will configure its resources;
- the strength it will seek to exploit and conversely
- the weakness it will seek to avoid.

In each of the specific areas mentioned above an objective or several objectives or goals are targeted. A business needs to know how well it is achieving the objectives laid down in the business strategy. The way to do this is by choosing a small number of pertinent performance measures that enable the business managers to constantly assess progress. These are measures that are congruent with the business strategy laid out above. For example, if the manufacturing business organisation stresses quality as its strategic business stance then congruent performance measures might be identified as field failures under warranty, in-process quality or in-coming parts quality. Performance measures have to reflect the processes existing, the structure in place, the system technology, the operational characteristics, the management style, the knowledge and skill base, the market, the customer base and other criteria which makes each individual manufacturing business behave in a unique fashion. Research has shown that performance measures should be congruent to the strategic objectives of the manufacturing business organisation, given a specific phase in the evolution of the manufacturing business and the adopted organisational stance, for it to be successful.

Zairi [29] wrote that performance measurement is the trigger for improvement. Improvement leads to strength, growth, prosperity and success. It is therefore not surprising to see manufacturing businesses that have adopted sound performance measures have eventually succeeded in securing commanding positions in the market place.
4.2.1 The Business Type Model

The following are detailed descriptions of the various ways businesses are classified. The classification can either be by its ownership, size, technology utilised or/and customer's function or group served.

'Ownership' is normally either private or public whilst 'size' is number of employee or annual turnover of the business. Some businesses are classified by the level of technology utilised by the businesses. Technology level could either be low, medium or advanced or heavy technologies. Businesses which are classified by the technology are often referred as low-level-technology businesses, medium-level-technology-businesses or advanced-technology-businesses.

Some businesses are classified by the group it served or by the customer's function. Example of customer's function type of business is educational purposes.

The examples of the types of business organisation quoted by the author in this research is based on work in the United Kingdom. A user of the methodology and EDSS developed by this research may, however adjust the classification of business type according to local fitting and practices. Whitting [2] in his work in the United Kingdom has outlined 13 different categories of business and for each type he has argued and chosen four measures that are judged to be the most important and suitable for the type of business. There may be other categories and measures adopted by other researchers, but for the purpose of developing the methodology Whitting's recommended measures would be a useful starter. Figure 4.3 lists the measures and its symbols and Figure 4.4 shows the 13 categories of business with the respective important performance measures used by the majority of businesses in the United Kingdom. The mechanics of measurement for each measure is given in Appendix 4.1.
<table>
<thead>
<tr>
<th>Performance Measures</th>
<th>Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Profit</td>
<td>A</td>
</tr>
<tr>
<td>Profit After Tax</td>
<td>B</td>
</tr>
<tr>
<td>Operating Cash Flow</td>
<td>C</td>
</tr>
<tr>
<td>Earnings Per Share</td>
<td>D</td>
</tr>
<tr>
<td>Gross Margin</td>
<td>E</td>
</tr>
<tr>
<td>Profit After Interest</td>
<td>F</td>
</tr>
<tr>
<td>Productivity Ratio</td>
<td>G</td>
</tr>
<tr>
<td>Turnover</td>
<td>H</td>
</tr>
<tr>
<td>Strategic Ratio</td>
<td>I</td>
</tr>
<tr>
<td>Value Added</td>
<td>J</td>
</tr>
<tr>
<td>Return On Capital Employed</td>
<td>K</td>
</tr>
<tr>
<td>Market Share</td>
<td>L</td>
</tr>
<tr>
<td>Quality Strategic Ratio</td>
<td>M</td>
</tr>
<tr>
<td>Operating Fund</td>
<td>N</td>
</tr>
<tr>
<td>Labour Productivity</td>
<td>O</td>
</tr>
<tr>
<td>Operating Ratio</td>
<td>P</td>
</tr>
</tbody>
</table>

Figure 4.3 - Performance Measures and the symbols used.
(Source: A Guide to Business Performance Measurements - by E Whitting)
### Figure 4.4 - Fitting Performance Measures To Business Type

(Source: A Guide to Business Performance Measurements by E Whitting)

<table>
<thead>
<tr>
<th>Business Type</th>
<th>Performance Measures In Symbol Form</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Single Business Public Companies</td>
<td>*</td>
</tr>
<tr>
<td>Single Business Private Companies</td>
<td>*</td>
</tr>
<tr>
<td>Business Divisions of Companies</td>
<td>*</td>
</tr>
<tr>
<td>Small Businesses</td>
<td></td>
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<tr>
<td>New Businesses</td>
<td></td>
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<tr>
<td>Old Businesses</td>
<td></td>
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<tr>
<td>Sales-Oriented Businesses</td>
<td></td>
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<tr>
<td>Production-Oriented Businesses</td>
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<tr>
<td>Capital-Intensive Businesses</td>
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<tr>
<td>Labour-Intensive Businesses</td>
<td></td>
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<tr>
<td>Co-operatives &amp; Co-Partnerships</td>
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<tr>
<td>Nationalised Businesses</td>
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<tr>
<td>Non-Profit-Making Businesses</td>
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</tr>
</tbody>
</table>

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Chapter 4

...theoretical framework
4.2.2 The Competitive Model

The second conceptual model used in developing the methodology for the selection of overall strategic performance measures is the competitive model developed by Porter [3]. Porter suggests that market competition is a function of five major groups of variables or forces. These are,

- Extent of industry rivalry
- Bargaining power of customers
- Bargaining power of suppliers
- Threat of new entrants
- Threat of substitutes.

These five groups of variables are interrelated and can be illustrated by Porter's five forces competition matrix shown in Figure 4.5a. The detailed explanation of each group of variables is given in Appendix 4.2. Porter suggests that the nature and intensity of competition within a market will depend on the relative strength and interaction of the above five forces. Knowledge of these underlying sources of competitive pressure provides the groundwork for developing the agenda of action and for every action a set of pertinent measures of performance would be required.
Figure 4.5a - Porters Five Forces Generic Competitive Model

(Source: Competitive Strategy by M.E. Porter)
Neely et.al [4] in their extensive research on 800 manufacturing businesses tested the hypothesis that managers of small and medium-sized United Kingdom manufacturing businesses will attribute greatest importance to those performance measures which most closely match their business's manufacturing competitive stance. They found that the hypothesis holds true for the majority of the cases. Neely et.al outlined quality, price, time and flexibility as the competitive stances and for each competitive stance a list of congruent measures are defined. Figure 4.5b below gives examples of measures which are congruent with the competitive stance.

<table>
<thead>
<tr>
<th>Competitive Stance</th>
<th>Examples of Congruent Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>Field Failure under warranty</td>
</tr>
<tr>
<td></td>
<td>In process quality</td>
</tr>
<tr>
<td></td>
<td>Incoming parts quality</td>
</tr>
<tr>
<td></td>
<td>Outgoing quality measures</td>
</tr>
<tr>
<td>Price</td>
<td>Costs versus budget</td>
</tr>
<tr>
<td></td>
<td>Unit material costs</td>
</tr>
<tr>
<td></td>
<td>Unit labour cost</td>
</tr>
<tr>
<td></td>
<td>Unit product cost</td>
</tr>
<tr>
<td>Time</td>
<td>Delivery lead time</td>
</tr>
<tr>
<td></td>
<td>Operation time</td>
</tr>
<tr>
<td></td>
<td>On-time delivery to customer</td>
</tr>
<tr>
<td></td>
<td>Production lead time</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Product change over time</td>
</tr>
<tr>
<td></td>
<td>Machine change over time</td>
</tr>
<tr>
<td></td>
<td>Product mix changes</td>
</tr>
<tr>
<td></td>
<td>Routing changes</td>
</tr>
</tbody>
</table>

Figure 4.5b - Congruence of Measures to Competitive Stance
(Source: Realising Strategy through Measurement by Neely et.al)
4.2.3 The Life-Stages Model Of Manufacturing Business

Figure 4.6 illustrates the typical life-stages of manufacturing business organisation, sometimes referred as the 's' curve of a manufacturing business. For each of the stages strategic performance measures are outline below. These strategic measures are derived from the work developed by Pedler, Burgoyne & Boydell [30].

Figure 4.6 - The Life-Stages of a manufacturing business organisation.
(Source: A Strategy for Sustainable Development - The Learning Company By M Pedler et.al)
Stage 1 - The Infant stage

An infant manufacturing business organisation is usually a brand new start up by an individual or a group of founder members with very limited business procedures and guidelines. It can also be a new subsidiary business or even a new department or section of an existing parent business. As an infant manufacturing business the most vital performance measures are the entrepreneurial management performance which includes leadership, market knowledge, research vision and the product innovation in the business. As indicated by the dotted lines in Figure 4.6, businesses can start to deteriorate even early in their life-cycle. The process of transforming it back onto the 's-curve' require that vital measures such as leadership and market knowledge mentioned above should be in place and properly utilised. Similarly for every stage of the life-cycle, proper selection of performance measures would improve the chances of deterioration not happening.

Stage 2 - The Pioneer manufacturing business

The pioneer manufacturing business is still typically a small business organisation but fast growing and dependent on the strength of the individual or group of managers driving it. Business rules and procedures are beginning to take shape, being tested and modified. As it grows bigger it will slowly operate in a more complex environment and become less and less dependent on its initiators or founder members. At this stage cost control and sales performances are paramount measures. In addition to those required in the infant stage other measures include process flexibility, quality assurances, and personnel performances.

Stage 3 - The Rational manufacturing business

The rational manufacturing business organisation is a business organisation that has outgrown its initiators and become independent, bigger and more complex. Management must concentrate on bringing order, rationality, consistency and fairness in all spheres of activities. New procedures and specialist functions are
normally needed at this stage of evolution of the manufacturing business. At this stage in addition to pioneer, other measures of performance in R & D and teamwork are vital.

**Stage 4 - The Established manufacturing business**

The established manufacturing business organisation is a well set up business organisation with standard and formal procedures being practised. Scientific management is a norm in almost all aspects of its functioning. Management needs to develop ways and means of encouraging entrepreneurialship, risk-taking and motivation. At this stage the performance measures of the various system of the business namely management, financial, manufacturing and marketing systems are the most vital measures. Costing and product flexibility are also important measures to be included.

**Stage 5 - The Wilderness manufacturing business**

The wilderness manufacturing business organisation is an organisation that has lost its way and got out of touch. A business which faces this situation will have to review its relationship with its customers and suppliers. It has to check whether it has the right client and search for potential allies and opportunities. It has to establish a new purpose of the business and a new set of performance measures have to be identified to fit the new purpose.

**Stage 6 - The Dying manufacturing business**

The dying manufacturing business organisation is one that is failing and moving towards bankruptcy. It has lost its way or the purpose of its creation has been completed.

This type of manufacturing business would need a complete review of its existence. Vital measures would be measures that are related to the process of
adaptation of the manufacturing business to a new profile. The ability of the business to adapt to changes would be the most critical performance measure at this stage. Other measures include financial, technological and manufacturing process performance.

**Stage 7 - The Transforming manufacturing business**

The transforming manufacturing business is one that has decided that it need not die and has found a new purpose, new identity and new life. Its situation will almost be similar to the infant stage, except that they have a conscious awareness of the past. Important measures at this stage are those related to the ability to analyse the market, utilisation of new technology and management techniques. Adaptivity therefore is also an important measure of its ability to transform to a new identity. Other measures include market creation, product quality and service performance measures.

The following Figure 4.7 summarised the important strategic performance measures corresponding to the life-stage of the manufacturing business.
<table>
<thead>
<tr>
<th>Life-Stage</th>
<th>Important Strategic Measurement Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant</td>
<td>Leadership, market knowledge, research &amp; development, product innovation.</td>
</tr>
<tr>
<td>Pioneer</td>
<td>Cost control, sales growth, product flexibility, quality assurances, product innovation and personnel performance</td>
</tr>
<tr>
<td>Rational</td>
<td>Research &amp; development, group/teamwork, manpower turnover.</td>
</tr>
<tr>
<td>Established</td>
<td>Management, financial, marketing systems, costing, product flexibility</td>
</tr>
<tr>
<td>Wilderness</td>
<td>Review existing performance measures. Rectify ineffective measures.</td>
</tr>
<tr>
<td>Dying</td>
<td>Complete overhaul of organisation. Introduce new measures in management, technology and manufacturing processes</td>
</tr>
<tr>
<td>Transforming</td>
<td>Market analysis, new technology utilisation, business adaptability, market creation, product quality, product services</td>
</tr>
</tbody>
</table>

Figure 4.7 - Strategic Performance Measures For Each Life-Stage
4.2.4 The Phase Requirement Model

Bolwijn & Kumpe [21] have shown and produced a conceptual phase model, as shown in Figure 4.8, which is applicable to the growth phases of manufacturing business organisation. They discovered that most manufacturing business organisations, especially in the 1960s, went through the phases of first being an efficient organisation before becoming a quality oriented organisation. They suggested that the reverse would not be true. However, in the present day situation this does not mean that a brand new business cannot start off with quality as a main objective. A quality organisation is more likely to have efficiency already under control. Bolwijn & Kumpe believe that for a manufacturing business organisation to be successful, it has to be really efficient before considering quality. They further state that quality will then be a necessary precondition for implementing flexibility in the organisation. Without quality, manufacturing business organisations will not meet flexibility requirements. Without the art of flexibility a business cannot really become an innovative business organisation, but not all types of manufacturing business need to reach and be an innovative business organisation.

For every phase of the evolution, specific performance criteria are established to meet the phase requirement. Figure 4.9a summarised the phases, the phase requirements and the performance criteria of the business organisation. The performance measures congruent with the performance criteria are shown in Figure 4.9b. The business organisation which has to fulfil specific performance criteria must possess specific characteristics. In Figure 4.8 the characteristics are shown in the rectangular box below each phase. The model shows that the manufacturing business organisation can only achieve the characteristics belonging to a certain phase once they have achieved the characteristics of the preceding phases.
Figure 4.8 - The Phase Model Developed By Bolwijn & Kumpe
Although each phase differs considerably from the previous ones, the strengths developed in each phase not only are retained during the evolutionary process, but newly acquired capabilities reinforce them. Co-operation and communication, for example, which are characteristics of the quality business organisation, are retained in the flexible business organisation. Even more important, the integration and decentralisation of the flexible firm only leads to success because of the good co-operation and communication obtained previously.

Even though businesses will never show the ‘pure’ characteristics of one phase, the model could act as a guiding pointer for managers to appraise and analyse the current state of the business and help the business to forecast the future situation.

<table>
<thead>
<tr>
<th>The Phase</th>
<th>Phase Requirements</th>
<th>Performance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Efficient Business</td>
<td>Price</td>
<td>Efficiency</td>
</tr>
<tr>
<td>The Quality Business</td>
<td>Price + Quality</td>
<td>Efficiency + Quality</td>
</tr>
<tr>
<td>The Flexible Business</td>
<td>Price + Quality +</td>
<td>Efficiency + Quality +</td>
</tr>
<tr>
<td></td>
<td>Product Line</td>
<td>Flexibility</td>
</tr>
<tr>
<td>The Innovative Business</td>
<td>Price + Quality +</td>
<td>Efficiency + Quality +</td>
</tr>
<tr>
<td></td>
<td>Product Line + Uniqueness</td>
<td>Flexibility + Innovative Ability</td>
</tr>
</tbody>
</table>

Figure 4.9a - The Phases, Phase Requirements & Performance Criteria
<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Strategic Congruent Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>Total earning productivity</td>
</tr>
<tr>
<td></td>
<td>Process work efficiency</td>
</tr>
<tr>
<td></td>
<td>Productive work efficiency</td>
</tr>
<tr>
<td></td>
<td>Profit productivity</td>
</tr>
<tr>
<td></td>
<td>Working capital productivity</td>
</tr>
<tr>
<td></td>
<td>Inventory productivity</td>
</tr>
<tr>
<td>Quality</td>
<td>Incoming quality measures</td>
</tr>
<tr>
<td></td>
<td>Statistical process control</td>
</tr>
<tr>
<td></td>
<td>Customers satisfaction</td>
</tr>
<tr>
<td></td>
<td>Inventory accuracy</td>
</tr>
<tr>
<td></td>
<td>Outgoing quality measures</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Number of new products per year</td>
</tr>
<tr>
<td></td>
<td>Number of different processes</td>
</tr>
<tr>
<td></td>
<td>Percentage of standard, common &amp; unique components</td>
</tr>
<tr>
<td></td>
<td>Number of different parts</td>
</tr>
<tr>
<td></td>
<td>Position of variability</td>
</tr>
<tr>
<td></td>
<td>Number of levels in materials bill</td>
</tr>
<tr>
<td>Innovativeness</td>
<td>Number of completely new products</td>
</tr>
<tr>
<td></td>
<td>Number of new market openings</td>
</tr>
<tr>
<td></td>
<td>Number of superior performance products</td>
</tr>
<tr>
<td></td>
<td>Percentage utilisation of advance technologies</td>
</tr>
<tr>
<td></td>
<td>Percentage utilisation of advance raw materials.</td>
</tr>
</tbody>
</table>

Figure 4.9b - Measures which are congruent with the performance criteria for the phase requirement model.
4.2.5 The Manufacturing Business Organisational Adaptation Model

The following are detailed descriptions of the characteristics and the strategic performance measures for the four different business strategy forms, as defined by Miles & Snow, namely the Defender, Prospector, Analyser and Reactor. If a company adapts to changing market pressures by adopting a different business strategy then performance measures must also change accordingly. At the end of each description a summary of performance measures required by each strategic business form is given. Miles and Snow divide the measures under three separate headings, namely entrepreneurial, engineering and administrative area as shown in Figure 4.1.

4.2.5.1 - The Defender

Defenders are businesses with a restricted product-market mission or scope. They are normally specialist in their field. In certain circumstances they might instead take a limited view of what they do and how it fits within the external environment. Senior managers in such organisations are highly expert in their business's limited field of operation, but they do tend not to search outside for new opportunities. They tend to concentrate their effort upon improving the efficiency and effectiveness of their existing operations.

This type of organisation tends to rely on continuing stability of the market and external environment. They are careful to protect their existing market segment provision and market share, innovating as necessary in order to maintain their leadership of a specialist area of operation.

The following are the summary of performance measures required by business organisation adopting Defender strategic form in each area.

Entrepreneurial Area
Measures which would capture a portion of the total market creating a stable set of products and customers.
Strategic performance measures are narrowness and stability of product domain, maintainability of product domain, market penetration and new similar product design.

**Engineering Area**

Measures which would improve efficiency in production and distribution of goods or services.

Strategic performance measures are cost-efficiency in single core technology and continuous improvement in technology.

**Administrative Area**

Measures which would maintain strict control of the business organisation in order to ensure efficiency.

Strategic performance measures are manpower turnover in financial and production departments, co-ordination mechanism and intensive planning capability.

### 4.2.5.2 - The Prospector

Prospectors are manufacturing business organisations that regularly search for new market opportunities, and experiment with potential responses to emerging trends within the wider environment. In this they are the antithesis of the *Defender*. Prospectors are the creators of change and uncertainty to which their competitors must respond. Their owners and managers tend to assume that markets and external environment are characterised by continuous change. Segment protection is regarded, at best, as a defensive tactic which can be out-manoeuvred by entrepreneurial or innovative strategies based upon effective market research or by experimentation.

The following are the summary of the performance measures required by business organisations adopting the Prospector strategic form in each area.

**Entrepreneurial Area**

Measures which would increase ability to locate and exploit new product and market opportunities.
Strategic performance measures are continuity of product development, monitoring ability of a wide range of environmental conditions and events, ability to create changes in the domain industry and adaptability to sudden changes in growth pattern.

**Engineering Area**

Measures which are associated with avoiding long term commitments to a single technological process.

Strategic performance measures are flexibility of technologies involved and degree of routinisation and mechanisation.

**Administrative Area**

Measures which are associated with facilitating and co-ordinating numerous and diverse operations.

Strategic performance measures are manpower turnover in marketing and research and development, competitors monitoring and labour productivity.

### 4.2.5.3 - The Analyser

Analysers are manufacturing business organisations that operate in two types of product-market domain, one relatively stable, the other changing. In their stable market these business organisations function as Defenders, protecting their existing segment provision and seeking operational efficiency. In the more turbulent areas, senior managers monitor the performance of competitors and look out for evidence of experimentation and innovation. They then adopt or imitate those new ideas that appear to them to be the most promising. They may also be able to use their operational efficiency to improve on the work of *Prospectors* by introducing better versions. Unlike Prospectors, Analysers are not risk takers. They concentrate on upgrading their operational efficiency to be better than Prospectors.

The following are the summary of the performance measures required by business organisations adopting the Analyser strategic form in each area.
Entrepreneurial Area

Measures must be related to the ability in locating and exploiting new product and market opportunities while simultaneously maintaining a firm base of traditional products and customers.

Strategic performance measures are marketing surveillance mechanism, market penetration growth and product-market development.

Engineering Area

Measures related to the efficiency of the stable portions of the domain and flexibility in the changing area.

Strategic performance measures are efficiency of dual technological core (stable and flexible component) and research and development capability.

Administrative Area

Measures must be related to the means of differentiating the business organisation's structure and processes to accommodate both stable and dynamic areas of operation.

Strategic performance measures are efficiency and effectiveness of marketing and research areas and intensive planning capability in production.

4.2.5.4 - The Reactor

Reactors are manufacturing business organisations whose owners or senior managers perceive change and uncertainty occurring within the external and market environment, but which are unable to make any effective response. The only competitive strategy of which such business organisations may be capable would be adjustments made as a result of irresistible external environmental pressures. The reactor is an unstable business organisation because it lacks a set of consistent response mechanisms. The inconsistency potentially may stem from at least three sources,

- management fails to articulate a viable business strategy
- a strategy is articulated but technology, structure and process are not linked to it in an appropriate manner or
- management adheres to a particular strategy-structure relationship even though it is no longer relevant to environmental conditions.
Figure 4.9c summarised the strategic performance measures which are congruent with the form of business organisational adaptation.

<table>
<thead>
<tr>
<th>Business Organisational Adaptation</th>
<th>Congruent Strategic Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Defender</td>
<td>Percentage of market share</td>
</tr>
<tr>
<td></td>
<td>Production efficiency</td>
</tr>
<tr>
<td></td>
<td>On-time delivery</td>
</tr>
<tr>
<td></td>
<td>Technology utilisation</td>
</tr>
<tr>
<td></td>
<td>Financial manpower turnover</td>
</tr>
<tr>
<td></td>
<td>Production manpower turnover</td>
</tr>
<tr>
<td></td>
<td>Planning capability</td>
</tr>
<tr>
<td>(2) Prospector</td>
<td>Product development continuity</td>
</tr>
<tr>
<td></td>
<td>Environmental monitoring</td>
</tr>
<tr>
<td></td>
<td>Growth pattern adaptability</td>
</tr>
<tr>
<td></td>
<td>Product flexibility</td>
</tr>
<tr>
<td></td>
<td>Process flexibility</td>
</tr>
<tr>
<td></td>
<td>Marketing manpower turnover</td>
</tr>
<tr>
<td>(3) Analyser</td>
<td>Product protection ability</td>
</tr>
<tr>
<td></td>
<td>New product development</td>
</tr>
<tr>
<td></td>
<td>New market development</td>
</tr>
<tr>
<td></td>
<td>Market surveillance &amp; penetration</td>
</tr>
<tr>
<td></td>
<td>Process flexibility</td>
</tr>
<tr>
<td></td>
<td>R &amp; D capability</td>
</tr>
<tr>
<td></td>
<td>Marketing effectiveness</td>
</tr>
<tr>
<td></td>
<td>Intensive planning capability</td>
</tr>
<tr>
<td>(4) Reactor</td>
<td>External Pressure Adaptability</td>
</tr>
</tbody>
</table>

Figure 4.9c - Strategic measures which are congruent with form of strategic adaptation.
4.3 Matching Performance Measures To Manufacturing Business

Based on the concepts and models discussed above, Figure 4.10 illustrates the major elements of the theoretical framework which was developed to match performance measures to various phases in the life-stage of a manufacturing business organisation. The decision support methodology and expert decision support systems which have been developed, organise and sequence the models according to a general strategic performance measurement framework. The models present different perspectives by incorporating different dimensions and criteria, providing managers with multiple views of the problem. The framework consists of three subsystems namely the business type, business environment and business phases subsystems. The business type subsystem established the general profile of the business in terms of the size, ownership, technology utilisation and customers function or grouping. The business type subsystem generates the first set of strategic performance measures referred to as PM 1 in the framework. Information obtained in the business type subsystem is also relayed to the business environment subsystem. The business environment subsystem comprises of two models namely the generic competitive model and the business organisational adaptation model. The competitive model establishes the competitive stance of the business and generates the second set of strategic performance measures PM 2 whilst the business organisational adaptation model produces the third set of strategic performance measures, PM 3.

Two models are used in the third subsystem, i.e the business phases subsystem. These are the 's' curve or life-stages model and the phases requirements model. The major difference between the 's' curve model and the phases requirements model is that the 's' curve explains the natural growing or ageing process of a business organisation while the phase model described the market requirements in a given period of time in the development of the manufacturing business. The life-stages models generate the performance measurement PM 4 and the phases requirements model, the performance measurement PM 5. The combination of the five sets of performance measures produced the complete set of strategic performance measurements covering the various perspective and dimensions for the development of the expert decision support system.
Chapter 4

...theoretical framework
In essence the strategic performance measures assigned to a particular manufacturing business based on the above concepts and models should be congruent to the system which are congruent to the strategic objectives of that manufacturing business. The strategic performance measures should also be in alignment with a given specific phase in the evolution of the manufacturing business and the adopted organisational form for it to be continuously successful for a considerable period of time.

Several other conceptual models like the 'value chain model' [31], the product portfolio matrix [32], the threat, opportunities, weakness and strength (TOWS) matrix [33], the multifactor portfolio matrix [34], the crescendo model of rejuvenation [35] and the strategic position and action evaluation (SPACE) models [36] could be other possible models to be incorporated into the system so as to enhance the performance of the expert decision support system. But due to limited time this research was designed to cover only those models shown in Figure 4.10. The main focus was on the evolution process of the manufacturing business, hence that explains the reason for the choice of business type, business competitiveness, organisational adaptation, life-stages and phases requirements models in this research. Suggestions for further work to analyse the possibility of incorporating the above mentioned models is given in Chapter 8.

REFERENCES


Chapter 4


...theoretical framework


CHAPTER FIVE

THE DEVELOPMENT OF EXPERT DECISION SUPPORT SYSTEM
CHAPTER FIVE

THE DEVELOPMENT OF THE EXPERT DECISION SUPPORT SYSTEM

This chapter discusses the justification for developing the decision support system and explains the reasons for choosing expert system technology for the development of the system proposed for the selection of manufacturing business organisation performance measures. The chapter then proceeds with discussion of the attributes of both decision support system (DSS) and expert system (ES). Integration of ES and DSS to produce an expert decision support system (EDSS) is explained, followed by discussion of the selection of EDSS type and tools which includes the selection of expert system shell (ESS). The chapter ends with the presentation of the design of an EDSS for the selection of manufacturing business performance measures.

5.1 Justifying the Development of Decision Support System

The following are the main justifications for the development of a DSS for the selection of manufacturing performance measures to be used in manufacturing business organisations in industrially developing countries. These are based on knowledge and information gathered concerning the behaviour and characteristics of manufacturing business organisations in a typical developing country and the usefulness of using decision support systems.

5.1.1 The DSS as a useful learning tool kit.

In a world where manufacturing business organisations tend to adapt, change, develop and transform rather rapidly from one state to another, it would be an almost impossible task for manufacturing executives and managers to firstly learn and understand the whole mechanics of change before embarking on the process of making
decisions. The development of a decision support system can in many ways help to ease these problems and change the manner in which managers of manufacturing business organisations make decisions. Large quantities of information captured, stored, analysed and reported on can provide top executives and managers with ample means of learning about a situation and enhance their ability to make a better judgement.

Radermacher [1] mentioned that the topic of decision support systems has stimulated great interest in research and application. He listed researches in the topic and forecast that the needs of and the means for good decision support systems will increase over time. He emphasised the point that decision making is one of the essential tasks that mankind must deal with on every level and at all times, and that human abilities in this task are among our most impressive cognitive strengths.

Generally, a DSS is defined as a computerised aid that assists management in translating information into effective actions for the organisation [2]. Other DSS designers such as Sprague and Carlson [3] gave a more specific definition that decision support systems are computer-based systems that help decision makers confront ill-structured problems through direct interaction with data and analysis models. Keen and Scott Morton [4] described DSSs as computer-based aids for management decision-makers dealing with semi-structured problems.

As the complexity of the environment and the build up of various constraints in today's management surroundings gets bigger, the need for decision support system for decision making and as a learning tool kit is therefore very essential and unquestionable.

5.1.2 The complexity of the performance measures selection process.

The process of selection of 'useful' and 'meaningful' manufacturing performance measures can be highly complex. 'Useful' and 'meaningful' measures refers to measures which when implemented help generate continuous improvement and an increment in the general performance of the manufacturing business organisation. From the research that has been conducted, it is noted that the
complexities arise from the fact that manufacturing business organisations are of varying types and exists in many different manufacturing environments. Also as shown in Chapter Four, a manufacturing business organisation tends to undergo various phase changes in its life-cycle. It moves from one phase to another with a speed and timing to suit the specific needs of the individual organisation rather than following any set of rules. The manufacturing performance measures that are selected and applied at any point in time must be compatible and congruent with many of the complex factors mentioned above. As shown in Figure 4.10, there are five different sets of performance measures that must be derived from five different factors or backgrounds. A DSS for the selection of manufacturing performance measures to suit the individual needs of a specific manufacturing organisation at any point in its life cycle would therefore be a very valuable tool for executives and managers of those businesses.

5.1.3 Semi-structured nature of manufacturing performance measurement problem.

According to Simon [5] decision making processes fall along a continuum that ranges from highly structured (sometimes referred to as programmed) to highly unstructured decisions. Structured processes refer to routine and repetitive problems for which standard solutions exist. Unstructured processes are 'fuzzy,' complex problems for which there are no cut-and-dried solutions. Decisions where some, but not all, of the phases are structured are referred to as semi-structured problems.

Gorry and Morton [6] classified problems as structured, semi-structured and unstructured as shown in Figure 5.1.
### Table 5.1

<table>
<thead>
<tr>
<th>Type of Problem</th>
<th>Examples of problem areas</th>
<th>Characteristics</th>
<th>How decisions are made</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structured</td>
<td>Order validation, Inventory reorder</td>
<td>Availability of standard operating procedure</td>
<td>Fully computerised</td>
</tr>
<tr>
<td>Semi-structured</td>
<td>Sales forecasting, Budgeting, Risk analysis, Measures selection</td>
<td>Programmable aspects present</td>
<td>Human decision maker supported by computer</td>
</tr>
<tr>
<td>Unstructured</td>
<td>Promotion of personnel, Introducing new technology</td>
<td>No standard procedures or aspects available</td>
<td>Principally by a human, with some computer support</td>
</tr>
</tbody>
</table>

#### Figure 5.1  Structured, Semi-Structured and Unstructured Problems

The nature of the selection of the correct performance measures for manufacturing organisation is such that it can be categorised into the semi-structured type of problem. The semi-structured nature of the problem is one of the main justifications for the use of a DSS as a means to provide the solution to the selection problem.

### 5.1.4 Complexity of today's manufacturing environment

Today's manufacturing businesses organisations exist in an uncertain and rapidly changing environment in terms of industry, raw materials, human resources, financial resources, market, technology, economic conditions, government...
and culture. Coping and making decisions in that sort of environment would require a whole range of information networks to support the system.

Hard decisions usually deal with processes over time. Major determinants of what will eventually happen are not controlled by the decision maker alone. Essential components come from the general processes at work in the world, which includes other decision makers like the government of the day which may introduce new regulations, competitive stance adopted by various organisations, trends in market and customers requirements, fluctuation of supply and demand of raw materials and various other chaotic behaviour in society. Such factors highlight the problem of deciding which measures are suitable for a specific manufacturing business at a specific point in time or in its development. A DSS containing all this information would definitely be a useful manufacturing management tool.

5.1.5 Demand for knowledgeable and highly skilled managers

The author of this thesis agrees wholly with Yoo and Digman [7], when they maintain the following to be the essential characteristics of a successful top executive in the manufacturing business organisation of the future.

- The ability to make strategic decisions which directly affect the future of the organisation, on the basis of complex, highly uncertain and often conflicting information.
- The ability to provide the driving force and sense of purpose necessary for the enterprise as a whole to become a learning or knowledge-based organisation.
- The ability to be adaptable in a changing and uncertain business environment.
- The ability to understand quickly the potential strategic impacts of the various new technologies developed.

The successful top executive of manufacturing business will be a person endowed with many skills. Even accepting this fact it will be difficult for any individual to perform well in all of the areas described above: the range of knowledge necessary will become too broad. It is here, that DSS technology can be of great benefit.
5.2 Utilisation of Expert System Technology for DSS

Gottinger and Weimann [8] explained that for the past few years there has been substantial attention devoted to the use of artificial intelligence (AI) methods and architectures, most commonly rule based expert systems, as tools for decision support systems. The rule based techniques have been proven to be very attractive for a variety of problems, particularly those which have fairly well structured problem spaces which can be solved through the use of heuristic methods and are currently solved by human experts. In these domains the reasoning and explanation capabilities offered by rule based expert systems are very effective.

Advances in artificial intelligence (AI), coupled with analytical techniques developed in the fields of system analysis and operations research, can provide a means of significantly improving the quality of decision making by individuals and manufacturing business organisations.

The nature of manufacturing processes has changed tremendously from the days of bulky mechanical machines to today's modern computerised automated machines. Without doubt the changes in manufacturing processes has resulted in the development of a new paradigm of how to effectively manage manufacturing business organisations. The development of expert system technology is among the latest contributions towards manufacturing process control and manufacturing management. Applications of expert system technology to perform process control, to diagnose process malfunctions and for planning activities such as computer aided process planning (CAPP) are already in place. However, as discussed in Chapter One, few such systems have been developed to assist strategic decision making processes in manufacturing organisation management. This research is aimed at fulfilling this very important gap.
The following are further reasons for the utilisation of expert system technology.

5.2.1 Avoiding high consultancy costs

It is important to justify the use of any new technology in terms of time and cost savings and the quality of output. Manufacturing businesses often turn to management consultancy services for advice when they are in serious trouble or not performing as well as expected. The amount of consultancy fees normally is quite large. Substantial time and consultancy cost savings may be made if an expert DSS is available to provide or assist good, timely decisions on business performance measures.

5.2.2 Importance of proper selection of performance measurements.

How important is the proper selection of performance measurement to a business? The literature has revealed that the difference in performance of manufacturing businesses can often be attributed to the way in which manufacturing performance measures were deployed. Numerous researchers are convinced that the solution to the problem of adopting the best possible performance measures is to institutionalise a process for continuously changing measures.

Performance measures are known to have to change with the evolution of a manufacturing business. A new business with less than say, 100 employees compared to a business two hundred years old with 10000 employees, will definitely use different kinds of performance measures. Different measures will be employed depending on the objective, nature and position of the business in its life-cycle. The ability to quickly respond to the need for appropriate performance measures in a dynamic business is one of the strong justifications for the use of expert system technology in this particular domain.
5.2.3 Ability to distribute expert knowledge

One reason for manufacturing businesses to use expert system technology is its ability to distribute the knowledge and expertise of experts to other employees. In other words, availability of knowledge and expertise in a specialised area would not be dependent on a particular individual. In circumstances where the expert individual is not available then others, with the help of an expert system, may still perform the required specialised task. Often a business may lose one of its experts. With an expert system available then loss of the expertise will not jeopardise the whole operation of the business. Of course this depends on how effectively the expert knowledge is captured in and retrieved from the expert system.

5.2.4 Availability of expert knowledge

A most important justification for the utilisation of expert system technology is to capture the more widely available expert knowledge in the chosen domain. For this research, expert knowledge in the domain of performance measures was assembled from various sources. Developed industrial countries have accumulated hundreds of years of experience and knowledge in managing manufacturing business organisations. Each and every manufacturing business in these countries has in one way or another experience in implementing performance measurement systems in their respective businesses. The difference is that some businesses may have failed whilst others prospered and continued to be successful. The purpose of this work was to accumulate as much knowledge and experience of performance measures in successful manufacturing businesses as possible. Sources of knowledge include publications such as academic and professional papers, and knowledge elicited directly from experts.

5.3 Attributes of Expert Systems and Decision Support Systems

There are significant philosophical, technological, and managerial differences between an Expert System and a Decision Support System. The disciplines of ES and DSS grew in parallel but largely independent paths. Only recently has the...development of EDSS
potential of integrating the two been recognised. Due to their different capabilities they could actually complement each other, creating a powerful, integrated, computer-based system that can considerably improve managerial decision making. The following section explains the general concepts and structures of an ES and a DSS.

5.3.1 Concept and features of an expert system

Figure 5.2 shows a typical structure of an expert system. An expert system can be viewed as comprising of three components; the knowledge base, the inference mechanism, and the user interface.

The knowledge base contains the facts, data and rules. The facts are normally represented in sets of rules, containing the expertise or knowledge of the human expert in the domain of interest. The rules give a picture of how a human expert would tackle the problem in the problem domain. Rules are also used to represent scientific formulae or specific patterns that can be deduced from any standard data.

The inference mechanism or inference engine is essentially the reasoner in an expert system. It contains the control strategy for an expert system to derive its conclusions, by drawing a sequence of inferences from the knowledge available to it in some order. It takes the rules one at a time and attempts to fire those rules whose conditions are satisfied.

The user interface is the communication link between the program and the user. It is particularly important for successful expert systems which require an opinion of what the user sees, hears, feels about the subject in question [9]. It is also required for input of specific application domain knowledge and data. An expert system user interface has to provide a good dialogue and a wide range and comprehensive explanation facilities, and also gives the systems output to the user in appropriate format.
5.3.2 Concept and features of a decision support system

Figure 5.3 shows a typical structure of a decision support system. A decision support system is composed of the following components; the database, the model base and the user interface.

The database consists of the internal and external facts and data concerning the manufacturing business organisation and also, normally, of the industry as a whole. The database also includes the means for retrieval and processing of data from formal databases and the tools to manage the data.
The model base is normally a software package that includes financial, statistical, management science, or other quantitative models that provide the system's analytical capabilities, and appropriate software management. In most cases the software package is a spreadsheet. In a spreadsheet environment, models consist of one or more worksheets containing variables and parameters as well as formulae interrelating them. The model base allows the user to define and store the contents of the worksheet. In other DSS environments, the models are described using a specially designed language. However the requirements remain the same: variables must be identified and interrelated through formulae and prescribed procedures.

The user interface and display is a mechanism to facilitate ease of use between the models/database and the user. To further enhance the method of presenting information to the user, it is vital that the interface has the capabilities to present results in a variety of formats and media. It must also be able to handle a variety of dialogue styles, perhaps with the ability to shift among them at the user's choice.
Figure 5.3 Common Features of A Decision Support System

Comparing the above two systems, the major differences in attributes between the two can be summarised as shown in Figure 5.4.
### Figure 5.4 Differences of Attributes between Decision Support System & Expert System

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
<th>DSS</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Assist human decision maker</td>
<td>Replicate a human adviser or expert</td>
</tr>
<tr>
<td>Decision making</td>
<td>The human and/or the system</td>
<td>The system</td>
</tr>
<tr>
<td>Major orientation</td>
<td>Decision making</td>
<td>Transfer of expertise</td>
</tr>
<tr>
<td>Major query direction</td>
<td>Human queries the machine</td>
<td>Machine queries the human</td>
</tr>
<tr>
<td>Nature of support</td>
<td>Personal, groups, and institutional</td>
<td>Personal and groups</td>
</tr>
<tr>
<td>Data manipulation method</td>
<td>Numerical</td>
<td>Mainly symbolic</td>
</tr>
<tr>
<td>Characteristics of problem</td>
<td>Broad and complex</td>
<td>Narrow domain</td>
</tr>
<tr>
<td>Type of problems treated</td>
<td>Ad hoc, unique</td>
<td>Repetitive</td>
</tr>
<tr>
<td>Database content</td>
<td>Factual knowledge</td>
<td>Procedural and factual knowledge</td>
</tr>
<tr>
<td>Reasoning capability</td>
<td>None</td>
<td>Yes, limited</td>
</tr>
<tr>
<td>Explanation capability</td>
<td>Limited</td>
<td>Yes</td>
</tr>
</tbody>
</table>

...development of EDSS
5.4 Integrating Decision Support System and Expert System

Most existing DSS and ES are not integrated. ES operate as independent expert consultation systems whereas DSS operate as support devices to decision makers. However, this situation is beginning to change. Evidence is emerging that integrated systems are being developed and implemented at an increasing rate [10].

The idea of integrating DSS and ES can be traced to the work of Turban and Watkins [11] in which they offer a general framework for a combined system. Many other researchers among which is Davis [12] considered ES as an intelligent DSS. Bonczek [13] for instance, developed a generic DSS which fits into the combined system category. According to the Bonczek framework, the generic DSS exhibits three major characteristics, all of which are present in ES. They are as follows;

• it aids a decision maker in solving unstructured or semi-structured problems
• it possesses an interactive query facility
• it uses an English-like dialogue language.

Similarly, Alter [14] classified DSS into six major categories which are similar to that of ES, which are,

• Retrieving a single item of information
• providing a mechanism for ad hoc data analysis
• providing prespecified aggregation of data in the form of reports
• estimating the consequences of proposed decisions
• proposing decisions
• making decisions

Most of the approaches view an ES as an expert component in a DSS. Based on this assumption there are five different types of the integrated form which from now on will be referred to in this report as Expert Decision Support Systems (EDSS ).
The following are the five types of EDSS,

- EDSS1 consisting of ES interaction with the database of DSS
- EDSS2 consisting of ES interaction with the model base of DSS
- EDSS3 consisting of ES interaction with the user interface of DSS
- EDSS4 consisting of ES interaction with the user of DSS
- EDSS5 consisting of ES as an integrated component of DSS

Figure 5.5.1 to Figure 5.5.5 shows the various type of integration of ES into the DSS component.

5.4.1 EDSS1 - ES1 interaction with data base

A study by Jarke and Vassiliou [15] showed how ES technology was incorporated into the data base of a DSS. The basis of the integration was that the DSS provides the ES with essential business data while the ES itself improved the construction, operation and maintenance of the data base. The argument was that a human expert frequently uses databases. It is therefore reasonable to assume that the computerised expert would need to do the same. Therefore the ES should be able to access the database to obtain factual knowledge and put expertly determined data and knowledge back into the DSS data base.

Figure 5.5.1 EDSS1-Integration of ES into data base component of DSS
5.4.2 EDSS2 - ES2 interaction with model base

Human experts often use quantitative models to support their experience and expertise. Examples are found in statistical ES [16] which are available in the market. These statistical ES packages are being used in industry and in educational institutions to support managerial decision making and research. They normally contain statistical tests and models that are included in the model base of a DSS. Goul et al. [17] have also developed this type of integrated ES/DSS system which uses the basis of ES interaction with the model base of a DSS.

![Diagram of EDSS2-Integration of ES into model base component of DSS]

5.4.3 EDSS3 - ES3 interaction with user interface

There are several possible areas of ES interaction with the user interface of a DSS, among which are ES that can add an explanation capability to the DSS to allow the user to follow the reasoning behind certain recommendations, ES that can provide terms that are familiar to the user and ES that can provide tutoring to the user [18]. The main objective of the ES introduction into the user interface of the DSS system is to achieve a friendlier environment. Turban [10] explained that among the critical obstacles of using DSS is the mismatch between the needs of end-users and
their ability to communicate these needs to the computer. The integration of ES technology into the user interface of a DSS would considerably reduce the obstacle.

![Diagram of EDSS3: Integration of ES into user interface component of DSS](image)

**Figure 5.5.3** EDSS3-Integration of ES into user interface component of DSS

### 5.4.4 EDSS4 - ES4 interaction with the user

In this case, the user is considered as part of a DSS component. A user may solicit the advice of an expert for complex issues such as the nature of the problem, the environmental conditions, or the possible implementation problems. Instead of consulting an expert, the user may consult an ES attached to the system to obtain a solution. In a situation where there exists several choices for a user to use different types of DSS, the user could also interact with an ES for advice.

![Diagram of EDSS4: Integration of ES into the user component of DSS](image)

**Figure 5.5.4** EDSS4-Integration of ES into the user component of DSS
5.4.5 ES as a separate DSS component

In this case the ES is placed in the combined system as a separate DSS component as shown in Figure 5.5.5.

Turban [10] classified this type of EDSS into four main categories namely,

- category 1 where ES output as input to a DSS
- category 2 where DSS output as input to ES
- category 3 where ES complement DSS in decision making
- category 4 where ES is the basis of DSS or ES-based DSS.

Figure 5.5.5 ES as a separate component of DSS
5.4.5.1 Category 1 - ES output as input to a DSS

DSS users may direct the ES output to the DSS. For example, the ES can be used during the intelligence phase of problem solving to determine the importance of the problem or to identify the problem. Then the problem is transferred to a DSS for possible solution.

5.4.5.2 Category 2 - DSS output as input to ES

In many cases the results of a computerised quantitative analysis provided by a DSS are forwarded to an individual or a group of experts for the purpose of evaluation. Therefore, it would make sense to direct the output of a DSS into an ES that would perform the same function as an expert.

5.4.5.3 Category 3 - ES complement DSS in decision making

ES can complement DSS in one or more of the steps in the decision making process. An example of such EDSS as the one proposed by Meador et al. [18]. Meador suggested that the decision making process can be viewed as an eight-step process consisting of:

Step 1 - Specification of objectives, parameters, probabilities
Step 2 - Retrieval and management of data
Step 3 - Generation of decision alternatives
Step 4 - Inference of consequences of decision alternatives.
Step 5 - Assimilation of verbal, numerical, and graphical information
Step 6 - Evaluation of sets of consequences
Step 7 - Explanation and implementation of decisions
Step 8 - Strategy formulation

Meador argued that from the eight steps, seven are typical DSS functions, whereas the last one, which requires judgement and creativity, can be done by an ES.
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5.4.5.4 Category 4 - ES-based DSS

This category of EDSS is based on the work of Davis [12], Alter [14] and Bonczek [13]. All three of them considered ES as an intelligent DSS. Reitman [19] points out that most current DSS help users evaluate and choose among potential courses of action (the choice phase of decision making). However these DSS cannot suggest the alternative courses of action that should be considered. He contends that this deficiency in existing DSS might be met by applying concepts and techniques taken from expert systems. Even though there are differences between ES and DSS, Davis, Alter and Bonczek have developed generic DSS which exhibit major characteristics of ES. Without doubt Alter [14] has shown that ES could be use as stand-alone DSS in several decision-related activities such as estimation of consequence of proposed decisions, proposal of decisions, and decision making.

Scott-Morton [20], who pioneered the concept of DSS, made the following remarks regarding the ES/DSS integration:

"............DSS as we know them may even become obsolete in the foreseeable future. They are being supplanted by expert decision support systems - EDSS. This next generation of DSS will combine existing DSS technology with the capabilities of artificial intelligence.....The messages users input and the computer's response will virtually duplicate everyday human conversation, and the EDSS will be able to supply a variety of alternative solutions to problems..............."

5.5 Selection of EDSS System Type and System Tools

Two main aspects have to be consider before an EDSS is designed, namely,

- The EDSS System Type
- The EDSS System Tools
5.5.1 Selecting the EDSS system type.

The selection of EDSS system tools depends on the type of ES/DSS integration or an EDSS system being adopted. Four main factors have to be considered before an EDSS system is chosen.

(1). The Benefits and Costs
The main concern of benefit and cost is that the EDSS system to be selected must offer economic benefits and the costs of the system, including installation, operation and maintenance must not exceed the economic benefit the manufacturing business is going to gain.

(2). The EDSS Tasks
The EDSS tasks must be made clear in terms of functions and support facilities. Once functions are clear then the choice of EDSS system is made much easier.

(3). The Organisational Environment
The organisational environment is an important factor to be considered in terms of support from both management and employee. Management as a user must agree to the installation of the EDSS system and employees must be willing to participate.

(4). The Development Considerations
Development considerations involve the availability of internal resources and requirement of external resources to build the EDSS system in the manufacturing business. The type of technology to be introduced and the possibility of disruption to existing systems are other development considerations.

Based on the above considerations this research has adopted the EDSS type mentioned in Section 5.4.5.4, that is the ES-based DSS. As suggested by Scott-Morton, ES-based DSS will be the next generation of advanced DSS possessing a higher level of capabilities. Among the capabilities needed to solve the problem of selecting manufacturing business performance measures are the capture of expert...
knowledge on performance measures and to interrelate large volumes of essential information from various manufacturing environment backgrounds. It is seen that these functions could be achieved by adopting an ES-based DSS. Normal DSS technology such as DSS generators would not have the capability to deliver the required functions.

5.5.2 Selection of EDSS System Tools

Having chosen the type of EDSS that fulfills the task requirements, the next step is to select the EDSS system tools. The main tools to serve this purpose are an appropriate computer hardware and an expert system shell for the EDSS application development. The expert system shell (ESS) is a ready-made software tool for developing and executing the EDSS. Several factors have to be consider before an ESS is adopted, namely,

- The ESS must be able to support the knowledge representation scheme needed
- The ESS must be able to support the inference techniques needed
- The ESS must be able to provide good development tools
- The ESS must provides a good user interface
- The ESS runs on hardware that is available
- Cost of ESS is in line with functionality
- Vendor of ESS and hardware provide after sale service

The author carried out an evaluation of two available ESS and supplemented this with studies of several other evaluation results carried out by other researchers. The two ESS at hand were NEXPERT OBJECT and LEONARDO. Several other ESS evaluation reports are on Crystal, GURU, ART-IM and including LEONARDO which were evaluated and investigated by Drenth and Morris [21], Bodkin and Ian [22] and Mettrey [23]. The adopted ESS for the development of the prototype EDSS was LEONARDO [24].
The reasons for adopting LEONARDO are as follows:

- it is readily available
- it is easy and quick to use for development and consultation
- it does not require high level computer hardware
- it has a frame structure which provides simple knowledge representation and maintenance.
- it has an extensive procedural programming language to support complex designs.
- it has a free form rule editor which allows easy editing

LEONARDO ESS is known to have been used to produce several expert system applications notably in scheduling in robotics manufacture, brain scanning and export control.

There are two versions of LEONARDO namely, a PC-version which runs on DOS and a VAX-VMS version. A PC with 640K RAM and a 20 Mbyte hard disk is sufficient to run LEONARDO. The latest version available in the market is Version 4.0 which includes graphics package, statistical functions, Lotus 123 and dbase interfaces.

The detail of several other expert system shells available in the market is given in Appendix 5.1.

5.6 EDSS for the Selection of Manufacturing Business Performance Measures

The development of the EDSS can either follow the process of developing an ES or a DSS. For example, the iterative DSS design by Alter [14] is also suitable for the development of ES as shown by Sprague and Carlson [3]. However, since the EDSS system adopted by this research is the ES-based DSS, it is more appropriate to use the process of developing an ES for its purpose. Figure 3.2 of chapter three illustrates the phases and task of the development of the EDSS. It consists of five fundamental phases namely, the concept formulation, initial
development, prototyping, final implementation and operation and maintenance. Detailed discussion on the various phases is given in sections 3.2.1 to 3.2.5.

5.6.1 The structure of the expert decision support system

The design of EDSS is considered as evolutionary in nature and relies on prototypes and fast development. There is no 'final' system. In most instances, the system evolves in response to user learning. Figure 5.6 shows the structure of the EDSS developed.

The EDSS is composed of two major environments, namely,

- the development environment
- the consultation environment.

The development environment is the area where knowledge and other input information is fed into the support system and contains the expert knowledge, knowledge acquisition, the knowledge engineer, and the knowledge base.

The consultation environment is the area where the user obtains the recommended performance measures and contains the user, user interface, the inference engine and the, ustifier.

The elements of the development environment.

- Expert Knowledge
  The expert knowledge on manufacturing business performance measures was compiled through a questionnaire survey, interviews, databases, special research reports, books, seminar and conference papers, manuals and other documented sources.

- Knowledge Acquisition
  The knowledge acquisition subsystem is the accumulation, transfer, and transformation of problem-solving expertise from the knowledge sources to a computer program for constructing or expanding the knowledge base. From
section 3.6 - Main sources of knowledge acquisition, it can be seen that there were 17 main knowledge sources and involved more than 2000 manufacturing business organisations.

• Knowledge Engineer
The knowledge engineer uses expert decision support system tools to create the EDSS. He is involved in the process of translating the knowledge from the various sources to the EDSS. In this research, the author acted as the knowledge engineer and elicited the domain knowledge from the sources mentioned in the knowledge acquisition subsystem.

• Knowledge Base
The knowledge base houses the facts, data, rules and models for the EDSS. An example of facts and data is detailed information of a manufacturing business or industry. The list of facts and models are represented in sets of rules in the knowledge base containing the expert knowledge on manufacturing business performance measures. All the rules are written in the form " IF conditions THEN actions". The inference mechanism will compare or try to match the conditions of the rules against the facts in the knowledge base.

The elements of consultation environment.

• Inference Engine
The inference engine is essentially a computer program that provides a methodology for reasoning about information in the knowledge base and in the clipboard, and for formulating conclusions by drawing a sequence of inferences from the knowledge available to it. It takes the rules one at a time and attempts to fire those rules whose conditions are satisfied. It does this by means of two basic modes of operation, namely forward chaining and backward chaining mechanisms [26]. The details of three types of chaining, namely forward, backward and mixed chainings is given in Appendix 5.2.
Figure 5.6 The structure of the EDSS for the selection of performance measures
• The Justifier (Explanation subsystem)

The justifier or explanation subsystem traces responsibility for conclusions to their sources. It can trace such responsibility and explain the EDSS behaviour by interactively answering questions such as the following:

- How was a certain conclusion reached?
- Why was a certain alternative rejected?
- What is the plan to reach the solution? For example, what remains to be established before a final diagnosis can be determined?

• The User Interface

The user interface is the communication link between the program and the user. At its most basic level, it is only what the user sees on the monitor. The interface is particularly important for successful EDSS which require opinion of what the user sees, hears, feels about the subject in question. [27]. The interface provide the dialogue and a wide range of explanation facilities.

• The User

The user is a person who uses the EDSS system. Most computer-based systems have evolved in a single user mode. In contrast, an EDSS could have several possible users examples of which are business practitioners and managers, academicians, students, EDSS builders and even an expert in the similar domain.

REFERENCES


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CHAPTER SIX

ANALYSIS OF SURVEY QUESTIONNAIRES RESULTS AND SYSTEM EVALUATION
CHAPTER SIX

ANALYSIS OF SURVEY QUESTIONNAIRES RESULTS AND SYSTEM EVALUATION

This chapter discusses the criteria for selection of the manufacturing business organisations used in the study and presents the results of the questionnaire survey conducted by the author on manufacturing performance measures used by manufacturing businesses in the United Kingdom. It also presents information gathered regarding manufacturing business performance measures employed in Malaysia which was obtained from interviews with various officers of manufacturing business organisations in Malaysia. The chapter then gives an evaluation of the prototype expert decision support system that was developed and discusses the validation process that was conducted.

6.1 Selection of manufacturing business organisation

The manufacturing business organisations selected for study in the United Kingdom were short listed from the database called Financial Analysis Made Easy (FAME) [1] available in Pilkington Library of Loughborough University of Technology. FAME is available on CD-ROM and provides profiles and financial details of about 125,000 major United Kingdom business organisations. FAME also includes in its database the addresses, telephone & fax numbers, balance sheet figures and lists of products of the various manufacturing businesses. For each business organisation the information is normally shown for a period of 5 years. An example of FAME profile of a business is shown in Appendix 6.1.

One hundred manufacturing business organisations were contacted. The author expected a 15 to 20% response from the business organisations, which was considered sufficient for the purpose of developing a methodology for the selection of
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overall strategic manufacturing business performance measures. The businesses selected from the FAME list were mainly on the following criteria:

- Firstly, the manufacturing business organisations chosen were those which possess some features which are similar to those found in manufacturing businesses in developing countries. This was mainly in terms of products being manufactured.

- Secondly, each organisation must provide information of five years running performance of the business. Examples of the information are the annual turnover, number of employees, profit margin percentages, liquidity ratios and shareholders funds.

- Thirdly, they could be classified into at least one of the following:

  Single business public company
  Single business private company
  Business division of company
  Small scale business
  Medium scale business
  Large scale business
  New business
  Old business
  Sales oriented business
  Production-oriented business
  Capital intensive business
  Labour intensive business
  Co-operative & Co-partnerships
  Nationalised business
  Charities & non-profit making business
From the 100 manufacturing businesses contacted, 35 businesses responded and were willing to participate in the study. The 35% response was more than expected and considered as good response for this sort of study. The list of these 35 businesses is shown in Appendix 6.2.

6.2 Results of Survey Questionnaires - UK Manufacturing Businesses

The primary objectives of the survey questionnaire was to gather information about the types of overall strategic performance measures used by different categories of manufacturing business organisation.

The questionnaire was composed of three major parts. The first part consisted of a request for some general data to be used to classify the respondents. The main items were the functional area in which the respondent worked, the classification of the business type, the businesses future vision and the general measures of success of the business. This part of the questionnaire provided the data for the business type and competitive stance models of the theoretical framework of this research.

The second part of the questionnaire dealt with the respondents' perception of what measures are important for improving the competitive effectiveness of the business and the extent to which those measures were being emphasised or being supported by the business management.

The third part of the questionnaire accessed the views of the respondent with regard to the evolution models of manufacturing business organisations. These are the organisational adaptational model, the life-cycle model and the phase requirement models as discussed in section 4.2.3, 4.2.4 and 4.2.5.

Results from the returned questionnaires were analysed using the Statistical Package for Social Science (SPSS) [2] and the results are as shown in the following sections.
6.2.1 Respondent's position

The following data indicates the positions of respondents in their business organisations.

<table>
<thead>
<tr>
<th>Respondents Position</th>
<th>(N)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales / Marketing Managers</td>
<td>10</td>
<td>28.6</td>
</tr>
<tr>
<td>Managing Directors / General Managers</td>
<td>7</td>
<td>20.0</td>
</tr>
<tr>
<td>Manufacturing Managers</td>
<td>7</td>
<td>20.0</td>
</tr>
<tr>
<td>Personnel / Administrative Managers</td>
<td>5</td>
<td>14.2</td>
</tr>
<tr>
<td>Finance / Accounting Managers</td>
<td>4</td>
<td>11.4</td>
</tr>
<tr>
<td>Business Efficiency Managers</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td>Unknown</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>35</td>
<td><strong>100 %</strong></td>
</tr>
</tbody>
</table>

Figure 6.1 - The Breakdown of The Respondents Position

6.2.2 Classification of business type

The following data indicates the types of business organisations that participated in the survey. Although there were few responses from some categories, the sample is considered sufficient for the purpose of developing the methodology for the selection of overall strategic performance measures.

<table>
<thead>
<tr>
<th>Type of Business Organisation</th>
<th>(N)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Division of Main Business</td>
<td>11</td>
<td>31.4</td>
</tr>
<tr>
<td>Single Business Public Company</td>
<td>9</td>
<td>25.7</td>
</tr>
<tr>
<td>Single Business Private Company</td>
<td>8</td>
<td>22.9</td>
</tr>
<tr>
<td>Production Oriented Business</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td>Medium Scale Business</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td>Heavy Manufacturing Business</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td>New Business</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>35</td>
<td><strong>100 %</strong></td>
</tr>
</tbody>
</table>

Figure 6.2 - The Breakdown of Type of Business Organisation
6.2.3 Business Organisation Future Vision

The following data describes the long term business vision of the business organisation as perceived by the respondent.

<table>
<thead>
<tr>
<th>Organisation Future Vision</th>
<th>( N )</th>
<th>( % )</th>
</tr>
</thead>
<tbody>
<tr>
<td>To Operate Internationally</td>
<td>21</td>
<td>60.0</td>
</tr>
<tr>
<td>Only At National Level</td>
<td>12</td>
<td>34.3</td>
</tr>
<tr>
<td>Unknown</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>35</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 6.3 - The Breakdown of Business Organisations Future Vision

6.2.4 Business Organisation Long Term Objective

The following information describe the respondent business organisation’s long term objective.

<table>
<thead>
<tr>
<th>Organisation Long Term Objective</th>
<th>( N )</th>
<th>( % )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Market Leader</td>
<td>13</td>
<td>37.1</td>
</tr>
<tr>
<td>Lowest Cost Product Producer</td>
<td>10</td>
<td>28.6</td>
</tr>
<tr>
<td>Highest Quality Product Manufacturer</td>
<td>10</td>
<td>28.6</td>
</tr>
<tr>
<td>Best Services Business</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>35</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 6.4 - The Breakdown of Business Organisations Long Term Objective
6.2.5 The Basis of Measure of Success of Business Organisation

The following information gives the basis of measure of success of the respondent business organisations.

<table>
<thead>
<tr>
<th>Basis of Business Success</th>
<th>(N)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial Performance Measures Only</td>
<td>18</td>
<td>51.4</td>
</tr>
<tr>
<td>Market Performance Measures Only</td>
<td>7</td>
<td>20.0</td>
</tr>
<tr>
<td>Both Financial and Market Measures</td>
<td>9</td>
<td>25.7</td>
</tr>
<tr>
<td>Efficiency Measures</td>
<td>1</td>
<td>2.9</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>35</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 6.5 - The Breakdown of Business Organisations Measure Of Success

6.2.6 The Market Performance Measures of Business Organisation

The following information describes the market performance measures of the respondents.

<table>
<thead>
<tr>
<th>Market Performance Measures</th>
<th>(N)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customers Satisfaction Only</td>
<td>21</td>
<td>60.0</td>
</tr>
<tr>
<td>Product Flexibility Only</td>
<td>3</td>
<td>8.6</td>
</tr>
<tr>
<td>Customers Satisfaction &amp; Product Flexibility</td>
<td>7</td>
<td>20.0</td>
</tr>
<tr>
<td>Market Share</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td>On-Time Delivery</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>35</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 6.6 - The Breakdown of Market Performance Measures

...results & evaluation
6.2.7 The Financial Performance Measures of Business Organisation

The following information describes the financial performance measures of the respondents.

<table>
<thead>
<tr>
<th>Financial Performance Measures</th>
<th>(N)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity Measures Only</td>
<td>23</td>
<td>65.7</td>
</tr>
<tr>
<td>Product Flexibility Measures Only</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td>Productivity &amp; Product Flexibility</td>
<td>5</td>
<td>14.3</td>
</tr>
<tr>
<td>Return On Investment</td>
<td>3</td>
<td>8.6</td>
</tr>
<tr>
<td>Profitability</td>
<td>2</td>
<td>5.7</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>35</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 6.7 - The Breakdown of Financial Performance Measures

6.2.8 Congruence Analysis

Congruence analysis was carried out on the data which was obtained from the second part of the questionnaires survey. An example of how the congruency analysis was carried out follows. The method is based on the work of Dixon et.al.[3]. It shows how gaps and false alarms are calculated. A gap is said to occur if little or low emphasis is given to an important performance measure for the success of the manufacturing business. A false alarm is sounded if great emphasis is placed on unimportant performance measures. Figure 6.8a shows an example of a gap and Figure 6.8b a false alarm.
Performance Measure used in this example is Customer Satisfaction

Figure 6.8a An Example of A Gap

Significant differences identified the gaps or false alarms, depending on the nature of the difference. In this research, a gap is defined as occurring when the average rated importance for a performance measure exceeds the average rated emphasis of that measure by the organisation, resulting in a negative difference. A gap signals the need for increased support in that area from the measurement system.

The opposite condition occurs when the relationship is reversed. If the organisation emphasis on a measure exceeds the importance of the measure resulting in a positive difference, this outcome is called a false alarm and signals the need to review that area of measurement.

A small difference between emphasis and importance means the business is exercising the right balance. A zero difference is considered as a perfect balance between emphasis and importance.

Performance Measure used in this example is Direct Labour Productivity

Figure 6.8b An Example of False Alarm
The respondents were asked to indicate on a scale of 1 to 10, with 10 being the most heavily emphasised, their businesses current emphasis on a number of performance measures. For the purpose of developing the methodology for the selection of performance measures, six businesses were selected randomly for the analysis and named A, B, C, D, E and F. The responses from the six businesses are shown below using the following presentation format (Figure 6.8c), where the meaning of 'Average' and 'Mean' used in this research are given.

\[
\text{Average} = \frac{\text{Sum of } a_i + b_i + c_i + d_i + e_i + f_i}{6}
\]

\[
= \text{Average rated for all business organisations}
\]

( Either Emphasis or Importance )

\[
\text{Mean} = \frac{\sum X_i}{N} = \text{Average rated for specific business organisation,}
\]

where \( X \) is the specific business organisation, and \( N \) is the number of performance measures

<table>
<thead>
<tr>
<th>Performance Measures</th>
<th>Organisation</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Ave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance Measure 1</td>
<td>a_1</td>
<td>b_1</td>
<td>c_1</td>
<td>d_1</td>
<td>e_1</td>
<td>f_1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance Measure 2</td>
<td>a_2</td>
<td>b_2</td>
<td>c_2</td>
<td>d_2</td>
<td>e_2</td>
<td>f_2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance Measure 3</td>
<td>a_3</td>
<td>b_3</td>
<td>c_3</td>
<td>d_3</td>
<td>e_3</td>
<td>f_3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance Measure 4</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance Measure 5</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance Measure n</td>
<td>a_n</td>
<td>b_n</td>
<td>c_n</td>
<td>d_n</td>
<td>e_n</td>
<td>f_n</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Mean                             | \( \frac{\Sigma a_i}{N} \) | \( \frac{\Sigma b_i}{N} \) | \( \frac{\Sigma c_i}{N} \) | \( \frac{\Sigma d_i}{N} \) | \( \frac{\Sigma e_i}{N} \) | \( \frac{\Sigma f_i}{N} \) |

Figure 6.8c - Format of data presentation.
The following is the results of the average rated emphasis, Ave 1.

Section 1.0  Financial Performance Measures

<table>
<thead>
<tr>
<th>Performance Measures</th>
<th>Manufacturing Businesses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Cost of quality</td>
<td>10</td>
</tr>
<tr>
<td>Inventory Turnover</td>
<td>5</td>
</tr>
<tr>
<td>Training Budget</td>
<td>3</td>
</tr>
<tr>
<td>Cost Reduction</td>
<td>7</td>
</tr>
<tr>
<td>Capital Investment</td>
<td>7</td>
</tr>
<tr>
<td>R &amp; D Cost</td>
<td>1</td>
</tr>
<tr>
<td>Unit Material Cost</td>
<td>10</td>
</tr>
<tr>
<td>Unit Labour Cost</td>
<td>10</td>
</tr>
<tr>
<td>Return On Investment</td>
<td>3</td>
</tr>
<tr>
<td>Department Budget Control</td>
<td>8</td>
</tr>
</tbody>
</table>

Mean 6.4 6.5 7.7 6.2 8.0 6.9

Section 2.0  Business Factors

<table>
<thead>
<tr>
<th>Performance Measures</th>
<th>Manufacturing Businesses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Customer Satisfaction</td>
<td>8</td>
</tr>
<tr>
<td>On Time Delivery</td>
<td>9</td>
</tr>
<tr>
<td>Vendor Quality</td>
<td>7</td>
</tr>
<tr>
<td>Vendor Lead Time</td>
<td>6</td>
</tr>
<tr>
<td>Number of Suppliers</td>
<td>3</td>
</tr>
</tbody>
</table>

Mean 6.6 7.8 8.4 7.6 8.4 4.8

Section 3.0 - Manufacturing Performance Measures

<table>
<thead>
<tr>
<th>Performance Measures</th>
<th>Manufacturing Businesses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Manufacturing Lead Time</td>
<td>4</td>
</tr>
<tr>
<td>Direct Labour Productivity</td>
<td>6</td>
</tr>
<tr>
<td>Indirect Labour Productivity</td>
<td>6</td>
</tr>
<tr>
<td>Set-up Time</td>
<td>4</td>
</tr>
<tr>
<td>Capacity Utilisation</td>
<td>3</td>
</tr>
<tr>
<td>New Product Introduction</td>
<td>5</td>
</tr>
<tr>
<td>New Product Lead Time</td>
<td>2</td>
</tr>
<tr>
<td>New Process Introduction</td>
<td>6</td>
</tr>
<tr>
<td>Environmental Monitoring</td>
<td>5</td>
</tr>
<tr>
<td>Minimising Waste</td>
<td>4</td>
</tr>
</tbody>
</table>

Mean 4.5 6.0 7.8 4.0 7.4 6.1
Section 4.0 - Operation Factors

Performance Measures | A | B | C | D | E | F | Ave 1
---|---|---|---|---|---|---|---
Record Accuracy | 5 | 7 | 5 | 9 | 5 | 9 | 6.67
Sales Forecast Accuracy | 7 | 8 | 8 | 8 | 7 | 4 | 7.00
Meeting Schedules | 8 | 9 | 8 | 8 | 8 | 10 | 8.50
Safety | 9 | 8 | 9 | 10 | 9 | 8 | 8.83

Mean | 7.3 | 8.0 | 7.5 | 8.8 | 7.3 | 7.8 |

The respondents were asked to indicate on the scale of 1 to 10, with 10 being the most important, the importance of the following performance measures to the business organisation. The results of the responses are shown below. The format of data presentation is the same as shown in Figure 6.8c. The average rated importance is Ave 2.

Section 1.0 - Financial Performance Measures

Performance Measures | A | B | C | D | E | F | Ave 2
---|---|---|---|---|---|---|---
Cost of Quality | 10 | 9 | 7 | 7 | 10 | 10 | 8.83
Inventory Turnover | 8 | 7 | 8 | 9 | 8 | 7 | 7.83
Training Budget | 5 | 3 | 8 | 4 | 3 | 5 | 4.67
Cost Reduction | 7 | 9 | 9 | 8 | 5 | 10 | 8.00
Capital Investment | 9 | 9 | 9 | 3 | 6 | 6 | 7.00
R & D Cost | 5 | 4 | 7 | 1 | 6 | 8 | 5.17
Unit Material Cost | 10 | 8 | 7 | 9 | 8 | 8 | 8.33
Unit Labour Cost | 10 | 8 | 8 | 4 | 9 | 9 | 8.00
Return On Investment | 3 | 9 | 7 | 2 | 8 | 9 | 6.33
Department Budget Control | 8 | 1 | 8 | 5 | 7 | 7 | 6.00

Mean | 7.5 | 6.7 | 7.8 | 5.2 | 6.4 | 7.9 |
Chapter 6

Section 2.0 - Business Performance Measures

<table>
<thead>
<tr>
<th>Performance Measures</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Ave 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Satisfaction</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>9.17</td>
</tr>
<tr>
<td>On Time Delivery</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>8.50</td>
</tr>
<tr>
<td>Vendor Quality</td>
<td>7</td>
<td>9</td>
<td>8</td>
<td>9</td>
<td>7</td>
<td>9</td>
<td>8.17</td>
</tr>
<tr>
<td>Vendor Lead Time</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>7.67</td>
</tr>
<tr>
<td>Number of Suppliers</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>4.50</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>7.0</td>
<td>7.8</td>
<td>8.4</td>
<td>8.4</td>
<td>7.6</td>
<td>6.4</td>
</tr>
</tbody>
</table>

Section 3.0  Manufacturing Performance Measures

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Ave 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing Lead Time</td>
<td>5</td>
<td>9</td>
<td>10</td>
<td>8</td>
<td>10</td>
<td>8</td>
<td>8.33</td>
</tr>
<tr>
<td>Direct Labour Productivity</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>10</td>
<td>7.50</td>
</tr>
<tr>
<td>Indirect Labour Productivity</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>6.50</td>
</tr>
<tr>
<td>Set-up Time</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>6.00</td>
</tr>
<tr>
<td>Capacity Utilisation</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4.83</td>
</tr>
<tr>
<td>New Product Introduction</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>5</td>
<td>7.00</td>
</tr>
<tr>
<td>New Product Lead Time</td>
<td>4</td>
<td>9</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>5</td>
<td>7.17</td>
</tr>
<tr>
<td>New Process Introduction</td>
<td>4</td>
<td>7</td>
<td>8</td>
<td>4</td>
<td>8</td>
<td>5</td>
<td>6.00</td>
</tr>
<tr>
<td>Environmental Monitoring</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>6.00</td>
</tr>
<tr>
<td>Minimising Waste</td>
<td>6</td>
<td>2</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>7.00</td>
</tr>
<tr>
<td>Mean</td>
<td>5.2</td>
<td>6.0</td>
<td>7.7</td>
<td>6.6</td>
<td>7.5</td>
<td>6.7</td>
<td></td>
</tr>
</tbody>
</table>

Section 4.0  Operation Factors

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Ave 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record Accuracy</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>9</td>
<td>7.00</td>
</tr>
<tr>
<td>Sales Forecast Accuracy</td>
<td>4</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>6.67</td>
</tr>
<tr>
<td>Meeting Schedules</td>
<td>5</td>
<td>9</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>8.33</td>
</tr>
<tr>
<td>Safety</td>
<td>4</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>8.17</td>
</tr>
<tr>
<td>Mean</td>
<td>4.8</td>
<td>8.0</td>
<td>7.8</td>
<td>8.5</td>
<td>7.5</td>
<td>8.8</td>
<td></td>
</tr>
</tbody>
</table>

The following gaps and false alarms are calculated based on average rated business emphasis and average rated importance of performance measures. A
positive average difference would indicate a false alarm while a negative average difference would indicate a gap.

\[ \text{Difference} = \text{Emphasis} - \text{Importance} \]

\[ = \text{Ave 1} - \text{Ave 2} \]

<table>
<thead>
<tr>
<th>Performance Measures</th>
<th>Ave 1</th>
<th>Ave 2</th>
<th>Difference</th>
<th>Gap/False Alarm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Quality</td>
<td>9.17</td>
<td>8.83</td>
<td>+0.34</td>
<td>False Alarm</td>
</tr>
<tr>
<td>Inventory Turnover</td>
<td>7.50</td>
<td>7.83</td>
<td>-0.33</td>
<td>Gap</td>
</tr>
<tr>
<td>Training Budget</td>
<td>5.50</td>
<td>4.67</td>
<td>+0.83</td>
<td>False Alarm</td>
</tr>
<tr>
<td>Cost Reduction</td>
<td>7.17</td>
<td>8.00</td>
<td>-0.83</td>
<td>Gap</td>
</tr>
<tr>
<td>Capital Investment</td>
<td>7.67</td>
<td>7.00</td>
<td>+0.67</td>
<td>False Alarm</td>
</tr>
<tr>
<td>R &amp; D Cost</td>
<td>3.83</td>
<td>5.17</td>
<td>-1.34</td>
<td>Gap</td>
</tr>
<tr>
<td>Unit Material Cost</td>
<td>8.50</td>
<td>8.33</td>
<td>+0.17</td>
<td>False Alarm</td>
</tr>
<tr>
<td>Unit Labour Cost</td>
<td>8.17</td>
<td>8.00</td>
<td>+0.17</td>
<td>False Alarm</td>
</tr>
<tr>
<td>Return On Investment</td>
<td>6.17</td>
<td>6.33</td>
<td>-0.16</td>
<td>Gap</td>
</tr>
<tr>
<td>Department Budget Control</td>
<td>6.50</td>
<td>6.00</td>
<td>+0.50</td>
<td>False Alarm</td>
</tr>
<tr>
<td>Customers Satisfaction</td>
<td>8.67</td>
<td>9.17</td>
<td>-0.50</td>
<td>Gap</td>
</tr>
<tr>
<td>On Time Delivery</td>
<td>8.33</td>
<td>8.50</td>
<td>-0.17</td>
<td>Gap</td>
</tr>
<tr>
<td>Vendor Quality</td>
<td>8.00</td>
<td>8.17</td>
<td>-0.17</td>
<td>Gap</td>
</tr>
<tr>
<td>Vendor Lead Time</td>
<td>7.17</td>
<td>7.67</td>
<td>-0.50</td>
<td>Gap</td>
</tr>
<tr>
<td>Number of Suppliers</td>
<td>4.17</td>
<td>4.50</td>
<td>-0.33</td>
<td>Gap</td>
</tr>
<tr>
<td>Manufacturing Lead Time</td>
<td>7.67</td>
<td>8.33</td>
<td>-0.66</td>
<td>Gap</td>
</tr>
<tr>
<td>Direct Labour Productivity</td>
<td>7.00</td>
<td>7.50</td>
<td>-0.50</td>
<td>Gap</td>
</tr>
<tr>
<td>Indirect Labour Productivity</td>
<td>5.83</td>
<td>6.50</td>
<td>-0.67</td>
<td>Gap</td>
</tr>
<tr>
<td>Set-up Time</td>
<td>5.17</td>
<td>6.00</td>
<td>-0.83</td>
<td>Gap</td>
</tr>
<tr>
<td>Capacity Utilisation</td>
<td>4.83</td>
<td>4.83</td>
<td>0.00</td>
<td>Perfect Balance</td>
</tr>
<tr>
<td>New Product Introduction</td>
<td>6.00</td>
<td>7.00</td>
<td>-1.00</td>
<td>Gap</td>
</tr>
<tr>
<td>New Product Lead Time</td>
<td>6.17</td>
<td>7.17</td>
<td>-1.00</td>
<td>Gap</td>
</tr>
<tr>
<td>New Process Introduction</td>
<td>6.17</td>
<td>6.00</td>
<td>+0.17</td>
<td>False Alarm</td>
</tr>
<tr>
<td>Environmental Monitoring</td>
<td>5.33</td>
<td>6.00</td>
<td>-0.07</td>
<td>Gap</td>
</tr>
<tr>
<td>Minimising Waste</td>
<td>5.50</td>
<td>7.00</td>
<td>-1.50</td>
<td>Gap</td>
</tr>
<tr>
<td>Record Accuracy</td>
<td>6.67</td>
<td>7.00</td>
<td>-0.33</td>
<td>Gap</td>
</tr>
<tr>
<td>Sales Forecast Accuracy</td>
<td>7.00</td>
<td>6.67</td>
<td>+0.33</td>
<td>False Alarm</td>
</tr>
<tr>
<td>Meeting Production Schedules</td>
<td>8.50</td>
<td>8.33</td>
<td>+0.17</td>
<td>False Alarm</td>
</tr>
<tr>
<td>Safety</td>
<td>8.83</td>
<td>8.17</td>
<td>+0.66</td>
<td>False Alarm</td>
</tr>
</tbody>
</table>

Figure 6.9 - Gaps and False Alarms
The following table summarizes the number of gaps and false alarms for each of the four sections.

<table>
<thead>
<tr>
<th>Section</th>
<th>Perfect Balance</th>
<th>Gaps</th>
<th>False Alarms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial Measures</td>
<td>0</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Business Measures</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Manufacturing Measures</td>
<td>1</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Operation Measures</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

**Figure 6.9a  Summary of Gaps and False Alarms**

Figure 6.9a illustrates that, although there is one perfect balance there are many gaps (80%). The manufacturing sections, therefore need to improve the emphasis on measures that management consider as important. Similarly for the business section, 100% of the business performance measures consist of gaps. Financial and operation sections performed rather better with only 40% and 25% gaps respectively but conversely there have 60% and 75% false alarms.

**Figure 6.9b  Control Limits for Gaps and False Alarm**
Figure 6.9b shows two control limits drawn to isolate the most significant gaps and false alarms. The location of these control limits is somewhat arbitrary; the limits have been selected so the focus is placed on only a few gaps and false alarms. In the above example performance measure 2, 11 and 15 are significant false alarms and 7, 10, 14 and 20 are significant gaps.

![Figure 6.9c  Gaps and False Alarms for Business Section](image)

Figure 6.9c illustrates the control limits for the business section. Consider that management has decided ±0.4 is the control limits, then the significant gaps are the performance measures 4 and 6 which are cost reduction and R & D cost while false alarms are performance measures 3, 5 and 10 which are training budget, capital investment and budget control. Action can then be taken by management to review the emphasis and the analysis of important measures by the business.

### 6.2.9 Results of Performance Measures for Business Type Model

The respondents were asked to identify the performance measures used by their organisation. The following are the top four measures for each type of business organisation mentioned by the respondents and is termed as 'observed measures'. These are compared to the 'theoretical measures' which were established in Chapter Four.

For the purpose of developing the methodology for the selection of overall strategic performance measures, only three types of business which individually formed more than 20% of respondents were considered for the business type model.
### Chapter 6


dataframe

<table>
<thead>
<tr>
<th>Business Type</th>
<th>Theoretical</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Division of Main Business (31.4% of respondents)</td>
<td>Operating Profit, Gross Margin, Profit After Interest, Turnover</td>
<td>ROI, Operating Profit, Productivity, Sales</td>
</tr>
<tr>
<td>Single Business Public Company (25.7% of respondents)</td>
<td>Operating Profit, Profit After Tax, Operating Cash Flow, Earning Per Share</td>
<td>ROI, Leadership, Operating Profit, Cost Reduction</td>
</tr>
<tr>
<td>Single Business Private Company (22.9% of respondents)</td>
<td>Operating Profit, Gross Margin, Profit After Interest, Productivity Ratio</td>
<td>Operating Profit, ROI, Productivity, Quality</td>
</tr>
</tbody>
</table>

Figure 6.10 Theoretical and Observed Measures for Business Type Model

#### 6.2.10 Results of Performance Measures for Competitive Model

The following figure gives the four most important performance measures as considered by the respondent for each of the competitive stances adopted by the business organisation compared to the theoretical performance measures. For the purpose of developing the methodology, Figure 6.11 demonstrates two stances, quality and price which individually formed more than 20% of the respondents.

<table>
<thead>
<tr>
<th>Competitive Stance</th>
<th>Theoretical</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>Costs versus budget, Unit Labour Costs, Unit Material Costs, Unit Product costs</td>
<td>Budgeting, Marketing, Unit Labour Cost, Unit Material Cost</td>
</tr>
</tbody>
</table>

Figure 6.11 Theoretical and Observed Measures for Competitive Stance Model
The results which follows from here will report only on 28 respondents. Seven businesses were unable to participate further due to closure, taken over by new management or simply did not respond to the third part of the questionnaire survey.

### 6.2.11 Results of Performance Measures for Organisation Adaptational Model

The respondents were given the description of the characteristics of the following four different types of manufacturing business organisation and were asked to identify which of the four best represented their business organisation. The four types are defender, prospector, analyser and reactor.

The following are the respondent's identification of the type of their business organisation based on the organisation adaptational model.

<table>
<thead>
<tr>
<th>Type of Business Organisation</th>
<th>(N)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defender Only</td>
<td>13</td>
<td>46.43</td>
</tr>
<tr>
<td>Prospector Only</td>
<td>3</td>
<td>10.71</td>
</tr>
<tr>
<td>Analyser Only</td>
<td>4</td>
<td>14.29</td>
</tr>
<tr>
<td>Reactor Only</td>
<td>0</td>
<td>00.00</td>
</tr>
<tr>
<td>Defender and Prospector</td>
<td>1</td>
<td>3.57</td>
</tr>
<tr>
<td>Defender and Analyser</td>
<td>1</td>
<td>3.57</td>
</tr>
<tr>
<td>Defender and Reactor</td>
<td>1</td>
<td>3.57</td>
</tr>
<tr>
<td>Prospector and Analyser</td>
<td>4</td>
<td>14.29</td>
</tr>
<tr>
<td>Prospector and Reactor</td>
<td>0</td>
<td>00.00</td>
</tr>
<tr>
<td>Analyser and Reactor</td>
<td>1</td>
<td>3.57</td>
</tr>
</tbody>
</table>

| TOTAL                        | 28  | 100 %|

**Figure 6.12** - Respondent view on the type of their business organisation based on the organisation adaptational model.
The respondents were asked to identify the performance measures used by their organisation. The following are the top four measures for each type of business organisation mentioned by the respondents compared to the theoretical measures.

<table>
<thead>
<tr>
<th>Business Organisation</th>
<th>Observed</th>
<th>Theoretical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defender</td>
<td>Profitability</td>
<td>Market share</td>
</tr>
<tr>
<td></td>
<td>Cost of quality</td>
<td>Production Efficiency</td>
</tr>
<tr>
<td></td>
<td>Cash flow</td>
<td>Planning capability</td>
</tr>
<tr>
<td></td>
<td>Customer Satisfaction</td>
<td>On-Time Delivery</td>
</tr>
<tr>
<td>Prospector</td>
<td>Return on investment</td>
<td>Growth</td>
</tr>
<tr>
<td></td>
<td>Cost of quality</td>
<td>Product development</td>
</tr>
<tr>
<td></td>
<td>Profitability</td>
<td>Process flexibility</td>
</tr>
<tr>
<td></td>
<td>Sales</td>
<td>Marketing</td>
</tr>
<tr>
<td>Analyser</td>
<td>Cost of quality</td>
<td>R &amp; D</td>
</tr>
<tr>
<td></td>
<td>Operating profit</td>
<td>New Product</td>
</tr>
<tr>
<td></td>
<td>Return on investment</td>
<td>Market surveillance</td>
</tr>
<tr>
<td></td>
<td>Leadership</td>
<td>Planning capability</td>
</tr>
<tr>
<td>Reactor</td>
<td>Operating profit</td>
<td>Ability to adapt</td>
</tr>
<tr>
<td></td>
<td>Marketing</td>
<td>to external pressure</td>
</tr>
<tr>
<td></td>
<td>Training</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Costing</td>
<td></td>
</tr>
</tbody>
</table>
6.2.12 The Age of The Business Organisation

The following are the spread of the ages of the manufacturing business organisations.

<table>
<thead>
<tr>
<th>(Age)</th>
<th>(N)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>1</td>
<td>3.57</td>
</tr>
<tr>
<td>6-10</td>
<td>2</td>
<td>7.14</td>
</tr>
<tr>
<td>10-20</td>
<td>3</td>
<td>10.71</td>
</tr>
<tr>
<td>20-50</td>
<td>13</td>
<td>46.43</td>
</tr>
<tr>
<td>50-100</td>
<td>5</td>
<td>17.86</td>
</tr>
<tr>
<td>100-200</td>
<td>4</td>
<td>14.29</td>
</tr>
<tr>
<td>&gt;200</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td>28</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 6.14 - The Spread of Business Organisations Age

6.2.13 Results on Performance Measures for the Life-cycle model

The following Figure 6.15 gives the four most important performance measures as considered by the respondent for each of the stages in the life-cycle of a manufacturing business compared to the theoretical measures.
<table>
<thead>
<tr>
<th>Life-Stage</th>
<th>Observed Measures</th>
<th>Theoretical Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant</td>
<td>Leadership</td>
<td>Leadership</td>
</tr>
<tr>
<td></td>
<td>Innovation</td>
<td>Innovation</td>
</tr>
<tr>
<td></td>
<td>Marketing</td>
<td>Marketing</td>
</tr>
<tr>
<td></td>
<td>Personnel</td>
<td>R &amp; D</td>
</tr>
<tr>
<td>Pioneer</td>
<td>Leadership</td>
<td>Personnel</td>
</tr>
<tr>
<td></td>
<td>Innovation</td>
<td>Innovation</td>
</tr>
<tr>
<td></td>
<td>Marketing</td>
<td>Cost control</td>
</tr>
<tr>
<td></td>
<td>R &amp; D</td>
<td>Sales growth</td>
</tr>
<tr>
<td>Rational</td>
<td>Quality</td>
<td>R &amp; D</td>
</tr>
<tr>
<td></td>
<td>Operating Profit</td>
<td>Turnover</td>
</tr>
<tr>
<td></td>
<td>Customer Satisfaction</td>
<td>Teamwork</td>
</tr>
<tr>
<td></td>
<td>Return On Investment</td>
<td>Cost control</td>
</tr>
<tr>
<td>Established</td>
<td>Quality</td>
<td>Management system</td>
</tr>
<tr>
<td></td>
<td>Operating Profit</td>
<td>Financial system</td>
</tr>
<tr>
<td></td>
<td>Return On Investment</td>
<td>Marketing system</td>
</tr>
<tr>
<td></td>
<td>Customer Satisfaction</td>
<td>Product flexibility</td>
</tr>
<tr>
<td>Wilderness</td>
<td>Leadership</td>
<td>Leadership</td>
</tr>
<tr>
<td></td>
<td>Sale Forecast</td>
<td>Ability to adapt</td>
</tr>
<tr>
<td></td>
<td>Return On Investment</td>
<td>to changes</td>
</tr>
<tr>
<td></td>
<td>Innovation</td>
<td></td>
</tr>
<tr>
<td>Dying</td>
<td>Leadership</td>
<td>Ability to overhaul</td>
</tr>
<tr>
<td></td>
<td>Operating Profit</td>
<td>and introduce new</td>
</tr>
<tr>
<td></td>
<td>Financial</td>
<td>performance measures</td>
</tr>
<tr>
<td></td>
<td>Budgeting</td>
<td></td>
</tr>
<tr>
<td>Transforming</td>
<td>Leadership</td>
<td>Market analysis</td>
</tr>
<tr>
<td></td>
<td>Customer Satisfaction</td>
<td>Product quality</td>
</tr>
<tr>
<td></td>
<td>Flexibility</td>
<td>New technology</td>
</tr>
<tr>
<td></td>
<td>Innovation</td>
<td>Business adaptability</td>
</tr>
</tbody>
</table>

Figure 6.15 - Observed top four most important performance measures for each life-stage compared to theoretical measures.
The following gives the breakdown of the respondents understanding of the position of their business organisations based on the life-cycle model.

<table>
<thead>
<tr>
<th>Life-Stage</th>
<th>(N)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Pioneer</td>
<td>1</td>
<td>3.57</td>
</tr>
<tr>
<td>Rational</td>
<td>2</td>
<td>7.14</td>
</tr>
<tr>
<td>Established</td>
<td>16</td>
<td>57.15</td>
</tr>
<tr>
<td>Wilderness</td>
<td>1</td>
<td>3.57</td>
</tr>
<tr>
<td>Dying</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Transforming</td>
<td>8</td>
<td>28.57</td>
</tr>
<tr>
<td>TOTAL</td>
<td>28</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 6.16 - Position of business organisation on life-cycle model

6.2.14 Results on performance measures for the phase model

The following chart gives the four most important performance measures as considered by the respondent for each of the phases in the evolution of the manufacturing business organisation compared to the theoretical performance measures.
<table>
<thead>
<tr>
<th>Phase</th>
<th>Observed Measures</th>
<th>Theoretical Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficient</td>
<td>Operating Profit</td>
<td>Profit productivity</td>
</tr>
<tr>
<td></td>
<td>Return On Investment</td>
<td>Total earning productivity</td>
</tr>
<tr>
<td></td>
<td>Unit Labour Cost</td>
<td>Work efficiency</td>
</tr>
<tr>
<td></td>
<td>Unit Material Cost</td>
<td>Process efficiency</td>
</tr>
<tr>
<td>Quality</td>
<td>Customer Satisfaction</td>
<td>Customer satisfaction</td>
</tr>
<tr>
<td></td>
<td>Vendor Quality</td>
<td>Incoming quality</td>
</tr>
<tr>
<td></td>
<td>Training</td>
<td>Inventory accuracy</td>
</tr>
<tr>
<td></td>
<td>Cost of Quality</td>
<td>Outgoing quality</td>
</tr>
<tr>
<td>Flexible</td>
<td>Flexibility</td>
<td>Flexibility</td>
</tr>
<tr>
<td></td>
<td>Customer Satisfaction</td>
<td>New product development</td>
</tr>
<tr>
<td></td>
<td>Operating Profit</td>
<td>New technology</td>
</tr>
<tr>
<td></td>
<td>On Time Delivery</td>
<td>On-time delivery</td>
</tr>
<tr>
<td>Innovative</td>
<td>R &amp; D</td>
<td>New product</td>
</tr>
<tr>
<td></td>
<td>Creativity</td>
<td>Creativity</td>
</tr>
<tr>
<td></td>
<td>New Product</td>
<td>New technology</td>
</tr>
<tr>
<td></td>
<td>New Technology</td>
<td>Market openings</td>
</tr>
</tbody>
</table>

Figure 6.17 - Observed top four most important measures for each phase compared to the theoretical measures of the phase evolution model

The following are the respondents view of the current phase of their manufacturing business based on the phase evolution model.

<table>
<thead>
<tr>
<th>(Phase)</th>
<th>(N)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficient</td>
<td>3</td>
<td>10.71</td>
</tr>
<tr>
<td>Quality</td>
<td>12</td>
<td>42.87</td>
</tr>
<tr>
<td>Flexible</td>
<td>8</td>
<td>28.57</td>
</tr>
<tr>
<td>Innovative</td>
<td>3</td>
<td>10.71</td>
</tr>
<tr>
<td>Not Known</td>
<td>2</td>
<td>7.14</td>
</tr>
<tr>
<td>TOTAL</td>
<td>28</td>
<td>100  %</td>
</tr>
</tbody>
</table>

Figure 6.18 - Respondent business organisation current phase in the phase evolution model
6.3 Results of interviews with Malaysian Business Managers.

The following are the centres and position of the person interviewed by the author in Malaysia. Full detail of dates and names of officers interviewed and the correspondence addresses of the centres are given in Appendix 6.3.

<table>
<thead>
<tr>
<th>Centre</th>
<th>Officer's Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Productivity Corporation</td>
<td>Deputy Director</td>
</tr>
<tr>
<td>Malaysian Institute of Economic Research</td>
<td>Business Secretary</td>
</tr>
<tr>
<td>Prime Minister Department Economic Planning Unit</td>
<td>Deputy Director General</td>
</tr>
<tr>
<td>Ministry of Finance Holding Company</td>
<td>Director of Business Management</td>
</tr>
<tr>
<td>Standards Industrial Research Institute Malaysia</td>
<td>Deputy Director</td>
</tr>
<tr>
<td>State Economic Development Commission (Johor)</td>
<td>Director of SMI</td>
</tr>
<tr>
<td>Federation of Malaysian Manufacturers</td>
<td>Executive Secretary</td>
</tr>
<tr>
<td>Malaysian Industrial Development Authority</td>
<td>Head of Computer Section</td>
</tr>
<tr>
<td>Ministry of International Trade &amp; Industry</td>
<td>Director of Policy Relation</td>
</tr>
<tr>
<td>Malaysian National Corporation Limited</td>
<td>Manager of Corporate Research</td>
</tr>
<tr>
<td>Manpower &amp; Management Planning Unit</td>
<td>Planning Unit Manager</td>
</tr>
<tr>
<td>Irshad Management Institute</td>
<td>Director General</td>
</tr>
<tr>
<td>Business Advanced Technology Centre</td>
<td>Director</td>
</tr>
<tr>
<td>Quality Research Centre Northern University</td>
<td>Director of Research</td>
</tr>
</tbody>
</table>

Figure 6.19 - The Office of Persons Interviewed in Malaysia and their respective Centres.

Figure 6.20 below gives the breakdown of Malaysian Ministry of Finance Holding Companies for the year 1993.
### Figure 6.20 - Breakdown of Malaysian Ministry of Finance Holding Companies in 1993.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Total Number</th>
<th>Companies With Financial Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>27</td>
<td>26</td>
</tr>
<tr>
<td>Construction</td>
<td>37</td>
<td>33</td>
</tr>
<tr>
<td>Extractive</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Financial</td>
<td>144</td>
<td>137</td>
</tr>
<tr>
<td>Utilities</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>323</td>
<td>285</td>
</tr>
<tr>
<td>Plantation</td>
<td>98</td>
<td>96</td>
</tr>
<tr>
<td>Property</td>
<td>88</td>
<td>79</td>
</tr>
<tr>
<td>Services</td>
<td>330</td>
<td>315</td>
</tr>
<tr>
<td>Timber</td>
<td>23</td>
<td>16</td>
</tr>
<tr>
<td>Transportation</td>
<td>70</td>
<td>67</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1180</strong></td>
<td><strong>1086</strong></td>
</tr>
</tbody>
</table>

Paid up capital for the above companies was Ringgit Malaysia 35 Billion (£8.75 Billion) and Malaysian Government shares of the above companies were Ringgit Malaysia 23.4 Billion (£5.85 Billion). Others owned about Ringgit Malaysia 11.6 Billion (£2.9 Billion).

Out of 1180 companies, the Federal Government of Malaysia have a share in 541 companies, State Governments have 593 while regionally there were 46 companies. Regionally owned companies are companies owned by a combined share between several states in a region.

From the report above it could be seen that 94 companies were without financial information. The rest of the companies relied solely on their annual financial statements.
In 1991 the Ministry of Finance Holding Companies of Malaysia owned a total of 877 companies of which only 466 or 53.14% were considered as successful while 411 or 46.86% were unsuccessful. The companies were classified as:

<table>
<thead>
<tr>
<th>Company</th>
<th>(N)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Sick Companies</td>
<td>97</td>
<td>11.06</td>
</tr>
<tr>
<td>Weak Companies</td>
<td>165</td>
<td>18.81</td>
</tr>
<tr>
<td>Satisfactory Companies</td>
<td>149</td>
<td>16.99</td>
</tr>
<tr>
<td>Successful Companies</td>
<td>466</td>
<td>53.14</td>
</tr>
<tr>
<td>TOTAL</td>
<td>877</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Figure 6.21 - Breakdown of successful and unsuccessful Malaysian Ministry of Finance Holding Companies in 1991.

The research carried out in this study has found out that most manufacturing businesses in Malaysia are still using their yearly financial report as the sole measure of success or failure. Many manufacturing businesses fail to realise the limitation of relying exclusively on financial measures of performance in today's highly competitive manufacturing business environment. Remedial action must quickly be taken if ever the vision 2020 (of becoming an industrialised nation) is to be achieved.
6.4 Evaluation of the Prototype EDSS developed

Evaluation is viewed as an integral part of the development cycle for any software system. Buchanan [4] lists nine steps of evaluation process in the implementation of an expert system. They are as follows,

1. Top-level design with definition of long range goals.
2. First version prototype, showing feasibility.
3. System refinement in which informal test cases are run to generate feedback from the expert and from the users.
5. Structured evaluation of acceptability to users.
6. Service functioning for an extended period in the prototype environment
7. Follow-up studies to demonstrate the system's large-scale usefulness.
8. Program changes to allow wide distribution of the system.
9. General release and distribution with firm plans for maintenance and updating.

From the above steps it could be seen that the evaluation process is a continual one, that begins at the time of system design and extends in an informal fashion throughout the various stages of the development of the system even after it has been released to the users.

Basically there are two main specific areas where the evaluation of the Performance Measures EDSS was conducted, namely the evaluation of the software and the validation of the performance measures that were selected for specific manufacturing business organisations. The following section 6.4.1 describes the main programme of the expert system software while section 6.5 discusses the validation aspects.

Generally the main body of the software consists of six modules, which are one for the MainRuleSet and five modules of subset rules called RuleSet. This is the final version of the software after going through a series of evaluation of its
general structure. The modular form of the software structure is considered to be the most appropriate.

### 6.4.1 Main Rule Headings of EDSS

The following is the main rule heading of the EDSS.

/* A KNOWLEDGE BASED EXPERT DECISION SUPPORT
/* SYSTEM FOR THE SELECTION OF OVERALL STRATEGIC
/* MANUFACTURING BUSINESS PERFORMANCE MEASURES

### 6.4.2 Main RuleSet

The following is the Main RuleSet of the EDSS. It consists of three rules.

Rule 1
Seek Performance_Measures

Rule 2
IF  Business_Type is known
    and Business_Nature is known
    and Business_Organisation is known
    and Business_Phase is known
    and Business_Niche is known
THEN Recommendation 1 is done

Rule 3
IF Recommendation 1 is done
THEN
    Find_Performance Measures is finished
    and Performance_Measures is completed

End of text
6.4.3 Object Frame

The following Figure 6.22 is a typical Leonardo object frame representation. It consists of a list of slots which define the object. The example used here is the object called 'business_nature'. 'Name' is the first slot in the frame. The name of the object is busi_nat a short form for business nature. The name of the object can be any length, but Leonardo will only use the first 24 characters for display.

The second slot is the 'long name'. The long name has no restrictions whatever. It is a synonym for the object, and will be used by Leonardo whenever the object is referenced in a Leonardo output.

The third slot used in this development is the 'type' slot. Type can be either real, text, list, procedure, class, slot referent or screen. The type is set by the Leonardo rule checker from the context in which the object is referenced. In this case, the type for the busi_nat is 'text', as shown in the example below.

The fourth slot used is the allowed value slot. The allowed values for the business nature are infant, pioneer, rational, mature, established, wilderness, dying and transforming. These are the life-stages of the manufacturing business organisation as given by the life-cycle curve in Chapter Four.

Other slot used are the query prompt and query preface which appears on the screen when user is using the software. The query prompt and preface are used to give instruction as well as to provide details of information required from the user.

The final slot used is the ruleset slot. Section 6.4.4 explains the details of a ruleset slot.
<table>
<thead>
<tr>
<th>No.</th>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Name</td>
<td>busi_nat</td>
</tr>
<tr>
<td>2</td>
<td>Long Name</td>
<td>business nature</td>
</tr>
<tr>
<td>3</td>
<td>Type</td>
<td>text</td>
</tr>
<tr>
<td>4</td>
<td>AllowedValue</td>
<td>infant, pioneer, rational, mature, established, wilderness, dying, transforming</td>
</tr>
<tr>
<td>5</td>
<td>Query Prompt</td>
<td>indicate the nature of your business organisation.</td>
</tr>
<tr>
<td>6</td>
<td>Query Preface</td>
<td>Please choose the nature of your organisation. Use the cursor key to point at the selected option.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Options are:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cate 1 = Infant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cate 2 = Pioneer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cate 3 = Rational</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cate 4 = Mature</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cate 5 = Established</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cate 6 = Wilderness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cate 7 = Transforming</td>
</tr>
</tbody>
</table>

**Figure 6.22** A Typical Leonardo Object Frame Representation.

### 6.4.4 RuleSet

A RuleSet is a subset of rules that is used to determine the value of an object, the value of which is required by a rule elsewhere in the KB. The RuleSet is placed within the object frame and is executed when the value of the object is sought. The following section describe the example of a part of each of the rulesets that are used in the EDSS.
6.4.4.1 - RuleSet 1 - Example for business_type

IF busi_turnover < £2.5M
    and busi_employee < 50
    and busi_sale < £1M

THEN
    business_type is Small_Scale_Industry
    and performance measures are ' 1 - Operating Cash Flow
    and performance measures are ' 2 - Gross Margin
    and performance measures are ' 3 - Profit After Interest
    and performance measures are ' 4 - Turnover
    and business_type is known

IF busi_turnover > £2.5M < £10M
    and busi_employee >50 < 500
    and busi_sale > £1M < £10M

THEN
    business_type is Medium_Scale_Industry
    and performance measures are ' 1 - Earning per share
    and performance measures are ' 2 - Operating cash flow
    and performance measures are ' 3 - Profit after tax
    and performance measures are ' 4 - Operating profit
    and business_type is known
6.4.4.2 - RuleSet 2 - Examples for business_nature/ Life-Cycle Model

IF busi_nature = cate 1
THEN
  business_nature is infant
  and performance measures are '1 - Leadership
  and performance measures are '2 - Innovation
  and performance measures are '3 - Marketing
  and performance measures are '4 - R & D
  and business_nature is known

IF busi_nature = cate 2
THEN
  business_nature is pioneer
  and performance measures are '1 - Personnel
  and performance measures are '2 - Cost of quality
  and performance measures are '3 - Sales
  and performance measures are '4 - Product flexibility
  and business_nature is known

6.4.4.3 - RuleSet 3 - Example for business organisation/ Adaptational Model

IF busi_organisation = cate 11
THEN
  business_organisation is defender
  and performance measures are '1 - Market share
  and performance measures are '2 - On-time delivery
  and performance measures are '3 - Production efficiency
  and performance measures are '4 - Planning capability
  and business_organisation is known
IF busi\_organ = cate 12

THEN

  business\_organisation is prospector
  and performance measures are '1 - Return on investment
  and performance measures are '2 - Cost of quality
  and performance measures are '3 - Profitability
  and performance measures are '4 - Sales
  and business\_organisation is known

6.4.4.4 - RuleSet 4 - Example for business phase/ Phase Requirement Model

IF busi\_pha = cate 21

THEN

  business\_phase is efficient
  and performance measures are '1 - Inventory turnover
  and performance measures are '2 - Process productivity
  and performance measures are '3 - Work efficiency
  and performance measures are '4 - Total earning
  and business\_phase is known

IF busi\_pha = cate 22

THEN

  business\_phase is quality
  and performance measures are '1 - Customer satisfaction
  and performance measures are '2 - Vendor quality
  and performance measures are '3 - Training
  and performance measures are '4 - Cost of quality
  and business\_phase is known

163  ...results \& evaluation
6.4.4.5 - RuleSet 5 - Example for business niche/Competitive Model

IF busi_niche = cate 31

THEN

business_niche is quality
and performance measures are '1 - Cost of quality
and performance measures are '2 - Warranty failures
and performance measures are '3 - Process quality
and performance measures are '4 - Incoming quality
and business_niche is known

IF busi_niche = cate 32

THEN

business_niche is price
and performance measures are '1 - Unit product cost
and performance measures are '2 - Budgeting
and performance measures are '3 - Productivity
and performance measures are '4 - Minimising waste
and business_niche is known

When the software is run, the five rulesets will identify the type of business (business-type model), the business organisational adaptation (adaptation model), the business competitive stance (niche), the business phase (phase model) and the business nature (life-cycle model). When all identification is known (as shown in the MainRule Set), the EDSS will recommend a set of 20 strategic performance measures suitable for the specific type of manufacturing business organisation.

The evaluation made on the software at its current stage of the development is by no means complete. As further knowledge on the characteristics and behaviours of the business organisations is gathered, the structure of the software would be further altered to accommodate new information.
6.5 Validation Process

The purpose of validation is to test the quality of output from the system, in terms of how well it meets the desired recommendation and to establish that the system has an acceptable level of confidence.

The validation process for the EDSS falls into two broad categories, namely, the formal validation and the informal validation processes. Informal validation, is a long term iterative feed-back process between the targeted user, the knowledge engineer and the sources of expert knowledge. Formal validation is a planned validation and begins once a prototype which is thought to meet design objectives, has been developed. Generally, as discussed by Green and Keyes [5], there is still no acceptable methodology for conducting validation studies. Each individual system tends to require a unique method of validation. The validity of a system depends on the validity criteria considered for the system. Certain systems would have the cost and benefit of implementing the system as the major validity criteria while others would not. Keen [6] reported that traditional cost-benefit criteria is not well-suited for the validity of a DSS. He cited that the benefits provided by a DSS are often qualitative, examples of which are the ability to examine more alternatives, stimulation of new ideas, and improved communication of analysis. Gaschnig [7] and Buchanan & Shortliffe [8] have treated the validation issues at a general level.

Research on methods for knowledge based validation has also been pursued by those attempting to automate the validation process. Early work in this field is reviewed by Nguyen [9]. He reported on a programme that can examine rules for syntactical error, such as mis-spelled names, identify sets of rules that are in conflict or redundant and a search for potential rules that may have been overlooked and suggest them to the expert. Effort to automate the generation of test cases for use in validation are also reported by Shore, Tu and Fagan [10].
The validity of the system developed in this research depends on the validity of the theoretical models which form the backbone of the system. Therefore validation exercises were first conducted to test the validity of the theoretical models, before validation of the output recommended performance measures was carried out.

The two validation exercises which were carried out in this research are as follows,

(1) checking the theoretical performance measures with the actual performance measures used by business organisation in the field.

(2) testing the 'correctness' of the recommended performance measures by comparing it with the theoretical performance measures.

6.5.1 - Results of validation exercises

The first validation exercise was conducted on 28 business organisations to test the theoretical performance measures with the actual performance measures used by business organisations in the field. The results of the exercise are shown in Figure 6.13, Figure 6.15, and Figure 6.17 above. It can be seen from the three theoretical models which were used that there are some differences between the theoretical performance measures compared to the observed performance measures. However, the performance measures for the life-cycle model seem to correspond reasonably well between the theoretical and observed performance measures. The full discussion of the results are given in the following chapter.

The second validation exercise is an on going activity which is being conducted to check that the recommended performance measures tally with those of the theoretical performance measures. This is done by inputting different set data obtained from manufacturing business organisation profile provided by FAME.
The EDSS described herein is a prototype which is not yet intended for practical application. More work to improve the EDSS seems to be warranted, especially in identifying more detailed characteristics and the behaviour of each module in the system.

REFERENCES


CHAPTER SEVEN

DISCUSSIONS AND CONCLUSIONS
CHAPTER SEVEN

DISCUSSIONS AND CONCLUSIONS

This chapter discusses the main research findings and outlines the main results of the survey conducted. The limitations and shortcomings of the prototype EDSS developed is discussed and the conclusions on the research presented.

7.1 Discussions

As stated earlier, the main objectives of this research are the creation of a methodology and an expert decision support system capable of selecting overall strategic performance measures for manufacturing business organisations within a developing country at any stage of their life-cycle. To arrive at the main objectives the researcher has undertaken a comprehensive study on the global problem of strategic performance measures; has investigated the situation of performance measurement in an industrially developing country; has comprehended the factors affecting performance measurement analysis, and has learned the concept and techniques of designing an expert decision support system. The following sections discuss the main research findings and the limitations and shortcomings of the prototype EDSS developed.

7.1.1 Main Research Results

The following are the main research findings,

(1) Methodology to assemble and recommend overall strategic performance measures using expert decision support system.

This study has presented a methodology to assemble the overall strategic organisational performance measures which are considered as relevant and
able to contribute towards a sustainable period of success for specific types of manufacturing business organisation. Using an expert system shell, an EDSS has been developed where the overall strategic measures were written in the form of production rules and stored in the knowledge base of the system. The system can output recommendations of appropriate overall strategic manufacturing performance measures suited to a business organisation, based on the input of information regarding the existing status and characteristics of that organisation.

(2) Findings and lessons from literature

Throughout the literature survey in Chapter Two, it is evident that performance measures can be used as a management tool to influence the behaviour of the manufacturing business organisation. There appears to be widespread agreement that strategies are realised through consistency of decision making and action. The manufacturing management literature revealed that performance measurement is the key to generating consistency of decision making and action. However, regardless of the voluminous literature, research on developing effective strategic performance measures for manufacturing organisations is still at an embryonic stage.

The literature also revealed that even though the discovery of the important role of performance measures in management was decades ago, it was not until recently that serious studies were undertaken to investigate the real practical benefit of performance measurement. The impetus for the investigation sprang from the realisation and discovery that traditional means of measuring performance were no longer effective. Successful manufacturing business organisations especially those with Japanese connections have revised or abandoned some of the outdated manufacturing performance measures. Most of the successful companies institutionalised a process of continuously changing performance measures in place of the old performance measurement system. From the literature it also appears that most investigation began in the United States of America where notable researchers such as Maskell [1], Kaplan [2], Porter [3], Dixon [4], Nanni [5] and Vollmann [6], and many more spearheaded the work. It was their work which provided part of the motivation and the foundation for this research. The other part of the motivation is to be able to help Malaysian manufacturing business organisations select appropriate strategic performance measures and to put performance measures to good use in their
progress towards the year 2020 when it is visioned Malaysia will be a developed nation.

(3) Using theoretical models for developing overall strategic measures.

This research has considered and suggested the use of five theoretical models to derive the overall strategic performance measures of which at least three models are already universally tested and accepted. The three are the life-cycle or s-curve model, the competitive model, and the organisation adaptational model. A further two models are the business type model developed by Whitting [7] and the phase requirement model developed by Bolwijn and Kumpe [8]. The author also felt that the competitive model by Porter which has been tested world wide and used universally does not warrant further validity test but could be wholly accepted as part of the EDSS module. Similarly for the business type model developed by Whitting (who researched UK business organisations), the author has decided to accept the recommended performance measures from the model and use it as part of the EDSS module.

The discussion on the theoretical models which were tested in 28 manufacturing business organisation in United Kingdom follows.

(4) The Life-Cycle/S-Curve Model

The data shown in Figure 6.14 on the distribution of business organisation age indicated that 78.6% of the business organisations involved are aged between 20 to 200 years old (46.4% aged between 20 to 50, 17.9% aged between 50 to 100 and 14.3% aged between 100 to 200 years old). Only 6 or 21.4% of the business organisations were aged between 1 to 20 years. It is expected therefore that most business organisations involved in the study would have already moved out of the earlier stages of the life-cycle.

Figure 6.15 and Figure 6.16 illustrate the results on the life-cycle model. It shows that 24 out of 28 or 85.8% of the manufacturing business organisations involved in the study are either in the established or transforming stage, (57.2% established and 28.6% transforming). This confirmed the above expectation that the respondent business organisations had undergone the early stages of the life-
cycle and would be in a position to provide the necessary knowledge on performance measures of the early stages. The author judged that even though the respondents (who are established and transforming) provided knowledge on performance measures for the other stages, that information is also useful even though it may be unlikely to be as accurate as the performance measures of the respondent's own life-stage. The information provided could still be useful in comparing the theoretical values with the observed values. The results of the observed values can be seen to be more specific when compared to the theoretical values which are more general in form.

As an example from the established stage, the theoretical value is 'financial measures' while the observed value is 'operating profit'. The observed value confirmed the theoretical value in providing a more specific form of performance measure. It is also observed that this seems to occur on all the other models as well.

(5) The Organisational Adaptation Model

Figure 6.12 and Figure 6.13 illustrate the results for the organisational adaptation model. It shows that 17 out of 28 or 60.7% of the manufacturing business organisations are either defender or analyser only (46.4% defenders and 14.3% analyser), while there are 3 prospectors only which account for 10.7%. None claim to be solely reactor. Only 1 organisation was a combination of analyser and reactor.

Similar to the life-cycle model which had a concentration of established and transforming stage type of business organisation, there is also a concentration of two types of business organisation in the organisational adaptation model. These are defender and analyser types of business organisation. In the case of this model, the questionnaire was designed in such a way that the respondents only provided information on the performance measures of their own organisational adaptation.

It is therefore safe to suggest that the observed values represent real experience of adaptation.

(6) The Phase Requirement Model.

Figure 6.17 and Figure 6.18 illustrate the results for the phase requirement model. It shows that 20 out of 28 or 71.5% of the manufacturing
business organisations involved are either in the quality phase or the flexible phase
(42.9% quality and flexible 28.6%). The situation in this model is similar to that of the
life-cycle model in which there is a concentration of two categories of business
organisation in this case 'quality' and 'flexible' phases. The observed values of the two
categories seem to conform with the theoretical values. Similarly with the other two
categories which are 'efficient' and 'innovative' phases, the observed values seem to
conform to the theoretical values.

7.1.2 Limitations of the EDSS

The following are the limitations and shortcomings of the prototype EDSS.

(1) Limitation of EDSS role

The prototype EDSS is limited to the role of recommending overall strategic performance measures for manufacturing business organisations within an industrially developing country. It was not designed to replace a human advisor. Like all DSS, its main objective is to assist human decision makers.

(2) Limited to existing theoretical models

The recommended overall strategic performance measures are limited to four measures for each theoretical model. Since there are five theoretical models, the number of recommended measures for each manufacturing business organisation would be twenty. Unless more models are introduced into the EDSS, the measures generated would only be limited to the existing five theoretical models.

(3) Limitation of the knowledge base

The knowledge that has been gathered and the rules that have been written in the EDSS knowledge base are currently adequate to recommend a minimum set of overall strategic performance measures for specific manufacturing business organisations, but by no means are sufficient to guarantee definite success for that manufacturing business organisation. All of the current knowledge elicitation for
the EDSS are derived from documented material written by experts in the organisational management and performance measurement fields. Further sourcing of expert knowledge is required before a totally viable EDSS is released to the users.

(4) Implementation problems

The successful implementation of the EDSS depends on many factors, namely, social, psychological, organisational, technical, economic, and environmental factors. Looking at the factor it is obvious that there is still a tremendous amount of work to be addressed. Further detailed studies have to be carried out in the areas mentioned above before the EDSS could be fully commissioned for actual commercial operation.

The definition of implementation of EDSS is complicated because of the iterative nature of their development. However, Dickson and Power [9] suggest four independent success criteria, which could be looked into as a measure of successful implementation in future work to be carried out. The success criteria are as follows,

- Ratio of actual project execution time to the estimated time
- Ratio of actual cost to develop the project to the budgeted cost for the project.
- User satisfaction; managerial attitudes towards the system and how well their information needs are satisfied.
- The impact of the project on the computer operation of the system.

7.2 Conclusions

(1) This thesis establishes a methodology to assemble and recommend overall strategic performance measures based on five conceptual models. These models are the life-cycle model, the competitive model, the organisational adaptation model, the phase requirement model and the business type model.
(2) The research has identified the performance measures appropriate to points on the life cycle of a business, and has related these to the five models which have been incorporated within the designed methodology for selection of performance measures.

(3) This thesis also establishes that an expert decision support system for the selection of overall strategic performance measures could be developed using expert system technology.

(4) The research can be considered successful and has achieved the stated objectives. A methodology and a prototype expert decision support system has been developed, capable of selecting and recommending overall strategic performance measures for manufacturing business organisations.

REFERENCES


CHAPTER EIGHT

RECOMMENDATIONS FOR FUTURE WORK
CHAPTER EIGHT

RECOMMENDATIONS FOR FUTURE WORK

This chapter offers some thoughts on the possible directions in which future research in this area might be pursued.

8.1 Recommendation For Future Work

Performance measurement is a research topic that spans many disciplines. There are areas that could not adequately be explained by models drawn from a single discipline and based on the experience of a single organisation. It involves manufacturing engineering and management, management accounting, business studies, economics and even computer and political sciences. This research has attempted to use several conceptual models which have been proven and accepted universally to derive the overall strategic performance measures for manufacturing business organisation. Even so there are still areas where further work could be investigated to enhance the performance of the system developed. The following are the possible recommendations which future work in the research area could be pursued.

8.1.1 Room for expansion of the system

The system can be further enhanced by providing explanations of the theoretical models, provide examples and tutorials, cases, and analogies that describe the application of models in familiar settings. Most
8.1.2 Case studies of individual and groups of business

Further empirical research by way of case studies on specific or groups of successful business organisations would strengthened the theoretical approach of this research. Some businesses which need to be studied are those which have transformed themselves from poor performers to sit among the industry leaders. Examples of specific industry which are currently predominant in industrially developing nations, specifically Malaysia are sheet metal, electronic, footwear, plastic, textiles, and local raw material industry such as rubber or oil palm.

8.1.3 Detailed investigation for each stage of organisational development.

Further detailed study for each stage of the evolution of the business organisation would be a useful extension of this research. For example a business organisation could fail or die at any stage of the development. It is not uncommon to find business organisations dying or failing in the first few years of their life. Business organisations which are able to turnaround and transform into successful enterprises would be worthy of investigation, so as to further elicit knowledge of the organisational behaviour and characteristics in such circumstances.

8.1.4 Expansion of the EDSS knowledge base

The work on expanding the EDSS knowledge base should be continuous. Apart from enlarging the knowledge base it is also vital that changes that occur in and around the manufacturing business world must be monitored. New knowledge is discovered almost daily and old
knowledge discarded. For the EDSS to be a useful tool the system must always be renewed and updated. Research into the area of managing change in the knowledge base coupled with the latest advances in computer technology and advanced knowledge management tools would further improved the EDSS.

8.1.5 Expansion to include other levels of performance measures

The current system only deals with overall strategic performance measures. Research can be further expanded to include total measures from the top to lower levels of the manufacturing business organisation. Figure 2.5 illustrates the various levels from top management to units, plants and cells. Performance measures in the administrative department and the operational areas could also be involved.

8.1.6 Integration of the EDSS with other ES

Currently the EDSS developed utilises an expert system shell to run the whole system. Future work could look into the possibility of integrating other expert systems into the EDSS. For example a special expert system could be interfaced with the user interface of the EDSS to solve the problem of initial identification of the manufacturing business organisations before going into the selection of performance measures.
CHAPTER NINE

SUMMARY

This chapter outlines the research contributions towards the management of manufacturing business organisation in industrially developing country and summarises the material presented in the thesis. It then presents the concluding remarks.

9.1 Research Contributions.

The following section explains the research contributions towards the management of manufacturing business organisation in an industrially developing country.

9.1.1 Short term contribution

In the short term, the EDSS developed could be used as a teaching aid in the higher learning institutions. The various conceptual models contain in the EDSS need to be exposed to potential industrial managers in colleges and universities. It could also be used as a learning tool in training and workshops to educate the managers in manufacturing business organisations. As mentioned earlier, some of the conceptual models are relatively new to the managers of manufacturing business organisations in an industrially developing country.

The EDSS will also act as a mean of gathering and storing knowledge in the field of performance measurement.

9.1.2 Long term contribution

In the long term the EDSS will provide a conceptual framework or model and guidelines for managers in industrially developing countries to better
manage their manufacturing business organisation and enabling them to decide their priorities in a more systematic and scientific way. The EDSS will also provide them with a better appreciation of the underlying relationships that influence a manufacturing business organisation performance. The usefulness of performance measures in terms of overall organisational improvement will also be appreciated.

The purpose of this research is not so much as to offer ready-made solutions, but more towards creating an awareness among the manufacturing business managers in the industrially developing countries of the existence of various organisational models which were developed and deployed through the years of experience of manufacturing business organisation of the developed nations, and from the complementary best new ideas and practices of successful business ventures.

The benefits all arise from using the EDSS is to improve the managers understanding and appreciation of what is happening, both within the organisation and in the external environment. It will also improve the quality of their strategic decision making and ultimately their business organisation performance.

Long term value of performance measurement tools such as the EDSS will also be dependent on the ability of manufacturing business management to continuously improve and embed information and intelligence technology in the organisation and enhance their use.

9.2 Summary

The research traces the evolution of manufacturing business organisation and investigates the function and utilisation of performance measures associated with it. A comprehensive review of the literature on the historical development of manufacturing performance measures and the evolution of market requirements was reported in chapter two. The review showed the complexity of the subject, presented the current trend in performance measurement systems and also reported the recent appreciation of industrialist and academician of the real potential of performance measurement towards improvement of business organisation performance.
Chapter 9

The development of an expert decision support system using expert system technology, provided a reasonable means of overcoming the complex task of selecting performance measures to suit a given manufacturing business organisation. Chapter five highlights the complexity of the performance measures selection process and explains the justification of the development of the EDSS.

The research has attempted to deal with the complex issue of performance measurement by using five conceptual models. These are the life-cycle, the adaptation, the competitive, the phase and business-type models. Reducing a complex issue to conceptual model will provide a start and general focus and guideline to solve the main problem. A large part of the complexity derives from the difficulty of adequately defining the nature and types of the manufacturing business organisation and assigning performance measures that fit it. The models which have been incorporated into the methodology developed in this research identify the characteristic of a business and how they change with time during the evolution of the business. However these models do not indicate the most effective measures to be used for the efficient control of a business at each stage of development or according to its characteristics. The results of this research, through the literature survey and questionnaire methodology, have identified the appropriate performance measures congruent with the stages of each model. The conceptual models are judged by the author to provide a solution to overcome the problem.

Apart from that, there are also the problem of various levels of performance measurements in a manufacturing business organisation. Each manufacturing business organisation may have a total of up to 50 or more performance measures but each level normally may only use 4 or 5 measures. Choosing the most suitable 4 or 5 measures to fit the level is also a big problem. To further reduce this complexity, the study in this research has concentrated only on the overall strategic performance measures which covers the top level measures. The detailed development of the theoretical framework is given in chapter four.

The adopted research methodology and procedure was discussed in chapter three. The major research instrument were three sets of survey questionnaires which were used to obtain information regarding manufacturing business organisation performance measurement practices and to compare them with the theoretical performance measures derived from the conceptual models. As discussed in chapter
six the results have provided a reasonable basis for adopting the methodology used in this research as a methodology for selecting overall strategic performance measures. Even though statistical confidence was not used, the results of the observed measures could still be used to compare with the theoretical performance measures. Further research in this area could involve the use of chi-square tests and using greater samples to compare the observed and the theoretical measures.

Finally the research recommended six areas for future work which includes the expansion of the system both in term of knowledge-base, integration with other expert systems and other levels of performance measures. This was described in chapter seven. Further in depth study for each stage of the life-cycle of the business organisation would also be a useful extension of this research. More case studies of individual and groups of businesses would strengthened the theoretical approach of this research.

9.3 Concluding Remarks

The main rationale for forwarding this EDSS to the industrially developing nation is the need for the business managers to be aware of the changes in the evolution of manufacturing business organisation and the need to be able to handle the change. Manufacturing business organisation could continue with its traditional activities and success would come from doing more of the same thing rather than doing different things. The stimulus for change is very important. Presenting the kind of models as contain in the EDSS, would initiate learning and would stimulate them to adopt new techniques and concepts.

In the past, information has often been seen as the domain of specialists. Accountants own the financial data, engineers the manufacturing data, market analyst the marketing data. While it is important to retain the concept of ownership and accountability, it is also important to build a vision of an organisation in which information and knowledge wherever it is located, is used for the benefit of the business organisation as a whole.

Systems such as EDSS can play a major role in breaking down the above paradigm, by providing managers and business professionals with ready access
to a wider range of cross-functional data. The EDSS have also been targeted at business professionals such as analyst and planners beside manufacturing managers because it provides specialist modelling and other tools to aid the interpretation and analysis of corporate information.

The concepts described in this research are not intellectually demanding. However the problem arises in applying them to an evolving situation where there are a number of conflicting interests to be reconciled. There are no simple methods for reconciling these differences. In the final analysis reconciliation must be based upon judgement, but informed judgement founded on a systematic analysis of all the influence that bear upon the future development of the manufacturing business organisation. Each conceptual model represents certain understanding and influence. Combination of the models allows managers to be aware of the difference types of influence and their interactions.

A successful architecture should create a framework of definitions and common standards which ensures that the 'top-down' business view of the organisation is reflected in a set of data definitions, down to the level of individual transactions, which are consistent across the whole enterprise. Penny [1] of Metapraxis have said the following,

' We have found that if you ask ten managers to name the top five strategic priorities of their companies, you may, in fact, get ten different answers '

The desire to overcome such an occurrence in a business organisation is one of the reason that the EDSS was developed. With the availability of EDSS, consistency of strategic performance measures throughout a business organisation could at least reasonably be guaranteed.

REFERENCE


Nayudamma, Y. - 'Factors Which Hinder or Help Productivity Improvement in The Asian Region' - Asian Productivity Organisation, Tokyo, Japan, 1980.


APPENDICES
The Framework of PMFS and ALCOA


4.2. Performance measurement and feedback scheme PMFS (General Motors):
A framework to relate performance to objectives and across activities and levels

At General Motors (GM), there has been a concerted effort to design a new performance measurement and feedback system (PMFS), which would provide a framework to link strategy to actions more effectively. The design phase of the system identified 62 measures which could be consistently applied at various organisation levels:
- to strengthen strategic business management process.
- to clarify management direction, and
- to improve organisational response.

Figure 3 shows the framework adopted and differentiates clearly between results measures and process measures. The approach puts operations firmly within the overall business context and uses a process model shown in Fig. 4.

For operations, the key management questions are identified as:
- How do we know the process is capable of building products to a target, and continuously reducing variability around the target?
- How do we know the process is capable of meeting delivery requirements?
- How do we know the process is capable of minimising the resources required.

Fig 3. Adopted framework.
An important aim of the GM approach has been to specify measures for each level of the organisation. This was seen as an important requirement in a complex organisation where comparability between diverse activities is needed as well as consistency between the internal and external measures relating to the activity itself. The breakdown of measures is given in Table 8.

Guidance is also given on the proper relationship between objectives (what), strategies (how), and goals (how much) – a simple, but often neglected hierarchy!

Table 8
Number of PMFS measures at each organizational level

<table>
<thead>
<tr>
<th>Organisational level</th>
<th>PMFS frame</th>
<th>Corporate</th>
<th>Group</th>
<th>Division/SBU</th>
<th>Plant/field</th>
<th>Department/cell</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>People development</td>
<td>3</td>
<td>6</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>employee satisfaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Product initiation</td>
<td>4</td>
<td>4</td>
<td>12</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Operations</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Marketing/sales and service</td>
<td>6</td>
<td>8</td>
<td>9</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Retail customer satisfaction</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shareholder satisfaction</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>26</td>
<td>32</td>
<td>52</td>
<td>45</td>
<td>30</td>
</tr>
</tbody>
</table>

Source: General Motors
43. Performance measurement in the context of strategy formulation (ALCOA): An approach for linking physical to strategic performance

An excellent example of the integration of performance measurement into strategic planning from the “bottom-up” is provided by ALCOA [10]. Although, essentially an approach to strategy formulation, the company takes the view that in many cases real progress can be made by building on existing expertise and knowledge, but that often the level of understanding of current operations is very poor.

The approach, therefore, begins with extensive data collection on current activities, and the development of a “systems model” by a multi-disciplinary team. Wherever possible, information is presented graphically and the team constantly seeks fundamental influences rather than aggregate measures. As well as time-series data, information on specific events, conditions and relationships, are also seen as valuable. Attention is paid to the physical, as well as organisational processes. The search is then extended to embrace technical forecasts for the key core technologies, competitor benchmarks, and importantly, the physical limits of the process. In this way, the team can plot a forward performance objective which is not limited by current internal or competitor performance, and has the opportunity to exploit future development swiftly and integrally. The original construction of the “systems model” of the current operation allows the strategic and quantitative significance of the potential developments to be assessed (Fig. 5).
An Example of Balanced Scorecard Approach


The "balanced scorecard" approach [1] is the most recent attempt to provide a framework for strategic and operational as well as financial measures. The approach is based on an intensive and practical research programme involving 12 major companies. The framework developed seeks to reconcile a number of the performance measurement perspectives set out at the beginning of this paper. Fig. 6 provides an example.

- The customer perspective captures customer expectation. Users found that the discipline of identifying both goals and measures forced them to understand precisely what a range of customers meant by "on-time delivery", so that differences of perception and expectation, for example, could be resolved.
- The internal measures required managers to establish explicitly those internal activities.

### ECI's Balanced Business Scorecard

#### Financial Perspective

<table>
<thead>
<tr>
<th>Goals</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survive</td>
<td>Cash flow</td>
</tr>
<tr>
<td>Succeed</td>
<td>Quarterly sales growth and operating income by division</td>
</tr>
<tr>
<td>Prosper</td>
<td>Increased market share and ROE</td>
</tr>
</tbody>
</table>

#### Customer Perspective

<table>
<thead>
<tr>
<th>Goals</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>New products</td>
<td>Percent of sales from new products</td>
</tr>
<tr>
<td></td>
<td>Percent of sales from proprietary products</td>
</tr>
<tr>
<td>Responsive supply</td>
<td>On-time delivery (defined by customer)</td>
</tr>
<tr>
<td>Preferred supplier</td>
<td>Share of key accounts' purchases</td>
</tr>
<tr>
<td>Customer partnership</td>
<td>Number of cooperative engineering efforts</td>
</tr>
</tbody>
</table>

#### Internal Business Perspective

<table>
<thead>
<tr>
<th>Goals</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology capability</td>
<td>Manufacturing geometry vs competition</td>
</tr>
<tr>
<td>Manufacturing excellence</td>
<td>Cycle time</td>
</tr>
<tr>
<td>Design productivity</td>
<td>Unit cost</td>
</tr>
<tr>
<td>New product introduction</td>
<td>Yield</td>
</tr>
<tr>
<td></td>
<td>Silicon efficiency</td>
</tr>
<tr>
<td></td>
<td>Engineering efficiency</td>
</tr>
<tr>
<td></td>
<td>Actual introduction schedule vs plan</td>
</tr>
</tbody>
</table>

#### Innovation and Learning Perspective

<table>
<thead>
<tr>
<th>Goals</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology leadership</td>
<td>Time to develop next generation</td>
</tr>
<tr>
<td>Manufacturing learning</td>
<td>Process time to maturity</td>
</tr>
<tr>
<td>Product focus</td>
<td>Percent of products that equal 80% sales</td>
</tr>
<tr>
<td>Time to market</td>
<td>New product introduction vs competition</td>
</tr>
</tbody>
</table>

Fig. 6. Example of balanced business scorecard approach.
which most closely influence external performance. A key issue here is the importance of on-line information systems to ensure timely provision of data for decision making.

- **Innovation and learning** measures are introduced to ensure that the business is not always reactive, but is constantly developing key strengths and ensuring that the organisation learns from, and build on, its experience. The requirement for continuous improvement is, therefore, embodied in the approach.

- Finally, the financial perspective reflects the demands of financial stakeholders. It highlights the requirement to maintain a sound financial position. Success on the other performance dimensions will not be sufficient if it does not lead to improved financial performance. The benefits of improved operating efficiency, for example, may only be fully realised if the released capacity is used to sell more product profitably.

This approach to the integration of performance measures should be seen as a framework rather than a process or a system to prescribe detailed measures, as in the GM case. However, it does not provide perhaps the most comprehensive, if high level, attempt to reconcile the key dimensions of performance measurement.
Review On LEONARDO Expert System Shell

Leonardo

Leonardo is an expert system development tool supplied by Creative Logic Ltd. The system runs on IBM XT or AT personal computers or close compatibles. Leonardo is available in three levels, each incorporating additional facilities. Level 1 costs £149, level 2 costs £995 and level 3 costs £1,995. A VAX version is also on sale at between £3,000 and £12,000, depending on machine configuration. Creative Logic Ltd. can be seen at Brunel Science Park, Kingston Lane, Uxbridge, Middlesex UB8 3PQ (BS4496). (The version reviewed in this article was release 3.00, level 3, for the PC, run on a Tandon PCX with 640K bytes RAM, a 20-megabyte hard disc and a monochrome monitor.)

Introduction

Expert Systems Shells are difficult products to review. When I sat down to get to grips with Leonardo I decided, after a skim through the manual and a run of some of the tutorial knowledge bases, to put in some knowledge of my own as a demonstration test case. I was forced to the conclusion that I don’t really have any knowledge.

This was disconcerting, but not far off the mark. After pondering for a while, I realised that I had merely re-discovered the first two rules of knowledge engineering.

Rule: ‘Scylla’
If the knowledge is easy_to_formalise then the application is trivial

Rule: ‘Charybdis’
If the knowledge is interesting then the knowledge is hard to formalise

which I have encased above in the Leonardo syntax. (You could call these two rules ‘meta-knowledge’ if you like.)

So I would ask the reader’s pardon if the short extracts quoted in the rest of this article seem like the sort of thing that could be knocked together in a dozen or so lines of Basic. This should not be taken to imply that Leonardo cannot support genuinely knowledge-intensive applications.

Product overview

Leonardo arrives in a smart blue box. The software is distributed on the two 360K floppy discs (or three if you buy one of the option modules, such as business graphics or the database interface). The manual is well organised and well written, but suffers from two defects. Firstly it is printed on loose leaves, for insertion into a 3-ring binder. In my experience, the metal rings on this kind of binder are usually slightly bent, and Leonardo’s was no exception. This makes frequent reference to the manual rather irritating, especially since there were somewhat too many pages to fit in comfortably. Secondly the manual has an addendum and some other extra sections detailing new features. Thus, if you cannot find what you are looking for in the printed manual, you still have to search the additional pages, in case it is there. (The addenda are not indexed.) This practice is so widespread as to be almost a de facto industry standard, but it is still one of my personal gripes.

The software requires at least 512k bytes of RAM to execute and also needs about 2 megabytes of free hard-disc space. Installation is very easy, though a bit slow; on my XT-class machine it took almost fifteen minutes.

The package supports forward and backward chaining and (in level 3) the use of certainty factors or Bayesian likelihoods for approximate reasoning. It has a straightforward rule syntax, which can be supplemented, where necessary, by the use of a built-in procedural programming language. I was unable to crash the system in three days’ usage, and formed the overall impression that Leonardo is a robust piece of software.

The base language is Fortran-77, which means that the system is very portable. Thus the VAX and PC versions are claimed to be functionally identical. (Of course, the user need not know any Fortran to use the system.)

One of the distinctive features of Leonardo is that it comes in three levels, each one including more facilities than the one before. Level 1 is the basic system: it allows applications containing up to 1000 lines of rule text (say 250 rules). It has all the facilities of the full system except uncertainty management and inheritance-based object frames. Level 2 removes any restriction on the size of a rulebase, as well as adding a frame-based representation for background knowledge using structured objects with property inheritance. Level 3 adds uncertainty management.
This three-way split is essentially a marketing play, but it has two valuable side-effects: 1. You can buy level 1 to see if you like the system without wasting a large sum of money; 2. You can progress in a pedagogically sound manner from beginner to expert. It actually encourages you not to try running before you can walk.

Rule language

An example Leonardo rule is given below.

if basicdata is known
and ability is high
and effort is average
then say 'Deserves ten percent."
raise = 10;
percent is done

The basic condition-action format (demarcated by IF and THEN) is familiar by now and simple to grasp. Conditions are formed from one or more assertions linked by ANDs and/or ORs. An assertion can be a numeric comparison, e.g.

temperature_reading < 30
or a test-equality test, e.g.
'test lamp status' is 'red alert'
or a set inclusion test, e.g.
favourite_subjects include computing

After the keyword THEN may come one or more conclusions. If more than one is present, they should be separated by semicolons. The keyword SAY, above, is a special conclusion that causes output on the screen. More commonly, conclusions assign values to objects.

One object is designated the goal of the rulebase: establishing its value will be the aim of the consultation. The goal object is defined with a SEEK directive, such as

: seek sale

which tells the system to use sale as the top-level goal of the inference process.

Reasoning methods

Leonardo's default method of reasoning is 'backward chaining with opportunistic forward chaining'. Essentially this means that the system looks for rules with the goal object as their final conclusion and attempts to satisfy them in a depth-first manner, but that it also propagates the immediate results of obtaining a value for any object.

This is typically more efficient than pure backward chaining, but still allows the HOW? and WHY? re-tracing facilities which expert systems users expect. In any case, the developer or user can request the system to employ pure backward (or forward) chaining for any given session.

In addition, Leonardo (level 3) provides means for handling uncertainty, if these are required, by employing Certainty Factors (as in Mycin) or Bayesian inferencing (as in Prospector). Creative Logic have not yet incorporated Fuzzy Logic, though they say that enhancement is under active consideration.

The proper way to deal with uncertainty in expert systems is still a live, and indeed controversial, research issue; but my own view is that tool-builders should provide the more commonly used methods of handling uncertainty and leave the decision of whether to use them to the developer - which is what Creative Logic has done. Approximate reasoning is easily misused, but that is no reason for avoiding it altogether (as some expert system shells have done).

Knowledge representation

As experience concerning the construction of expert systems has accumulated, knowledge engineers have come to realise that pure rule-based formalisms are not adequate for building large knowledge-based systems. Consequently most shells provide other kinds of representation as a kind of back-up to the rules.

Leonardo offers, as well as rules, an additional representation scheme based on structured objects. Each object is described by a frame, and (in levels 2 and 3) frames may be linked by subset/superset relations to form an inheritance lattice.

A simple rule such as

if traffic_light is red
then action is 'stamp on brakes'

actually declares the existence of four distinct objects, although the novice user need not be aware of this. These objects are named

traffic_light
red
action
stamp on brakes

and each one is of type text. Objects are given frames as soon as they are created. A frame consists of a number of slots (i.e. attributes), such as
Name: traffic_light
LongName:  
Type: text 
Value: amber  
Certainty: [1.0] 
QueryPrompt: What is the colour of the traffic light?

and many more besides. Some slots are filled by the system with default values; others are optional. Thus to get started, you do not need to know much about objects and frames. For advanced developers, however, they provide the means to control interaction with the user and, ultimately, to model complex real-world knowledge.

Some slots, such as Value: and Certainty: above, can only be altered by Leonardo itself. Others, such as QueryPrompt: above, can be filled by the knowledge base designer, in this case to override the standard system request for information about the object concerned.

The idea of property inheritance for objects (popularised by SmallTalk-80 and its derivatives) has been added to Leonardo levels 2 and 3. This permits the construction of prototype class frames, from which particular instances may be spawned. It is an extremely powerful concept, but there are signs that it has been "grafted on" to the Leonardo system. For instance, the section on the manual dealing with inheritance is part of the addendum, and it is not very fully explained. In other words the object-oriented paradigm is not as well integrated with the rest of Leonardo (primarily rule-based) as it might be: although once you have learned to use it, it makes the package an exceedingly powerful development environment.

Procedures

A rather special type of object in Leonardo is the procedure. So far, we have discussed chiefly declarative representations. Knowledge bases can be built in a purely declarative style, but in large applications it is often convenient to incorporate more conventional computing modules. To allow for such cases, Leonardo is equipped with its own high-level programming language, which I would characterise as "the spirit of Fortran brought up to date". (That's meant to be praise: it's neat, unfussy and relatively powerful.)

Procedures are called from rules by the RUN keyword. Thus

```plaintext
if run_done is not done
    and fiddly_bits are needed
then run get_fiddly_bits (a,b,c,d);
run_done is done
```

could be used to perform some computation on objects a, b, c and d that would be awkward or impossible in the rule language alone (e.g. reading a record from database).

Procedures are defined, as objects, in their own frames. Procedure slots such as

```plaintext
AcceptsReal: ReturnsReal: LocalReal:
```

are concerned with passing parameters and declaring local variables. One special slot called Body: is the one that contains the actual code. This is entered in free format using the Leonardo text editor, or an external word-processor. The usual control constructs (REPEAT, IF-THEN-ELSE etc.) are provided; and procedures can call each other freely (recursively if desired).

Trial runs

The actual test of any software tool is what you can do with it in practice, so, since the system was delivered to my door on the day of the Grand National, I decided to put together a little Grand National betting advisor with the help of some old racing yearbooks.

This particular race — the most popular single betting medium in the country — is widely regarded as a lottery. But in fact there is enough regularity in the pattern of results to make it interesting (if sometimes intensely frustrating). For example, though the race is known as a "graveyard for favourites" it is still usually won by a well-backed horse. This was well illustrated by the 1988 running of the event. The favourite, Sacred Path, fell at the first fence. This appears to confirm the trend; but the winner, Rhyme 'N' Reason, started second favourite, and was first favourite for a while on the course, as prices fluctuated. In other words, the winner might easily have started favourite.

To be quantitative, just under 40% of the winners since 1946 have been returned at odds of 10/1 or less, while 65% have been returned at odds of 20/1 or less. Yet in a typical race less than 10% of the horses will have odds of 10/1 or less, while only
25% will have odds of 20/1 or less. Thus 65% of the winners come from 25% of the runners. So the betting is actually a reasonable guide to a horse's prospects.

Another reliable indicator is the weight carried. The obvious first thought is that the lighter the load which the horse is required to carry round 4.5 miles and thirty fences the better. But historically, horses carrying heavier weights have done better than those with lighter burdens. To be specific, of the last twenty-nine races, twenty-four have been won by a horse carrying more than ten stone; yet in an average race, 65% of the horses carry ten stone. Thus 83% of the winners come from 35% of the horses.

The reason for this is quite simple. The race is a handicap, so the better horses are given heavier loads. As the minimum weight allotted is ten stone, many of the runners carrying exactly ten stone, should on the basis of their past form be carrying less — sometimes far less. Despite the relative lightness of their cargo, they are actually overloaded.

Another point concerns age. There has been a tendency, over the last twelve races, for nine, ten and eleven year-olds to do better, in terms of finishers in the first four as a proportion of starters, than other age groups. Presumably somewhere round ten years is a kind of equine athletic peak for such an event. (This effect is less strong than the two already mentioned).

That then is the reasoning behind the rulebase shown opposite.

Some readers may care to try it out on next year's race. It is simple enough to apply without the aid of a computer.

The goal object, called backability, is a judgement of whether a proposed selection has a good chance of finishing in the first four (on which an each-way bet will at least collect something). This object has a frame with an Introduction: slot that gives instructions about using the rulebase and a Conclusion: slot which expands on the advice to go with one of the conclusions.

backability is poor
or
backability is ok

which, of themselves, are not particularly informative.

Also in the object frame for forecast_odds is further information about what the term means, and in the frame for weight_carried are the allowed values ('more than 10 stone' and '10 stone or less') which are presented to the user as a pop-down menu. Thus the bare rulebase is supplemented by additional information even in a small-scale application like this one.

Note also that the rules for eliminating a horse, i.e. for deducing that

backability is poor
are complemented by a rule concluding
backability is ok

which incorporates the inverse of all the elimination conditions. There is no 'ELSE' clause in Leonardo rules, so you have to provide rules to arrive at all the possible conclusions explicitly. If you do not, you will typically get the message

unable to reach any conclusion....

which can be extremely annoying after replying to half a dozen questions.

One of the problems with the rulebase shown is

/* Leonardo Rule-base for the Grand National (non-Bayesian): */
/* by R.S.Forsyth, April 1988 */

seek backability
ask age_of_horse

/* ASK forces a query before backward chaining starts. */
if age_of_horse < 9
or age_of_horse > 11
then backability is poor
if forecast_odds > 20
then backability is poor
if weight_carried is '10 stone or less'
then backability is poor
if going is heavy
then backability is poor

/* heavy going tends to produce funny results. */
if age_of_horse > 8
and age_of_horse < 12
and forecast_odds <= 20
and weight_carried is 'more than 10 stone'
and going is not 'heavy'
then backability is ok

/* Preamble should be in Introduction: slot of backability */
that it gives no account of the fact that the different rules have different weightings. Thus the age of the horse is less important than the weight it is carrying, but this is not reflected in the rules. The remedy is to revise the rule-set to incorporate some notion of probability estimation. After all, gambling is all about estimating probabilities. This has been done in the example below.

/* Rule-base for the Grand National (Bayesian version):*/
/* by R.S. Forsyth, April 1988*/
control bayes
control 'threshold 0.02'
seek backability
ask age_of_horse
if won_in_last_4 > 0 \[ Ls 2 Ln 0.5 \]
then backability is ok \[ Prior 0.1 \]
if age_of_horse > 8
and age_of_horse < \[ Ls 1.2 Ln 0.7 \]
then backability is ok \[ Prior 0.1 \]
if forecast_odds <= 20 \[ Ls 2.6 Ln 0.46 \]
then backability is ok

if weight_carried is 'more than 10 stone' \[ Ls 2.36 Ln 0.44 \]
then backability is ok

if going is not heavy \[ Ls 1.5 Ln 0.8 \]
then backability is ok

/* heavy going tends to produce funny results*/
/* Preamble should be in Introduction: slot of backability*/

Leonardo follows the practice of using LS (Logical Sufficiency) and LN (Logical Necessity) factors to update odds-in-favour as new pieces of evidence are given. Backward chaining is no longer used (which means that HOW? questions are answered differently); instead, each rule relevant to the goal object is fired until the probability reaches 1.0 (certainty) or a user-defined threshold near zero (0.02 in this case) meaning that the conclusion is false for practical purposes.

LS and LN are pure guesswork for the going. For won_in_last_4, forecast_odds, age_of_horse and weight_carried they have been estimated from past results (back to 1946 in the case of the odds and to 1960 in the case of weight_carried). They should be reasonably accurate.

Note that the Bayesian version of the rulebase does not need to calculate the probability of 'backability is poor' as well as 'backability is ok' since they are mutually exclusive. This allows some simplification of the rule-set.

The meaning of 'backability' here is the chance of a horse finishing in the first four. No doubt this rulebase suffers from correlated evidence to some degree, a common problem with Bayesian inference. In particular, the forecast odds are influenced by its position in the handicap, hence by the weight it is carrying. This could well lead to overoptimistic probability estimates when both factors are favourable. Nevertheless, I intend to dust it down and give it a proper test next year.

Conclusions

The British market for expert systems shells, post-Alvey, is far smaller than the optimistic projections of even two years ago led us to expect. Nevertheless it is an important leading edge area of the wider software market. At present, four major contenders — Crystal, Leonardo, Savoir, and Xi+ — are competing for a share of a marketplace that can probably only sustain two main rivals. For what it's worth, I would like to see Leonardo as one of the survivors in that struggle.

It has some rough edges, but overall it is a well-made, fully featured, expert system shell. If you have an application that is beyond Leonardo's capability, it is probably too big for a desktop personal computer. The package places very few irksome restrictions on the knowledge base developer and, for the entry-level version at least, is very reasonably priced.

Leonardo follows the practice of using LS (Logical Sufficiency) and LN (Logical Necessity) factors to update odds-in-favour as new pieces of evidence are given. Backward chaining is no longer used (which means that HOW? questions are answered differently); instead, each rule relevant to the goal object is fired until the probability reaches 1.0 (certainty) or a user-defined threshold near zero (0.02 in this case) meaning that the conclusion is false for practical purposes.

LS and LN are pure guesswork for the going. For won_in_last_4, forecast_odds, age_of_horse and weight_carried they have been estimated from past results (back to 1946 in the case of the odds and to 1960 in the case of weight_carried). They should be reasonably accurate.

Note that the Bayesian version of the rulebase does not need to calculate the probability of 'backability is poor' as well as 'backability is ok' since they are mutually exclusive. This allows some simplification of the rule-set.

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PERFORMANCE MEASUREMENT QUESTIONNAIRE

This questionnaire is part of a research project investigating manufacturing performance measurement which is being conducted by Research Student at the Department of Manufacturing, Loughborough University of Technology. The purpose of this questionnaire is to gather data about the approaches to manufacturing performance measurement used by different types of manufacturing industries.

Your help will be greatly appreciated. Your responses are to be anonymous; please do not put your name anywhere in this questionnaire. Please answer all questions as frankly as possible. Thank you.

Part I - Profile Of Respondent And Organisational Unit

1. What is the name of the organisational unit for which you are responding?

________________________________________________________________________

2. Please tick the box for the one functional responsibility which best describes the nature of your primary activity.

- Manufacturing Line Management
- Manufacturing Related Management
- Finance / Accounting Management
- Sales / Marketing Management
- Engineering Management
- Other Type ____________________________

3. Please tick the type of business category of the whole organisation.

- Single Business Public Company
- Single Business Private Company
- Business Division Of Company
- Small Scale Business
- Medium Scale Business
- Heavy Industry
- New Business
- Old Business
- Sales-Oriented Business
- Production-Oriented Business
- Capital Intensive Business
- Labour Intensive Business
- Co-operative & Co-Partnerships
- Nationalised Business
- Charities & Non-Profit-Making Business
- Other Type ____________________________


4. The organisation has a vision of becoming a
   Multi-National Company [ ]
   International Company [ ]
   National Level Company Only [ ]
   Localised Level Company [ ]
   Other Type ___________________________ [ ]

5. The company aimed to be
   Product Market Leader [ ]
   Lowest Cost Product Producer [ ]
   High Quality Product Industry [ ]
   Best Services Industry [ ]
   Other Type ___________________________ [ ]

6. Success of this company will be based on
   Market Performance Measures [ ]
   Financial Performance Measures [ ]
   Other Measure ___________________________ [ ]

7. The company is currently using the following performance measures to gauge its market performance
   Customers Satisfaction [ ]
   Company Product Flexibility [ ]
   Other ___________________________ [ ]

8. The company is currently using the following performance measures to gauge its financial performances
   Productivity Measures [ ]
   Company Product Flexibility [ ]
   Other ___________________________ [ ]

9. If you answer 'other' in question (6) please state the performance measures used to gauge its success.
   ___________________________ [ ]
   ___________________________ [ ]
   ___________________________ [ ]

10. Please state any other measures which in your opinion is relevant to measuring performances of your company
    ___________________________ [ ]
The Manager,

........................................

........................................

........................................

Dear Sir,

Please find enclosed a questionnaire which has been sent to you as part of my research project investigating the various approaches to manufacturing performance measurement used by different type of manufacturing industries.

Your responses will contribute much to the findings of the research project. Kindly complete the space provided and tick the appropriate places. For each question you may have more than one answer.

Every detail of information will be highly appreciated and held in confidence.

I would appreciate it if you could complete the questionnaire by 30th August 1993. Please return it to me using the enclosed envelope as soon as you possibly can.

Thanking you in anticipation,

........................................

(Azhari Bin Md Salleh)
PERFORMANCE MEASUREMENT QUESTIONNAIRE

INSTRUCTION TO PARTICIPANT

LEFT-HAND SCALE

The following list presents factors which many companies attempt to evaluate their performance. For each of these manufacturing performance factors circle the number on the left hand scale that indicates your assessment of how important achieving excellence in this factor is for the company.

RIGHT-HAND SCALE

On the right-hand scale, circle the number that corresponds to the extend to which you feel the company presently emphasizes measurement of each factors.

EXAMPLE

The first area for which you are requested to provide ratings on importance and emphasis of performance factors is cost of quality, i.e. the amount of time and money spent on improving quality. If you believe that cost of quality is an extremely important factor, you should circle 10 on the left-hand scale. If, however, you believe that cost of quality is of little importance to your company (that is, it is a factor that may be ignored in the success of your company), you should circle 1 on the left-hand scale.

Similarly, if you believe that cost of quality is strongly emphasized in measuring performance, you should circle a high number on the right-hand scale (a "10" for example). If this measure is virtually ignored, circle a low number on the right-hand scale (a "1" for example).
PERFORMANCE MEASUREMENT QUESTIONNAIRE

Section I  FINANCIAL FACTORS

<table>
<thead>
<tr>
<th>Importance Of Performance Factor</th>
<th>PERFORMANCE FACTORS</th>
<th>Firm's Emphasis On Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>None &gt;&gt;&gt;&gt;&gt;&gt;&gt; Great</td>
<td>None &gt;&gt;&gt;&gt;&gt;&gt;&gt; Major</td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Rating</th>
<th>Cost of Quality</th>
<th>Inventory Turnover</th>
<th>Training Budget</th>
<th>Cost Reduction</th>
<th>Capital Investment</th>
<th>R &amp; D Cost</th>
<th>Unit Material Cost</th>
<th>Unit Labour Cost</th>
<th>Return on Investment</th>
<th>Department Budget Control</th>
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</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
</tbody>
</table>

(Please add if there is any other financial performance measure. Thank you.)

1 2 3 4 5 6 7 8 9 10 ................................................................. 1 2 3 4 5 6 7 8 9 10

1 2 3 4 5 6 7 8 9 10 ................................................................. 1 2 3 4 5 6 7 8 9 10

1 2 3 4 5 6 7 8 9 10 ................................................................. 1 2 3 4 5 6 7 8 9 10

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### Section II: BUSINESS FACTORS

<table>
<thead>
<tr>
<th>Score</th>
<th>Factor</th>
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</thead>
<tbody>
<tr>
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<td>VENDOR QUALITY</td>
<td>1-10</td>
</tr>
<tr>
<td>1-10</td>
<td>VENDOR LEAD TIMES</td>
<td>1-10</td>
</tr>
<tr>
<td>1-10</td>
<td>ON TIME DELIVERY</td>
<td>1-10</td>
</tr>
<tr>
<td>1-10</td>
<td>CUSTOMER'S SATISFACTION</td>
<td>1-10</td>
</tr>
<tr>
<td>1-10</td>
<td>NUMBER OF SUPPLIERS</td>
<td>1-10</td>
</tr>
</tbody>
</table>

(Please add if there is any other business performance measure. Thank you)

<table>
<thead>
<tr>
<th>Score</th>
<th>Factor</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1-10</td>
</tr>
<tr>
<td>1-10</td>
<td></td>
<td>1-10</td>
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### Section III: PRODUCTION FACTORS

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<td>MANUFACTURING LEAD TIME</td>
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</tr>
<tr>
<td>1-10</td>
<td>DIRECT LABOUR PRODUCTIVITY</td>
<td>1-10</td>
</tr>
<tr>
<td>1-10</td>
<td>INDIRECT LABOUR PRODUCTIVITY</td>
<td>1-10</td>
</tr>
<tr>
<td>1-10</td>
<td>SETUP TIMES</td>
<td>1-10</td>
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<tr>
<td>1-10</td>
<td>CAPACITY UTILISATION</td>
<td>1-10</td>
</tr>
<tr>
<td>1-10</td>
<td>NEW PRODUCT INTRODUCTION</td>
<td>1-10</td>
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</table>
12345678910 NEW PRODUCT LEAD TIME 12345678910
12345678910 NEW PROCESS INTRODUCTION 12345678910
12345678910 ENVIRONMENTAL MONITORING 12345678910
12345678910 MINIMIZING WASTE 12345678910

(Please add if there is any other production performance measure. Thank you)

12345678910
12345678910
12345678910
12345678910

Section IV : OPERATION FACTORS

None >>>>>>> Great None >>>>>>>> Major

12345678910 RECORD ACCURACY 12345678910
12345678910 SALES FORECAST ACCURACY 12345678910
12345678910 MEETING PRODUCTION SCHEDULES 12345678910
12345678910 SAFETY 12345678910

(Please add if there is any other operation performance measure. Thank you.)

12345678910
12345678910
12345678910
12345678910

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The following are the description of the characteristics of four different types of manufacturing organisation. Each has a particular configuration of technology, structure, and process that is consistent with its strategy.

(1) **DEFENDER**
Defenders are manufacturing organisations which have a narrow product-market domain. Top managers in this type of organisation are highly expert in their organisation's limited area of operation but do not tend to search outside of their domains for new opportunities. As a result of this narrow focus, these organisations seldom need to make major adjustment in their technology, structure, or methods of operation. Instead, they devote primary attention to improve the efficiency of their existing operations.

(2) **PROSPECTOR**
Prospectors are manufacturing organisation which almost continually search for market opportunities, and they regularly experiment with potential responses to emerging environmental trends. Thus, these organisations often are the creators of change and uncertainty to which their competitors must respond. However, because of their strong concern for product and market innovation, these organisations usually are not completely efficient.

(3) **ANALYSER**
Analysers are manufacturing organisations which operate in two types of product-market domains, one relatively stable, the other changing. In their stable areas, these organisations operate routinely and efficiently through use of formalised structure and processes. In their more turbulent areas, top managers watch their competitors closely for new ideas, and then they rapidly adopt those which appear to be the most promising.

(4) **REACTOR**
Reactors are manufacturing organisations in which top managers frequently perceive change and uncertainty occurring in their organisational environments but are unable to respond effectively. Because this type of organisation lacks a consistent strategy-structure relationship, it seldom makes adjustment of any sort until forced to do so by environmental pressures.

**QUESTION**

From the description above please describe your company by ticking the appropriate column below. You may be a single type or a combination type of organisation. A combination type means you may have characteristics of more than one type.

<table>
<thead>
<tr>
<th>Organisation Type</th>
<th>Defender</th>
<th>Prospector</th>
<th>Analyser</th>
<th>Reactor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your Company</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The life stages of a company

Description Of The Above Stages

(1) INFANT COMPANY
The infant company is a brand new start-up by an individual entrepreneur or group or it can be a new project, department or section in an existing company, or a joint venture between existing companies.

(2) PIONEER COMPANY
The pioneer company is small and fast-growing with a central, powerful figure or group driving it.

(3) RATIONAL COMPANY
The rational company has outgrown its initiators and become independent, bigger and more complex.

(4) ESTABLISHED COMPANY
The established company is just that - well set up with formal procedures and scientific management applied to most aspects of its functioning.

(5) WILDERNESS COMPANY
The wilderness company has lost its way and got out of touch.

(6) DYING COMPANY
The dying company is one that is failing or bankrupt or where the purpose of its being has been completed.

(7) TRANSFORMING COMPANY
The transforming company is one that has decided that now is not the time to die and has found new purpose, new identity, new life.

(Q1) From the above description, where would you place the stage of your company currently?
1. INFANT
2. PIONEER
3. RATIONAL
4. ESTABLISHED
5. WILDERNESS
6. DYING
7. TRANSFORMING
The following are a list of performance measures which may or may not be important to each stage of company. From your assessment please choose five most important measures for each company. Please write down the numbers corresponding to each measure in the boxes provided below.

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

26.......................... 27.......................... 28.......................... 29.......................... 30..........................

Please add if there is any other performance measures. Thank you.

**EXAMPLE**

<table>
<thead>
<tr>
<th>INFANT</th>
<th>[ ]</th>
<th>[ ]</th>
<th>[ ]</th>
<th>[ ]</th>
<th>[ ]</th>
<th>[ ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIONEER</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>RATIONAL</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>ESTABLISHED</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>WILDERNESS</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>DYING</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>TRANSFORMING</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

**Q2** How old is your company?

1. 0 to 5 years old [ ]
2. 6 to 10 [ ]
3. 10 to 20 [ ]
4. 20 to 50 [ ]
5. 50 to 100 [ ]
6. 100 to 200 [ ]
7. above 200 years old [ ]

**Q3** Please write down five most important performance measures of your company currently.

1. ..........................................
2. ..........................................
3. ..........................................
4. ..........................................
5. ..........................................

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E V O L U T I O N O F M A N U F A C T U R I N G C O M P A N Y

The diagram above illustrates the evolution of companies as they move from efficient company to the quality company on to the flexible company to, finally, the innovative company.

(Q5) Do you agree with the above evolution of manufacturing companies?  
[ ] Yes  [ ] No

(Q6) Which category do you believe your company belongs to currently?  
[ ] Efficient  [ ] Quality  [ ] Flexible  [ ] Innovative

(Q7) The following are the list of performance measures which may or may not be important to each type of company. Please circle the number on the scale that indicates your assessment of its importance for that type of company.

Performance factor (1) Cost Reduction is used as an example.

A. THE EFFICIENT COMPANY
B. THE QUALITY COMPANY
C. THE FLEXIBLE COMPANY
D. THE INNOVATIVE COMPANY

<table>
<thead>
<tr>
<th>Performance Factors</th>
<th>Company A</th>
<th>Company B</th>
<th>Company C</th>
<th>Company D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. COST REDUCTION</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
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<tr>
<td>2. QUALITY COST</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>3. FLEXIBILITY</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>4. CREATIVITY</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>5. R &amp; D</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>6. UNIT MATERIAL COST</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>7. UNIT LABOUR COST</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>8. RETURN OF INVESTMENT</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>9. BUDGETING</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
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<tr>
<td>10. VENDOR QUALITY</td>
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<td>11. ON TIME DELIVERY</td>
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<td>12. NUMBER OF SUPPLIERS</td>
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<td>1 2 3 4 5</td>
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<td>14. CAPITAL INVESTMENT</td>
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<td>1 2 3 4 5</td>
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<tr>
<td>15. DIRECT LABOUR</td>
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<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
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<td>16. INDIRECT LABOUR</td>
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<tr>
<td>17. NEW PRODUCT</td>
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<td>21. SALES FORECAST</td>
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<td>23. TRAINING</td>
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<tr>
<td>24. RECORD ACCURACY</td>
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<td>1 2 3 4 5</td>
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<tr>
<td>26. OPERATING PROFIT</td>
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<td>28.</td>
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## List of UK Participating Business Organisations

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<tr>
<th>COMPANY</th>
<th>MANUFACTURING AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bally Shoe Factories (UK) Limited</td>
<td>Footwear &amp; Accessories</td>
</tr>
<tr>
<td>SPS Technologies Limited</td>
<td>Precision Fasteners</td>
</tr>
<tr>
<td>Varian - Tem Limited</td>
<td>Radiography Equipment</td>
</tr>
<tr>
<td>Roll - Royce Public Limited Company</td>
<td>Gas Turbine Engines</td>
</tr>
<tr>
<td>SCSL (GPT) Limited</td>
<td>Telecommunication Product</td>
</tr>
<tr>
<td>ZETA Communication Limited</td>
<td>Communication Equipment</td>
</tr>
<tr>
<td>Forged Rolls (UK) Limited</td>
<td>Steel &amp; Alloy Forged Rolls</td>
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<tr>
<td>Harlow Sheet Metal Public Limited Company</td>
<td>Sheet Metal Works</td>
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<tr>
<td>International Fish Canners (Scotland) Limited</td>
<td>Canned Fish Products</td>
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<tr>
<td>Medi Cine International Public Limited Company</td>
<td>Medical &amp; Pharmaceutical</td>
</tr>
<tr>
<td>Siemens Measurement Limited</td>
<td>Electrical Products</td>
</tr>
<tr>
<td>Adam Furniture Group Public Limited Company</td>
<td>Kitchen &amp; Bedroom</td>
</tr>
<tr>
<td>British Alcan Aluminium Public Limited Company</td>
<td>Aluminium Products</td>
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<tr>
<td>Airsprung Furniture Group Public Limited Company</td>
<td>Company Furnitures</td>
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<tr>
<td>Electrical Boiling Plates Limited</td>
<td>Boiling &amp; Grilling Plates</td>
</tr>
<tr>
<td>Micro Computer Workshop Limited</td>
<td>Computer Equipments</td>
</tr>
<tr>
<td>Rubber &amp; Plastic Engineering Limited</td>
<td>Moulding/Extrusion Work</td>
</tr>
<tr>
<td>ABG Rubber &amp; Plastic (Industrial) Limited</td>
<td>Rubber/Plastic Products</td>
</tr>
<tr>
<td>A 1 - Paper Stationery Limited</td>
<td>Stationery Products</td>
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<tr>
<td>Sterling Tubes Company Limited</td>
<td>Stainless Steel</td>
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<tr>
<td>Micro Circuit Engineering Limited</td>
<td>Integrated Circuit</td>
</tr>
<tr>
<td>Babcock Thorn Limited</td>
<td>Naval Vessel</td>
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<tr>
<td>Rankins (Glass) Company Limited</td>
<td>Glass &amp; Glazing Work</td>
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<tr>
<td>Trafford Edible Oil Refiners Limited</td>
<td>Oil Refiner</td>
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<tr>
<td>Atlas Rubber Mouldings Limited</td>
<td>Rubber/Plastic Moulders</td>
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<tr>
<td>Rubber &amp; Plastic Industries Limited</td>
<td>Rubber/Plastic Products</td>
</tr>
<tr>
<td>Arkana Furniture Limited</td>
<td>Furnitures</td>
</tr>
<tr>
<td>Floral Textiles Limited</td>
<td>Lace Manufacturer</td>
</tr>
<tr>
<td>York International Limited</td>
<td>Fridge/Heating Equipment</td>
</tr>
<tr>
<td>British Airways Gatwick Limited</td>
<td>Aircraft Engineering</td>
</tr>
<tr>
<td>Electrodrives Company Limited</td>
<td>Electric Motors</td>
</tr>
<tr>
<td>Yard Company Limited</td>
<td>Defence Equipment</td>
</tr>
<tr>
<td>Blackburn Yarn Dyers Limited</td>
<td>Textiles</td>
</tr>
<tr>
<td>Great Yarmouth Cardboard Box Company Limited</td>
<td>Cardboard Boxes</td>
</tr>
<tr>
<td>Form UK Public Limited Company</td>
<td>Printed/Media Products</td>
</tr>
</tbody>
</table>
List Of 30 UK Successful Companies & Their Areas Of Operation - Research Work Carried Out At Durham University Business School, Mill Lane, Durham, DH1 3LB
By Dinah Bennett

**COMPANY** | **AREA OF OPERATION**
--- | ---
1. ABI Electronic | Electronic Test Equipment
2. Ace | Conveyor System
3. Bede Scientific | X-Ray Diffraction Instruments
4. Bonas Machine Company | Weaving Machines
5. Canford Audio | Audio & Broadcasting Equipment
6. Chameleon Design | Decorative Mirrors
7. Compass Caravans | Touring Caravans
8. Cresstale | Lipstick holders & Compacts
9. Derwent Valley Foods | Snack Foods
10. Electrix Northern | Stainless Steel Equipment
11. Elfab Hughes | Safety Equipment
12. Fellowes | Office Supplies
13. Great Northern Knitwear | Men's Outer Garments
14. Higgins | Potato Processing
15. Integrated Micro Products | Multi-User Computer System
16. Metro FM | Broadcasting
17. NB Print & Design | Print & Design
18. Neat Ideas | Office Supplies By Mail Order
19. Nicholson Seals | Gaskets and Seals
20. Osborne Engineering | White Metal Bearings
21. Osborne Kay | Printers
22. Panda Supplies | Protective Clothing & Equipment
23. Paul & Loughran | Gas Compressor
24. Polydon Industries | Production Engineering
25. Shield Engineering | Precision Toolmakers
26. South Riding Video | Video & TV Films Makers
27. Superior Cleaning Specialist | Contract Cleaning
28. Tolag | Defence Components
29. Topline | Business Services
30. Tyne Tec | Access Control Equipment & Alarms.

The thirty successful companies are divided into three groups.

1. **FAST-GROWTH SUCCESSFUL COMPANIES**
2. **AVERAGE SUCCESSFUL COMPANIES**
3. **SUCCESSFUL MATURE COMPANIES**
## Performance Measurement And Practices Of Selected UK Manufacturers

<table>
<thead>
<tr>
<th>Company</th>
<th>Sector</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Toolmaking</td>
<td>15</td>
</tr>
<tr>
<td>B</td>
<td>Computerised Machines</td>
<td>28</td>
</tr>
<tr>
<td>C</td>
<td>Temperature Controller</td>
<td>350</td>
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<tr>
<td>D</td>
<td>Computer Software</td>
<td>35</td>
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<tr>
<td>E</td>
<td>Footware Manufacture</td>
<td>441</td>
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<tr>
<td>F</td>
<td>Timber Frame Construction</td>
<td>400</td>
</tr>
<tr>
<td>G</td>
<td>Diesel Engines</td>
<td>41</td>
</tr>
<tr>
<td>H</td>
<td>Interfacing Products</td>
<td>300</td>
</tr>
<tr>
<td>I</td>
<td>Cable Harnesses</td>
<td>300</td>
</tr>
<tr>
<td>J</td>
<td>Injection Moulding</td>
<td>60</td>
</tr>
<tr>
<td>K</td>
<td>Electronics</td>
<td>300</td>
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<tr>
<td>L</td>
<td>Mechanical Seals</td>
<td>150</td>
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<tr>
<td>M</td>
<td>Automotive</td>
<td>35000</td>
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<tr>
<td>N</td>
<td>Robotics</td>
<td>25</td>
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<tr>
<td>O</td>
<td>Automotive</td>
<td>90</td>
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<tr>
<td>P</td>
<td>Mechanical Locks</td>
<td>435</td>
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<tr>
<td>Q</td>
<td>Ceramics</td>
<td>1300</td>
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<tr>
<td>R</td>
<td>Electromechanical Switches</td>
<td>995</td>
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<tr>
<td>S</td>
<td>Image Processing</td>
<td>14</td>
</tr>
<tr>
<td>T</td>
<td>Inkjet Printers</td>
<td>700</td>
</tr>
<tr>
<td>U</td>
<td>Automotive</td>
<td>430</td>
</tr>
</tbody>
</table>

The Study entitled, 'Performance Measurement In Manufacturing Sector', was commissioned by the Department Of Trade And Industry (Manufacturing And Technology Division) and undertaken by CIMA, Cambridge University, Glasgow University, NIMTECH and Warwick University. The full report is being published by CIMA.

### CONCLUSION

The companies studied suggest that, while performance measures reflect particular circumstances facing particular enterprises, certain common characteristics can be seen. The following conclusions stem from the overall study:

1. Although advocates of reforms in performance evaluation and measurement systems strongly tend to recommend the greater adoption of non-financial manufacturing measures, most companies (small, medium and large) have a tendency to base their decisions primarily on financial monitors of performance.

4. There appears not to be an optimal mix of specific financial and non-financial indicators applicable to all manufacturers. Rather, each company must find a balance of measures which it views as sufficient for the management of its operational activities. Nevertheless, broad guidelines as to which dimensions of performance may be appropriate can be developed. Thus for financial measures, a company may develop its own measures in relation to the following: working capital, capital market, financial return and lender security. Likewise, for non-financial measures, the company could adopt the following broad categories: quality, delivery, process time and flexibility.
Performance Measurement Mechanics of Measurement

OPERATING PROFIT, (OP)

Operating profit is profit before interest and tax. It is the difference between total revenue and total expenditure which includes interest and any items relating to the financing of the business.

Operating Profit, OP = Total Revenue - Total Expenditure

PROFIT AFTER TAXATION (PAT)

Profit after tax means profit after deducting tax based on that profit for the period in question.

OPERATING CASH FLOW (OCF)

Cash flow can be defined as an adjustment to profit, i.e. profit before tax plus depreciation.

Cash flow is the operating profit plus depreciation, plus sundry provisions, plus or minus change in working capital, comprising stocks, debtors and creditors.
PROFIT AFTER INTEREST (PAI)

There are two definitions of the interest that may be deducted from profit before interest to arrive at the profit after interest.

1. Interest actually payable in a period by a company or division on the loans and bank overdraft advanced to it.

2. Interest that would normally be payable if the company or division were financed entirely by loans at market rates of interest or at a rate that would have some relation (for a division) to the overall cost of finance to the group.

PRODUCTIVITY RATIOS (PR)

The common definition of productivity is 'a measure of the quantity of output of goods and services that can be produced for a given input in factors of production'. Examples are, tons of coal, litres of paint, number of cans, kilos of biscuits, number of employees involved, number of man-hours worked and number of machines available.

TURNOVER (T)

Turnover is defined as the amount derived from the provision of goods and services falling within the business's ordinary activities, after deduction of trade discounts, value added tax and any other taxes based on the turnover.

STRATEGIC RATIOS (SR)

The strategic ratios are indicators of profit or value added to come as a result of pursuing the strategic objectives of the business. Examples of SR are market share, speed of delivery and level of service.
Example of operating cash flow,

Receipts from sales... ... ... ... £6036.00

Payment for,

Materials... ...£3362.00
Salaries... £1950.00
Services... £ 198.00

£5510.00

Operating Cash Flow £ 526.00

EARNINGS PER SHARE ( EPS )
Earning per share is a measurement of performance tailor-made for the shareholder.
Earning per share is normally expressed in terms of pence per share. If profit after taxation is £84,000 and there are 700,000 shares issued then,

\[
\text{Earning Per Share} = \frac{£84,000.00}{700,000} = 12 \text{ Pence per share}
\]

GROSS MARGIN ( GM )
Gross Margin is defined as turnover less directly related variable costs in producing that turnover. Other similar terms are gross profits, contribution, trading profit and gross profit margin.
There can be no standard definition of the 'directly related variable costs' that will suit all cases.
VALUE ADDED (VA)

The value added of a business is simply the amount of value created by it (output) less the amount of the value put into it (input).

The value of total output of a business is its turnover.

The value of the input to a business is materials purchased, fees for services, licences, i.e. any goods or services obtained originally from outside the business.

RETURN ON CAPITAL EMPLOYED (ROCE)

Return on capital employed is basically of two types,

(1) Equity Based where,

   The denominator is shareholder's funds, i.e. share capital, reserves and retained profit.

   The numerators is profit after interest and before tax.

(2) Entity Based where,

   The denominator is shareholder's fund plus long term loans and plus short term loans and overdraft.

   The numerator is profit before interest i.e. operating profit.
QUALITY INDEX

EG. Percentage Conforming To Standard Targets ①
Percentage Of Satisfied Customers ②
STATISTICAL PROCESS CONTROL (SPC)

- widely used for measuring, identifying and reducing variations in the production process. SPC is a simple and effective tool for continuously monitoring the process and calculating the average (mean) performance.

PROCESS IN CONTROL

PROCESS OUT OF CONTROL

PROCESS WITH TREND
Analysis of Market Competition

A widely used technique for the analysis of the market competition is the 'five-force' competition model of M.E. Porter. Porter suggests that market competition is a function of five major groups of variables or forces. These are,

- Extent of industrial rivalry
- Bargaining power of buyers
- Bargaining power of suppliers
- Threat of new entrants
- Threat of substitutes

These five groups of variables are interrelated and are illustrated by Porter's five forces competition matrix shown in Figure 4.5 of Chapter 4.0

Extent of industry rivalry

This is determined by such factors as:
1. The number and diversity of competitors, and the degree of balance (or equality) between their relative market strength. This factor includes the degree of concentration within the industry. British grocery retailing is highly concentrated, while the European tourist industry is highly fragmented.
2. The degree to which the industry can be classified as 'young' or 'mature'. Growth prospects are, in particular, limited in a mature and slow-growing industry. This may prompt intense competition among the participants. It may also burden their resolve to hold on to market share. This situation characterises the foodstuffs industry in the United Kingdom.
3. The degree to which product differentiation is effective. The harder it is to differentiate the product or services, or the more difficult it is to establish an effective brand acceptance, the more competitive the market is likely to become.
4. The degree to which operational capacity is 'lumpy', i.e. only increased in large increments. The addition of large increments of operational capacity may lead to the risk of over-supply in the market, and the emergence of price competition.
5. The incidence of high burdens of fixed cost associated with the market operations. Price competition may increase the risk that fixed cost cannot be covered, particularly where the margin of safety is relatively low. Competition may as a result be so intensified by the major players that weaker contestants give up altogether and leave the industry, or potential newcomers are strongly discouraged from entering the sectors.
6. High exit barriers causing businesses to remain in the market, however unattractive it is, because of the costs and risks attached to leaving it. If a business is committed to, or dependent on a market, it is likely to be unwilling to leave it except in the direst of circumstances. And the more dependent it is upon any particular market, the more competitive its behaviour may become.
Buyers' bargaining power

This is determined by such factors as:

1. The degree of buyer concentration relative to suppliers. A classic example of the exercise of 'buyer power' that can result from such buyer concentration is to be found in the UK grocery market. This is dominated by a very small number of very large retail chains whose combined purchases exceed 70 per cent of the total in the sector.

2. The relative volume of the buyer's purchases in that market, combined with the relative importance of the purchase to that buyer.

3. The availability of close substitutes.

4. The commodity nature of the products or services in the market, which makes it difficult to effectively differentiate the supplier's offering. Commodity products could include general forms of insurance, industrial paint or lubricants, staple foodstuffs, etc.

5. The degree of threat of backward integration by buyers wishing to control their sources of supply more closely, or wishing to gain competitive advantage over their own competitors by controlling that supply.

6. The relative cost of switching between alternative suppliers. The easier it is to switch suppliers, the more competitive is the market. Suppliers therefore attempt to 'lock-in' their customers to unique supply conditions or deals in order to reduce the opportunity for switching. Credit and finance packages often have this effect in industrial markets, as do information technology (IT)-based ordering and transaction systems.

7. The degree to which buyers are price-sensitive. Price-sensitive buyers are likely to 'shop around' more than those buyers to whom quality and reliability of supply are more important.

8. The degree to which buyers wish to build up long term relationships with suppliers to ensure the quality and reliability of supply. This will reduce their price sensitivity, and provides the supplier with an effective form of product or service differentiation.

Suppliers' bargaining power

This is determined by such factors as:

1. The degree to which suppliers are able effectively to differentiate their product or service. This differentiation may, for instance, be based on product or service specification, possession of unique selling propositions, strong brand identity, quality, or reputation for reliability and customer service.

2. The degree of supplier concentration. The fewer the suppliers, or the scarcer the product they supply, the greater will be the competition among buyers to secure their supplies. This strengthens the supplier's market position. Supplier power within the market is further enhanced where the possession of effective patent protection means that the supplier is in a monopoly position to provide the product, or to license others to manufacture it.

3. The relative importance to the buyer of the product or service being purchased from the supplier.

4. The availability (or otherwise) of close substitutes as satisfactory inputs to the buyer's requirement.

5. The degree of threat of forward integration by suppliers, wishing more closely to control their own market outlets. Hence, for example, the control of UK retail outlets by companies in the brewing and vehicle fuel sectors. Ownership and control of retail outlets by UK brewers has, in particular, been the subject of significant government intervention seeking to reduce the market power of brewing companies and to increase competition in the on and off-licensed trade.
Threat of new entrants

The degree of competitive threat posed by newcomers to the market will be determined by *the ease of entry to that market*. This, in turn, will be a function of the relative strength of *barriers to entry* to that market. These barriers to entry include:

1. The effectiveness of product differentiation and the strength of customer loyalty to the brands of existing suppliers in the market.
2. The capacity of would-be entrants to gain access to channels of distribution. This is an essential issue for companies planning to expand their operations on a European or worldwide basis.
3. The capacity of would-be entrants to gain access to the necessary inputs or operational experience.
4. The capacity of existing competitors to deter new entrants by the deliberate use of price reduction tactics and the offer of extra discounts to existing customers.
5. The possession by existing competitors of absolute cost advantages deriving from economies of scale or a pre-eminent position on the industry's experience curve. (The importance of the experience curve will be explained in a later chapter.)
6. The absolute size of the capital cost to be incurred in establishing a presence in the market. Given the likely return on investment this may represent, it may simply not be worthwhile entering a market by 'starting from scratch'. The likely preferred route would be to take over or merge with an existing supplier, *if this option is available*. Many companies have found it difficult, for instance, to gain a foothold in the Japanese market, since take-overs of Japanese companies are often impossible.
7. The difficulty for newcomers in building effective brand loyalty and customer perception of quality or service, especially where existing suppliers are at their strongest in these areas.
8. Government policy discouraging further entry to the market, e.g. to protect home suppliers from the entry of foreign competitors. Post-war Japanese governments have restricted entry to foreign companies so as to build up a powerful home base of companies capable of global international marketing and supply.
Threat of substitutes

The competitive threat posed by substitute products or services will be determined by such factors as:

- Buyer propensity to substitute between the products/services on offer. This is related to
- The relative price of existing and substitute products, and to
- The relative price-performance perception held by customers
- The relative cost and perceived risk involved in switching between the existing and substitute products/services

The significance of the threat posed by substitutes depends on the ease with which customers, existing suppliers and potential newcomers can identify substitute products and the nature of the competitive threat they imply. This, in turn, raises the problem of clearly defining the industry/sector in which the competitive analysis is being carried out. To what extent, for example, is distributed terminal-based work in people’s homes a competitor to the office accommodation market?

The nature of competition

Porter suggests that the nature and intensity of competition within a market will depend on the relative strength and interaction of these five forces. The effect of this competition may then take such actual forms as:

- Price competition, which may reduce industry margins and profits or drive some businesses out of the market
- Non-price competition in mature markets, based on brand and product differentiation, promotion and new product development (etc.)
- ‘Locking-in’ customers or channels by the use of discounts, credit and preferential financial arrangements (etc.)
- Mergers and takeovers of competitors or newcomers so as to consolidate and protect market position
- Direct government regulation and intervention
List of commercially available Expert System shell.
( In alphabetical order )

ACQUIRE is knowledge acquisition system and expert system shell. It is a complete
development environment for building and maintaining knowledge-based application. It
provides a step-by-step methodology for knowledge engineering that allows the domain
experts themselves to be directly involved in structuring and encoding the knowledge. ( The
direct involvement of the domain expert improves the quality, completeness and accuracy
of acquired knowledge, lowers development and maintenance costs, and increases their
control over the form of the software application. ) Features include a structured approach
to knowledge acquisition; a model of knowledge acquisition based on pattern recognition;
knowledge represented as objects; production rules and decision tables; handling
uncertainty by qualitative, non-numerical procedures; extremely thorough knowledge bases
in a hypertext environment. There are two options for delivering the knowledge-based
application to end user:

(1) a Run Time System Acquire-RTS for delivering stand-alone application and

(2) a Software Development Kit, Acquire-SDK for embedding finished
applications seamlessly with other software.

The Acquire development package ( knowledge acquisition system and expert system
shell ) costs $995 for Windows 3.1 and includes manual, a tutorial, on-line help and
telephone helpline. For more information contact Acquire Intelligence Inc., Suite 205,
1095 McKenzie Avenue, Victoria, Canada V8P 2L5.

ART* Enterprise and CBR Express ( Inference Corporation ).
ART* Enterprise is the latest of the family of rule-based development environments
originating with ART in the mid- 1980s. It is a development environment for enterprise-
wide applications, incorporating rules, a full object system which includes features
currently not present in C++, and a large collection of object classes for UI development
across platforms ( from Windows to NT to OS/2 to Unix ), access to databases
(SQL-based and Q+E based), multi-person development. The ART* Enterprise environment provides a forward chaining engine where backward chaining can be implemented, though it is not supported directly. CBR Express family of products supports case-based retrieval of information. The CBR technology is available as part of ART* Enterprise for those who are interested in incorporating it into their applications. For further information contact Inference Corporation, 550 N. Continental Blvd., El Segundo, CA 90245.

CRYSTAL runs on personal computers and is available from Intelligent Environments. It has a wide range of applications in finance, manufacturing, sales, marketing, engineering, personnel, production, research and development, management information services and operation. Applications range from help desk to real-time price monitoring, from analysing the efficiency of a government department to engineering design, and from optimising steel cutting to advising on tax. The development environment consist of screen printer, rule animator, rule interpreter, rule editor and over 150 other integrated functions. There are interfaces to Lotus and business graphics as well as a dBase compatible database. The Crystal reference manuals include a written tutorial to help the beginners and a 350 page Reference manual with a section on special techniques for more advanced user. There is also a telephone Helpline to give immediate advice and support. For more information, contact write to Intelligent Environments Europe Limited, Crystal House, P O Box 51, Sunbury-On-Thames, Middlesex TW16 7UL, United Kingdom.

ECLIPSE runs on personal computers (DOS, Windows). System V Unix and POSIX versions are also available. The syntax is derived from Inference Corporations' ART and is compatible with NASA's CLIPS. Features include data-driven pattern matching, forward and backward chaining, truth maintenance, support for multiple goals, relational and object-oriented representations, and integration with dBase. For more information, write to The Haley Enterprise Inc., 413 Orchard Street, Sewickley, PA 15143. See also IEEE Computer, February 1991, pages 19-31.
FLEX is a hybrid expert system toolkit available across a wide range of different hardware platforms which offers frames, procedures and rules integrated within a logic programming environment. FLEX supports interleaved forward and backward chaining, multiple inheritance, procedural attachment, an automatic question and answer system. Rules, frame and questions are described in an English-like Knowledge Specification Language (KSL) which enables the development of easy-to-read and easy-to-maintain knowledge bases. FLEX is implemented in, and has access to, Prolog. FLEX is available from LPA (Who originally developed FLEX on the PC), and also from most major Prolog vendors under license, including Quintus, BIM, Interface, and ISL. FLEX has been used in numerous commercial expert systems, and prices on a PC running Windows or on Macintosh start at around $1000. For more information contact: Logic Programming Associates (LPA) Limited, Studio 4, R.V.P.B., Trinity Road, London, SW18 3SX United Kingdom.

G2 is a real-time expert system shell that runs on workstations and personal computers. It has real-time temporal reasoning, with rules, procedures, and functions built around an object-oriented paradigm. One can interface, both locally and over a network (TCP/IP and DECnet), to other programs (C and ADA), control systems, and databases. G2 provides distributed computing and multi-user client/server architecture. For more information, write to Gensym Corporation, 125 Cambridge Park Drive, Cambridge, MA 02140.

GURU is an expert system development environment and RDBMS that offers a wide variety of information processing tools combined with knowledge-based capabilities such as forward chaining, backward chaining, mixed chaining, multi-value variables, and fuzzy reasoning. For more information about GURU and the other database engines and development tools contact Micro Data Base Systems, Inc., 1305 Cumberland Avenue, P.O. Box 2438, West Lafayette, IN 47906-0438.
KEE was developed by IntelliCorp Inc. of Mountain View, California. IntelliCorp's management includes the well-known pioneers of AI, Professor Ed Feigenbaum and Richard Fikes. Outside technical advisors include the AI researcher Johan de Kleer from the Xerox Palo Alto Research Centre. KEE was announced in 1983 and has continued to evolve. Version 3.0 was introduced in the summer of 1986, with some new features. It is supplied either in a full programming environment form or a run-time capability only version. The complete program development version system runs on several different workstations including the Symbolics 3600, TI Explorer, Xerox 1100, and Sun-3 ranges. KEE is a collection of high level inferencing and knowledge base management facilities built on top of Common Lisp, with all the features of Lisp still being available. It incorporates a graphical interface for both programmers and end user. This interface implements the mouse/icon/pop-up menu style of interaction pioneered at the Xerox Research Centre in Palo Alto, California. For most applications KEE provide two major sub-systems - a frame-based simulation modelling sub-system and a rule-based reasoning sub-system. Facts are held in frames and then rules can be used to make deductions from these facts by using backward chaining, or rules can be used to augment the explicit facts by using forward chaining. For more information write to IntelliCorp, Inc., 1975 El Camino Real West, Suite 101, Mountain View, California, USA.

KES was introduced by Software Architecture and Engineering (also known as Software A & E) in 1982. KES was originally based on KMS (Knowledge Management System), an expert system tool developed at the University of Maryland. The early version of KES were implemented in Lisp, but it was ported to C in version 2.1. KES historically consisted of three subsystems; KES Bayes, KES HT and KES PS. KES Bayes is a statistical pattern classification subsystem for applications that have a large body of data expressed as probabilities. KES Bayes is not applicable to most expert system applications, and Software A & E has recently stopped supporting it. KES HT is a hypothesis-and-test subsystem that is useful for specialised diagnostic applications where all possible outcomes are described by a minimal covering set. KES PS, the production system module, is the most frequently used of KES's subsystem. KES supports forward chaining, backward chaining, and classes. KES runs on personal computers, workstations, minicomputers, and IBM mainframes. For more information
NEXPERT OBJECT runs over 30 platforms supported including personal computers, Macintosh, workstations, minicomputers, and mainframes. Nexpert Object is written in C, and includes a graphical user interface, knowledge acquisition tools, and forms system. The Nexpert Object development system is a hybrid rule-based and object-based expert system building tool that provides an environment for application development. It features include integrated forward and backward chaining using the same symmetric rule format, optional automatic goal generation, customisable inference strategies, pattern matching, interpretations, dynamic creation of objects, classes, properties, methods, and demons, multiple and user defined inheritance, and non-monotonic reasoning.

With Nexpert's graphic interface, developers and domain experts can edit rules, objects and control structures, and display an overview of the rule and object structure using Nexpert's dynamic, graphic browsing mechanism. An agenda monitor also allows the developer to follow the current and future inference path. This interface will let new users move quickly along the learning curve, and makes knowledge bases much easier to debug. These two features bring the domain expert closer to the system.

The application programming interface gives the developer access to the functions of the Nexpert's Object library. External routines written in standard programming languages (C, FORTRAN,) can be called from within Nexpert's rules and methods, or Nexpert can be embedded within user own application. Application programming interface externals which are not interface dependent are also portable across all platforms.

Nexpert Object is integrated with many standard spreadsheets and flat files databases. This integration takes place through transparent, built-in bridges to both spreadsheet formats, such as NXP (Proprietary format), Syllk (Microsoft Excel), and WKS (Lotus), as well as the following databases: dBase III Plus (DBF Format), NXPDB (Nexpert's own proprietary database), SyllkDB (Excel), and WKSDB (Lotus). There is one-to-one mapping between records and fields in databases and objects and properties in knowledge-bases, respectively. Efficient queries to these databases or spreadsheets can be achieved using a Nexpert SQL-like language.

Nexpert Object is also integrated with the major relational databases on the market (Oracle, Sybase, Ingres, Informix). Any SQL query can be triggered from within Nexpert and passed to a DBMS. There is also the one-to-one mapping between tables, records,
and fields in databases, and classes, objects, and properties in knowledge bases, respectively. Nexpert can display various graphic formats: MacPaint on all platforms, as well as Dr Halo, Windows Paint, and PaintBrush on IBM-PCs, PICT/PICT2 on Macintosh, BMP on UNIX, X11, BMP and UIS format on VAX. Nexpert can also display plain ASCII text.

For more information, write to Neuron Data, 156 University Avenue, Palo Alto, CA 94301.

YAPS is a tool for building expert systems and other programs that use a rule-based knowledge representation in Lisp. The YAPS library provides CLOS class and appropriate methods which the programmer may mix into his/her own classes or use directly. Rules and facts about an instance are associated with the instance. Instead of one large knowledgebase with many rules which are hard to debug and maintain, the programmer creates smaller knowledge-bases which are modular and more efficient. The YAPS knowledge-bases can interact with and be controlled by the programmer's other modules, making hybrid systems straightforward. YAPS is now available on Apple Macintosh, Sun 3 and Sun 4 (SPARC), DEC VAX under VMS and Ultrix, and 88)pen platforms. YAPS runs in most commercial Common Lisps including Allegro CL, Harlequin LispWorks, Lucid CL, IBUKI CL, and Macintosh Common Lisp. For more information contact College Park Software, 461 W. Loma Alta Drive, Altadena, CA 91001-3841, USA.
Illustration of Forward, Backward and Mixed Chaining

The following set of rules are used to explain both mechanisms.

IF E AND C THEN F
IF A THEN C
IF B THEN D
IF D THEN A

Forward Chaining - works by taking all the true facts and examining each rule to see if all the IF parts of the rule are true. With this new extended list of true facts the process is repeated until either a suitable goal has been derived or no more information can be discovered. It is also known as data-driven inferencing since the method will not work unless there is some data available to drive the inference procedure - when there is no (more) data the inference engine stops.

Looking at the example above and assume the fact that B and E are true.

"IF E AND C THEN F " Rule ignored since not all IF parts are known
"IF A THEN C " Rule ignored since IF part not known
"IF B THEN D " Rule is fired since B is true and D is added to the knowledge base
"IF D THEN A " Rule is fired and A is added to the knowledge base
"IF A THEN C " Rule is fired and C is added to the knowledge base
"IF E AND C THEN F " Rule is fired. No more rules to prove so the inference engine stops.

Backward Chaining - starting with a goal expression whose value must be determined, the mechanism searches the knowledge base for rules that allows it to conclude a value for the goal. These then serve as the new goals and the search continues. In the process, the system is using rules and facts from the knowledge base and may also seek the value of certain expressions from the user. This strategy is also called goal-driven inferencing.
Base on the example above.
Consider the system is trying to determine or prove F.

The first rule states that F can only be true if both E and C are true. E cannot be proved by using any other rules, so it must asked directly of the user. The next clause to be proven is C. C can be proven using the second rule. To prove C we need to prove A. To prove A we need to prove D in rule four. This recursive idea of trying to prove one thing by proving others is repeated one last time as B is needed to prove D. There is no rule that can prove B so once again the user is asked for the value of B.

Mixed Chaining - One of the main advantages of forward chaining is that it does not require that information is added in any particular order - this means that the systems that assist shop floor real-time systems data can simply be input directly into the expert system. On the other hand, if the user is entering information "by hand" then the system can offer no assistance in directing the user to enter the required information.

Backward chaining is entirely directed - it asks the user for specific items of information and it can usually "justify" why it is requesting the information. The problems with backward chaining occur when the system has heuristics do not prevent it from either asking irrelevant questions or asking the wrong questions.

In those circumstances where the inference strategy being used cannot allow the disadvantages stated above, an alternative compromise strategy is possible. This involves using backward chaining as the main inference strategy whilst using forward chaining to provide the advantage of data driven inferencing.
An Example of FAME Profile of A UK Business Organisation

WINGROVE & EDGE LIMITED

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>Turnover</td>
<td>2,077,670</td>
<td>1,786,174</td>
<td>2,373,697</td>
<td>2,398,698</td>
<td>2,505,609</td>
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<tr>
<td>Prof/Loss b.Tax.</td>
<td>35,676</td>
<td>-344,696</td>
<td>-290,246</td>
<td>-3,793</td>
<td>42,232</td>
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<td>Net Tang. Assets</td>
<td>325,547</td>
<td>286,575</td>
<td>617,610</td>
<td>859,889</td>
<td>879,912</td>
</tr>
<tr>
<td>Sharehold. Funds</td>
<td>122,251</td>
<td>86,575</td>
<td>331,271</td>
<td>605,013</td>
<td>623,608</td>
</tr>
<tr>
<td>Profit Margin (%)</td>
<td>1.72</td>
<td>-19.30</td>
<td>-12.23</td>
<td>-0.16</td>
<td>0.37</td>
</tr>
<tr>
<td>Ret. Sharehold.F. (%)</td>
<td>29.18</td>
<td>-398.15</td>
<td>-87.62</td>
<td>-0.63</td>
<td>6.77</td>
</tr>
<tr>
<td>Ret. Capit. Empl. (%)</td>
<td>10.96</td>
<td>-120.28</td>
<td>-47.00</td>
<td>-0.44</td>
<td>4.80</td>
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<tr>
<td>Liquidity Ratio</td>
<td>0.37</td>
<td>0.30</td>
<td>0.48</td>
<td>0.72</td>
<td>0.60</td>
</tr>
<tr>
<td>Gearing (%)</td>
<td>916.83</td>
<td>1,175.02</td>
<td>260.40</td>
<td>42.13</td>
<td>107.46</td>
</tr>
<tr>
<td>Number of Employees</td>
<td>31</td>
<td>30</td>
<td>48</td>
<td>44</td>
<td>42</td>
</tr>
</tbody>
</table>
Appendix 6.2

List of names, dates and correspondance addresses of officers interviewed in Malaysia.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Date of Interview</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mr Ismail Adam</td>
<td>04-03-1993</td>
<td>National Productivity Corporation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P.O. Box 64, Jalan Sultan, 49605, P.J. Selangor.</td>
</tr>
<tr>
<td>3.</td>
<td>Dr Shamsuddin Hitam</td>
<td>05-03-1993</td>
<td>Economic Planning Unit, Prime Minister Department, Jalan Dato' Onn, Kuala Lumpur.</td>
</tr>
<tr>
<td>4.</td>
<td>Mr A.Wahab Mulajat</td>
<td>06-03-1993</td>
<td>Standard Industrial Research Institute Malaysia, P.O. Box 35, Shah Alam, Selangor.</td>
</tr>
<tr>
<td>5.</td>
<td>Mr Bakhtiar Safran</td>
<td>08-03-1993</td>
<td>Johor SEDC, Bangunan Tun Razak, 80990, Johor Bahru, Johor D.T.</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Date</td>
<td>Address</td>
</tr>
<tr>
<td>-----</td>
<td>------------------</td>
<td>---------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>10.</td>
<td>Mrs Asiah Ahmad</td>
<td>12-03-1993</td>
<td>Manpower &amp; Management Planning Unit, 4th Floor, PKNS Building, Jalan Raja Laut, Kuala Lumpur.</td>
</tr>
<tr>
<td>12.</td>
<td>Dr Roshaimi Zein</td>
<td>16-03-1993</td>
<td>Quality Research Centre, University Utara Malaysia, Jalan Sintok, Changloon, Jitra, Kedah D.A.</td>
</tr>
</tbody>
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