Management for Engineers, Scientists and Technologists

Second Edition

John V. Chelsom
Andrew C. Payne
Lawrence R. P. Reavill

John Wiley & Sons, Ltd

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With thanks to Jo for all she gave me, especially our family, Joanna and Tim with their Sophie and Robert John, and John J and Angela with their Jay Harold, and our friends.

J. V. C. 2004

To the memory of Dorothy, her love, forbearance and courage.

A. C. P. 2004

To Anne, for her continuing patience and help, especially in periods of overload and stress.

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Contents

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Introduction to the Second Edition

In the light of the continuing success of *Management for Engineers*, published in 1996, it has become clear that, while the needs of undergraduate and graduate engineers were being met, the very similar needs of scientists and technologists were not being addressed. The purposes of this new edition are to bring to the attention of a much wider readership the fundamentals of management, and to bring the text more up to date.

While there have been significant changes in the business environment since 1996 there has been no really important addition to the basic management skills and knowledge required by engineering, science and technology students about to start their working careers, nor for those who wish to move from being specialist practitioners into 'management'.

Where there have been developments in some aspects of management, we considered that these could be incorporated without major change to the book's structure. And where sections were out of date, such as the chapter on employment law or the appendix on the Single European Market, we felt they could be removed without much loss. Thanks to the Internet, current information on such topics is readily available elsewhere.

There are two new chapters, Chapters 19 and 23, and one new appendix, Appendix 1. Chapter 19, which originally concerned itself with the project management of large projects, has been rewritten to consider the especial circumstance in which an engineer, scientist or technologist might find himself on the project management team for the procurement of the design and construction of a new facility, whether it be new buildings, a new manufacturing or processing facility or a new laboratory. There have been some major new initiatives in managing construction procurement and these are addressed in this chapter. The only all new chapter is Chapter 23, which relates to small and medium enterprises (SMEs). It takes the form of a case study, based on close observation of a start-up new technology company that was founded by a young engineer and that now includes several scientists and technologists in key positions. There is a related appendix, Appendix 1, providing guidelines to developing a business plan. Other new material has been integrated with the updating of each of the original chapters, and new references have been added to help locate material that had to be excluded because of space constraints. Where possible, we have given Internet references.

With these changes we believe we have made the book a useful 'primer' for all students of management. From our experience and feedback we know that, as well as engineers, the first edition was used by business studies students and management students – and even by managers. We hope that in its updated form scientists and technologists can be added to its readership, and that all readers and users will enjoy it.

John Chelsom Andrew Payne Lawrie Reavill

Preface

Management skills make engineers, scientists and technologists better at their jobs. This is true even if they are working as specialists in the field for which they have trained. A study of 30 major UK government-funded collaborative scientific research and development projects [1] found that almost 90% of them failed to meet their objectives. Many projects foundered, overrunning their cost and timing objectives, due to conflicting objectives, perspectives and expectations, and lack of project management, teamworking and communication skills. Studying management can overcome such shortcomings. This book is designed to assist such learning.

The need for management-trained scientists extends far beyond collaborative R&D projects. It exists in commerce, industry, government and education. The *Sunday Times* (13 June 1993) said: 'British management's biggest defect is its lack of technocrats: managers combining technical know-how with financial acumen.' This defect is not peculiar to Britain, and it persists more than 10 years on. The defect can be remedied more readily by management training of those with the technical know-how than by trying to provide accountants, lawyers and economists with an understanding of science and technology.

In business, the need for technocrats is now even greater. The top business issues of the 1990s, identified by PA Consulting [2] and shown in Figure P.1, continue to be important, but the search for winning products now extends deeper into the science base. Management of the costs and risks of new technology is therefore more demanding, and the time-to-market issue now focuses on harnessing market-driven science to accelerate the introduction of top-quality products featuring technological advances. More recent research [3] puts 'strategic planning for technology products' top among management of technology issues. When combined with the 'advanced materials revolution' [4] these developments take management deep into the 'supply system' (see Chapter 21) and create many opportunities for those technocrats with scientific and business know-how. Career prospects for 'techies' who are skilled managers have never been better.

The skills and knowledge required by those who wish to be successful managers were summarized by W. Edwards Deming [5] as:

- appreciation for a system;
- some knowledge about variation;
- some theory of knowledge; and
- some knowledge of psychology.

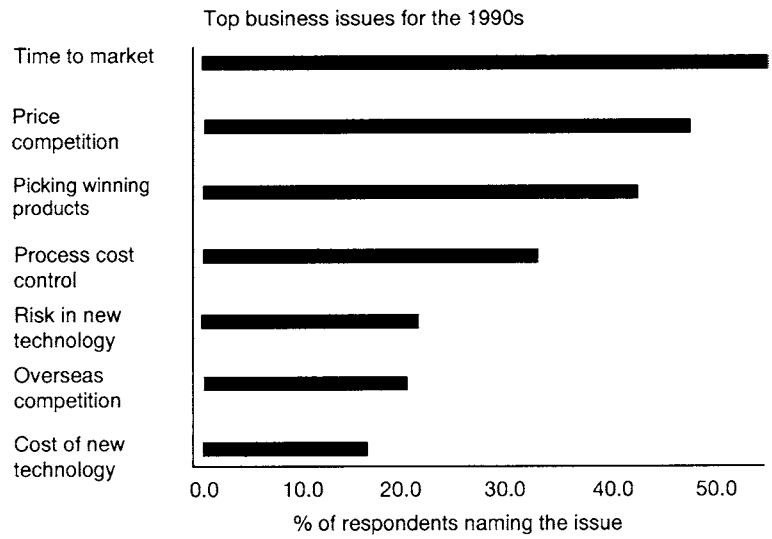

Figure P.1 Top business issues

This book makes a start in the direction that Deming would have us travel. It treats business as a system, takes a systemic approach and describes ways of dealing with variation. The implicit theory of knowledge is the traditional inductive/deductive scientific method, which was translated by Deming into his Plan–Do–Study–Act cycle. We incorporate some psychology in Chapters 9 and 10. The book was not deliberately based on Deming's philosophy, but the coincidence is not altogether surprising. When the first edition was written, the authors were in the Systems Science Department of City University, London, teaching management to undergraduate and postgraduate engineers, and 'management and systems' to other undergraduates. They all came to City University after careers spanning a total of more than 80 years as managers in companies with multinational systems and organizations, and before that they all had a science-based education. So their systemic thinking had common roots with Deming's – he trained initially as a physicist. This all suggests that scientific training is a good basis for becoming a manager or, for the really talented, as in Deming's case, a world-class management expert.

The book is in two parts: Part I is a series of chapters on management applications and concepts, starting with basic issues such as 'What is a business?' and 'What is management?', continuing through management of quality, materials and new product development, and concluding with examples of companies who provide models of good management.

Part II starts with chapters on human resources management and communication, and goes on to provide some tools and techniques, such as critical path networks, discounted cash flow and inventory control – with exercises and worked examples. These examples relate mainly to large organizations, but the lessons apply also to small and medium enterprises. 'Know your customer' is good advice for any company, and large companies, directly or indirectly, are the customers of small companies. To balance this emphasis on large organizations, this

second edition includes a new chapter (Chapter 23), dealing with the challenges facing small start-up companies. The main body of Part II continues to unveil some of the mysteries of activities such as finance, marketing and purchasing – a greater understanding of these functions is a precondition for greater cooperation with them.

To assist those who may wish to pursue a particular subject further, references and bibliographies are provided throughout. These make specific recommendations for further reading, identifying useful chapters and passages or outlining the contents of the referenced material.

We hope that the book will be useful to students and to teachers, that it will be occasionally enjoyable as well as informative, and that it may inspire and assist many young engineers, scientists and technologists to become successful managers. There are opportunities vacant and awaiting you.

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'W. Edwards Deming (1900–1993): The man and his message', the 1995 Deming Memorial lecture delivered by Dr Henry Neave to the First World Congress on Total Quality Management, traces the development of Deming's philosophy of management from Statistical Process Control to the Theory of Profound Knowledge. The Congress proceedings were published by Chapman & Hall, ISBN 0 412 64380 4.

'Getting equipped for the twenty-first century', an article by John V. Chelsom in *Logistics Information Management*, Volume 11, Numbers 2 and 3, 1998, published by MCB University Press, deals with changes in the focus of competition and the concept of total quality. The article adapts some of Deming's teaching as presented by Henry Neave, and suggests modifications to other management models presented by Professors N. Kano and Y. Kondo, to accommodate the impact of the materials revolution and other new technologies. Articles in *Logistics Information Management* are available online at `http://www.mcb.co.uk`.

Part I

Business Basics

1

Business Basics

Don't skip this chapter! It may be basic = simple, but it is also basic = provides a framework or base for your better use of the rest of the book.

1.1 INTRODUCTION

This chapter identifies the basic business functions and shows how they relate to each other to form a 'system' that leads from the idea – the concept of a product or service – to satisfying the customers for that idea. It identifies the need to find funds – that is, money – to get the business started, and to generate more funds by operating the system so that the business can be sustained and expanded. The first part of the chapter describes 'management' and the various roles of managers. The basic business functions are then introduced, and the way they relate to each other to form the 'business chain' or business system is outlined. The chapter concludes with a description of some of the ways in which the performance of business systems may be measured.

1.2 ABSOLUTE BASICS

In absolutely simple terms, businesses, and many other organizations, are concerned with obtaining reward from an idea. How this is done is the task of management, as shown in Figure 1.1.

What is management? This question can be answered by considering first what it is that managers manage – that is, the inputs to the business system – and secondly the roles of managers as they help to transform the inputs to outputs, products or services, through the business process.

So, what are the inputs? Through the nineteenth century it was normal to consider three inputs to a business system:

- land;
- labour;
- capital.

This has its roots in agriculture-based economies, where the capital was used to provide tools for the labour to work the land, plus 'material' in the form of livestock, feed and seed. As economies became more industrialized, the emphasis moved away from land and capital became a more important element, to provide

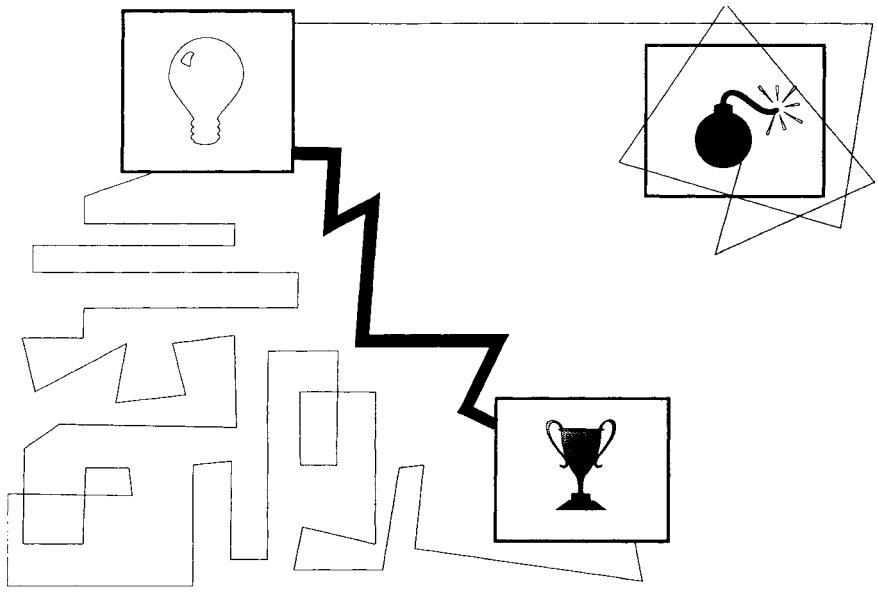


Figure 1.1 From the idea to the rewards – management's task is to find the most efficient, most effective route

more equipment for the labour as well as a wider range of material inputs. Even in manufacturing, labour was the most important cost element from the late nineteenth century until the mid-twentieth century. At this point, mechanization was supplemented by automation and labour's share of total costs fell rapidly. Mechanization had increased labour productivity through devices such as the moving assembly line, which was introduced in the automotive industry in 1913 by Henry Ford I, initially for the assembly of magnetos in the Highland Park plant in Detroit and subsequently for the assembly of the complete vehicle. Automation, through numerically or computer-controlled machines for cutting, shaping and joining materials, through materials handling equipment and through reprogrammable universal transfer devices (UTDs) – better known as robots – has accelerated this decline in labour's share of cost. As a result, material and equipment costs have become progressively more significant.

Managing materials and equipment requires a lot of data about them and about the companies that supply them. Managers also need to know what is going on inside their own organization, and what is happening outside in the marketplace and general environment. So, by the 1980s a new input became a vital part of many businesses: *information*. Developments in information technology (IT) and the advent of the Internet have increased the importance of information management as a means of optimizing business performance. Some organizations, for example Asea Brown Boveri (ABB), have used their IT skills as a source of competitive advantage (see Chapter 8).

Thus there are now four inputs or factors to be managed: land, labour, capital and information. But what does it mean, 'to manage'?

From the 1950 edition of *Chambers' Dictionary*, 'to manage' means: 'To have under command or control; to bring round to one's plans; to conduct with great

carefulness; to wield; to handle; to contrive; to train by exercise, as a horse', or the intransitive form, 'To conduct affairs.'

Some of these terms are rather militaristic or dictatorial, but most of the elements of later definitions of management are there. Note that the manager has 'plans' and brings others round to them, and that 'training' is included. These are elements that have grown in importance.

The 1993 edition of *Chambers* adds: 'to administer, be at the head of; to deal tactfully with; to have time for; to be able to cope with; to manipulate; to bring about.' This suggests that the world outside business and industry has detected little change in management in more than 40 years, and still sees it as a form of constraint or control. Some authorities closer to the action share this view. Stafford Beer, a deep thinker and prolific writer on the subject, described management as 'the science and profession of control' [1]. As shown briefly below and in more detail in Chapter 3, these definitions are too restrictive – *good management entails more positive features, such as initiative and leadership.*

Mintzberg [2] quotes a definition from 1916 by a French industrialist, Henri Fayol, who said that the manager 'plans, organizes, coordinates and controls' but goes on to show that managers actually do rather different things most of the time. Mintzberg defines a manager as a 'person in charge of an organization or one of its subunits'. From his own observations and from studies by others in the US and the UK, Mintzberg concluded that managers spend their time in ways that can be grouped into three separate roles: interpersonal, informational and decisional. Elements of each role are shown in Figure 1.2.

While some of the old dictatorial terms from the dictionary definition are still there in Mintzberg's analysis – 'figurehead', 'monitor', 'handler', 'allocator' – there are some important softer additions – 'disseminator', 'negotiator' *and, most important, 'leader' and 'entrepreneur'.*

Within the role of leader, Mintzberg notes, 'Every manager must motivate and encourage his employees, somehow reconciling their individual needs with the goals of the organization.' This is more like the style that most organizations aim for today. It recognizes that employees are individuals, with needs that may sometimes conflict with corporate goals, and that corporations do have goals.

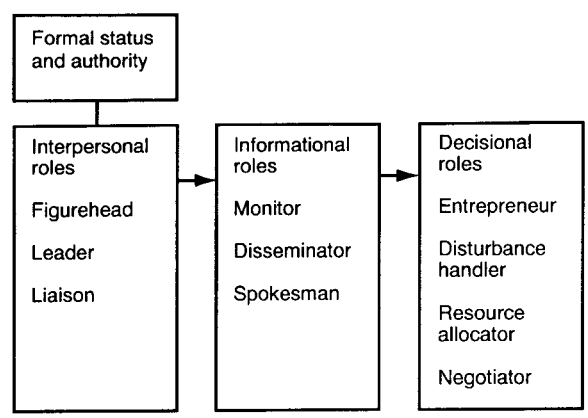


Figure 1.2 Mintzberg's three roles of management

Setting corporate goals, and encouraging and enabling all employees to share them and work towards their achievement, is one of top management's major tasks.

Mintzberg also states, 'As entrepreneur, the manager seeks to improve his unit, and adapt it to changing conditions in the environment ... is constantly on the lookout for new ideas ... as the voluntary initiator of change.' Many organizations are still striving to realize this image of the manager at all levels, and to create a working environment where constant improvement and new ideas are encouraged by involvement and empowerment of all employees, not just managers, to the limits of their abilities.

So, today's manager is enabler, coach and counsellor, as well as leader, entrepreneur, communicator, planner, coordinator, organizer and controller. The manager performs these roles within the business system, and in some cases in setting up the business system.

1.3 THE BUSINESS SYSTEM

The manager performs within an environment and manages resources to achieve some end or objective. Whatever the resources and the objective, there are some features common to the route from the idea or concept to the end result. The sequence of processes and the functions to be performed are similar whether the product is a dynamo or a doughnut, software or a

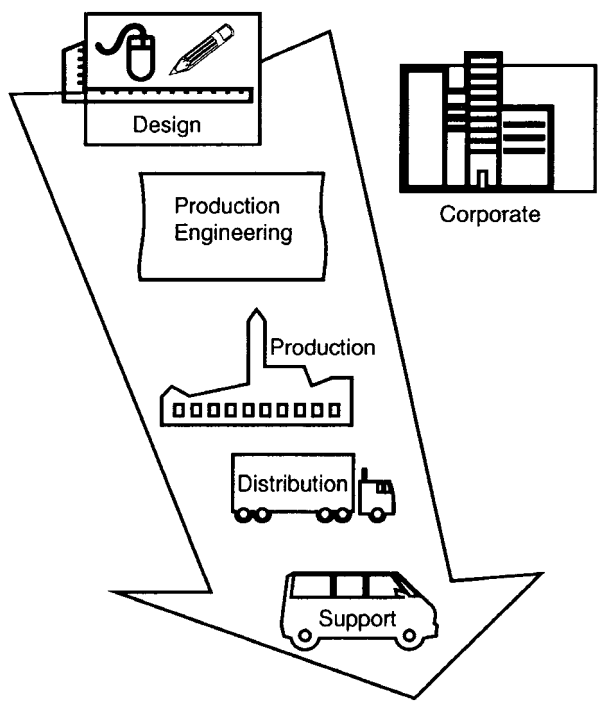


Figure 1.3 Business functions

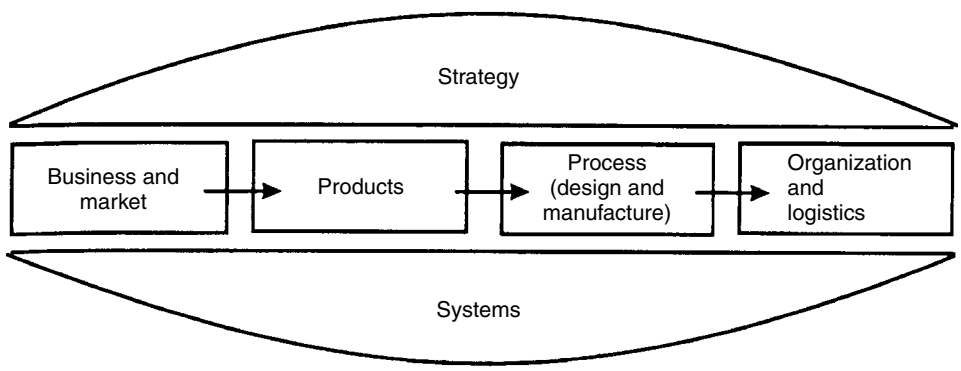
symphony, a car or a cure. A chart identifying the major functions is shown in Figure 1.3.

What the organization does (i.e. what is to be produced, where it is to be sold, where the facilities are to be located) is largely determined in the 'corporate' box.

'Design' is concerned with *what* the product or service or system contains, what its dimensions are, what it is made from and how it performs to meet the market requirement. 'Production engineering' is concerned with developing *how* – how the components of the product or service or system are made and assembled. The production, distribution and support functions are concerned with *when* operations are performed – when material, labour or information is brought in, when production, distribution and service activities are performed. A more detailed list of the decisions and actions in each of these groups of functions is shown in Figure 1.4.

The collection of processes and functions can be regarded as a system, or a business or a business system, through which the idea is turned into a design, which is turned into a product, which is made, sold, distributed, serviced and eventually replaced and scrapped or recycled. Figure 1.5 represents such a system.

Within the system, the core functions of design, sales and production are supplemented by analysts, advisers and scorekeepers concerned with financial, legal and personnel matters. In Figure 1.3 these are contained in the remote 'corporate' box, which is sadly realistic – one of the most difficult management tasks is to close the gap between advisers and monitors in one group, and 'doers' in other parts of the organization.



What business?:

What markets?
Product scope
Nature of business
Positioning of the business
Competitive scope
Design and manufacturing policies

What to make:

Product definition and specification
Product planning
Core and strategic parts
Product life cycle
The base or standard product
The specification and options offered
Product variety and specials
Existing products
Future products
Product rationalization

How to make/design it:

Make or buy
Design workload and priorities
Design procedures
Design for manufacture, assembly and test
The control and admin. of product data
How to modify the product
How to build the product

Making the 'how' happen:

The facilities, tools and aids required
How these are arranged, used and scheduled
The organization structure required to undertake the processes
The flow of data
Part structures and BOM
Communications, links and interfaces

Support and control
The systems used to provide information and control the facilities

Figure 1.4 Business chain

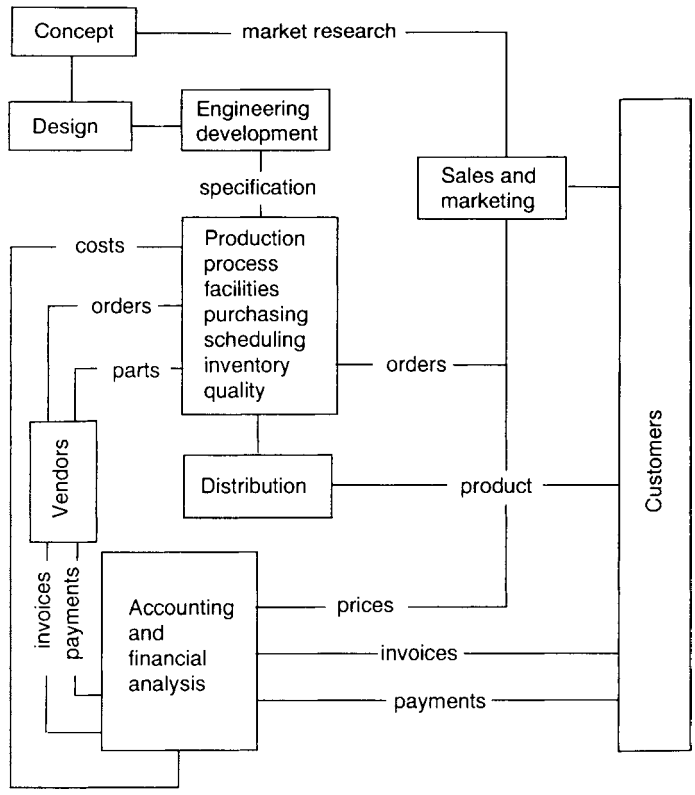


Figure 1.5 A corporate system

1.4 HOW THE SYSTEM WORKS

The entrepreneur, or research team, with a brilliant idea may find that a great deal of waste is avoided if the appeal of the idea is checked first with potential users or buyers. This may be done by market research through specialists, or by the entrepreneur, or by the organization's own sales and marketing activity. This is not an infallible process. One of the most famous market failures was the Ford Edsel, a car introduced for the US market in the 1950s, which was also one of the most expensively researched. As at election times, what the pollsters think the public say they will do is not always what they in fact do. Internal committees may be no better – the video cassette recorder was invented in the Victor company of the USA, but its management thought it had no market. The idea was only brought to market by Matsushita, through its ownership of the Japanese Victor Company (JVC). The Sony Walkman, on the other hand, was the result of logical and lateral thinking rather than third-party market research, and was enormously successful.

Market tested or not, the idea will need design and development to turn it into something fit for production. The production processes have to be developed, production personnel put in place with any necessary equipment, materials procured and the completed product delivered to the customer. The customer in

most cases has to be charged, and suppliers of goods and services paid. Some products need support or service after they have been sold and taken into use, and disposal or recycling at the end of the product life have to be considered.

Many of these activities have to be performed, and paid for, before payments are received from customers, so the idea needs backing with money to bring it to market or into use. This may be the entrepreneur's own money, or it may be borrowed – in which case the lender will require a return in the form of interest – or it may be subscribed in exchange for a share in the business. Shareholders will require either interest payments or dividends – that is, a share of profits – as reward for risking their capital. In Figure 1.6, the shaded lines represent flows of information, product or funds, or actions that have to be completed before money starts to flow into the organization as payments from customers.

The first few months in the life of any business are critical, as the owners wait for the inflow of payments for sales to overtake the outflow of payments for costs. Of course these 'cash flows' have to be carefully considered at all times, not just at start-up. Cash-flow management through the 'working capital cycle', as described in Chapter 14, is vital to a company's survival. Lack of control in this activity is the most frequent cause of failure in start-up companies – the enterprise runs out of money before it is firmly established in the marketplace. Cash-flow problems

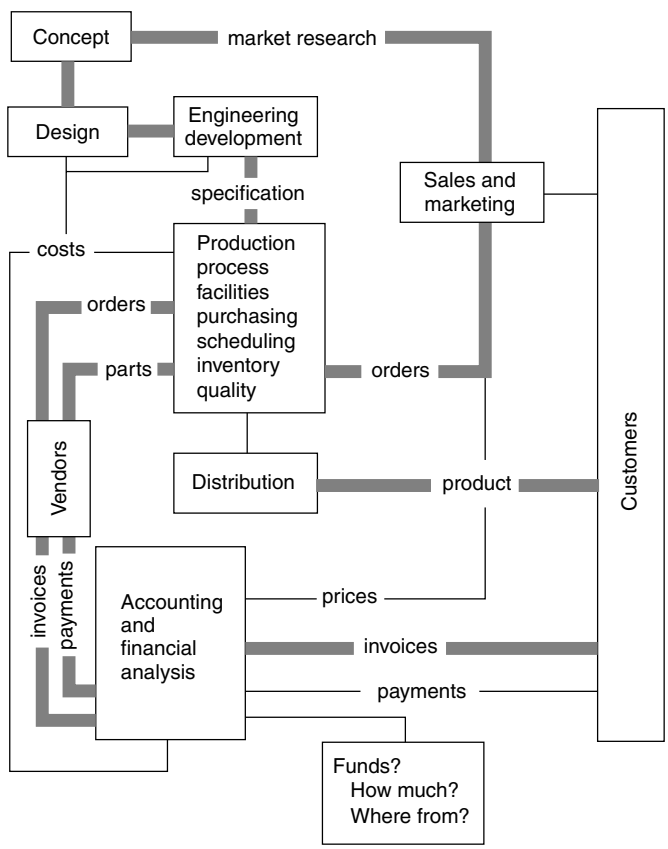


Figure 1.6 A corporate system with cash flow out (shown by shaded areas)

can also create difficulties for large, well-established concerns – see the example of ABB in Chapter 8.

For short-term success, the entrepreneur has to meet all the organization's costs from sales of the product, and have something to spare to make it all worthwhile. Longer term, the 'something to spare' has to cover continual generation of more and better ideas, the maintenance and renewal of facilities, development of personnel, and reaction to competitors and other external factors. Long-term success comes from doing all these things better than other organizations in the same or a similar business – that is, better than the competition.

The more successful the original idea turns out to be, and the more successful the company becomes, the greater the likelihood that competitors will appear. A management tool for dealing with competitive threats – Porter's Five Forces analysis – is shown in Chapter 22.

1.5 MEASURING PERFORMANCE

Managers need to measure several aspects of company performance. Where 'other people's money' is involved, those other people will want to know how 'their' company is doing.

Some measures come from the financial accounts that most companies are required by law to keep. The accounts comprise two major elements – the profit and loss (P&L) accounts and the balance sheet (described in more detail in Chapter 14).

A very simple indication of what appears in P&L and balance sheets is shown below. The P&L accounts show revenues – the value of sales – and the costs incurred in making those sales. The difference between revenue and costs is the profit (if revenue exceeds costs) or loss (if costs exceed sales revenue). The trend of profit or loss in successive accounting periods is one important performance measure.

The balance sheet shows the company's assets on one side and its liabilities on the other. The total value of the assets equals the total of the liabilities – hence the name 'balance sheet'. Growth in the balance sheet total is normally seen as 'a good thing', but much depends on why the figure has grown, and what use has been made of the investment or assets.

Two of the most common performance measures that can be derived from the accounts and give an indication of how well the assets have been used are return on capital employed (ROCE) and return on sales.

Return on capital employed is calculated as

$$\frac{\text{profit before tax}}{\text{capital employed}}$$

The normal target is 10% or more.

Return on sales is calculated as

$$\frac{\text{profit before tax}}{\text{sales revenue}}$$

The normal target is 5% or more.

Some of those terms may need explanation: profit before tax (PBT) is the difference between sales revenue and costs. The following simple P&L account shows £5m PBT.

Sales revenue (£m)		100
Costs (£m)		
Labour	10	
Material	60	
Overhead	25	
		95
Profit before tax (£m)		5

'Overhead' includes (but may not be limited to):

- Depreciation – the portion of fixed assets written off each year, recognizing that they wear out and will need to be replaced.
- Utilities – the costs of gas, electricity, fuel oil, water.
- Rates – taxes on property paid to local government.
- Central staff etc. – these costs are usually allocated to 'operations', so much per employee in each operating unit.

(See Chapter 13 for more information on overheads.)

'Assets' comprise:

Fixed assets
  such as land, buildings, machinery, equipment

Current assets
  cash and near cash (e.g. bank balances)
  debtors (amounts owed to the company)
  inventory

less
  creditors (amounts the company owes its suppliers)
  short-term loans (e.g. overdrafts)

'Total assets' are the sum of fixed assets and current assets.

It is easy to understand why companies wish to make more than 10% annual return on their assets – the money could earn between 4% and 7% invested in government bonds. This is a lot easier and, for most governments' bonds, less risky than creating and running a business.

Another performance measure normally available from the accounts is 'sales per employee'. This is a rather crude indicator of labour productivity, and not very helpful for interfirm comparisons. It can be useful to indicate productivity changes over successive accounting periods, but, as already stated, labour is a reducing element of cost, and there are other more powerful indicators of a company's overall performance.

For manufacturing, one such indicator is 'inventory turnover', which is the ratio of total cost of materials during a year to average stock or inventory. This

measures the frequency of inventory 'turns' in a year. In the very simple P&L account above, material costs were £60m for the year. If average inventory was £6m, it would have 'turned over' 10 times a year. This is a fairly typical rate, but not a good one. Manufacturers such as the car producers Nissan Manufacturing UK and General Motors Saturn company in Tennessee claim turnover rates of 200 times a year – that is, not much more than one day's stock. Such rates can only be achieved with 'perfect' quality within the plant and from suppliers, plus balanced production facilities, well-trained labour, and careful management of incoming suppliers' material and distribution of the assembled product. *That is why inventory turnover is such a good business performance indicator.* An article in *The TQM Magazine* [3] describes how inventory turnover can not just be used to measure past management performance, but can also predict future performance of manufacturing organizations.

Another powerful measure is the percentage of sales derived from products less than two years (or one year) old. This shows how innovative the company is and can be applied to many types of business. As shown in the Preface, new product 'time to market', or innovativeness, was the top business issue of the 1990s. This measure cannot be derived from the financial accounts, but some progressive companies are including such information in their reports. It is an *output* measure, and therefore a better indicator of the effectiveness of a company's research and development (R&D) effort than the alternative *input* measure, R&D expenditure as a percentage of sales, which may be high because R&D is inefficient or misdirected.

These financial and nonfinancial performance indicators are very much measures of management performance, and should be seen as a package to be used together, rather than as separate indicators for shareholders or managers. This was neatly expressed by one of the UK's most successful managers, Gerry Robinson. His summary of the overall aim of businesses and the role of managers is:

> 'You are in business to manage the corporate affairs of the company in which people put their money. I have never seen a dilemma between doing what shareholders want and what is good for the company and the people in it. The two go hand in hand' [4].

1.6 SUMMARY

In this chapter a general form of business system was described and an indication given of the major elements or functions that make up the system, and the processes that turn inputs to the system into outputs. Changes in the relative importance of the land, labour and capital inputs were indicated, and the newer, significant input – information – was introduced. Some definitions of 'management' and the manager's task were given, including a reference to Mintzberg's 'three roles of management' – interpersonal, informational and decisional. The chapter concluded with outlines of some of the ways in which the performance of the business and its managers is measured by managers themselves, and by outside observers and analysts.