QUANTITATIVE APPROACHES TO MANAGEMENT

ROBERT BALL

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Quantitative Approaches to Management

Robert Ball

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To Christopher Ball

Preface

This book was written to provide undergraduate management students with an understanding of and ability to use quantitative methods. It assumes only basic numeracy on the part of the reader, and the mathematical content is restricted to a straightforward level throughout. Likewise, no prior computing skills or knowledge of spreadsheets are assumed.

Since the publication of the author's earlier text, *Management Techniques and Quantitative Methods*, there have been substantial increases in the use of the personal computer and software tools such as LOTUS 1-2-3 in this field. To an extent, this has meant that it is possible for a manager to build his own models and carry out his own evaluations rather than having to rely on experts from the management services or computer field to undertake this work for him. This development is reflected in the orientation of the book; spreadsheets and LOTUS 1-2-3 are introduced at an early stage and these applications are developed at appropriate sections throughout subsequent chapters. As mentioned earlier, no prior computing knowledge is required. The book outlines how with the help of the LOTUS Tutorial an appropriate level of knowledge of LOTUS can be obtained. It should be stressed, however, that knowledge of LOTUS and access to a PC are not essential to the use of this book – they would simply enhance its value.

The main emphasis is on practical application of methods described. There is, however, sufficient coverage of underlying concepts and theory for students to develop an informed and critical outlook. Particular emphasis is given to the context and limitations of the approaches described in this book. A number of the practical examples originate from the author's own management and consultancy experiences. There is also due emphasis on problem formulation, and student exercises are introduced at regular intervals throughout the text.

Students on generalist postgraduate management courses such as the MBA should also find this text valuable. In addition, it should be useful in supplementing distance learning material in this area and meeting the needs of students on management development programmes in this field.

Robert Ball

Contents

1 The quantitative approach to management

1.1 Management

From primitive times people have sought to enhance their welfare through cooperation. Over time came organizations through which such cooperation could be channelled to achieve mutually agreed objectives. Management can be regarded as the control of the activities which are undertaken to achieve the objectives of the organization. It thus includes such activities as taking decisions about the acquisition or allocation of resources within an organization, and control of the organizational structure, together with leadership and motivation. Management is intimately related to decision-making.

It thus follows that all organizations, whether economic, political, religious or sporting, will require good management if they are to operate effectively. The task of the manager may become increasingly difficult as organizations become more complex: for example, the managerial task of completing an oil-platform project, which includes coordinating the efforts of thousands of people working for many organizations, may be almost as complex as the technology of the project itself.

Increasing rates of change, not only in terms of new technology, inventions, innovations but also in value systems, make management even more important. Thus an essential management problem is not only to manage change but to create change, so that organizations can function more effectively.

1.2 Management thinking

People have thought about management from the earliest days when mankind first worked together in groups to achieve a common purpose. Sometimes the ideas of an individual (or more often a group of individuals) are regarded as so important that it gives rise to a particular 'school' of management thinking or specific approach to management.

One of the earliest schools of management thinking was the school of *scientific* management. This school is closely associated with the work of Frederick Taylor, who, in the late nineteenth century, rose from a position on the shop floor to become chief engineer of a steel company. Taylor's work was intimately concerned with increasing efficiency and productivity. This was achieved by a 'scientific' approach to both physical production and management functions, through observation, data collection, analysis and implementation of improvements. Although it is sometimes suggested that scientific management is based on the fundamental idea that economic factors are of paramount importance in human motivation, Taylor's writings do emphasize the importance of obtaining harmony in group activities and cooperation among human beings.

Other very important contributors to the scientific management school were Henry Gantt and Frank Gilbreth. Gantt is particularly remembered for developing graphical methods for improving management work. He stressed the importance of time as well as cost in planning and controlling projects. This led to the development of the Gantt chart as a forerunner of modern network planning techniques for managing projects. Gilbreth was particularly interested in studying the actions that a worker took in accomplishing his task ('motion' study). In his youth Gilbreth had worked as a bricklayer; he managed to reduce the number of bricklaying motions from eighteen to five, more than doubling productivity with no additional effort.

Another important school of management which developed in the first half of the twentieth century was the *administrative management* school. Henri Fayol and L. Urwick are noted as principal contributors to this school, which is very much concerned with questions of design and management of organizations on a rational basis. Fayol and Urwick also studied the problems of managing an organization. An example of this is the idea of unity of command (employees should receive orders from one superior only) and centralization (the degree to which authority is concentrated or dispersed) and how this relates to particular circumstances.

The *human relations* school provided the first systematic attempt to investigate the way in which human factors influence productivity. The names of Mary Follett and Elton Mayo are intimately linked to this school; and the experiments carried out by Elton Mayo at the Hawthorne plant of Western Electric Company between 1927 and 1932 are particularly important. These experiments found that changing the illumination of the test group, say, or changing breaks and hours of work and incentive pay systems did not seem to explain changes in productivity. It was found that, in general, improvement in productivity was due to social factors such as morale, interpersonal relationships and an enlightened management.

These studies led to increased recognition that managers operate in social systems, and emphasis on insights that could be gained from studies of sociology or psychology. Behavioural scientists have since applied more rigorous scientific methods in investigating employee morale, motivation, social interaction, patterns of power and authority.

The *quantitative* approach to management emphasizes the application of mathematical and statistical methods to managerial problems. One of the first recorded cases of elements of this approach is an attempt to analyse deaths from horse kicks in the Prussian cavalry recorded in the nineteenth century.

We have already mentioned how the scientific management school towards the end of the nineteenth century stressed approaching problems by measuring and quantifying data. Progress in the quantatitive field was maintained after World War I. Notable developments were the Wilson Lot Size formula for calculating optimal batch sizes in stock control and the Schewart Chart for use in quality control.

The approach of World War II led to a concerted attempt to apply quantitative methods to managerial problems in the military field. Groups of scientists were set to study the operational (rather than the technical) aspects of military studies. As a result, the term operational research was used to describe this activity. Colcutt (1987) describes one of the earliest operational research studies. In 1940 when the Germans advanced into the Low Countries and France, great pressure was brought to bear to reinforce the fighter squadrons based in France to try to check the German advance. The operational research group carried out an analysis on attrition of fighters already in Europe and produced a graph showing how the losses from the proposed reinforcements would cripple Fighter Command's ability to defend the UK. This graph was used by Dowding (Commander in Chief of Fighter Command) in his confrontation with Churchill, and in the words of the former 'did the trick'. Historians agree that retaining the aircraft in the UK was decisive in the successful attempt to prevent the Luftwaffe gaining control of the air in the subsequent Battle of Britain.

Following the war, elements of the quantitative approach to management were applied to many areas of industry and government. Progress was further enhanced by developments in the computer field, which have led to major developments in information technology and given the analyst much greater amounts of available data and computational power.

There have been a number of other recent contributions to management thinking which would be too lengthy to summarize here (see Koontz and Weihrich Chapter 2). Practising managers will of course make use of appropriate insights from the whole area of management thinking, rather than slavishly follow a particular school throughout.

1.3 The contribution of the quantitative approach to management decision-making

An integral part of the manager's job is making decisions. Depending on his level of responsibility, a manager may find himself responsible for making major strategic decisions as well as handling large numbers of routine daily decisions. Even where a manager is making a strategic decision largely by judgement, a more quantitative approach could at least provide an assessment of the consequences of those choices and some of the opportunities the company may be forgoing in pursuing its chosen strategy.

The quantitative approach may enable us to establish 'decision rules' for some of our day-to-day decisions. For example, this approach might enable us to decide to purchase another 300 units when stock on hand falls to 200 units.

It is of course important to use quantitative information in appropriate and meaningful ways. No organization should, for example, measure performance simply on success or failure of one department. It is also essential to understand that the quantitative approach is not designed to replace judgement, intuition and experience of managers, but to support them in allowing possible consequences of decisions to be evaluated.

1.4 The elements of the quantitative approach to management

The elements of the quantitative approach to management can be considered as the following:

- The systems approach.
- The scientific approach.
- The interdisciplinary approach.
- The modelling approach.

1.4.1 The systems approach

In many cases a decision made in one part of an organization may also have important implications for other parts of the organization. Many companies are organized in divisions and departments. Unless implications of decisions in one division for the organization as a whole are taken account of, then the whole organization will suffer. Poor quality, uncompetitive prices and bad service in the fresh produce department of a grocery superstore may affect all the other departments, since customers unable to obtain satisfactory service on essentials may well take their custom elsewhere. The systems approach of quantitative methods recognizes, and takes into account, these interrelationships.

The author once worked for an organization which had responsibilities for transporting a commodity throughout England and Wales. One study attempted to optimize transport movements over Oxfordshire, completely ignoring interactions with the rest of the country. This process, called suboptimization, could have given rise to results which, though optimal for Oxfordshire, were poor for the country as a whole. It would therefore have been very dangerous to base the transport system on the results of this study.

Any industrial and commercial organization operates in relation to its suppliers and within the financial, legal and social systems in which it is situated. It is therefore important to identify the systems, their boundaries, interdependencies and purposes. This step is essential in preventing unforeseen and overcompensatory and detrimental feedback from other parts of the system.

A further example of the system approach is that used by the electricity companies in assessing the economics of constructing a new power station, which cannot be considered in isolation. The effect of the new station on the grid as a whole must be considered; its building may enable older, fuel-inefficient stations to be employed only at peak times instead of being used practically continuously, i.e. as part of the base load.

In real life we will need, on occasion, to define the system boundary rather tightly in order to contain a problem to manageable proportions. For example, we may attempt to improve the operation of a retail chain's stock-control system in isolation when we could widen the system boundary to incorporate consideration of which lines should be stocked and even the company's entire corporate strategy. Nevertheless the interaction of the operations of the stock-control system with these other factors may be slight. Thus improving this system in isolation may be a reasonable course of action. Checkland (1981) gives a more detailed discussion of the systems approach.

1.4.2 The scientific approach

The scientific approach calls for a formalized reasoning process, which begins with a study of the problem area. Difficulties may be encountered here, since what is perceived as the problem may be only a symptom of a more fundamental malaise. For example, excessive investment in stock might be a symptom of using an inappropriate stock-control system or a policy of reordering excessively large batches.

The scientific approach makes a statement (known as a hypothesis) about the problem, and that statement is capable of verification. Relevant observations are then made and their results used to decide whether or not the hypothesis should be accepted or rejected. For example, had we developed a new drug for the treatment of AIDS, we might start with the hypothesis that the new drug was no more effective than the existing treatment. We might then randomly divide a set of patients into two groups – one that gets the new treatment and one that gets the existing treatment. We would then analyse the progress of both sets of patients and decide whether or not to accept or reject the hypothesis in the light of these results. This approach, as we shall see, can be used in many practical applications. For example, in quality control, where sampling techniques may be used to check a number of products for quality; or in market research, where testing is carried out to ascertain where a new brand of soap sells better than an existing brand.

There are, however, certain situations where the scientific approach can be unduly limiting in carrying out an evaluation. If, for example, we are looking at a manager's experience of motivating his workforce to improve quality, the scientific approach can be unduly constraining if we are forced into formulating the research as a series of verifiable hypotheses. In such situations 'naturalistic methods' (see Gubba and Lincoln, 1981) may be adopted. Naturalistic methods might call for wide-ranging interviews with managers about a framework of standard questions.

1.4.3 The interdisciplinary approach

Human knowledge has for convenience been classified into a number of academic disciplines: mathematics, engineering, physics, economics, etc. This approach has been hugely successful in allowing advances to be made in each discipline. It is a mistake, however, to expect real problems to confine themselves to somewhat arbitrary disciplinary boundaries. Further, an analytical approach which has been useful in a distinct discipline may be helpful in handling managerial problems. Thus a team of workers with different backgrounds may be able to provide such an appropriate interdisciplinary approach.

1.4.4 The modelling approach

It is impractical to adopt a trial and error or experimental approach in real-life situations. For example, it would be dangerous to ask pilots to practise coping with rare emergency situations while actually flying a plane. If we are trying to decide where to situate a new store, it would be impractical and impossible to try out the results of situating the store in different positions to compare the results. Instead we build a representation of reality and experiment with this. This representation is called a 'model' and the process of construction is called 'model-building'. It is inevitable that a model will be a simplified representation of reality, because reality is too complex to copy exactly and, for practical purposes, some of the complexities can be ignored.

It is important, however, that the aspects of reality in which we are interested are properly represented. Model building can be an expensive process, and it is important that the potential benefits obtained from the approach will be worth the cost. We can have different types of model:

- Physical models provide a physical representation of the subject under investigation. For example, an architect may provide a scale model of a new shopping complex.
- Analogue models attempt to represent the system by a physical quality. For example, the flow of water through a system can be represented by an electrical voltage.
- Mathematical models represent those aspects of the system we are studying by a series of mathematical relationships. Such a model may perhaps be used to try to understand how the system operates under different conditions and perhaps the effect of making different decisions. For example, we may wish to prepare a financial model of next year's budget. Having done this, we shall probably be interested in sensitivity or 'what-if' analysis, which will require taking a hard look at the assumptions in the model. For example, what is the effect of a 10 per cent increase in costs, of sales being 5 per cent higher than predicted, or of a 1 per cent increase in wages costs? These are all questions the conscientious analyst will want to investigate.

1.5 An example of the use of mathematical models

Let us consider the example of a distribution company which fixes its charges to customers on the basis of a flat fee of £15, together with a mileage charge of 10p. per mile travelled. Then the relation between the cost of the hire (C pounds) and distance travelled (D miles) is given by:

$$C = £15 + £0.10 \times D$$

This, a simple mathematical model of the relation between cost and distance, can also be represented in graphical form (see Figure 1.1).

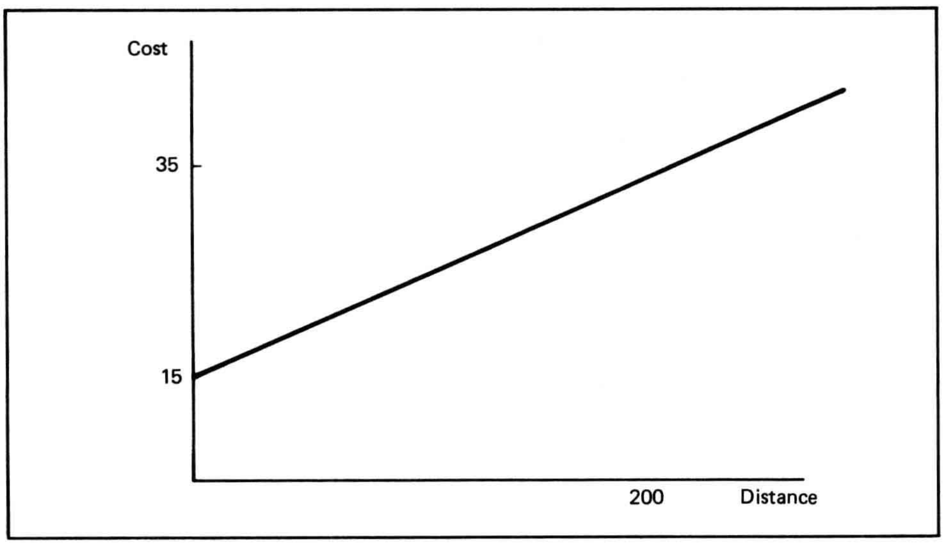

Figure 1.1 *Relation between cost and distance for a distribution company*

The model can be used to predict the cost of making a particular journey. For example, if we plan a round trip of 200 miles ($D = 200$), then:

$$C = £15 + £0.10 \times 200 = £35$$

If we plan 60 trips a day, 6 days a week, with an average journey between depot and stores of 63 miles, then the total weekly cost on the above changing basis of £15 flat fee per journey and a 10p. per mile charge would be:

$$C = (£15 + 0.10 \times 126)\,(60 \times 6)$$
$$= £27.60 \times 360 = £9,936$$

(note 126 miles is the round trip)