A Manager's Guide to Operations Research

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A MANAGER'S GUIDE TO OPERATIONS RESEARCH

To

CLAY H. HOLLISTER

and

DONALD HICKS

The Managers who guided Us

Preface

OVER THE last twenty years the science of OR has grown rapidly. It has grown not only in the sophistication of the techniques which it uses, not only in the rapid intake of the personnel employed, not only in the rapid increase of the salaries of all those working in this field, but it has also grown in the type of problem it tackles and in the maturity it brings to these problems. Such has been its rapid growth that notwithstanding the great deal of interaction between the OR scientist and the industrialist, the management executive often hasn't a clue what it is that the OR men in his company are doing. For the man who does not yet have OR within his company, there is the perplexing problem of whether he should undertake OR and, if he does, what is going to happen, what sort of people will he employ and how will they go about their business. To introduce OR into a company requires a tremendous act of faith on the part of the executive.

Justification by faith is a well established doctrine, but equally faith without understanding is a questionable basis for managerial action. It is the purpose of this book to enable the industrial executive to reduce the faith he requires to undertake OR in his organization. The techniques of OR are now so highly developed that it is difficult, and in fact probably not very useful, to take the executive through them. In fact, one wonders how far the industrial executive needs to know the manipulative techniques of his staff. Should the executives of a chemical company be able to analyze a compound for the presence of copper? Should the executives of a petroleum company be able to operate an oil refinery? We feel the answer here is, No. What we do feel, however, is that there is a need for the executive to become acquainted with what OR is doing, with how the OR worker goes about his task and what is likely to be involved in setting up OR.

Over the last 15 years we have both, in our own and each other's countries, met hundreds of executives who have come up with the same pattern of questions regarding the use of OR. In comparing our notes while writing this book, we have been fascinated to find how common is our experience in this regard. It seemed to us that we would like to share the answers to these questions so that the industrial executive may be able to find out a little bit about this field for himself and may be introduced to some of the introductory references for reading in this area. Equally, we hope that this book will appeal to the harassed OR worker who is called upon within his company, from time to time, if not from week to week, to explain what it is he is doing and how he goes about it and how he fits in with the whole picture of industrial OR. It is, therefore, at the industrial executive that we have aimed this book, in the hope that it will be of assistance and encouragement to him.

We should like to express our appreciation to Frank Benson, Glen D. Camp and Vern Mickelson for their helpful suggestions in preparing this work.

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The evolution of management and related scientific aids

Let us begin this story with a familiar part of our past. Until the second half of the last century, most industrial organizations in the United States and United Kingdom employed only a handful of people and occupied a space about the size of a two-car garage. These enterprises were usually owned and managed by the same individual.

This picture began to change in the last quarter of the nineteenth century because of the first industrial revolution. This revolution was based on the development of power-generating equipment and machine tools. Mechanization of production, together with the development of national transportation and establishments with an eye to the sources of material and labor and to the location of consumers, rather than to natural sources of power. As industrial enterprises expanded, it was no longer possible for one man to perform all the necessary managerial functions. Consequently mechanization, which led to a division of manual labor, also led to a division of managerial labor. Functional managers were created, usually responsible for production, marketing, finance, personnel, and engineering or research and development.

Industries continued to grow and required further division of managerial functions. For example, a new level of production management was sometimes created to care for such functions as shop operations, maintenance, procurement, quality control, and transportation. As companies merged or expanded into multi-plant operations, this complex of managers then had to be reproduced in several locations. That is, product diversification and the geographical expansion of the market required still further segmentation of management. This process of segmentation continues even now.

Throughout this division of management and the growth of industry, the scientists, whose research had helped to make it possible, turned to the new class of problems created by the application of the instruments and knowledge that they had produced. Some physical scientists became experts in power, machines, and materials and began to differentiate themselves from other physical scientists on the basis of their interests in industry and their preoccupation with the application of available knowledge rather than with the discovery of new knowledge. In this way mechanical engineering came into existence as a development of applied physics. Chemists and engineers together created chemical engineering. For a quarter of a century or more, mechanical and chemical engineers concentrated on increasing the productivity of the equipment employed in the productive process.

In the early part of the twentieth century, it became apparent that further significant increases in productivity could only be obtained by giving more attention to the worker than he had hitherto received. Taking advantage of the newly developing science of psychology, a number of engineers began to study the interactions of man and the machine which he operated. In this way, industrial engineering and work study were born.

Similar applications of science were made to other functions of business. For the marketing function, statistics, economics, psychology, and sociology were combined to create market and marketing research. In finance, the economics of the firm (or micro-economics) was created, and accounting grew into a profession. In the human area, industrial psychology and sociology developed out of the study of human relations in industry. Science kept pace with the specialization of management. For example, in production, statistical quality control and engineering specialities in maintenance, procurement, transportation and materials handling, all came into existence.

In this parallel development of management and applied science, however, there was one conspicuous gap. Except for a few abortive efforts, science did not come to the aid of the *executive* function created by the segmentation of management. Before we examine this and the reasons for it, let us consider the nature of the executive function.

The function of an executive consists, among other things, of integrating the policies and operations of the diverse departments reporting to him, in order to obtain an overall operation that comes as close as possible to realizing the organization's overall objectives. This integrating function is quite complex because of the conflict of interests that always develop between the units coordinated by an executive.

For example, in a functional type of organization, the executive wants to evaluate separately the performance of each function. To do so, objectives are established for each function. The objective of the production department is usually formulated as 'to maximize output and to minimize the unit production costs'. For marketing, the objective might be 'to maximize sales volume and to minimize the unit cost of sales'. For finance it might be 'to minimize the capital required to operate the business'. For personnel, it might be 'to maximize employee morale' or, more specifically, 'to minimize labor turnover'.

Like the ten commandments, these objectives represent aspirations which are easier to accept in principle than to follow in practice. Practical difficulty arises out of their inconsistency. Consider, for example, the question of an appropriate inventory policy for the company.

Each function has a different concept of what inventory policy should be because of the difference in objectives. The production department would like to make long continuous manufacturing runs in order to minimize setups and in order to get the efficiency that comes with long practice. To produce in this way requires a large inventory spread over relatively few products. Therefore, from the production department's point of view, the shorter the product line, the better.

The marketing department also favors a large inventory, because it would like to be able to ship today anything that is ordered tomorrow. Its interest in obtaining and maintaining customers leads it to press for a long product line containing as many interrelated products, models, sizes, shapes and colors as the customer may want to purchase from a single source. Hence a basic conflict between the production and marketing departments usually develops concerning the 'length' of the product line and the composition of inventory.

The finance department looks on 'inventory' as a dirty word. When sales drop, this department wants to reduce the amount of capital tied up in the business. It generally finds inventory a convenient place from which to withdraw capital. Hence, it usually presses for reduced inventories during slack periods but may allow inventory to grow during good periods.

Personnel managers, on the other hand, want to maintain the production rate when sales drop in order to retain skilled and trained workers, to reduce hiring and firing costs, and to maintain high morale among the workers. Hence, they want to produce inventory during slack periods. Therefore, they come into conflict with financial management.

Now, the executive has the responsibility of finding an inventory policy that is best for the organization as a whole, not for any particular department. He must consider the effects of a policy on each department, but his evaluation should depend on the overall effect. It is this type of integrating decision that we take to characterize the role of the executive.

Executive-type problems occur at places other than the top level of a business. For example, once the production function is divided, the production manager must integrate and coordinate the activities of the various functions reporting to him: maintenance, quality control, procurement, and so on. There are not only functions, but plants and regions to be coordinated. In effect, then, we consider an executive-type decision to be one that involves putting together the activities of parts of an organization in such a way that the overall operation comes as close as possible to attaining the organization's objectives.

Now let us return to the earlier remark that, during the era of mechanization, science was not applied to executive-type problems in any organized way. Both the executive and the scientist had a reason for this.

The first industrial revolution took place gradually: in fact, it was an evolution rather than a revolution, and it is still continuing. As a consequence, industries grew slowly enough for executives to grow with them. Because of the continuity and gradualness of development, executives could rely on their judgment and past experience to guide them through new problems. The new problems were seldom very different from the old, and so the executives felt no great need for outside assistance.

On the other hand, in the 1920's and 1930's, as the executive function came into increasing importance, scientists found themselves in one of the most underpaid professions in society. They had to find status satisfaction in noneconomic symbols. Consequently, they relied heavily for status on the 'purity' of their research, that is, on the lack of their involvement with practical problems, particularly ones involving the profit motive in any way. They rationalized their position by arguing that practical problems were not as difficult and hence not as challenging as pure research problems. For this reason engineers were looked down upon by the scientist as an inferior lot. Remnants of these attitudes still remain.

Scientists came into very little contact with executives, compared with today, but this changed during World War II. To examine this, we must turn from an industrial setting to one that is military.

It should be noted first that the military had gone through a completely parallel evolution because of mechanization and hence through the same division of labor and management. Major functional divisions had been made (administration, intelligence, operations and services) and subfunctional divisions as well (e.g., signal, transportation, ordnance, engineer and chemical corps). In short, the industrial revolution was mirrored in the military establishment, except for one important difference. The experience of military executives was not continuous. Two decades had passed between the two world wars and there had been a tremendous change in the technology of warfare during that time. Consequently, with the outbreak of World War II, military executives were confronted with the necessity of waging war with a system with which they had had very little real experience. Under these circumstances, military executives turned to the scientists, who had been closely involved in the technological development, for assistance in the operation of the new system. Some scientists put aside their prejudices against applied research and took up the challenge.

More specifically, starting in 1937 British scientists were asked increasingly to assist military executives in learning how to use the then newly-developed radar to locate enemy aircraft. By 1939 this had become a formal activity. The initial objective was to extend the range over which radar could be used, in order to increase the time between the first warning and the attack by enemy aircraft. The scientists recognized that gains could also be made if the time between the first warning and the deployment of defenses could be reduced. This led to study of the communication system linking the detection centers to the defenses. Attention was first given to physical equipment and communication networks, and later to the personnel and executives involved. As the number of early-warning stations was increased, it was observed 'that there was a substantial variation in performance between them, even when operated by the same group of test operators. At the same time with the spread of the number of stations, there was an ever-growing number of operators, and variations in skill of the operators was suspected of being an important factor in the variation of performance of stations . . .'. Analysis revealed ways of improving the operators' techniques and, in the process, also revealed 'hitherto unappreciated limitations in the network, some of them due to local geographical conditions'. (Crowther and Whiddington, 1947, p. 93.)

The scientists working on different aspects of this problem were brought together in September 1939 to H.Q. Fighter Command and '. . . they were encouraged to regard themselves as part of the Command staffs . . .'. The Section steadily extended its scope of activities beyond radar and its uses and, by the time of the Battle of Britain, was consulted on an ever-widening variety of subjects . . . (p. 93)*.

'By the summer of 1941 . . . it was decided to set up OR Sections very widely in the RAF' (p. 94). Similar developments took place in the British Army and Navy, and in both cases radar instigated the activity. In the Army, OR grew out of the initial inability to use radar effectively in controlling the fire of anti-aircraft weapons. In the course of studying this problem

> A new point had emerged. Radar apparatus that worked perfectly in the testing-laboratory often failed to work

* *Ibid.*

> properly on the sites where it was erected. Thus the traditional method of proofing equipment did not completely apply to the new apparatus. A new gun-sight behaved in the same way in the workshop as in the battlefield. Thus the scientist who tested it need not leave the workshop. He did not need to inspect it on the battle site . . . This would not work with radar gun-sights, for they were 'temperamental' and were affected by the neighborhood (p. 96).*

To solve this problem, in September 1940 the distinguished British physicist, P. M. S. Blackett decided to

> bring together a number of men with good scientific training but without specialist radio knowledge, to study the new problems from a more general point of view. They were to study the performance of gun control equipment in the field, especially during its actual use by the troops against the enemy. The first two members of the group were physiologists, the next two were mathematical physicists, then an astro-physicist, followed by an Army officer, an ex-surveyor . . . The team was later completed with a third physiologist, a general physicist and two mathematicians . . . The group became known as 'Blackett's Circus' (p. 96).*

This type of scientific activity came to be known in Britain as 'Operational Research' because the first studies were devoted to the operational use of radar and were carried out by scientists known as working in radar research. Under this and other names it flourished in the United Kingdom.

In *Three Steps to Victory* (London: Odhams Press, 1959), Sir Robert Watson-Watt, who claims to have launched the first two OR studies in 1937, wrote, 'In January and March, 1942, I made, in my reports on my mission of inspection on the Pacific Coast and in the Panama Canal Zone, urgent representations that OR should be introduced into the departments of the Secretary of War and the Secretary of the Navy in the U.S. I gave specific descriptions of some immediate OR tasks in radar. By 1st April, 1942, decisions to introduce operational research at high level in both "War" and "Navy" had been made and implemented' (p. 204). In the Air Force, it came to be known

* *Ibid.*

as Operations Analysis, and in the Army and Navy as Operations Research and Operations Evaluation.

The activity grew not only in the British and U.S. military services, but in the Canadian and the French as well.

At the end of the war, a number of British operational research workers moved to government and industry and began to spread the 'word'. This extension of the work was largely stimulated by the new types of management problems created by the nationalization of industry that began to take place in Britain and by the need to rebuild large segments of the nation's industrial facilities.

One of the first industrial Operational Research groups to be set up was at the National Coal Board where the Board member for science, Sir Charles Ellis, had previously been responsible for the Army's Operational Research. Electricity and transport (rail and air) were other nationalized industries which very soon began to employ Operational Research workers. The private sector of the economy very soon followed suit, and in particular the steel and textile industries took on their first OR men. A feature of British industry which is not extensively matched in the United States is the cooperative research association which operates for all the firms in a particular industry. These research associations, in particular the British Iron and Steel Research Association, aggressively developed OR.

The early development of this new science was cautious and slow. For some years, most British industries where OR was carried out had only one or two men in this field. During the latter half of the 1950's, the germinating seed burst into full flower and existing OR groups expanded to cope with the greatly increased demand from their firms, and in addition other companies went into the OR activity. British OR is partly dominated by a number of large OR groups. The United Steel Companies group now has over eighty people, the National Coal Board over sixty, British Iron and Steel Research Association, British Petroleum and Richard Thomas & Baldwins all have over forty OR workers. In addition, there are a very large number of medium-sized firms with groups of two or three people, and at the present time it is difficult to think of any single type of industry which has not got OR going on somewhere within it.