OPERATIONS RESEARCH AND THE APPLICATION OF ADVANCED MANAGERIAL TECHNIQUES — AN INTRODUCTION

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Hierdie artikel is bedoel as 'n inleiding tot Operasionele Navorsing en die toepassing van Gevorderde Bestuurstegnieke, 'n gebied wat omskryf kan word as die toepassing van wetenskaplike, spesifiek kwantitatiewe metodes, op bestuursprobleme.

In hierdie veld is daar 'n verskeidenheid tegnieke beskikbaar, baie waarvan nog betreklik onbekend is by bestuur. Sommige word reeds as standaard-tegnieke beskou, en andere mag hulle in die ontwikkeling- of verbeteringstadium bevind.

'n Artikel soos hierdie is dus in ooreenstemming nie slegs met die ontwikkeling van akademiese navorsing in die veld nie, maar ook met 'n steeds groeiende vraag na kwantitatiewe ontleding in die sakepraktyk.

Die moderne bestuurder tree in 'n toenemend komplekse omgewing op waar kwantitatiewe metodes 'n alledaagse verskynsel is. Hy kan dus nie die veld en sy probleme slegs aan deskundiges oorlaat nie. Die bestuurder moet weet wanneer kwantitatiewe metodes betroubaar en van waarde is. Hy moet 'n basiese begrip hê van hulle aard en rol, hulle koste-voordeel-verhoudinge, asook hulle beperkinge. Dit behoort hom die nodige vertroue in te boesem om die aanbevelings van die spesialis na waarde te skat in die besluitnemingsproses.

1. INTRODUCTION

Although the United States has held, and still holds, a leading position in this as in so many other areas of applied science, the importance of this field for managerial planning and control has been increasingly recognized in Western Europe, and South Africa seems well on her way to making full use of its merits. It may seem odd that even such countries as Soviet Russia or certain Eastbloc Countries have adopted some approaches so "typically American", but, as is probably known, their centralized planning systems cause even more complex and comprehensive planning problems than those of, say, a capitalistic enterprise, and therefore requires sophisticated planning and control techniques on both the macro- and micro-economic level.

Increasing size of enterprises, increasing complexities of organizations, increasing amounts of capital involved and, hence, increasing capital risks, increasing speed of communication, values of sales and contracts, mass production, competition, and the necessity for higher productivity in order to fight inflation, these are some of the driving forces behind the development of management information systems (MIS) the use of Electronic Data Processing (EDP), the growing interest of business practice in such fields as Operations Research (OR), Production Operations Management (POM) and Management Science (MS), all of which are concerned in one way or another with the development and/or use of quantitative planning and control techniques. The areas of application range from the design of information systems to the solution of transportation problems, from financial and/or budget planning to production line balancing and from the determination of optimal marketing strategies to the simulation of competitive situations or alternatively applied business policies. These observations show clearly that the range of techniques, and even more of applications, is far too wide to be entirely covered in one introductory article.

The rapidly increasing flow of management data creates pressure on management to exploit this data advantageously with a very limited space of time. But it comes as a surprise, that management facing this growing burden makes so little use of quantitative advanced managerial techniques.

One of the reasons is the communication gap, experienced quite frequently in a majority of companies. In other words, one of the major obstacles for both managers and operations research specialists is that of communication (and to some extent credibility). The manager finds it difficult to think in terms of variables and parameters, he might not understand the "jargon", since often the specialist does not fully understand business problems, particularly their practical and economic aspects, as the totality of running a business.

It is an essential task to bridge this communication gap.

2. DEFINITION OF TERMS

Some of the terms used in the introduction require explanation. Operations Research (OR) is, according to Churchman, Arnoff and Ackoff, "the application of the scientific method to provide executives with a quantitative basis for decisions regarding operations under their control".[1] This is a widely accepted definition and is satisfactory for the purpose of an introduction.

A more descriptive definition is that given by the British Operational Research Society: "Operational Research is the attack of modern science on complex problems arising in the direction of management of large systems of men, machines, materials and money in industry, business, government and defence. The distinctive approach is to develop a scientific model of the system, incorporating the measurements of factors such as chance and risk, with which to predict and compare the outcome of alternative decisions, strategies or controls. The purpose is to help management determine its policy and actions scientifically."[2] Churchman maintains that OR and management science[3] are essentially the same. Generally it should be borne in mind that there are two facets to OR and management science:

a) Research and the development of new methods.
b) The application of suitable methods to specific practical problems.

Within the area of management science we have the field of Production or Operations Management which Buffa[4] defines as "design, operation and control of productive systems".

Hence Operations Management is that particular area of management science or OR that is concerned with the production of physical goods and the provision of services in business enterprises.

In contrast to OR Management Information Systems (MIS) are closely connected with standard costing and the management-by-exception principle, providing not only predetermined cost standards but also automatic feedback and control of deviations from these standards. The use of electronic computing devices for MIS is imperative because of their complexity and high value of immediate feedback and corrective action.

3. A BRIEF HISTORY OF OPERATIONS RESEARCH

The first solution of problems that today would be considered typical OR work appeared as early as during World War I, when Thomas Edison made use of a "tactical game board" in order to minimize merchant shipping losses due to enemy submarine activity. In 1911 A.K. Erlang laid the foundation of modern waiting line theory by developing mathematical models involving the fluctuation of demand for telephone equipment upon automatic dialing facilities.[5]

During the early 1930s, H.C. Levison developed high-standard mathematical models which involved large amounts of data (for example, customers refusing acceptance of C.O.D. assignments on a large scale) for problems that would otherwise have been completely unmanageable.[6] In 1937, Sir Robert Watson-Watt,[7] who claims to have launched the first two OR studies, recommended the introduction of OR into the departments of the Secretary of the US Navy and the British Secretary of War, and by April 1942 this recommendation had been implemented. A team of scientists under Prof. P.M.S. Blackett was assigned to the British Fighter Command. The group scored significant successes in the solution of military problems and as a result similar groups were attached to other R.A.F. Commands, the Admiralty and the Army operational headquarters. After the United States had entered the war similar groups were established in the US. From then onward the development of OR techniques was a joint allied activity with important contributions made by both parties. The type of problems investigated by these groups is reflected in their rather interesting composition. The OR team led by Prof. Blackett was composed of two physiologists, two mathematicians, two mathematical physicists, an astrophysicist, a surveyor and an army officer. The group soon became known as "Blackett's circus."[8]

This military group tackled problems such as:

(a) the selection of fighter bases in England to secure maximum security for a number of objects (cities, defence plants, power stations, etc.) with a limited fighter force;
(b) the co-ordination at gun sites between radar installations and a newly developed instrument which indicated the altitude of attacking aircraft.
(c) anti-submarine warfare, and
(d) optimal ratio between members of merchant ships and naval escorts to minimise losses due to submarine attacks.

Post-war military OR comprises problems such as:
(a) optimal defence against nuclear attacks
(b) design of complex weapon systems such as "Hound Dog" and "Polaris" (now obsolete)
(c) light and heavy arms fire control for entire battalions
(d) target selection for missile attacks, and
(e) spacing and manoeuvering of naval units in the light of possible nuclear attacks on a fleet.

Post-war non-military OR was initiated and significantly supported by a number of factors, such as the availability of skilled OR staff and an existing set of basic techniques which were originally developed for military purposes. Although the progress of OR in business enterprises was slow in the beginning, an ever-increasing range of newly developed techniques together with the advent of electronic computers has led to remarkable growth rates of OR in the United States since 1950 and in Western Europe since the late nineteen-fiftees.

Today OR can be regarded as a methodology widely accepted in nearly all industrialized and industrializing countries.

Although by its very nature OR is technique-oriented rather than problem-oriented, the field has expanded so phenomenally that today there are not only military and business specialists in OR but also production, finance and marketing specialists who find it difficult enough to keep up with the rapid development in any one of these areas.

4. SUCCESSFUL OPERATIONS RESEARCH APPLICATIONS IN BUSINESS MANAGEMENT

The following list comprises only the most outstanding of successful applications of OR methods in business management for the functional areas of the firm, as the wide range of problems are normally better understood by discussing them in terms of their content. Most managers are not immediately familiar with problem analysis in terms of. the underlying logical structure.

4.1 Planning for plants and equipment

The following OR methods have been applied successfully:

(a) optimum location of plants,
(b) optimum layouts of plants,
(c) optimum plant and equipment maintenance and replacement
(d) optimisation of investment decisions, and
(e) balancing of production lines.

4.2 Production planning and scheduling

Effective OR methods are available for
(a) the determination of optimal production-lot sizes in relation to demand (planning)
(b) the determination of optimal production programmes, that is, selection of products and quantities so that, for example, profits are maximised (planning),
(c) scheduling of small and large production lots without creating bottlenecks (scheduling);
(d) Scheduling of large none-time projects (network planning and control) (scheduling);
(e) allocation of scarce resources to large one-time projects (scheduling and planning)
(f) determination of minimum cost production rates and workforce sizes for production periods from three to twelve months (planning and scheduling); and
(g) determination of optimum procurement and inventory policies (planning)[9] and scheduling)[10]

4.3 Marketing and financial sectors

A number of applications have proved successful in the fields of marketing, selling and finance. Some of these are:

(a) the determination of geographical sales areas and the sales quotas for these areas:
(b) optimum strategies, indirect v. direct sales
(c) the optimal geographical location of warehouses,
(d) the optimal choice of transport facilities
(e) modifications of the distribution patterns in the light of anticipated expansion
(f) allocation of funds to the various advertising media ("media scheduling")
(g) investigations into: product v. brand advertising, and nation-wide v. regional advertising, with the objective of determining optimum budgets,
(h) bidding models to determine optimum bids for contracts and
(i) cash planning and control systems, including the optimum use of excess liquidity and the minimum-loss liquidation of variable assets in times of cash shortages.

4.4 Research and Development

The following problems have been (among others) carefully scrutinized
(a) determination of budget amounts
(b) allocation of funds and staff to the projects in question
(c) determination of facility sizes
(d) investigation of research effectiveness, and
(e) optimization of organisational structures in research and development activities, in order to reduce time and cost requirements of the various projects.

4.5 General information

Much progress is presently being made in this field. Two types of systems developed with the aid of OR have been fairly successful in practice:

(a) Management Information Systems (MIS) (see section 2); and
(b) general report and control systems for use in banks, (capital and particularly cash flows) and industrial establishments (automatic inventory control systems, for example).

Thus OR already exhibits a fairly impressive record, and this record is improving as practice-oriented researchers concentrate increasingly on solutions to practical problems rather than on the development of basic theories and techniques. As in modern technology, a sound balance between research and application must be the ultimate objective of OR development

5. THE APPROACH OF OPERATIONS RESEARCH

The basic approach of any OR study can only be an updated version of a scientific method. This systematically planned approach can be subdivided into several distinct steps which will be discussed here only very briefly.

5.1 Problem formulations

A clear understanding of the nature of the problem being studied is a prerequisite for its formulation or formal definition, which, in turn, is one of the prerequisites for constructing a model at a later state. Also to be included here is a measurement of efficiency such as cost, profit or contribution which will later be converted into an "objective function" and as such incorporated in the model.

5.2 Data collection

Closely related to 5.1 is the process of collecting the relevant data and information of such factors as may influence the problem. Thorough analysis of these will frequently yield additional insight into the nature of the problem and occasionally even necessitate its reformulation. It is important to differentiate at this stage between "parameters" and "variables", also known as "uncontrollable" and "controllable" variables. Generalising in regard to the model, we can say that the former must be taken as given values (hence uncontrollable) and the latter must be determined by the model. For example, in the production plan for the coming month, the available capacity, perhaps even the manpower, must be considered to be uncontrollable, whereas the company may well decide to change one or both in the long run (long-term-controllable). Certain quantities of certain products to be produced, however, are controllable.

5.3 Model construction

An important step in an OR investigation is the construction of the model, which must accurately reflect the most important interrelations among controllable and uncontrollable variables as observed during step 2 (section 5.2). The decision on which interrelations should be taken into account and which should not is very crucial. It is by no means unusual to have to return to this point and reconstruct the model at a later stage, because some of the relations deemed of lesser importance proved to be otherwise.

The model is usually mathematical, thus offering a number of advantages such as flexibility, ease of handling and the possibility of using standard mathematical techniques to arrive at a solution. Usually such a model comprises the objective function which establishes a relation between the controllable and uncontrollable variables on the one hand and the measure of efficiency on the other. The usual objective is then to maximise efficiency which entails either minimised cost or maximised profit or contribution. Maximisation of efficiency is usually referred to as optimisation. The use of this term does away with the necessity of specifying a general problem as a maximisation or minimisation problem. The optimum may be defined as the solution for which it can be (mathematically) proved that no better solution exists. This definition applies to both maxima and minima.

Besides strict optimisation models, we also find heuristic models which aim not so much at a mathematical optimum as at a satisfactory solution. Here we speak of "satisficing" instead of "optimising". This approach is of particular value when the nature of the problem precludes an exact mathematical formulation, and also when such a formulation and the use of the resulting model would be so complicated as to be economically unjustifiable. Most frequently the absence of an analytical technique requires the use of heuristics or "rules of thumb".

5.4 Obtaining a solution

The solution to the problem (satisficing or optimal) is obtained by applying an adequate technique to the model. This technique will so define the values of the controllable variables that the efficiency criterion (objective function) attains an optimal or satisfying value, while at the same time none of the existing constraints (if any) will be violated by this solution.

5.5 Tests of model and solution

This step involves the validation of the model: Does it perform as expected? Is its performance (i.e. the solution) reasonable? The solution must be "implemented" theoretically, that is, it must be judged by reality and by what it was expected to be. Any doubts about the validity of the solution must lead to a review of all previous steps.

5.6 Adaptation

The solution depends on both controllable and uncontrollable variables. Frequently the parameters, that is, the uncontrollable variables, change over time, thus requiring an adaptation of the solution. This step helps to determine exactly how the solution changes and how it must be changed, given certain parameter changes.

5.7 Implementation

This last step is self-explanatory. The solution obtained from the model and validated adequately in tests is now translated into a set of operating procedures which can be understood by those responsible for carrying out the actual operations.

Obviously the distinction of these seven steps is based on logic rather than on actual proceedings. Depending on the nature of the problem, the order of the steps may have to be changed – some of them will have to be performed simultaneously, etc. Still, the fact remains that these steps characterise distinct tasks each of which must be fulfilled to secure the success of the study undertaken. This need is further emphasised by the high costs so often incurred in carrying out an OR study.

6. STANDARD OPERATIONS RESEARCH TECHNIQUES

Certain standard OR techniques have evolved during the past three decades, for example, the Simplex Method, the Transportation Method, the Assignment Method, network techniques, simulation and waiting line techniques, basic concepts of strategies, Line of Balance Technique (LOB), etc.

They deal with certain standard problems which in varying guises appear again and again in many OR investigations. For example, the question of defining optimal inventory levels is nothing but a problem of an optimal trade-off between increasing storage costs and decreasing set-up costs, as the lot size increases. This trade-off situation, however, is one of the most typical situations in Business Economics and in business practice altogether.

Standard techniques are characterised by the standard problem for which they were originally developed, or to which they are best applicable, such as:

(a) inventory
(b) replacement
(c) queuing
(d) sequencing
(e) competition
(f) search, and
(g) routing.

7. THE FUTURE OF OPERATIONS RESEARCH

The new techniques and concepts as offered by OR will be welcomed by tomorrow's managers as their tasks are going to be so vast, demanding and complex that only by applying quantitative OR methods the bewildering number of problems could be comprehended. OR methods have offered real hope to systematize the chaos of conflicting and unordered information.

Federal, state and local government will turn increasingly to OR tools which are absolutely essential to any efficient government management. In this connection a growth in delegation of public tasks to private firms (which then have to find solutions to public problems) seems to be inevitable, because many private corporations can be considered skilled practitioners of the "systems approach". Particularly the planning sector including socio-economical, social-political and military problems will have an urgent need for sophisticated quantitative techniques.

The need in the field of private business will be scarcely less acute bringing about certain changes at the various management levels. Top management has to strive increasingly to acquire, through some experience and training, skills that enable it to value the benefits and possible advantages of quantitative techniques as well as to interpret their results. Moreover, there will be an increasing number of staff specialists to advise top management on special aspects. The middle management too will be affected by organisational structure changes. Many of the activities in decision making will be gradually taken over by computers performing specific procedures. The underlying OR programmes will provide the basis for an optimum course of action. Examples include the optimisation and control of direct shipments of goods, procurement and inventory policies, inspection and quality procedures, standardisation programmes and financial activities and strategies of all kind. Time will tell the impact of the new OR methods on middle management, but it seems to be certain, that the staff used on this level of management will be minimized or reduced considerably, thus causing a more drastic shift and transformation in middle management than in lower or top management.

Both, top and middle management have to become steadily more scientific and analytical, otherwise they will surrender their role and titles as managers in the future as they inevitably will become subservient to the superior knowledge of professional specialists who are experts in the field of the new science of business.

Among the methods of OR that still have to be developed it is one ultimate goal on which attention is focused. This will be the mathematical construction of a model for the optimal performance of the undertaking as a whole. This super model will demonstrate all interrelationships of all parts, levels, branches, sections and departments of the entire firm, enabling management to take action accordingly. The future generations of computers[11] will provide the required hardware and technology to handle such a large scale model and the enormous task involved. But it should be remembered that even a well working gigantic model will leave the basic nonprogrammable decisions to top management.

8. CONCLUSION[12]

Obviously OR differs from other management techniques in method, technique and field of application. The confusion about the real nature of OR apparently stems from the manner in which it is applied in practice.

In the first place, OR is still being applied largely to lower-order or tactical problems, which are the traditional domain of techniques such as work-study and industrial engineering. More important, perhaps, is that these lower-order problems often yield more easily to the OR approach than the strategic type of problem which occurs at a high level within the organisation. This is one of the reasons why OR is often thought of (incorrectly of course) as industrial engineering with a different name.

In the second place there is confusion about the nature of OR, because very often the method employed in tackling a strategic type of problem does not correspond to the defined method of OR, that is, building a mathematical model of the problem and obtaining a solution from this model. Frequently this approach cannot be used because of the complexity of the problem, and/or many factors involved cannot be quantified sufficiently, or because even if a model could be constructed, it would be too complex to manipulate with the mathematical techniques available.

Finally, it should be borne in mind that OR solutions are seldom optimal, despite the fact that the phrase "optimal solution" is so often used. In practice OR is, on the one hand, seldom able to provide an exact optimal solution to a management problem, the complexity of actual management problems makes it impossible to consider all the facets of a problem, but, on the other hand, a succcessful OR investigation can, in most cases, provide a better, though not the best solution for management.

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[9] Planning in this connection refers to the determination of quantities only.

[10] Scheduling refers to the distribution of tasks over real time.

[11] Thierauff, R.J. and R.A. Grosse, ibid., p. 538.

[12] See also: Du Plessis, H.I.D. Advanced managerial techniques, MBL, Unisa, Pretoria, 1969, pp. 42-3.