A REALISTIC APPROACH TO THE IMPLEMENTATION OF MANAGEMENT SCIENCE[1])

by Kalman J. Cohen

Recent advances in the development of quantitative models for finance and banking, along with the increasing utilization of electronic computers, have made it feasible to adopt a management science framework in approaching many types of financial problems. A realistic philosophy concerning the manner in which management science models should be utilized in order to improve financial planning and decision making is set forth in this paper. As indicated in Section A, this is the approach which has been successfully followed in two major American corporations with which I am familiar (and which undoubtedly is the pattern employed in many other companies as well). The so-called „implementation problem", which is concerned with how to get executives actually to utilize either existing or newly developed management science models, is considered in Section B. The paper concludes in Section C by examining the relative roles that traditionally trained executives and management scientists should play in the problem-solving process.

The term „ management science" refers to the *application of quantitative techniques and scientific concepts to help executives solve the planning, decision-making, and control problems of large, complex organizations.* Any management science approach to problem solving utilizes formal models. Since a model is an abstraction of reality, it must necessarily be „incomplete" or „inaccurate" in some respects.[2]) The real world is itself far too complex to manipulate and understand without the aid of the intellectual simplifications that models represent. The real basis for judging the usefulness of a model is not whether it is entirely accurate (which it never is) but, rather, whether it contains enough relevant features of the world so that it can be effectively used by executives to improve their performance.

---

1) I would like to thank Messrs. David M. Ahlers, E. Eugene Carter, Robert H. Larson, and Howard M. Schneider for some constructive criticisms and helpful suggestions on an earlier draft of the material presented in this paper. Any remaining defects are, of course, my sole responsibility.

2) Many people who do not understand the process by which management science models can in fact be implemented often falsely criticize the management science approach. They look at the management science models, and they indicate that these models are unrealistic because this particular factor or that specific aspect of the world are not taken into consideration. It can be obvious that many features have been left out of the model because of the explicitness with which any good management science model is formulated. Thus, one can see not only exactly what is in such a model, but one can also readily note what has been left out. Since every „model" is necessarily an abstraction of reality, it is clear that any formal management science model can never portray the world as it really is, in every detail.

Conventionally trained businessmen who criticize the quantitative approach fail to recognize a most important point: a person who applies thirty years of experience and who uses judgment and wisdom in making business decisions in effect is using some models that are implicit in his head. These subjective models are not the same as the real world which objectively exists. These subjective models are never well formulated; rather they are generally implicit, subconscious, and ill-understood. Hence, it is often not easy to know exactly what is wrong with these subjective models, i.e., to identify the aspects of the real world that are left out of them. You can be sure, however, that a great deal is left out.

A. The Utilization of Mathematical Programming Models for Financial Portfolio Problems in Two Major Corporations

Since the focus of this paper is on the use of management science models for financial planning and decision making, let me specifically consider the type of management science model which is most commonly suggested for this purpose, i.e., mathematical programming models.[3]) In this section, I shall discuss the manner in which two leading American corporations have extensively and successfully utilized these types of models. In particular, mathematical programming models have been applied with notable success in the investment planning process at Standard Oil Company of New Jersey (and its various subsidiary and affiliated companies)[4]) and in the dynamic balance sheet management process at Bankers Trust Company.[5]) Neither of these corporations is utilizing mathematical programming models in an automatic, routine fashion. Instead, some creative dialogues and interchanges take place that involve conventionally trained executives, „management-oriented" management scientists, the models that are programmed in the computer, and a data base. It is important to realize that in practice management science models (especially those involving mathematical programming) are utilized in a far more flexible manner than their bare-bones mathematical formulations might indicate.

Even though authors (myself included) discussing a linear programming model for bank dynamic balance sheet management may talk about an „optimal" solution in some mathematical sense, one must recognize that the model of the world being utilized is not necessarily correct. Given that the real business situation is only approximated by the model, that some of the inputs are not always accurately known, that the model contains many expressions of policies that management may not be absolutely convinced are correct, and that many forecasts (which might be wrong) are used to generate some inputs, then it is clear that the „solutions" produced by the model to real world problems, are not going to be truly optimal. All that we can hope for is that the solutions obtained with the aid of the model are

---

3) For a review of the nature and purpose of various mathematical programming models that have been developed for several different types of financial planning and decision-making applications, see Part II of Kalman J. Cohen, „Portfolio Approaches to Financial Planning," Working Paper No. 61-68-9, Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.

4) Information about the uses of mathematical programming models for investment planning at Standard Oil Company of New Jersey and its subsidiary and affiliated companies was obtained in conversations with Mr. Lowell K. Strohl, Manager, Operations Research and Systems Department, Esso Mathematics and Systems, Inc. For an example of one type of model that has been implemented for this purpose, see Leo A. Rapoport and William P. Drews, „Mathematical Approach to Long-Range Planning," *Harvard Business Review*, Vol. 40, No. 3 (May-June, 1962), pp. 75-87.

5) Information about the uses of mathematical programming models for dynamic balance sheet management (which is more commonly, but incorrectly, referred to as „asset management") at Bankers Trust Company was obtained by the author in his capacity as a consultant to that bank for the past decade. Detailed discussions of one type of model that has been implemented for this purpose are presented in Kalman J. Cohen and Frederick S. Hammer, „Linear Programming and Optimal Bank Asset Management Decisions," *Journal of Finance*, Vol. 22, No. 2 (May, 1967), pp. 147-165; and Kalman J. Cohen, Frederick S. Hammer, and Howard M. Schneider, „Harnessing Computers for Bank Asset Management," *The Bankers Magazine*, vol. 150, No. 3 (Summer, 1967) pp. 72-80.

better than the solutions that we otherwise would have arrived at using the same degree of effort.[6])

Let us consider more specifically how a mathematical programming model is utilized in practice. Long before anything even approaching an „optimal" solution is acted upon, a great deal of conversation and an exchange of ideas takes place that involves executives, management scientists, and the model itself. In this process, the mathematical programming model in the computer serves as an extension of the peoples' brains. In effect, the computer model serves as another member of the committee that „sits" around the table „discussing" what should be done. In this process, the resulting plans and decisions are very much influenced by the human components, and not just by the mathematical programming model in the computer.

One example of a creative, flexible use of a mathematical programming model would be to explore relationships among various possible goals. Goal programming techniques have been specifically developed for this purpose. The more common linear programming models can also be used in a similar manner, however. For example, a linear programming model is typically formulated in terms of *one* goal; nonetheless in practice it can be used to explore the consequences of alternative goal formulations. In this way, LP models are not necessarily used to optimize only a single goal, but to establish trade-off relationships that exist among many goals. Other common but imaginative uses of mathematical programming models would be sensitivity analyses to determine how important is an accurate knowledge of inputs, to what extent some ill-understood constraints need to be specified more accurately, etc.

B. The Implementation Problem

One reason why management science efforts in banks and business firms often fail to improve the planning and decision-making process is that from the outset the projects are organized in the wrong way. If the executives of a company are so busy „on the firing line" making day-to-day and week-to-week decisions that they can seldom spare half-an-hour to talk to their management scientists, then the management science analysts become „the boys in the back room". It is then difficult for them to learn enough about the real business world so that they can build relevant models. If the „back room" management scientists are successful in formulating a model that they feel could be relevant, this is usually communicated to the executives in a

6) There is one important reason why it often is the case that the use of a mathematical programming model will produce better decisions than conventional procedures. The model can simultaneously consider all aspects of a particular problem, whereas traditional methods frequently focus on what is only a subset of the crucial issues. The more comprehensive viewpoint permitted by the mathematical programming model in effect transforms all of the assumptions that are made concerning the nature of the business and the values of input data into specific implications concerning the courses of action that might be taken. There is, however, a price that must be paid in order to obtain such an overall understanding of the situation. Because of its greater complexity, a relevant mathematical programming model requires a great deal more effort to develop and implement than the traditional procedures which it is designed to supplant.

written memorandum. These decision makers all too often merely put the memorandum into a desk drawer or a waste basket, usually without understanding it and certainly without acting upon its recommendations. In this manner the so-called „implementation problem" arises, which is the problem of how to induce executives to utilize management science models to improve their planning and decision-making activities.

My own pessimistic viewpoint is that the implementation problem is almost impossible to solve, once it has arisen. In an optimistic vein, however, I feel that it is possible to organize the management science activities in a business firm so that the implementation problem will not arise. To illustrate how this can be done, let me describe the realistic approach to the implementation of management science which has been successfully utilized in Bankers Trust Company, where I have been a consultant for the past decade. At Bankers Trust, we have found it possible to eliminate the distance between the executives „on the firing line" and the management science analysts „in the back room". In practice we bring these two groups together in frequent meetings and discussions, and they effectively collaborate in developing and implementing truly relevant management science models. Since our management scientists do not generally know very much about banking when they start, it is necessary for them to learn what are the crucial problems of banking, what are the new opportunities that might be exploited, what types of information are available, how good are the data, etc. Our management science analysts in practice learn this through the eyes, ears, and mouths of the experienced bankers. Effective learning can occur only when these two different types of people can work together and communicate in ordinary banking language. In effect, the bank executives are teaching the management scientists a great deal about the banking business. At the same time, the management science analysts are gradually winning the confidence of the senior officers. Then both groups can jointly determine the types of considerations that will be embodied in the models, and together they can decide how the models will be utilized.

Most of the bank's executives never themselves learn any mathematics or computer programming, because it is unnecessary. But the executives understand the economic and banking substance of the models, have an intuitive (i.e., a „big picture") understanding of the techniques for solving them, realize how the models could be used, appreciate when it is dangerous to use them, are aware of the qualitative considerations that have been left out of the models, know what extensions may be feasible, etc.

For effective, two-way communication to occur between executives and analysts we found it essential to recruit „management-oriented" management science analysts, i.e., people who have the ability (and perhaps also the motivation) to become senior corporate officers someday. They must have the types of personalities and human relations skills that permit them to interact effectively with older, conventionally trained bankers. The resulting communication, of course, takes place in the ordinary language of the executives, rather than in terms of technical jargon or mathematical symbols.

When „management-oriented" management scientists work jointly with senior executives to develop the economic substance and banking meaning of the management science models, the results are usually very relevant to the executives' problems. The models are to some extent unrealistic, in that many aspects of reality are not incorporated in them. They are utilized, however, in a way which involves a great deal of interaction, many reruns, and insightful interpretations of the results. This realistic approach produces far better results in practice than would be obtained either by „conventional" (people only) decision-making techniques or by „straw man" (computer only) management science models that are run only once to generate allegedly „optimal" solutions.

C. The Roles of the Executives and the Management Scientists

Let me now consider more explicitly the role of the traditionally trained executive in the management science efforts. If management science is going to be profitable for a business firm, it has to change the way in which planning and decision making take place. If all the executives think that they are doing a great job and that there is no need for any change, management science is not going to help that corporation. On the other hand, if some executives realize that, no matter how good a job they might have done in the past, the environment is becoming more competitive (perhaps in part because competitors are effectively utilizing new management science tools), new kinds of markets are emerging, the problems are growing more difficult, and the executives themselves may not in fact have been doing the best possible job in the past, then there is a good possibility of profitably using management science in that firm. It is important, however, to realize that the conventional executive cannot alone and unaided develop and implement useful management science models. Some knowledge of the mathematical tools and the computer systems (which need not be overwhelming in terms of academic research standards) is necessary. Most executives do not have this type of technical knowledge.

On the other hand, it is also essential to realize that the young management scientist who might have had a sound academic training, and perhaps even some experience in another industry before coming to work in his present corporation, is not going to develop and implement these tools by himself. Traditional executives and management scientists must work together in order to develop and implement relevant management science models. There must be a team approach to the management science efforts.

The most effective way to accomplish this, in my opinion, is to have the management scientists who work in a given area invited to attend every management meeting that has anything to do with that particular area of the firm.[7]) Initially the management science analysts will be silent observers, but gradually they will be asked questions by the traditional officers present, and eventually the analysts will be brought into the decision-making process. I feel that this type of development should be encouraged. It will lead to mutual understanding and effective communication between more

conventionally trained and older bank executives and the younger management scientists. Hence, when the development of a management science model is finished, there should not be great difficulty in implementing it. In the process of building the model, the managers are involved in numerous discussions of goals, constraints, and alternative courses of action. These discussions will change the manner in which the executives think. Also, the management scientists in this process are themselves becoming effective managers. Because of the comprehensive understanding they obtain of the company's problems from their management science work and because of their frequent exposure to senior officials, the management science analysts are well along the road to becoming corporate executives. There will, of course, always be some „management-oriented" management science analysts who will prefer not to become general managers but instead to remain staff specialists (or even some who will leave the business world and return to an academic career). In the future, however, there will be an increasing number of senior corporate officers who have been management scientists earlier in their careers. This does not mean that management scientists will „take over" banks and other corporations in the future any more than it would now be proper to say that engineers have „taken over" oil companies and that actuaries have „taken over" life insurance companies.

Let me again stress that management science efforts require the enthusiasm of and cooperation from senior management before they can be successfully implemented. Traditional executives should realize that the growing use of management science need not necessarily cause them to be insecure in their jobs, and they certainly will not be replaced by computers. Unfortunately, however, some particular subset of present-day executives, those who refuse to learn and adapt to new ways of doing things, will be replaced by other executives who are willing and able to keep up with the times.

An analogy that illustrates this point is to consider what happened to the drivers of horses and wagons around the turn of the century when the internal combustion engine was introduced. It undoubtedly is true that there were a few horse-and-wagon drivers who never learned to drive automobiles and trucks, and who consequently may have eventually lost their jobs. Most of the horse-and-wagon drivers, of course, did learn to become chauffeurs, and they found gainful employment (probably at higher wages) driving

---

7) The extent to which the management scientists actually attend these meetings will vary over time. In the early stages of the project, the management science analysts will find it useful to attend almost all of these meetings, since they will be learning what the problems are, observing the process by which decisions are made, and becoming acquainted with the executives involved. During the intermediate stages of the project, the analysts should probably curtail the time that they spend in general management meetings in order to have enough time for building and analyzing the management science models. Once the models have been developed to the point where they should be utilized in the management process, the analysts will find themselves participating in increasing numbers of meetings to help executives formulate plans and make decisions. At some stage the management science analysts must decide whether to become managers in this particular area of the firm (in which case they will continue to attend and participate in all relevant meetings), or else to continue on their careers as management scientists (in which case they will start working on other projects).

trucks and automobiles. The blame for the loss of work of those few horse-and-wagon drivers who refused to learn new and more efficient ways of transporting passengers and hauling freight should lie with them, and not with the internal combustion engine.

In order for today's executives to learn to utilize management science techniques to improve their planning and decision-making processes, they do not have to become management scientists themselves. Instead, as I have already indicated, they need only hire „management-oriented" management scientists, organize the management science effort in the proper manner, and learn to interact effectively with their management scientists. Neither management scientists nor computers will truly „run" any corporation in the future, any more than it is fair to say that corporations today are „run" by telephones, jet airplanes, and dictating machines. Today's corporations are, in the last analysis, „run" by people. The fact that today's executives have learned to utilize telephones, jet airplanes, and dictating machines means, however, that their corporations are „run" today in a far different and more efficient manner than would be the case if these particular tools were not being used. In much the same manner, people will „run" the corporations of the future. In the future, however, executives will make increasing use of such tools as management science models, computer-based information systems, and the like.

As the business world becomes more complex and more competitive, it is increasingly important for executives to learn to utilize new and more powerful tools to improve their planning, decision-making, and control activities. For this to happen, organizational doors must be opened to permit management scientists to attend meetings that heretofore had been considered to be „in bounds" for only members of senior management. Otherwise, the management science analysts will not be able to gather information and to build effective management science models that will help the top-level executives improve the planning and decision-making process. It takes a special type of management scientists to be effective in this particular role. He must not only be a good mathematician and econometrician, but he must also possess a great deal of tact and diplomacy, the ability to communicate freely and easily both orally and in writing, and perhaps even the personal desire to become a senior corporate executive some day. This type of „management-oriented" management scientist can successfully make the transition from „analyst" to „executive". As he does so, the corporation for which he works will be more profitable as the effective implementation of management science techniques improves the quality of the plans and decisions that are made.

Reeds eerder geplaatst in The Magazine of Bank Administration, U.S.A., september 1969.